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A thesis submitted for the degree of
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Abstract

This dissertation is part of the MSc in Energy Building Design at the International Hellenic University.
In the European Union, the energy spent in buildings accounts for 40% of the total energy consumption and 36% of CO_2 emissions. Most of the already existing European buildings have been constructed before the compliance of the member states national legislations with the EPBDs. They have low to insufficient insulation of the envelope, inefficient heating cooling and ventilation mechanical systems, low air tightness, lack of proper shading and are generally designed with little or no consideration regarding the environment and the energy consumption. About 35% of this stock is older than 50 years, which means the buildings were constructed before any national legislation or regulation concerning the energy efficiency was applied. This research, discusses the European building stock characteristics, the European Energy in buildings policy and legislation, the typology and methodology used for the study of building retrofitting measures. It will present direct and indirect benefits of such actions, from a thermal comfort, energy conservation, carbon-emission optimization and cost-effectiveness point of view. Finally, it applies the energy retrofitting methodology in several case studies, to retrieve results and extract conclusions for the energy behaviour of the buildings and the typology used.

Paschalis Akrivopoulos
18/12/2017

Contents

Abbreviations

Abbrevia-tions	Meaning of the Abbreviations
DHW	Domestic Hot Water
EN	European Norm
EPBD	Energy Performance of Buildings Directive
EU	European Union
GR	Greece
IO	Input – Output
UHI	Urban Heat Island
IEQ	Indoor Environment Quality
IAQ	Indoor Air Quality
SBS	Sick Building Syndrome
BRI	Building Related Illness
KWh	Kilowatt-hour
λ	Lambda Value
LCC	Life Cycle Cost
LCA	Life Cycle Assessment
NZEB	Nearly-Zero Energy Building
PV	Photovoltaic(s)
Ref	Reference
RES	Renewable Energy Sources
XPS	Extruded Polystyrene
RW	Rockwool
BEMS	Building Energy Management System(s)
HVAC	Heating Ventilation Air Conditioning
SFB	Single Family Building
MFB	Multi Family Building
U-value	Thermal transmittance
BPIE	Buildings Performance Institute Europe
IEA	International Energy Association
EC	European Commission
EBC	Energy in Buildings and Communities
IEE	Intelligent Energy Europe
UNFCCC	United Nations Framework Convention on Climate Change
EED	Energy Efficiency Directive
EUR/m^{2}a	Euros per square meter per annum
NOA	National Observatory of Athens
IERSD	Institute for Environmental Research and Sustainable Development
MTOE	Million Tonnes of Oil Equivalent
KTOE	Kilotonnes of Oil Equivalent

SFH	Single-Family House
MFH	Multi-Family House
PEC	Primary Energy Consumption
APEC	Average Primary Energy Consumption
CEH	Cogeneration of Electricity and Heat
HDD	Heating Degree Days
KENAK	Regulation for the Energy Performance of Buildings (K.EN.A.K.)
TOTEE	Technical Directions of Technical Chamber of Greece
GRBT-ESD	Greek Residential Buildings Typology – Energy Saving Dynamic
TCG	Technical Chamber of Greece
PES	Primary Energy Savings
PP	Payback Period
A/S	Adiabatic Surface

1 Introduction

The retrofitting of the existing building stock has a direct connection with the climatic change mitigation efforts, first introduced in the 1992 United Nations Framework Convention on Climate Change (UNFCC), followed by the Kyoto Protocol. In this frame, the EC published the first Energy Performance of Buildings Directive (EPBD) in 2002, followed by a series of directives under the target of CO_2 emissions reduction, the EPBD recasting in 2010 and the Energy Efficiency Directive in 2012. These actions happened since 40% of the overall energy consumption and 36% of the CO_2 emissions in the European Union result from the building sector. The building sector is expanding, which is bound to furthermore increase energy consumption [1]. Considering that a significant percentage of the total energy consumed in buildings is consumed by residential buildings, and that the majority of the residential buildings extant were built before the introduction of thermal standards, the crucial role of the existing building stock energy renovation in the European targets for mitigation of the climatic change is easily understandable. This climatic change mitigation strategy is starting from the EPBD 2010 with the commitment of 20-20-20 (20% reduction in greenhouse gas emissions, 20% decrease in energy consumption and 20% production of energy from Renewable Energy Sources (RES) – compared to 1990) for the year 2020 and moves to 2050 with a predicted reduction of the total greenhouse gas emissions by 80-95% in the Energy Efficiency Directive (EED) 2012 comparing to 1990 [2]. The EED is also clearly stating the importance of increasing the rate of building renovations as the existing European building stock represents “the single biggest potential sector for energy savings”.

The European residential building stock is a mix of various construction types designed with different considerations and employing different technologies and materials. The insulation of the envelope, the user habits, the national sources composition for energy production, the urbanization level, the financial context differ from one European country to the other and in some cases within the countries themselves. It would be ineffective trying to set a policy with the same approach for all the European countries, as even the application of a country-based uniform policy under the EC supervision would be hard to meet. Market, administrative, legal, economic and social barriers, impede the uptake of energy building performance measures. To surmount those impediments, scientists of different fields had to combine their knowledge in a complicated procedure affected by several parameters inside and outside the field of engineering. This work will present a cost-benefit analysis of the impact of the energy building retrofitting, aiming at the greenhouse emissions mitigation and the energy conservation without compromising user comfort.

2 Literature review

2.1 European policy

2.1.1 European Directives for building efficiency

Although the EU policy makers have recognized the importance of the building performance in the effort for the mitigation of the climate change, each direction they published was mainly focused on new buildings. From the first EPBD in 2002 to the revision in 2010, the efficiency of all new buildings has been improved. On the other hand, the old building stock has been affected less by the new performance requirements. The 2010 Energy Performance of Buildings Directive (2010/31/EU) and the 2012 Energy Efficiency Directive (2012/27/EU) comprise the EU's main legislation frame for the reduction of energy consumption in buildings.

2.1.2 Directives 2010 EPBD & 2012 EED

Under the 2010/31/EU - Energy Performance of Buildings Directive [1]:

- Energy performance certificates must be presented in all advertisements for sale or rental of buildings.
- European Union states must establish inspection procedures for heating and air-conditioning systems or put in place measures with equivalent effect.
- All new buildings must be NZEB by the 31st of December 2020 and all new public buildings must be NZEB by the 31st of December 2018.
- All the EU member states must set minimum of energy performance requirements for new buildings, for the major renovation of buildings and for the replacement or retrofit of any of the building elements or HVAC equipment.

Under the 2012/27/EU - Energy Efficiency Directive [2]:

- All EU countries must make energy efficiency refurbishments to at least 3% of the buildings owned and occupied by the state.
- EU governments must only purchase buildings which are highly energy efficient.
- EU member states must plan long-term national building renovation strategies, which can be included in their National Efficiency Action Plans.

In 2012 Energy Efficiency Directive, the policy makers increase the support to the significance of the existing building stock renovation, for the EU to succeed in its effort to maintain the global temperature rise below 2^{o}C, looking forward to achieving the European Union objective of reducing the greenhouse gas emissions by 80-95% by 2050 compared to 1990.
Furthermore, the directive demands that the member states set an annual rate of renovation in the buildings owned and occupied by the central government, to upgrade their energy efficiency. The buildings owned by public bodies, account for a considerable

share of the existing building stock and have great visibility in the public life. This renovation rate must follow the EPBD obligations regarding the Nearly Zero Energy Building efficiency, which requires that when existing buildings are under major renovation, their energy performance must be upgraded so that they meet the minimum energy performance requirements. Reliable data are necessary for this process in order to outline efficient policies and to be able to assess the results. Those data sets are available through the Energy Efficiency Certificates data sets.

2.1.3 National strategy for the building stock

Within the 2012 EED [2], the EU demanded that by 2014 all member states establish a first version long-term strategy for mobilizing investment in the renovation of the national stock of the residential and commercial buildings. This strategy should include:

- An overview of the national building stock based on statistical data.
- Identification of cost effective approaches to renovations relevant to the building type and climatic zone.
- Policies and measures to stimulate cost effective energy renovations of buildings including complete renovations or energy renovations in stages (e.g. building envelope elements renovation, HVAC renovation etc.).
- A forward-looking perspective to guide investments decisions of individuals, the construction industry and financial institutions.
- An evidence-based estimate of expected energy savings and wider benefits (user wellbeing, mitigation of energy poverty and energy security).

In compliance with this directive, in December 2014, Greece published a report on the long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private [3].

2.2 Benefits of energy and carbon emissions optimization

Energy efficiency and greenhouse gas emissions mitigation have many implications besides the direct CO_2 reduction and the operational cost of the buildings. Those benefits include effects in different levels of economy and society and can be sensed at the building level and observed at a social and economic level from a macroeconomic perspective.

2.2.1 Building user level benefits

*Building quality***.** The building renovation impacts the building internal air quality resulting in the elimination of condensation, mould and humidity problems. The use of thermal insulation throughout the whole building envelope, eliminates the thermal bridges, the increase of the indoor air temperature in winter, the use of vapour barriers and the use of air supply systems and control of the ventilation rates, reduce the internal humidity preventing condensation. The renovated building is using new technology systems and controls offering easier use and control experience to the users. New automatic thermostats are introduced, DHW delivery is faster and stable, the shading devices are automatic or easily operated etc. The new materials and applications offer an increased aesthetics and architectural integration, which in the first place is the most usual cause for building renovations. The impact of the measures taken for the renovation, depends on the building specifications the way those measures are implemented, and the overall design. The useful area of the spaces increases as a result of the cold surfaces elimination or the creation of sun spaces in the balconies with the application of glazing as a result of bioclimatic design. Finally, the modern safety standards of the new building elements, greatly reduce the risk of accidents, fire or intrusion.

Economic benefits. The user of a highly efficient building obtains safety over the energy prices uncertainty. The desired level of comfort can be constantly maintained with increased feeling of certainty and control over the energy bills.
User comfort. The dwellings have higher thermal comfort as a result of the correct control of the room temperatures. The radiant temperatures are higher in winter and lower in the summer, while the temperature differences between spaces or building surfaces, the humidity and possible air drafts are eliminated. The increase of south transparent surfaces may impact on the daylight use inside the conditioned space, and the visual contact with the outside results in a better mood and morale, reducing eyestrain and tiredness. The use of controlled ventilation with the application of filtering of the incoming air, is one of the most important ways to improve the IAQ. The Indoor Air Quality (IAQ) of the refurbished building is greatly improved contributing to the elimination of Sick Building Syndrome (SBS) and Building Related Illness (BRI) resulting from the mitigation of the emitted gases, particulates and microbial contaminants presence. The insulation of the building facades and roof combined with the new standards glazing, isolates the external noise effectively. Measures have to be taken, though, because the minimization of the sounds of the outside environment may increase the need for insulation from the internal noises of the building. In all cases, users of a contemporary building have every excuse being proud, enhance prestige and value of their property, while in parallel they seem to develop an improved sense of responsibility regarding the environment and being more relaxed in their everyday living.

2.2.2 Macroeconomic Benefits

Environmental Improvement. The energy refurbishment results in producing less environmental pollutants, which has a positive impact on the surrounding environment and people (better health, improved mood, less building damages). This reduction is due to reduced fossil fuel consumption, as a result of improved HVAC efficiency and the minimization of the energy demand. It also has the side effect of the decrease of the Urban Heat Island effect, causing a further decrease in the energy needed for cooling. Building retrofit is also a passive way to reduce reuse and recycle construction waste in comparison with the demolition of the existing building stock and its replacement with new buildings.

Economic advantages. High building and HVAC efficiencies, especially when complemented with the use of RES, lead to the direct reduction of energy demand and peak energy demand. Decreased demand reduces energy costs. This seems to create a rebound effect on the user behaviour creating the need for costumer education (cheap energy creates the feeling that it is ok to consume more than needed). This effect is reducing the overall cost efficiency of the energy efficiency measures. With the legislation and application of energy efficiency measures in the existing building stock, new business opportunities appear in the market, such as the Energy Service Companies. Unemployment is reduced due to the need for human resources in a chain of companies connected with the energy efficiency renovation: from raw material extraction and alternation, to standardized building material and the transport companies, to the wholesale merchants, the

labour personnel, the engineering companies, the ESCOs, the accountants, the banks etc. The growth of the construction and energy market has a very positive impact to every economy it is applied, increasing the GDP growth. In many countries, the economically weaker social layers are receiving subsidies for the energy they use. If those countries choose to invest in energy retrofitting subsidizing, in the long-run they will greatly reduce the amounts of money spent in energy subsidies.
Social impact. Increase in energy efficiency of the equipment and decrease in the energy need of the building has the direct benefit of decreasing the money spent for energy while, in parallel, increasing the IEQ of a dwelling. This results in reducing the Energy Poverty percentage. According to the report for the Energy poverty transacted by the INSIGHT_E project, funded by the EU: "Energy poverty most commonly refers to the situation where individuals are not able to adequately heat (or provide necessary energy services) in their homes at affordable cost" [1]. Giving the opportunity to poor people to adequately condition their living spaces and reducing the external air pollution, the UHI effects and the thermal stress, results in the decrease of the vulnerable groups' mortality rate due to environmental extremes. This also results in reducing the need for medical care, medication received, restrictions in the activity of vulnerable groups, affecting positively their wellbeing, morale and productivity. The reduction of the SBS and the BRI impacts positively work productivity and academic achievements , decreases the state energy needs and energy dependence on third parties, improving energy security.

2.3 EU Projects and studies

2.3.1 The Intelligent Energy Europe Programme (2006)

In 2006 the European Parliament with the decision 1639/2006/EC [4], established the Intelligent Energy Europe Programme (IEE), as a part of the Competitiveness and Innovation Framework Programme. Intelligent Energy Europe programme offered funds to organisations willing to improve energy sustainability. It supported the European Union energy efficiency and renewable energy policies to reaching the EU 2020 targets (20% cut in greenhouse gas emissions, energy efficiency improvement by 20% use of renewables in the European energy consumption).

2.3.2 IEE PROJECT - DATAMINE (2006-2008)

The idea under the DATAMINE project [5], was to improve the knowledge about the energy performance of the existing building stock by using data from the energy performance certificates. Twelve project partners from twelve European countries agreed on a set of values, which they recommended to be used for establishing of Energy Performance Certificate (EPC) databases in European countries. Pilot projects were implemented in all countries in which data collection and evaluation of EPC data was realized. Those partners collected 19,000 datasets from European countries, after transferring the collected national EPC datasets to a common database. Those data were analysed and compared. "Average building" types were defined representing the respective samples, classified according to their age and size.

2.3.3 IEE PROJECT – TABULA (2009-2012)

TABULA project was launched in 2009, using the common DATAMINE data structure and the experiences of classification typology [6], [7], [8]. TABULA project was created for adding the energy related properties of the buildings as a classification term towards building typology definition. Under the TABULA project, building typologies for 13 European countries were studied and developed. Each national typology of buildings consists of a classification scheme which groups buildings by age, size and other parameters adding a set of prototypical buildings, used to represent each building type. The results were published in national "Building Typology brochures". Common element of those brochures is that all of them include double page building display sheets, for all case study buildings where the energy-related features and the effects of renovation measures are illustrated in a graphical way. TABULA project includes a "TABULA Webtool", providing an online calculation method for the prototypical buildings from all European countries. It displays their energy related features and the possible energy savings by implementing retrofitting measures. The TABULA Webtool, consists of a simple and transparent reference procedure for calculating the energy needs of a building, the energy use by energyware, and the energyware assessment regarding the primary energy used, the CO_2 emissions and the cost assessment. Except for this reference calculation procedure, which is used for cross-country comparison, the energy use can be further calibrated to the typical levels of the true consumption. This intends to promote a realistic assessment of the energyware and the HVAC cost savings. Building stock models have been created for seven European countries through TABULA residential building typologies, projecting the actual energy consumption and potentials for the residential sector.

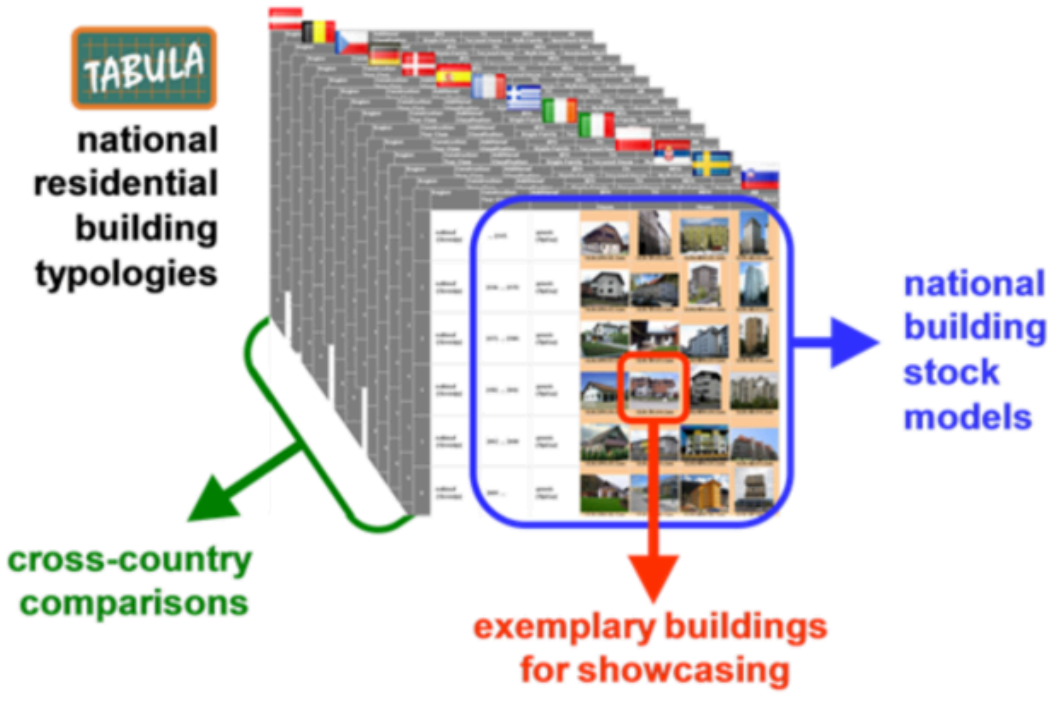


Figure 2.3.3-1: General Idea of TABULA building typologies. [6] [7]

2.3.4 IEE PROJECT – EPISCOPE (2013-2016)

The EPISCOPE project is based on the TABULA project. It uses the TABULA building typology to record the progress of the energy performance of buildings on the energy saving and climate change mitigation targets. The objective of the EPISCOPE project is to give directions and the incentive, to the groups of people involved in the procedure of retrofitting, for ameliorating interventions [6], [9].
The purpose of the EPISCOPE project is to increase the transparency and effectiveness of the energy related retrofitting procedure on the European Union residential building stock aiming at the assurance of the climate protection actions effectiveness by taking corrective measures when they are needed. The idea is for the project to be using the national TABULA building typology for each European country it already exists and the addition of more countries in the project [8][10]. The TABULA Webtool will be updated to include the national NZEB approach for each member state. The outcome of this methodology will comprise the base for the assessment procedure and the comparison core for different energy relative renovation strategies and implementation results. The primary objective of the EPISCOPE project will be the monitoring of the energy retrofitting progress of specific residential stock units [10]. Several typology-based tentative applications characterized as "pilot actions" will focus on distinct residential groups in a local, regional or national level. The application of energy renovation measures will be compared with the activities and measures that are needed to ensure the success of the relevant climate protection European Union commitment. Furthermore, the actual energy efficiency and consumption after the retrofit will be assessed and compared to the simulation results, to confirm the true savings. The continuous efficiency and consumption recording, the assessment and presentation of the results will give the incentive to building owners, to conduct high efficiency energy refurbishments, in a cost-effective manner, and to evaluate the results of an energy efficient property [10].

It is expected to increase the list of the countries listed in TABULA, adding more classification elements, case study buildings and supply system data. In addition, pilot actions will take place on local, regional or national level with the consideration of national typological criteria regarding the renovation progress achieved in the past and current rates of retrofitting by measure type, the compliance with the refurbishment demands, the identification of difficulty level for the application, the RES installation potential and the benchmarks for consumption and energy efficiency indexes. For those sets and pilot actions, different scenarios will be drawn for each residential building stock [11], [12] considering the last renovation trends for different stock subdivisions, the true energy savings and CO_2 reduction achieved in previous refurbishments and the combinations of measures that are needed to comply with the long-term European standards plus the necessary rate of retrofitting for each region. The indexes of energy performance will be used to enable a comparison of scenarios between different countries. Those energy performance indicators will be introduced in energy performance certificate datasets, representative surveys, census heating or energy bills, strategic asset development, energy management etc.
The total strategic objective is to improve the transparency and effectiveness of the energy retrofitting procedures in the European residential sector [10]. This result will be achieved with the installation of bottom up procedures in the fields of: energy certificate databases, representative surveys, regional or national census, energy bills, asset development and energy management.

2.4 IEA – EBC

2.4.1 Role and purpose of the International Energy Agency

The International Energy Agency (IEA) organisation was established in 1974, after the oil crisis of 1973 [13]. Its foundation purpose was to help the countries coordinate a major and cooperative response to important oil supply disruptions, evolving and expanding since then to more energy related fields. The organisation nowadays observes all primary energy sources supply and demand, the RES technologies, the electricity markets, the energy efficiency aspects, the access to energy, the demand management and more [14]. IEA consults in policy measures that will enhance the energy affordability, sustainability and security in its 29 country members. IEA is an international organization in the centre of the global energy related discussion providing data and statistics analysis through publications and a series of presentations, workshops and resources. The main areas that IEA is focusing on are four: energy security by promoting diversity, efficiency, flexibility and reliability for all the primary energy sources; economic development by supporting the growth of free markets and the mitigation of energy poverty; environmental awareness by offering environmental policy solutions regarding the climate change; and finally, worldwide engagement with countries to analyse the possibilities, propose and apply functional energy and environmental concerned denouements [14].

Member countries of the International Energy Agency are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, The Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States [15].

2.4.2 The Energy in Buildings and Communities Programme (EBC)

Three years after its foundation in 1977, recognizing the importance of the energy consumption in buildings, IEA established the Implementing Agreement on Energy in Buildings and Communities (EBC). The priority of EBC is to undertake research and provide the countries a focus for energy efficiency in buildings. The tasks are undertaken through a series of “Annexes”, so called because of their legal establishment as annexes in the EBC implementing agreement.

The participation of national programmes in EBC offers bonuses to the countries involved, such as increase of research and development resources, technology transfer and training and boosting of skills. Countries with lower knowledge level can obtain faster and easier needed expertise, avoiding duplicated research efforts. The IEA- EBC programme acts as a pool of expert professionals funded by different nations assisting the production of high quality reports. The participants themselves create their own personal human resources network, increasing connectivity amongst international professional experts. All the 26 country members of the EBC programme have the right to propose new projects and the right to accept or deny participations.

While most EBC projects use a task-shared basis where the participant organizations are funding their own experts to contribute their task in the project, in some of the projects the cost is shared for a common result. The typical time duration needed to complete an annex is 3-4 years. Many outcomes of completed or ongoing research are published, available on the Web. [16]

2.5 IEA EBC project: Annex 56

2.5.1 The EBC Annex 56 - Overview

IEA EBC Annex 56 is a project which started in 2010. The objective of the Annex 56 is to study and analyse the “Cost-Effective Energy & CO_2 Emissions Optimization in Building Renovation”. In the last 20 years, many regulations and national standards regarding the specification of improved energy efficiency have emerged. Nevertheless, they mostly target new constructions without effectively taking into consideration the technical, economic and functional particularities of the existing building stock.
The regulations for the existing building stock, generally demand the increase of energy efficiency of the building envelope which are applied using complex and expensive procedures. Those measures are hardy welcomed by the occupants, the owners and the developers. On the other hand, the renewable energy systems application can often be as cost effective as the building energy efficiency measures or more. Hence, it is important to approach the cost-effectiveness of an existing building retrofitting as the proper merging of energy efficiency and RES utilization interventions.
This means that it is critical to analyse the case characteristics, achieving the fine balance point between the RES use and the envelope and HVAC energy efficiency. To accomplish this goal, it is crucial to define the meaning of “best performance”, as it can be defined in terms of total energy consumption, primary energy consumption, carbon emissions, operational cost and to achieve this performance using the minimum capital and with the least disturbance to the occupants. This is the contemporary approach to be used by the governments and a great step forward towards the energy efficiency optimization, the CO_2 emissions mitigation and the energy poverty elimination, dealing with the existing building stock.
Annex 56 is leading the way to:

- Designate a methodology for succeeding in cost optimizing solutions regarding the efficiency in energy consumption and the CO_2 emissions mitigation targets in existing building refurbishment.
- Define the connection between the energy efficiency and CO_2 emissions targets and set the priority in each case.
- Specify cost-effective combinations of energy efficiency and RES use.
- Explain the co-benefits of the retrofitting procedure.
- Present case studies to inspire the policy makers and the property owners in promoting efficient and cost effective existing building retrofits.

Annex 56 is focusing mostly in residential buildings, and simple office buildings without complex HVAC systems.
The project is still ongoing. The objectives, scope, work, methodology and deliverables have been set. The term “Energy Effectiveness” is approached using the cost optimization of energy consumption and CO_2 emissions mitigation definitions. Case studies have been published and a glossary has been created to provide a common path and a common terminology base to enhance the comparison of data and outcomes. [17]

2.5.2 Annex 56 deliverables

With the project reaching its completion, the deliverables have been completed and published available to everyone.:

- Co-benefits of energy related building renovation [18]

- Evaluation of the impact of energy related renovation measures on selected Case Studies [19]
- Life Cycle Assessment [20]
- Methodology for cost-effective energy and carbon emissions optimization in building renovation [21]
- Owners and residents acceptance of major energy renovations of buildings [22]
- Results of the parametric calculations with generic buildings and case studies [23]
- Shining examples brochure [24]
- Terminology and definitions [25]
- Tools and procedures to support decision making [26]

2.5.3 Annex 56: Co-benefits of energy related building renovation

The refurbishment of the building stock has inherent potential in mitigating the climate change. This potential is present both with the improvement of the total energy efficiency of the existing constructions and with the reduction of resource depletion and minimization of waste production related with new construction. The usual evaluation of the building retrofit, ignores relevant indirect benefits underestimating the true value of renovation and reuse of the existing building stock in many levels of society and economy. The Annex 56: "Co-benefits of energy related building renovation document", focuses on the indirect benefits of the building renovation, that can be felt at the building, the societal and the macroeconomic level [table 2.6.3-1] [table 2.6.3-2] , with the intention to highlight and evaluate the way they can be considered in the decision-making process. This evaluation plans to enhance the owners and policy makers in understanding how the energy efficient refurbishment of the existing building stock may influence other areas of policy action or property value, motivating the key-players to plan and conduct energy efficient actions. The report was supported by the analysis of the case studies by several countries that participated in the Annex 56 and it consists of the following components:

- Definition of the concept and the relevance with the total added value derived from the energy related building refurbishment.
- Distinction between the levels of co-benefits at the building, the societal and the macroeconomic levels.
- Definition of a matrix to identify the co-benefits as results of certain refurbishment measures, planning to enhance the owner's and promoter's awareness and the use of the information gained in the decision-making procedure.
- Emphasis on the relationship between energy and other policy actions, planning to augment the awareness on the energy efficiency retrofit co-benefits.
- Development of an integrative approach, necessary to understand the extent of the impact of the energy related refurbishment on distinctive societal fields [table 2.6.3-3].
- Literature review and summary of the usual mechanisms to determine and quantify the co-benefits of the energy related building renovation.
- Evaluation of the co-benefits in the Annex 56 case studies reports (Generic Buildings, Shining Examples and Detailed Case Studies) focusing on the comparison between cost-optimal and cost-effective measures with packages that could possibly provide additional co-benefits.

- Recommendations for the stake holders that Annex 56 is focusing on (policy makers, real-estate professionals) for the integration of co-benefits in the decision-making procedure.

Table 2.6.3-1: Typology of private co-benefits of cost effective energy related renovation measures. [18]

Category	Co-benefit	Description
Building Quality	Building physics	Less condensation, humidity and mould problems
	Ease of use and control by user	Ease of use and control of the renovated building by the users (automatic thermostat controls, easier filter changes, faster hot water delivery, etc.)
	Aesthetics and architectural integration	Aesthetic improvement of the renovated building (often depending on the building identity) as one of the main reasons for building renovation
	Useful building areas	Increase of the useful area (taking advantage of the balconies by glazing or enlarging the existing ones) or decrease of useful area (like the case of applying interior insulation or new BITS). This can also occur because of removal of cold surfaces, making it more comfortable to be nearer to e.g. windows.
	Safety (intrusion and accidents)	Replacement of building elements with new elements at the latest standards, providing fewer risks such as accidents, fire or intrusion.
Economic	Reduced exposure to energy price fluctuations	Reduced exposure to energy price fluctuations gives the user a feeling of control and increased certainty to be able to maintain the desired level of comfort.
User well-being	Thermal comfort	Higher thermal comfort due to better control of room temperatures, higher radiant temperature, lower temperature differences, air drafts and air humidity.
	Natural lighting and contact with the outside	More daylighting, involving visual contact with the outside living environment (improved mood, morale, lower fatigue, reduced eyestrain).
	Indoor Air Quality	Better indoor air quality (less gases, particulates, microbial contaminants that can induce adverse health conditions) better health and higher comfort
	Internal and external	Insulation against outside noise but increased

	noise	risk of higher level of annoyance due to internal noise after the reduction of external noise level
	Pride, prestige, reputation	Enhanced pride and prestige, an improved sense of environmental responsibility or enhanced peace of mind due to energy related measures
	Ease of installation and reduced annoyance	Ease of installation can be used as a parameter to find the package of measures that aggregates the maximum of benefits

Table 2.6.3-2: Typology of macroeconomic benefits of cost effective energy related renovation measures. [18]

Category	Subcategory	Description
Environmental	Reduction of air pollution	Outdoor air pollution is reduced through reduced fossil fuel burning and the minimization of the heat island effect in warm periods. Less air pollution has positive impacts on environment, health and building damages.
	Construction and demolition waste reduction	Building renovation leads to reduction, reuse and recycling of waste if compared to the replacement of existing buildings by new ones.
Economic	Lower energy costs	Decrease in energy costs due to reduced energy demand
	New business opportunities	New market niches for new companies (like ESCOs3) possibly resulting in higher GDP4 growth when there is a net effect between the new companies and those that are pushed out of the market.
	Job creation	Reduced unemployment by labour intensive energy efficiency measures
	Rate subsidies avoided	Decrease of the amount of subsidized energy sold (in many countries, energy consumed by vulnerable users is heavily subsidized).
	Improved productivity	GDP/income/profit generated as a consequence of new business opportunities and job creation
Social	Improved social welfare, less fuel poverty	Reduced expenditures on fuel and electricity; less affected persons by low energy service level, less exposure to energy price fluctuations
	Increased comfort	Normalizing humidity and temperature indicators; less air drafts, higher level of air purity; reduced heat stress through reduced heat islands.

	Reduced mortality and morbidity	Reduced mortality due to less indoor and outdoor air pollution and reduced thermal stress in buildings. Reduced morbidity due to better lighting and mould abatement.
	Reduced physiological effects	Learning and productivity benefits due to better concentration, savings/higher productivity due to avoided “sick building syndrome”.
	Energy security	Reduced dependence on imported energy.

Table 2.6.3-3 [18]: Relationship between co-benefits in a private perspective and specific renovation measures

CO-BENEFIT	Thermal comfort	Natural lighting	Air quality	Building physics	Internal noise	External noise	Ease of use	Reduced exposure to energy price fluctuations	Aesthetics / Architectural integration	Useful living area	Safety (intrusion and accidents)	Pride/prestige	Ease of installation
Facade insulation (external)	1, 2, 6, 7, CS +++	EX -	CS +	EX, CS ++	EX -	6, CS ++		5, CS ++	6 --+	CS +		7, CS ++	
Facade insulation (internal)	1,2,6,7 -++	EX -		EX -	EX -	6 ++		5 ++		3 --		7 +	
Roof insulation	1, 2, 6, 7, CS +++		CS +	CS +	EX -	6, CS ++		5, CS ++		CS +		7, CS ++	
Ground floor insulation	1, 2, 6, 7, CS +++							5, CS ++				7, CS +	
Cellar ceiling insulation	1, 2, 6, 7, CS +++							5 ++				7 +	
Windows replacement	1, 2, 6, 7, CS +++			CS +	EX -	1, 6, 7 +++		5, 7, CS +	7 +		7 ++	7, CS +	
Insulation of entire building envelope	EX +++	EX -		EX, CS ++	EX -	EX ++		EX ++	EX -+			EX ++	
Larger window areas	EX -	6, CS +++											
Roof light or Sun pipes		3 ++						5 +					
External shading	5 ++					5 +		5 +					
Balconies and loggias	6 -++	6 --		6 ++		EX +			6 ++	6, CS ++			
Heat Pump for heating								5,7 +					7, EX ++-
Biomass heating system								5 +					
Efficient DHW system								5,CS ++				CS +	
Automatic control systems							CS +						
Air renewal systems	EX, CS ++		1,4,5, CS +++	1, CS ++	EX -		EX -	5 +					
MVHR systems	EX, CS ++		CS +-	CS +	3 --			5 +				CS +	
Solar Thermal systems								7,CS ++				7,CS ++	7 ++

2.5.4 Annex 56: Evaluation of the impact of energy related renovation measures on selected Case Studies

Within this scheme, six unique case studies from six different countries were chosen, studied and analysed. Those case studies are presented as exemplary projects for building retrofitting, in each participant country. The target is to provide significant and practical results with a scientific background. For this reason and for each of the case studies, measurements on LCC, CO_2 emissions and primary energy consumption were issued, with the target of testing the correlation between different refurbishment approaches on the building envelope, the use of RES and their meeting point. For the residential buildings analysed in the case studies, the hypotheses of the generic calculations were tested.

Figure 2.6.4-1 [19]: Fundamental hypotheses of the generic calculations in Annex 56

1. **The energy performance of the building depends more on how many building elements are renovated than on the energy efficiency level of individual building elements.**
2. **A switch to RES reduces emissions more significantly than energy efficiency measures on one or more envelope elements.**
3. **A combination of energy efficiency measures with RES measures does not change significantly the cost optimal efficiency level.**
4. **Synergies are achieved when a switch to RES is combined with energy efficiency measures.**
5. **To achieve high emission reductions, it is more cost effective to switch to RES and carry out less far-reaching renovations on the building envelope than to focus on energy efficiency measures alone.**

Figure 2.6.4-2 [19]: Results of the hypothesis testing for the five residential buildings of the case studies

Hypothesis	Austria	Denmark	Portugal	Spain	Sweden
The energy performance of the building depends more on how many building elements are renovated than on the energy efficiency level of individual building elements.	✓	✓	(✓)	✗	✗
A switch to RES reduces emissions more significantly than energy efficiency measures on one or more envelope elements.	✓	✓	✓	(✓)	✓
A combination of energy efficiency measures with RES measures does not change significantly the cost optimal efficiency level.	✓	(✓)	✓	✓	(✓)
Synergies are achieved when a switch to RES is combined with energy efficiency measures.	✓	✗	✓	✓	✓/✗
To achieve high emission reductions, it is more cost effective to switch to RES and carry out less far-reaching renovations on the building envelope than to focus on energy efficiency measures alone.	✓	✓	(✓)	✓/✗	✓

Conclusions were drawn for each case study regarding the annual carbon emissions, the life cycle cost, and the total primary energy consumption. Diagrams plotted to visually compare the results are presented below.

Carbon emissions. In the Figure 2.6.4-3 the calculated annual carbon emissions of the six case studies are plotted. The reference cases carbon emissions are in light green and compared with the lowest carbon emissions resulting from the investigation for the refurbishment packages. The distance between the minimum and the maximum CO_2 emissions resulting from the study of the packages is shown using the arrow. Figure 2.6.4-4 demonstrates the carbon emissions potential for each of the case studies. The absolute (light yellow) and the relative (orange) reduction potentials. The arrow indicates the range between minimum and maximum reduction.

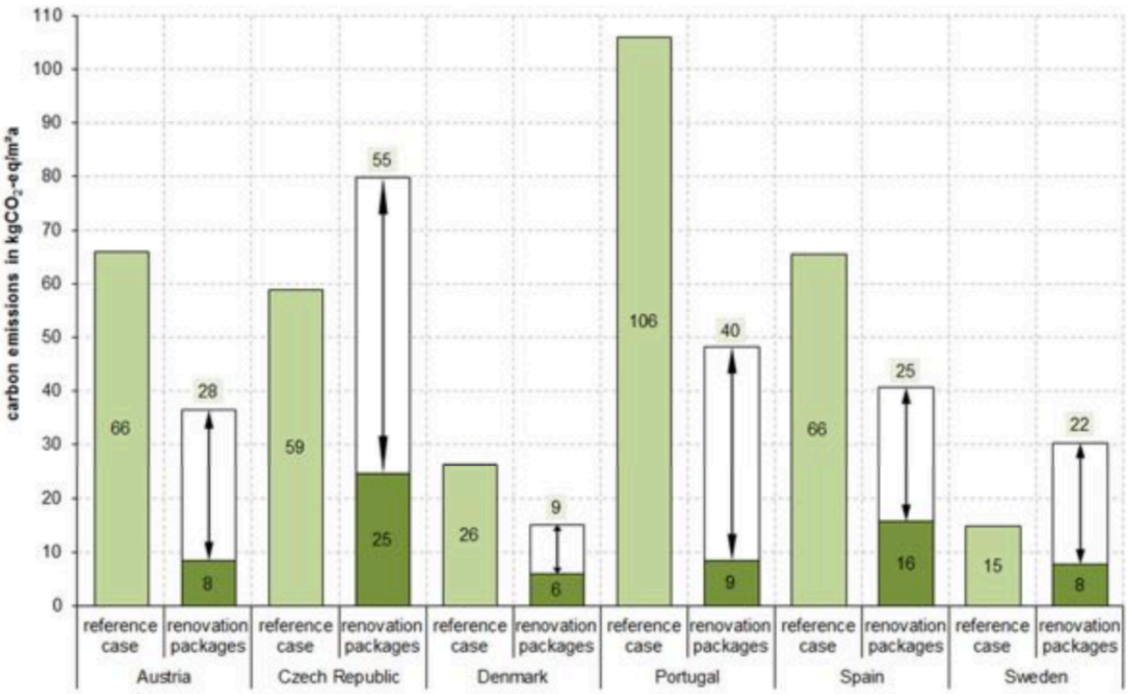


Figure 2.6.4-3: Carbon emissions of the six case studies. [19]

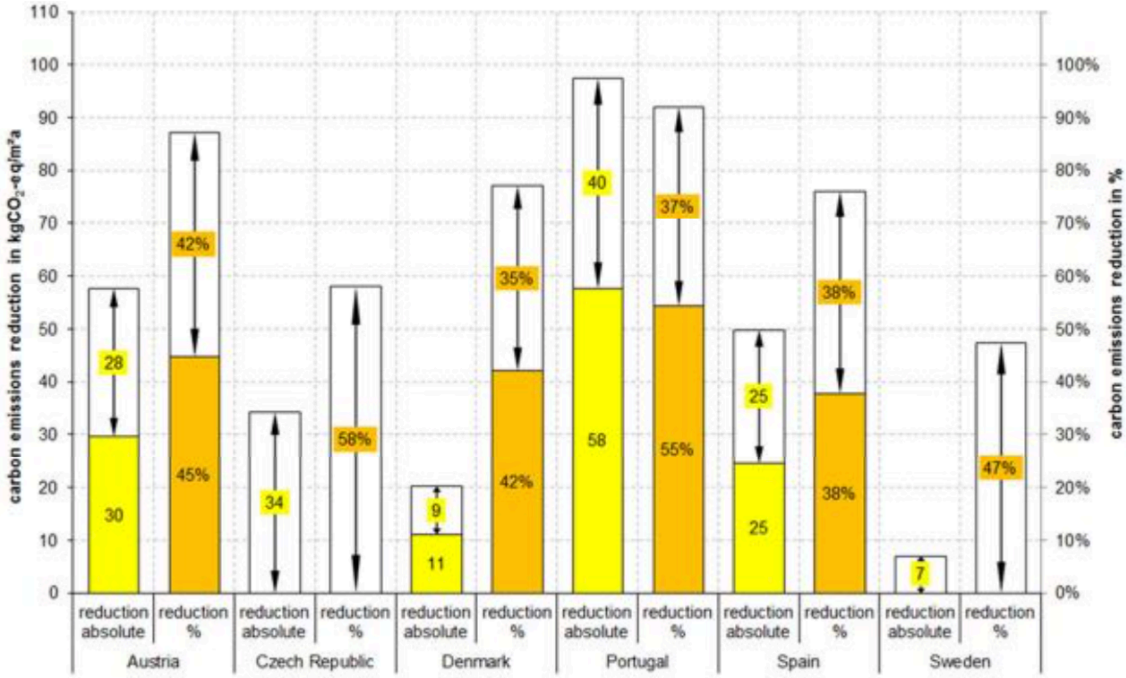


Figure 2.6.4-4: Carbon emissions reduction potential of the six case studies. [19]

Life Cycle Cost. In Figure 2.6.4-5, a comparison of the reference cases (light red) with the renovation packages achieving the lowest carbon emissions (dark red) is presented. In most studied cases, the renovation packages appear be cost-effective, that is to have lower Life Cycle Cost than the LCC of the reference case. The cost-optimum cases are also marked with the yellow arrows. In addition, Figure 2.6.4-6 shows the estimated Life Cycle Cost reduction of the case studies, in the CO_2 emissions optimal renovation package scenario compared with the individual reference cases LCC.

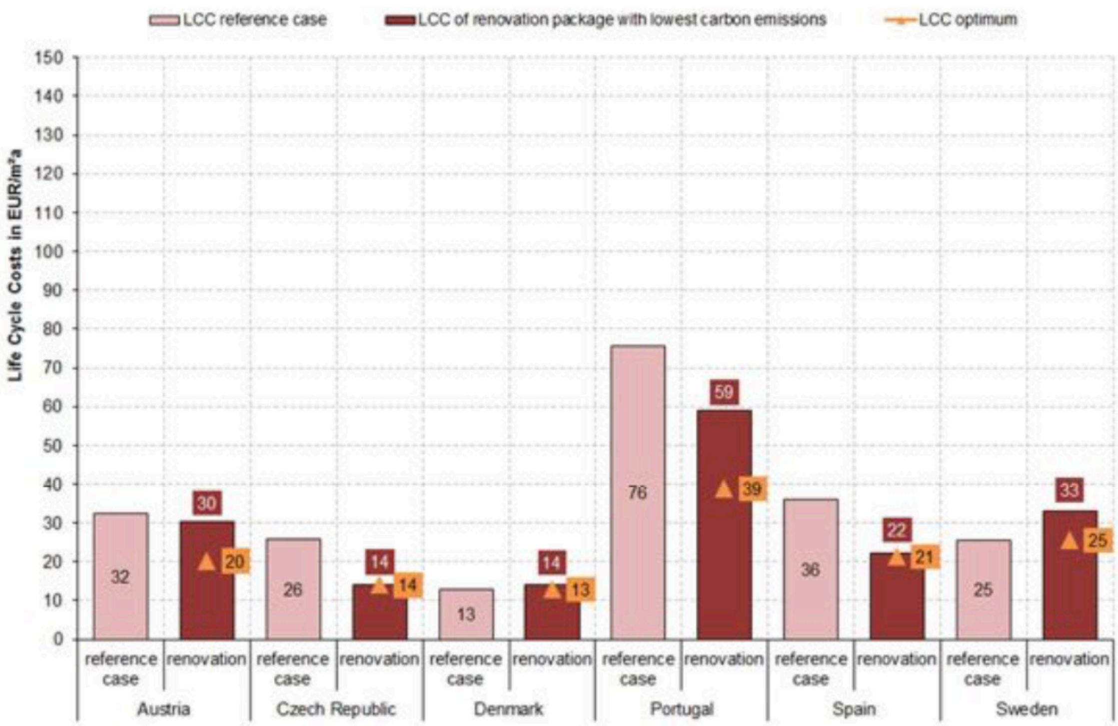


Figure 2.6.4-5: Life Cycle Cost comparison chart. [19]

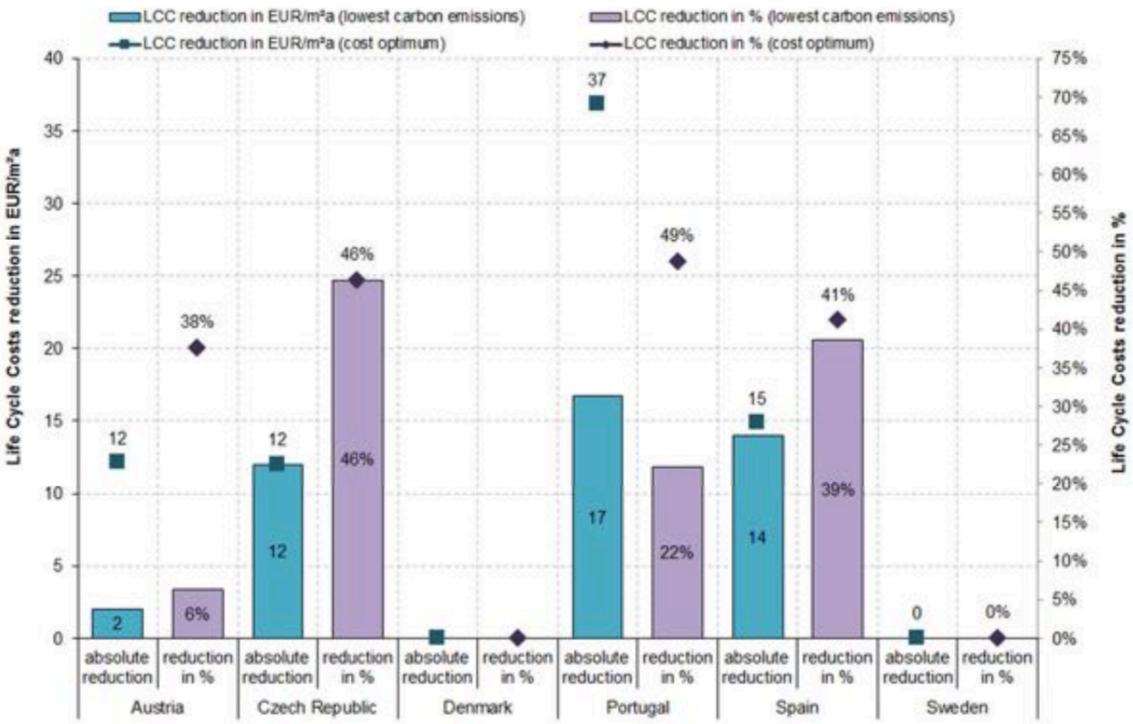


Figure 2.6.4-6: CO_2 optimal renovation scenario with reference Life Cycle Cost comparison chart. [19]

Total primary energy. In Figure 2.6.4-7 the total primary energy of the reference cases (light blue) is compared to total primary energy of the case studies renovation packages (dark blue). The range between renovation package scenarios is demonstrated using the arrow. Figure 2.6.4.8 demonstrates the total primary energy reduction potential of the six case studies in absolute (light yellow) and relative (orange) terms. The arrow shows the difference in potential between distinct refurbishment scenarios for the same case study.

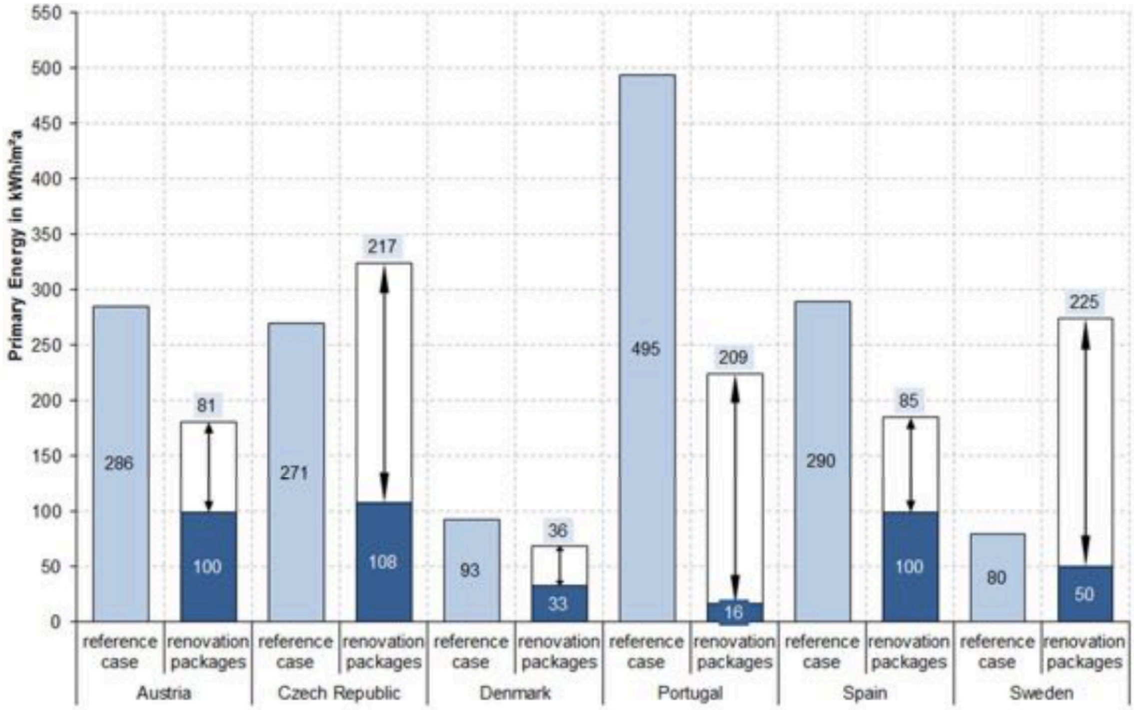


Figure 2.6.4-7: Comparison between the total primary energy of the reference case with the total primary energy of the six case studies. Arrows indicate the range between the renovation package scenarios. [19]

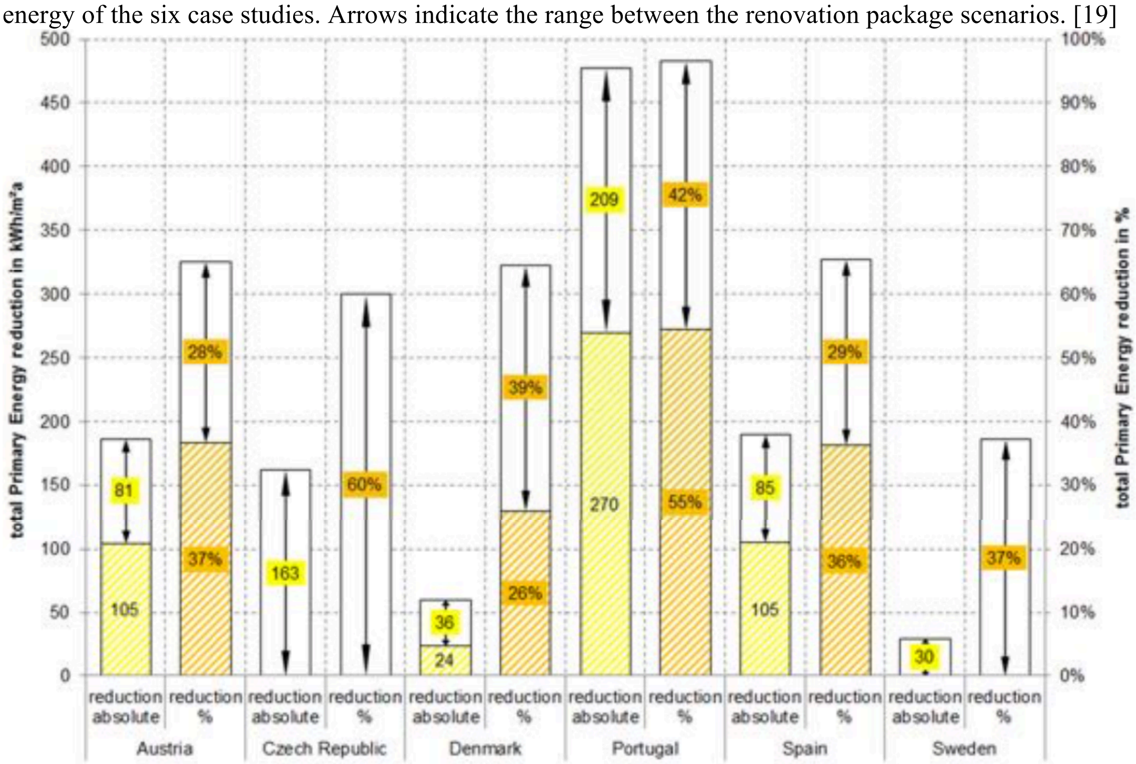


Figure 2.6.4-8: Comparison between the total primary energy of the reference case with the total primary energy of the six case studies. Arrows indicate the range between the renovation package scenarios. [19]

Figure 2.6.4-9 presents the comparison between the LCC of the reference cases (light red) with the primary energy optimal renovation scenarios of the case studies (dark red). The chart indicates that almost all renovation packages achieving the lowest primary energy are cost effective. The potentials of the LCC reduction while minimizing the total primary energy, are shown in Figure 2.6.4-10. The reductions are presented in absolute values of EUR/m^{2}a and in relative reductions.

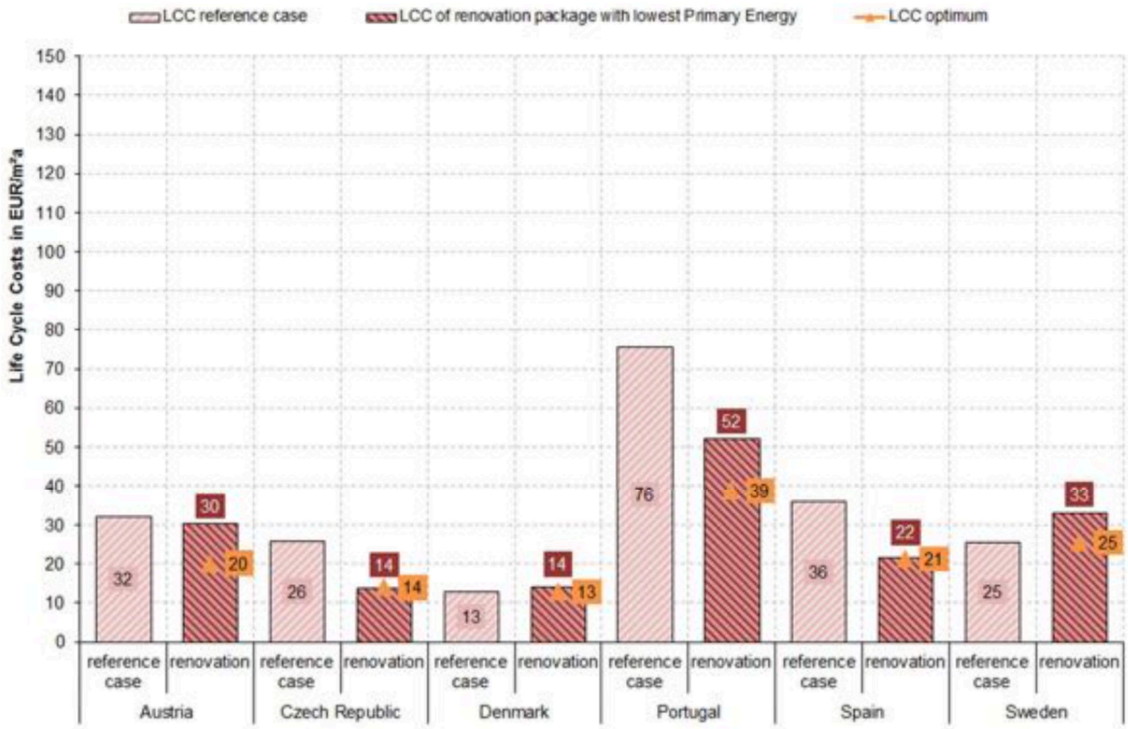


Figure 2.6.4-9: Comparison between LCC of the reference cases with the lowest primary energy renovation scenarios of the case studies. [19]

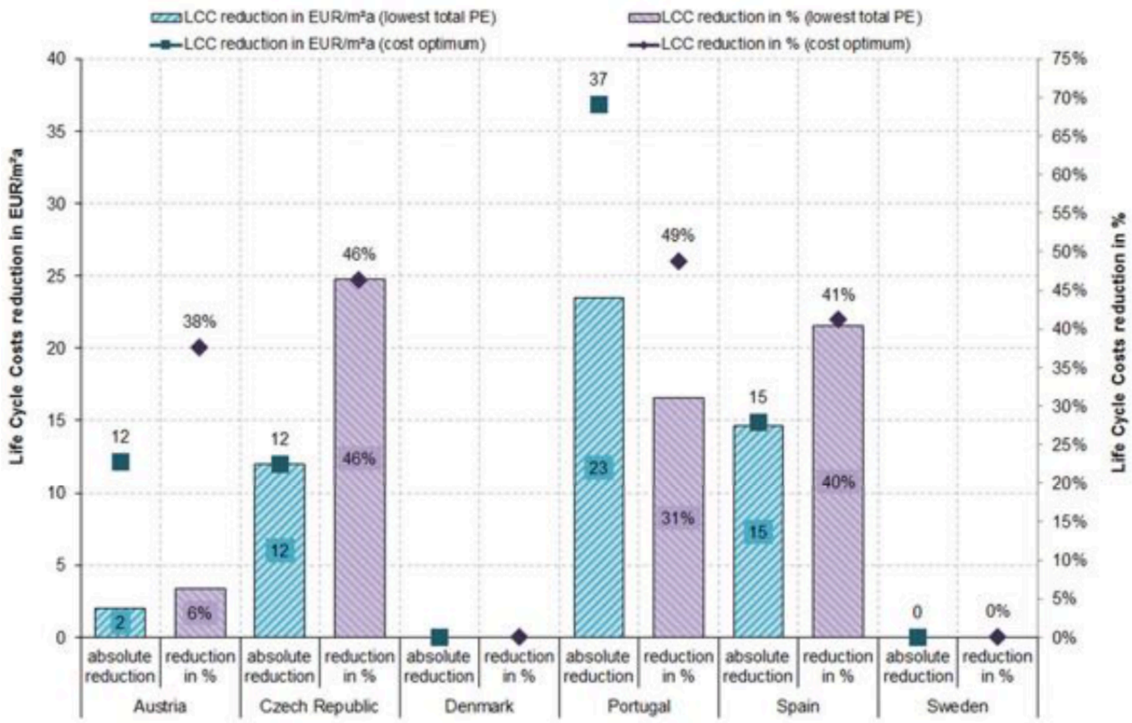


Figure 2.6.4-10: Absolute and Life Cycle Cost reduction potentials of the case study lowest total Primary Energy and the Cost Optimum reference case scenario. [19]

2.5.5 Annex 56: Life cycle Assessment

The Life Cycle Assessment report presents the LCA methodology and its implementation on the six European case studies. It concludes with some recommendations derived from the results regarding the Life Cycle Assessment and the embodied energy in building renovation. The report includes the following parts [20]:

- The LCA methodology for energy related retrofitting.
- The implementation of the LCA methodology in the six case studies.
- The national conversion factors for primary energy and CO_2 emissions.
- The influence assessment of the embodied energy and carbon emissions in the results of the case studies.
- Recommendations for the policy makers and the building owners.

2.5.6 Annex 56: Methodology for Cost - Effective Energy and Carbon Emissions Optimization in Building Renovation

This report presents the methodology and methodological guidelines, focusing in residential and small office buildings with simple HVAC systems. The methodology report concerns the following fields [21]:

- Evaluation and assessment of cost-effective mitigation of the primary energy and carbon emissions, considering the Life Cycle Impacts of the renovation.
- Explanation of the connection between the CO_2 emissions and the energy targets, the correlation of energy efficiency and RES development and use.
- Evaluation of different measures of cost-effective energy retrofitting actions and combinations.
- Presentation of the co-benefits deriving from the energy refurbishment.

The report includes the following parts:

- Scopes and perspectives for the assessment. Scope of energy use and carbon emissions, private and societal perspective for the cost and impact assessment.
- Definition of the system boundaries for the cost assessment and the CO_2 emissions, taking into account the energy use and the production of renewable energy.
- Definition of the concepts, approaches, units, metric, conversion factors.
- Establishing a scheme for the cost assessment and defining the cost-optimality and the cost-effectivity in the energy efficiency and RES use measures.

- Determine the energy demand of the building for heating and cooling considering its location and weather data.
- Employ LCA methodology to acknowledge the life cycle impacts of the retrofitting regarding the embodied primary energy.
- Identification of co-benefits and methods to integrate them into the assessment procedure of the refurbishment results.

The general basic approach in the cost analysis is the application of a reference situation, an "anyway" renovation [Figure 2.6.5-1] as a measure to compare the scenarios. This "anyway" reference renovation includes all the building renovation measures that are not executed with an energy related intention, but they are needed to support the maintenance and functionality of the building. In order to determine the results of the energy related scenarios, it is assumed that the energy related measures are undertaken at the exact moment of a building "anyway" retrofit, for unrelated to energy improvement reasons Figure 2.6.5-1.

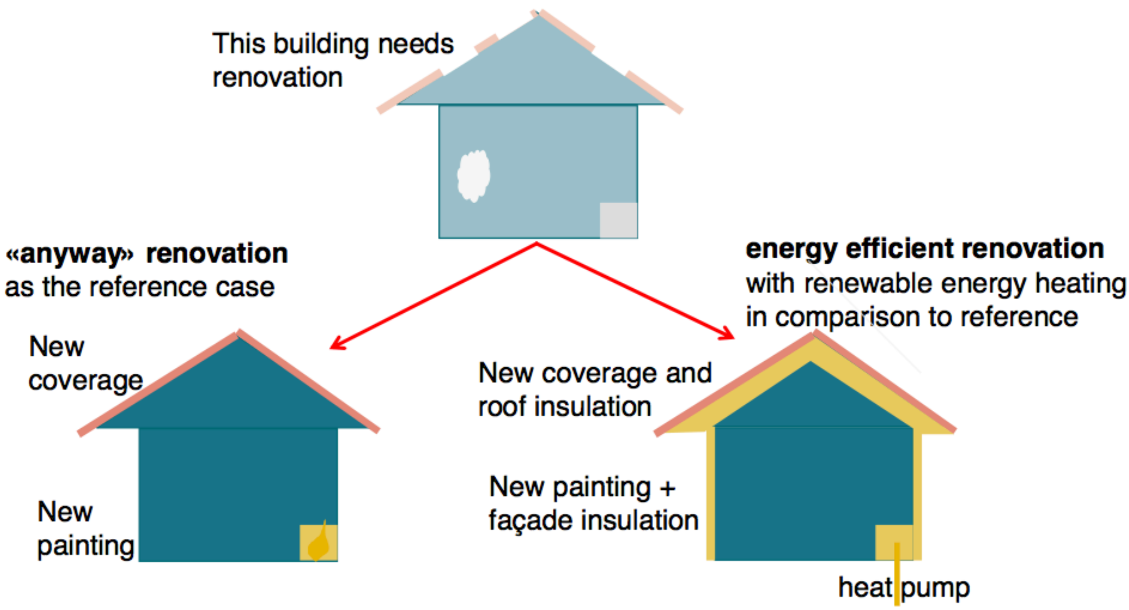


Figure 2.6.5-1: Anyway renovation in comparison to Energy related renovation example [21]

2.6 Greek Residential Building Stock Typology

2.6.1 Research for the typology of the Greek residential buildings

In 2016, the Energy Saving Team of the Institute for Environmental Research and Sustainable Development (IERSD), National Observatory of Athens (NOA), published two reports under EPISCOPE project. The report "Greek Residential Buildings Typology – Energy Saving Dynamic" [27] and the report "Possibilities and prospects for the energy upgrading of the Greek building stock" [28].

2.6.2 Greek Residential Buildings Typology – Energy Saving Dynamic

"Greek Residential Buildings Typology – Energy Saving Dynamic" report, was the result of a project that took place between 2012 – 2016. This study is created to integrate the TABULA - EPISCOPE typology and methodology with the Greek building stock condition. Taking into consideration the necessity for the greenhouse gas emissions mitigation, it studies Greek building stock characteristics through the issued energy certificates data provided by the Ministry of Environment and Energy.

After referring to the European and Greek legislation and expected efficiency achievements under 2010/31/EC and 2012/27/EC, the report presents in a simplified way, some energy saving general measures, identifying the positive and the negative effects associated with each specific measure (e.g., the use of insulation on the walls increases the energy efficiency of the building envelope. It may reduce significantly the energy need, but it has a high initial cost). It also gives practical directions to the building users for the energy use mitigation, such as the adaptation the user's dressing even inside the residence depending on the season, to maintain the heating equipment at the end of the winter every year, reduce the thermostat temperature for the DHW and more.

The third and main part of the report, delivers examples of energy saving interventions in existing buildings. The TABULA typology included 24 building types describing the majority of Greek residential buildings. What happened with EPISCOPE, regarding Greece, is that the building certificates data were extended to include residential buildings, constructed after 2011 under the directions of the 2010 Greek regulation for the energy performance of buildings [29].

The TABULA building typology approach for Greece, was made using the main parameters of building age and building size (SFH-MFH) already described in paragraph 2.4.3 [2.4.3 IEE PROJECT – TABULA], adding the parameter of the climatic zone [30], of the building location.

Age of the building. The age is important because of the energy efficiency and insulation regulation existence. The buildings constructed until 1980 had no insulation at all. The buildings constructed between 1980 – 2001 had poor insulation. Even though "Thermal Insulation of Buildings Regulation" [31] was introduced in 1979, little or poor true application on the construction sites happened at least until 2000. The buildings constructed between 2001-2010 are considered having all the insulation demanded by the "Thermal Insulation of Buildings Regulation". The buildings after 2010 are considered being fully insulated according to the "Regulation for the Energy Performance of Buildings" [29].

Size of the building. Statistical observations (presented in the next chapters) showed that the size of the building matters a lot in its energy needs. Apart from the statistics, it is more expected for a Multi-Family House (MFH) to be located inside a city than in a rural area. Thus, the environmental conditions are different and those buildings' energy efficiency approach cannot be the same.

Climatic zone. According to the Third Technical Direction of the Technical Chamber of Greece [30], published under the Greek regulation for the energy performance of buildings [29], the Greek national area is divided in four climatic zones from the warmest to the coolest, depending on the Heating Degree Days (HDD) of each area.

- Zone A (601-1100 HDD)
- Zone B (1101-1600 HDD)
- Zone C (1601-2200 HDD)
- Zone D (2201-2620 HDD)

A location with an altitude more than 500 m, is transferred in the next coolest climatic zone.

The overall TABULA Greek generic building types are 32 as the result of 2 sizes (SFH & MFH) x 4 construction periods (<1980, 1981-2000, 2001-2010, 2011<) x 4 climatic zones (Zones: A, B, C, D), plus 2 more types depending on the construction characteristics of the building envelope and the heating & DHW system used with a total of 34 types.

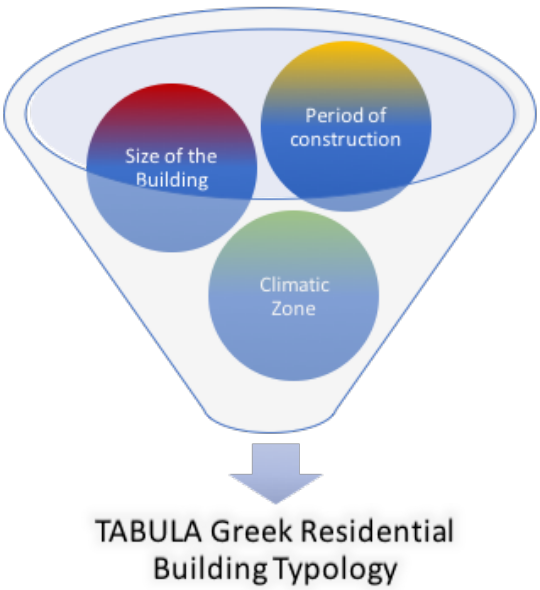


Figure 2.7.2-1: Parameters defining the Greek TABULA residential building typology. [27]

Figure 2.7.2-2: Table of parameters defining the Greek TABULA residential building typology. [27]

Parameter	Number of Parameters	Explanation
1. Size if the Building	2 sizes	SFH - MFH
2. Period of Construction	4 periods	up to1980, 1981-2000, 2001-2010, 2011+
3. Climatic Zone	4 zones	A,B,C,D (KENAK)

As shown in later paragraphs, the data indicate that the energy demand for heating in residential buildings is as high as 73% of the total energy need. The emphasis of this study was in energy need for heating and DHW as it represents most the energy needed.

For each building type, the team selected an existing building as a representative example of the building type. Depending of the building type, four energy refurbishment scenarios were applied, the basic scenario, the optimistic scenario, the upgraded building scenario and the KENAK+ scenario.

Basic scenario. The basic scenario applies all the typical interventions suggested by KENAK in the case of full building refurbishment. Especially for the buildings of the period 2001-2010, the interventions target the energy rating class B, as for those relatively new buildings there is not a full renovation option.

Optimistic scenario. The optimistic scenario uses the basic scenario adding sustainable energy sources and innovative energy saving technologies.

Regarding the buildings constructed from 2011 onwards, the interventions are essentially alternative construction solutions for the same building, including three different thermal system solutions (Oil boiler, Gas boiler, Heat pump).

Upgraded building scenario. This scenario applies lower thermal conductivity coefficient (U_{value}) on the opaque elements by 0.05 W/m^2K, while the transparent surfaces have 20% lower U_{value} compared to KENAK. The heating systems scenarios are applied per climatic zone:

- Climatic zones C: Condensing oil of natural gas (only zone C) boiler for space heating. DHW is 75% heated by solar thermal and 25% from the boiler.

KENAK+. U_{value} of opaque elements lowers by 0.15 W/m^2K and of transparent elements by 40% comparing to KENAK. The heating systems scenarios include the following:

- Climatic zones A & B: Condensing oil boiler or high temperatures heat pump both combined with solar thermal for space heating. DHW is 100% heated by solar thermal systems. Photovoltaics are installed for sustainable electricity supply.

- Climatic zones C & D: Condensing oil or natural gas boiler or low temperatures heat pump connected to floor heating system and combined with solar thermal for space heating. DHW is 100% heated by solar thermal systems. Photovoltaics are installed for sustainable electricity supply.

The software used for the energy calculations is TEE KENAK software, which is the official calculation tool for the energy certification of buildings in Greece. For the calculations, the assumptions made were in accordance with the Technical Directions of Technical Chamber of Greece, with the most significant being the directions included in TOTEE 20701-1/2010 [32] for the operating period of a residence (18h per day for a 365 days year), the heating period (1st of November to the 15th of April in climatic zones A & B, 15th of October to the 30th of April for zones C & D) and the thermostat set at 20^{o}C.

The results are presented in the form of two-page brochures [Figure 2.3.7-2]. In the first page the building technical characteristics and energy systems are described including the results for its energy performance. In the second page the results of the scenarios are presented for both scenarios depending on the building type. A short description of the renovation measures, the primary energy saving percentage, the per source energy per square meter, the energy need, the CO_2 emissions, the annual operational cost and the reduction percentage are also included in the second page. The initial investment cost and the payback period were calculated excluding VAT

17	**Multi Family House** *(GR-ZONEB-MFH-02)*				
Age class	1	**2**	3		
Climatic zone	A	**B**	C	D	
Heated area (m2)	1356				
Volume (m3)	4610				

Description

Free standing building, with four exposed facades (4 floors). A total of 12 apartments. The long axis of the building is oriented SW-NE. Sub-urban area.

Construction

Walls	Not insulated. Brick with concrete rendering.
Load bearing	Not insulated
Roof	Not insulated, flat. Concrete.
Windows	Single glazed with metal frames
Shutters	External plastic shutters
Floor	Not insulated, pilotis.

Thermal transmittance (W/m²K)

Wall	2.2 / 3.4
Roof	3.1
Floor	2.75
Windows	6.1
g-windows (-)	0.58

Expenditure coefficients

	SH	DHW
Generation	1.25	1.00
Storage	--	1.00
Distribution	1.14	1.02

Systems

Generation	Central oil boiler, well thermally insulated, well maintained.
Distribution	Single pipe, well insulated.
Solar system	21 m²
DHW	Electric heaters

Annual Energy Performance

Demand	92.6 kWh/m²
Thermal energy	137.6 kWh/m²
Electricity	6.7 kWh/m²
Primary energy	171.6 kWh/m²
CO_2 emissions	58.2 tn
Fuel (oil)	184151lt
Electrical	9085 kWh
Operational cost	15.6 €/m²

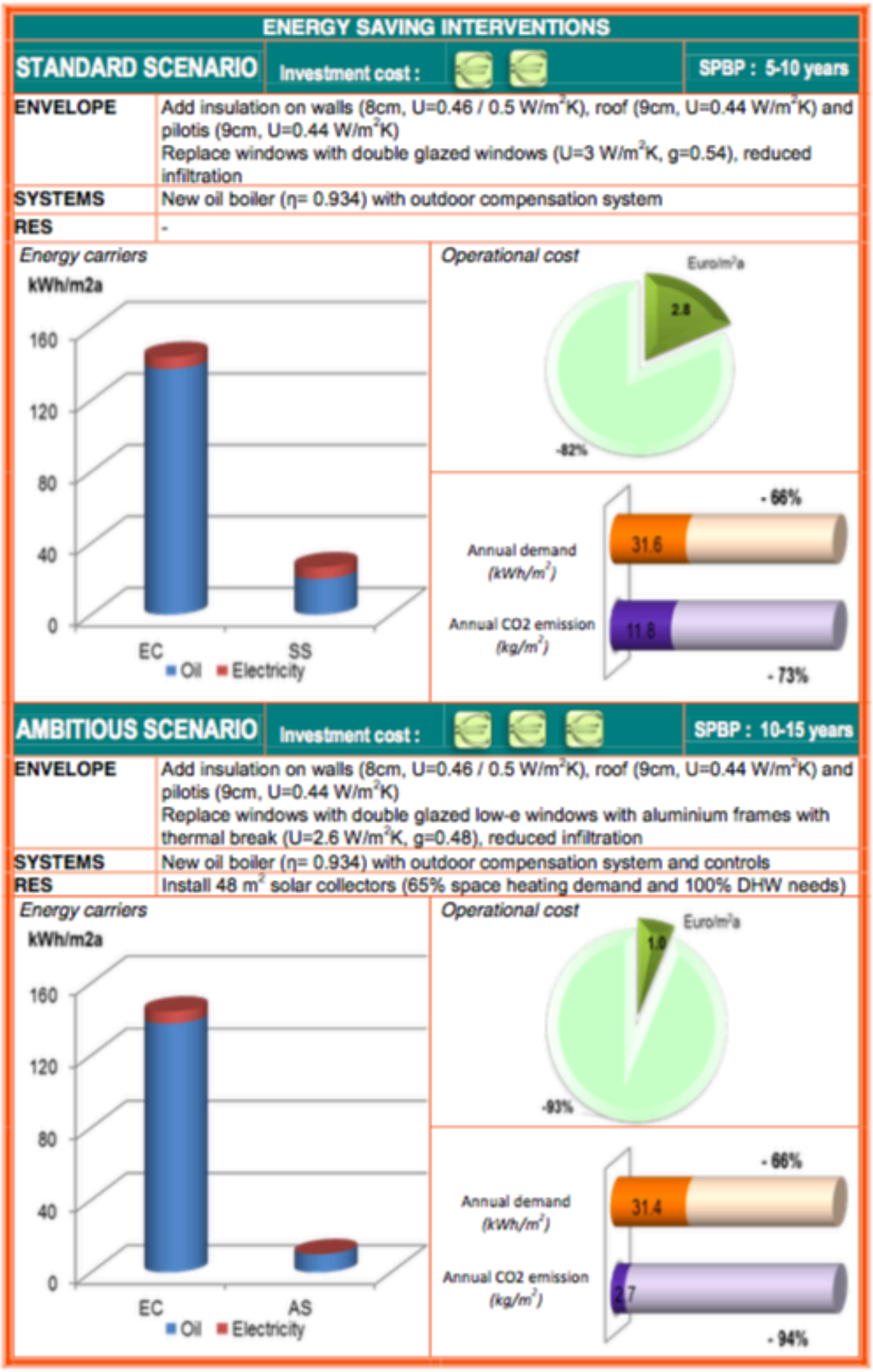


Figure 2.7.2-3: Exemplary two-page TABULA Brochure. [27]

3 Problem Definition - Data

3.1 Energy consumption, climate change and IAQ

The increase in the world energy consumption along with the climate change rate increase, demand scientific and political action, to find a solution in the next years. The scientific studies agree on the need for reduction of the primary energy consumption and the necessity for independence from fossil fuels. These actions will have an immediate impact in the CO_2 emissions reduction, mitigating the greenhouse effect. On the other hand, the building structures, must comply with the latest standards for IAQ and the range of each parameter affecting it, must be maintained inside the desired limits. To achieve the IAQ targets and at the same time reduce the CO_2 emissions of a building, a dynamic approach is needed with the use of engineering software to create models simulating the environmental conditions and the building properties, to achieve the desired building performance.

3.2 The energy balance in Greece

According to the report "Typology of Greek Residential Buildings – Energy saving potential" conducted by the National Observatory of Athens (NOA), Institute for Environmental Research and Sustainable Development (IERSD), Energy Saving Team, under EPISCOPE program [27], the final energy consumption in Greek buildings equals to approximately 5.6 millions tons of oil equivalent. This amount, accounts for 37% of the total in 2013. The building sector in Greece is responsible for the 65% of the total electricity consumed and for the 56% of the total national carbon emissions.

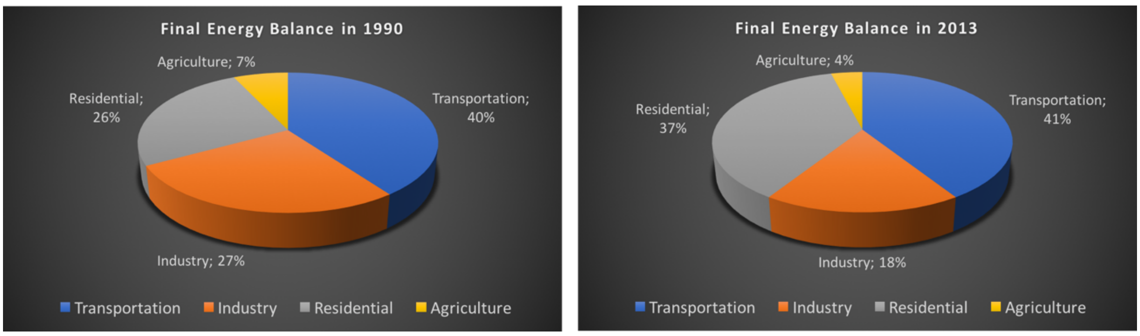


Figure 3.2-1: Final Energy Balance in Greece (1990 and 2013). [27]

In 2013 the final energy consumption in residential buildings was 3.8 MTOE, accounting for 25% of the total energy consumption while the commercial buildings accounted for 1.8 MTOE or 12%. The amounts of these values in 2012 were respectively 5,04 MTOE in residential and 2.23 MTOE in commercial buildings sectors. The cause of the decrease in energy consumption though, is not a result of energy efficiency of the building stock increase but a result of IAQ reduction in Greek buildings because of the economic crisis.

3.3 Greek National Targets under 2012/27/EU

In 2014, with the National Action Plan for Energy Efficiency, Greek Ministry of Environment and Energy introduced the National Targets for Energy conservation, for the period 2014-2020, at 3.33 MTOE [33]. According to 2012/27/EU in 2020 the European Union primary energy consumption, must not exceed 1474 MTOE (902,1 KTOE per year) [2]. The Greek policy measures in buildings, target mainly the residential sector, with a conservation plan of 523 KTOE per year until 2020.

3.4 Properties of National residential building stock

3.4.1 Yearly final energy consumption per household

In 2013, the press release on energy consumption in households, was published by the Hellenic Statistical Authority [34]. This report is the result of data collected during October 2011 – September 2012. The data have been collected by end-use energy consumption (domestic heating – cooling, DHW, lighting etc.), as well as on quantities and type of fuels used. Additional data was also recorded regarding the energy consumption habits of the users, the type and number of devices used and the systems installed while concerning the use of energy efficient technologies and the socio-economic characteristics of the households. The results have shown that on average every household in Greece, consumes annually 13994 KWh of primary energy.

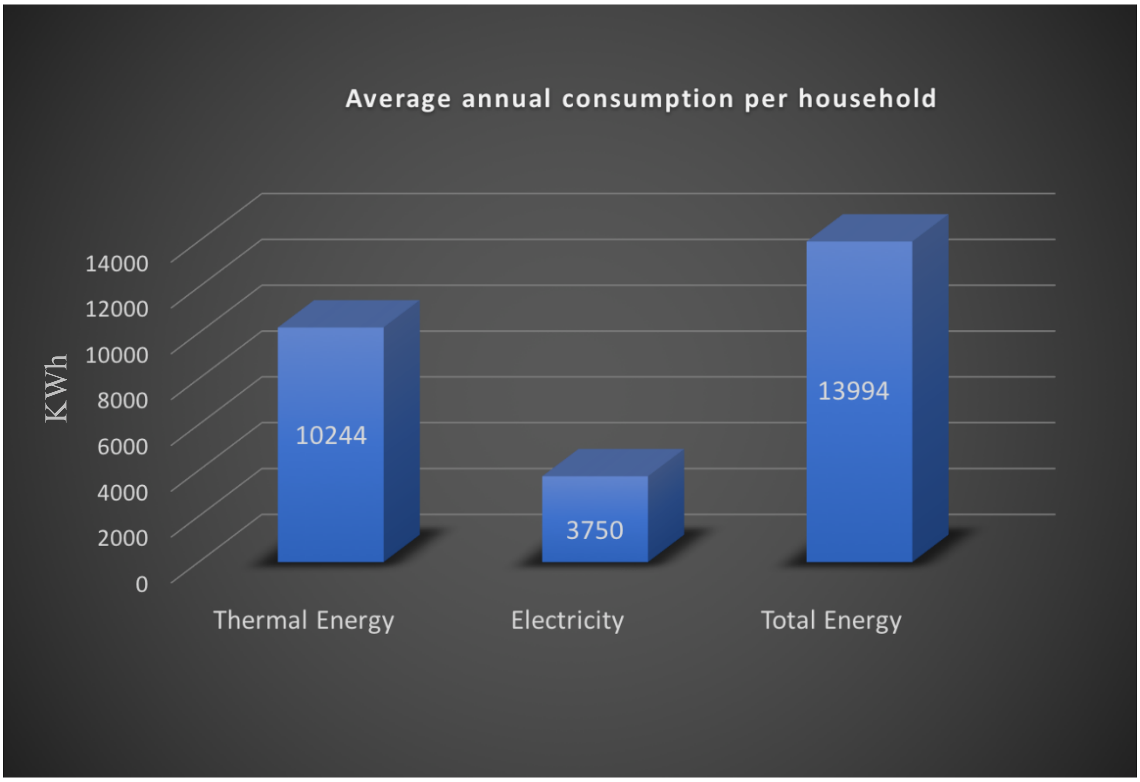


Figure 3.4.1-1: Average yearly primary energy consumption per household. [34]

Through the survey it has also been possible to estimate the annual average total consumption by fuel type used, as well as by type of end use.

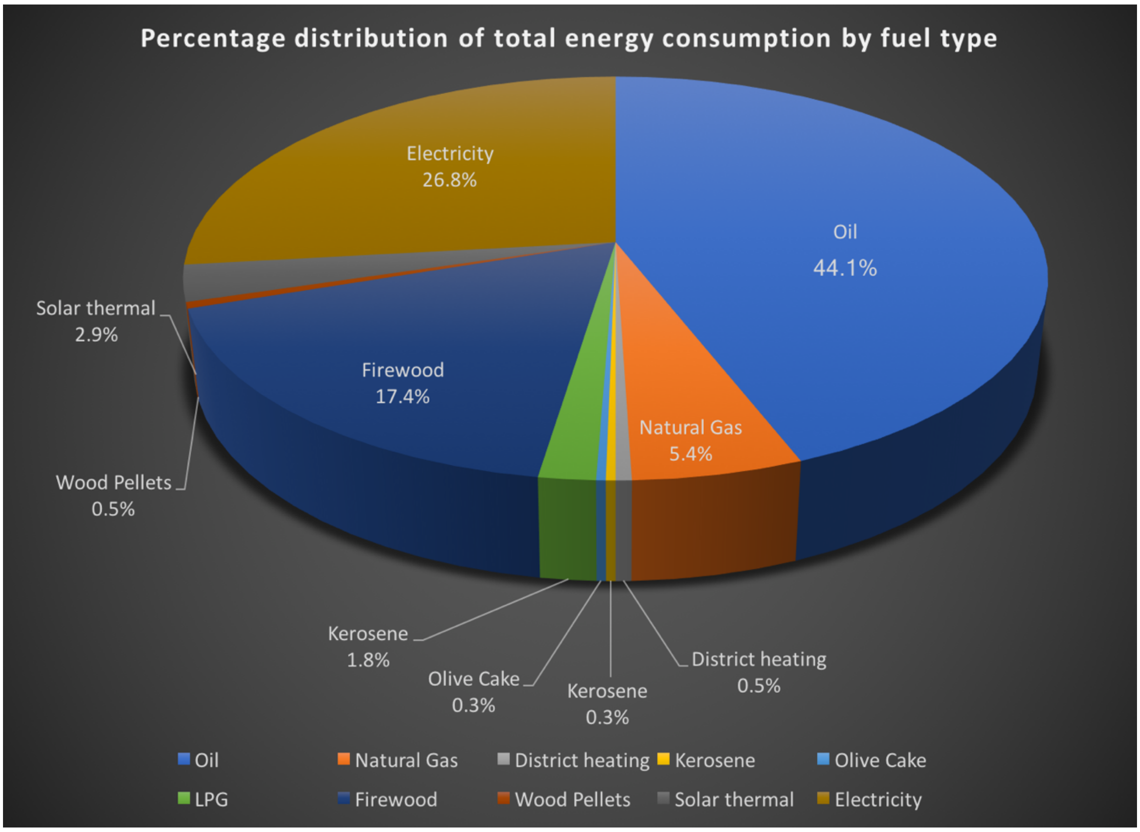


Figure 3.4.1-2: Percentage distribution of total primary energy consumption by fuel type. [34]

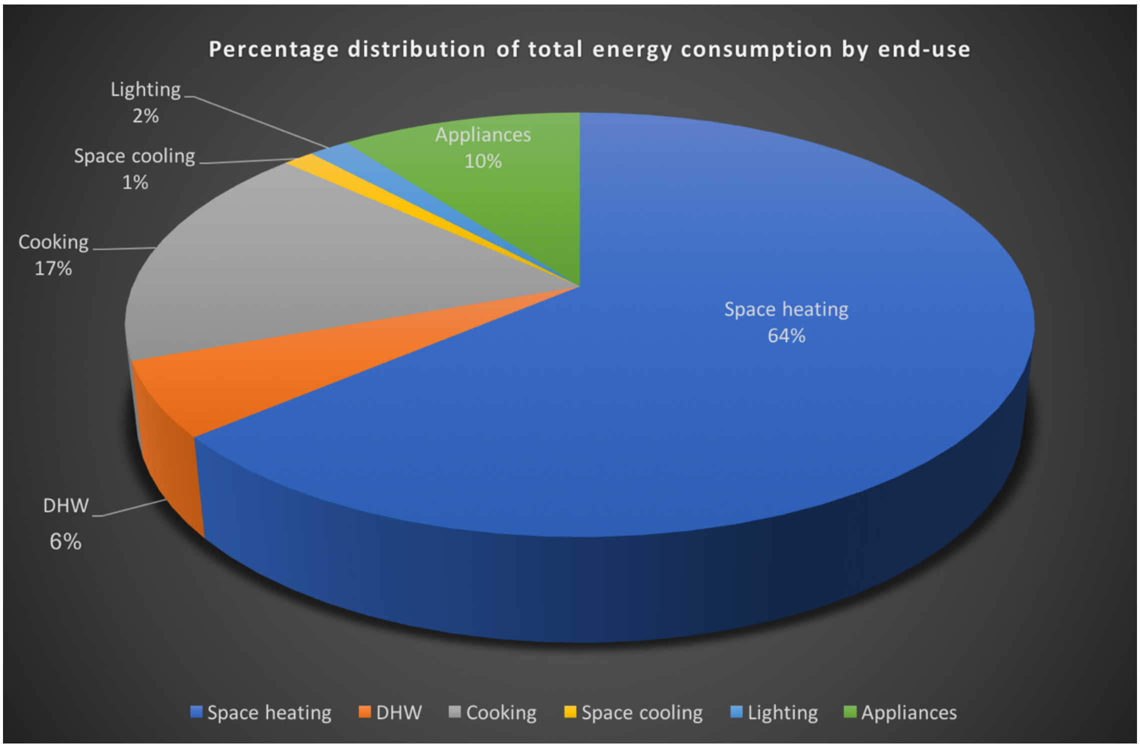


Figure 3.4.1-3: Percentage distribution of total primary energy consumption by end-use. [34]

3.4.2 Thermal energy by end-use

It is shown in Figure 3.4.1-1 that thermal energy consumed in residential buildings, on average accounts for 73% of the total final energy used, with a value of 10440 KWh per household per year. Of this amount, it is estimated that 85.9% is intended to cover the needs for heating, 4.4% is needed for DHW provision and 9.7% is used for cooking. The annual average consumption of thermal primary energy by fuel type is presented in Figure 3.4.2-1. The dominating fuel is oil with a use of 60.3%, while Natural Gas is only at 7.4%.

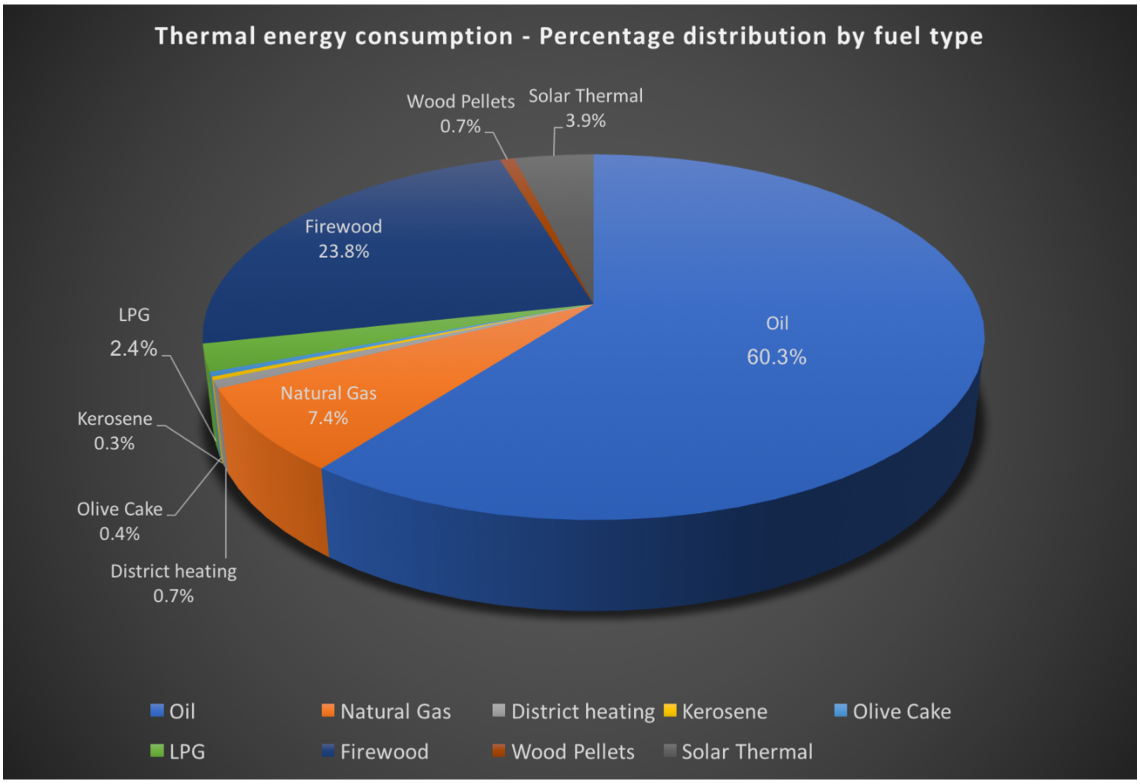


Figure 3.4.2-1: Thermal energy consumption - Percentage distribution by fuel type. [34]

3.4.3 Electricity consumption by end-use

Electricity consumption was estimated based on the electricity bills and the characteristics and use of the appliances during a four-month period, extrapolated for the whole year. The results shown that 38.4% of electricity is used for cooking, 14.7% for refrigeration, 10.6% for the laundry machine, 6.6% for lighting and 4.9% for cooling.

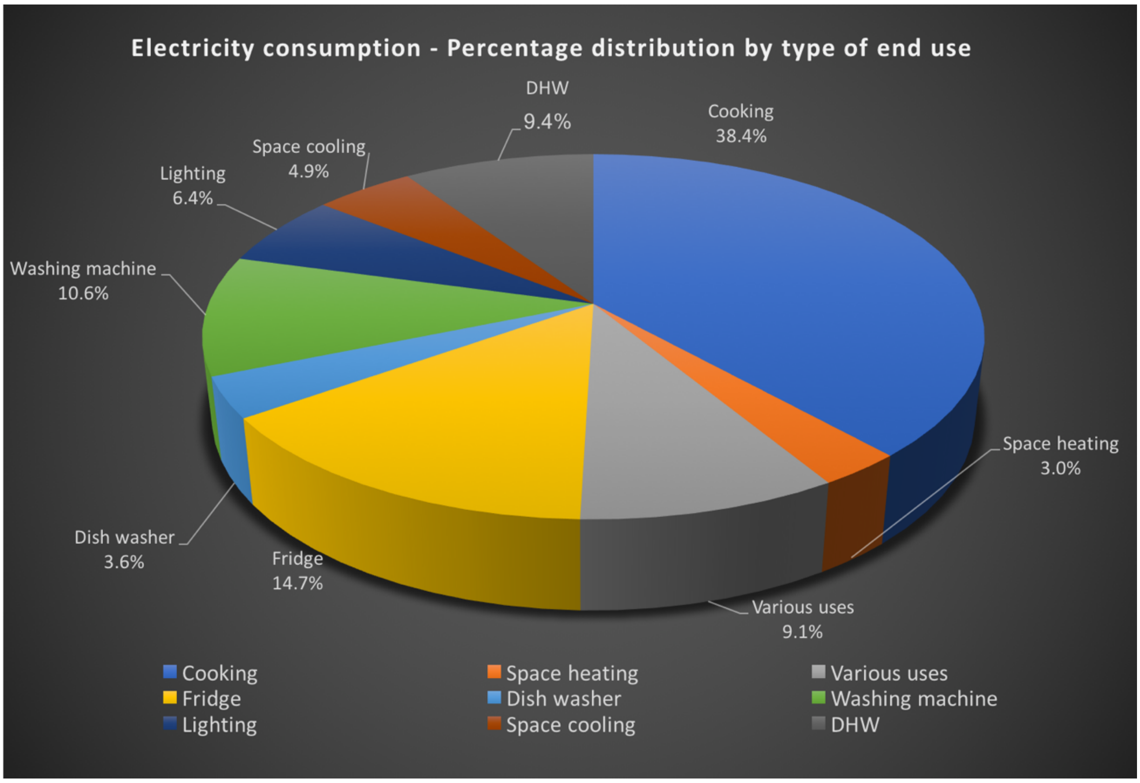


Figure 3.4.3-1: Electricity consumption - Percentage distribution by type of end use. [34]

3.4.4 Urbanization as a consumption parameter

The energy consumption in Greek households, is influenced by the level of urbanization of the area the building is located. It has been calculated that a Greek household uses almost half the total thermal energy compared to a rural area residence. On the other hand, the urban households consume approximately 25% more electricity than a residence established in a rural area [Figure 3.4.4-1]. The urbanization related distributions of the total energy consumption by end-use and by fuel type are presented respectively in the Figure 3.4.4-2 and Figure 3.4.4-3.

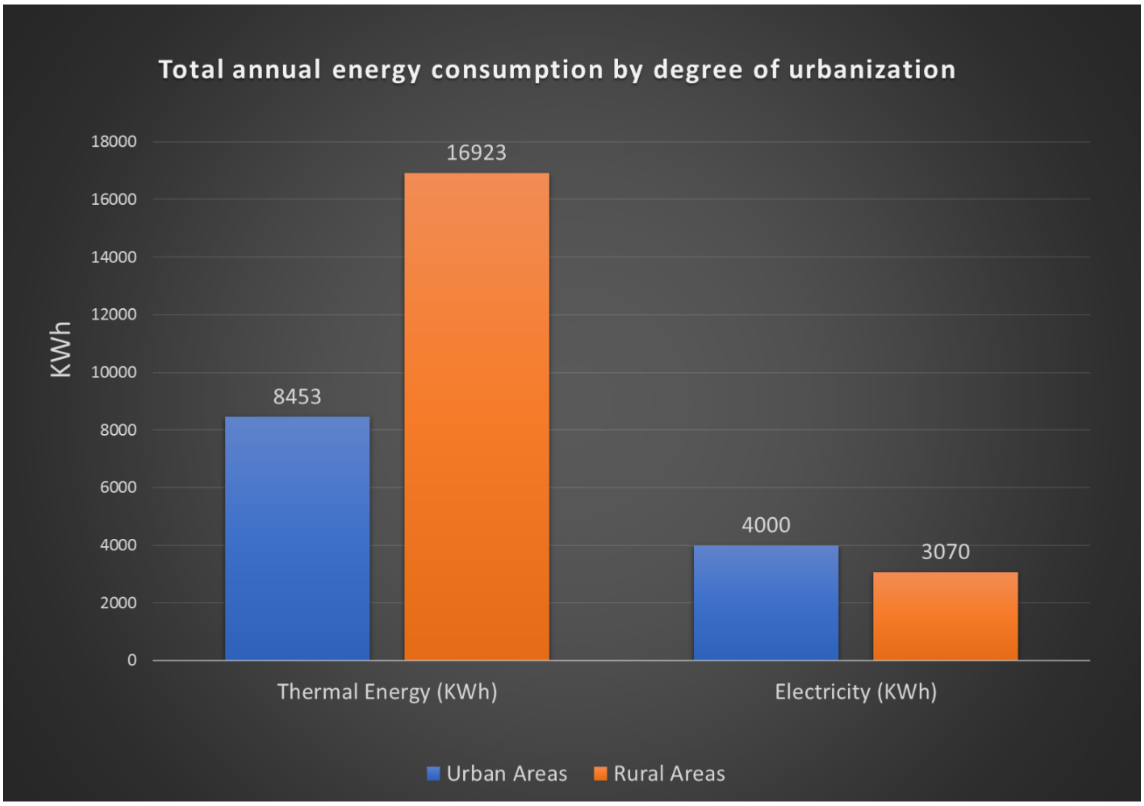


Figure 3.4.4-1: Percentage distribution of annual total energy consumption by degree of urbanization.[34]

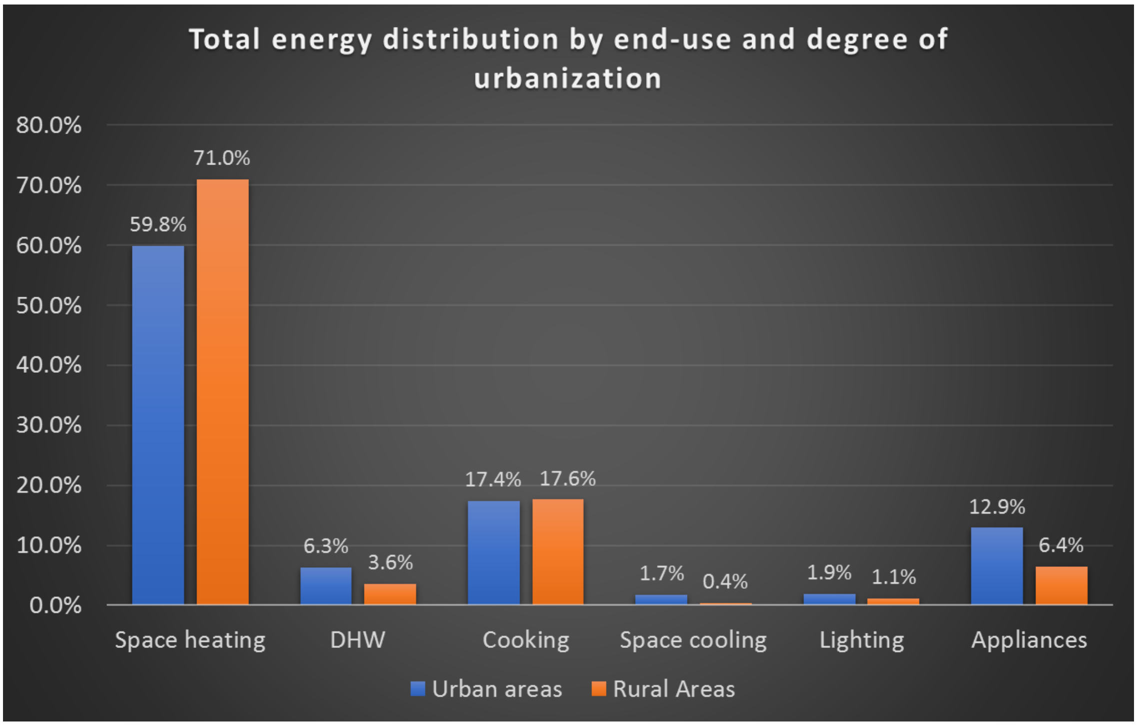


Figure 3.4.4-2: Percentage of total energy distribution by end-use and degree of urbanization. [34]

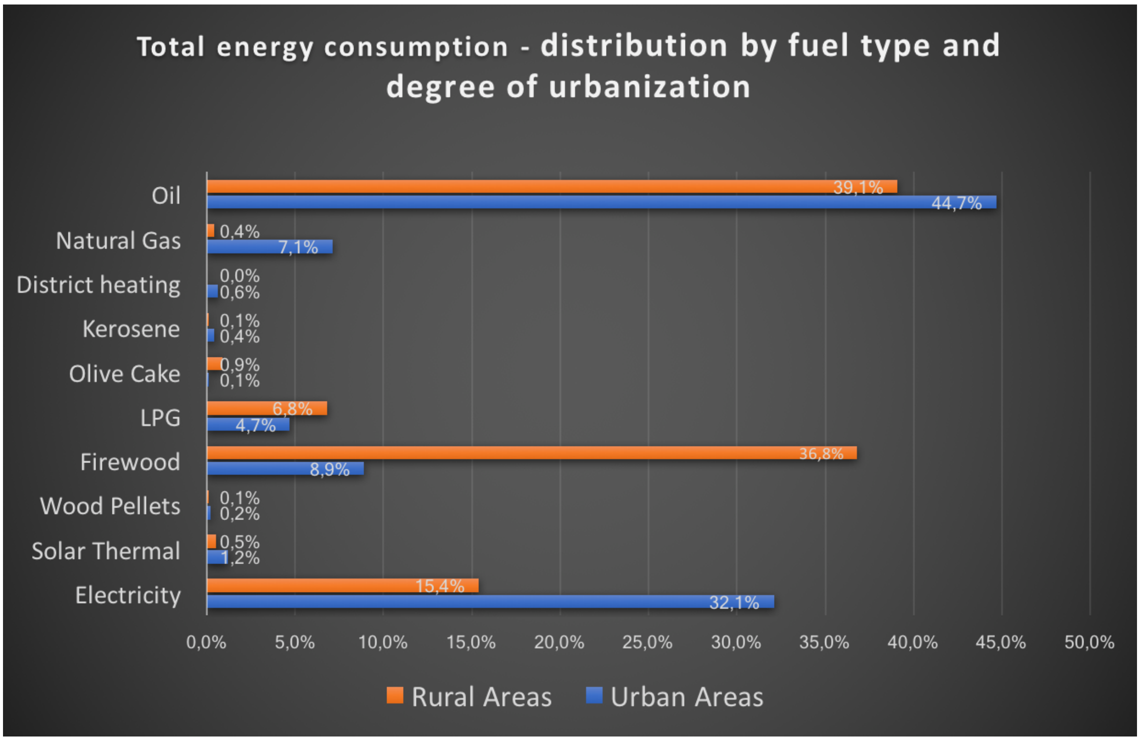


Figure 3.4.4-3: Percentage of total energy distribution by fuel type and degree of urbanization. [34]

3.4.5 Characteristics of the permanent use residential building stock

By the term permanent use building stock, it is meant that the buildings studied are used at least six months per year, translating into three months in the winter and three months in the summer.

Area. A percentage of 42% is on the ground floor of buildings while 53.4% are on the upper floors. The surface of the residences on average is 84.8 m^2. 23.6% have an area up to 60 m^2, 41.7% from 60 up to 90 m^2 and 34.7% have a floor of more than 90 m^2.

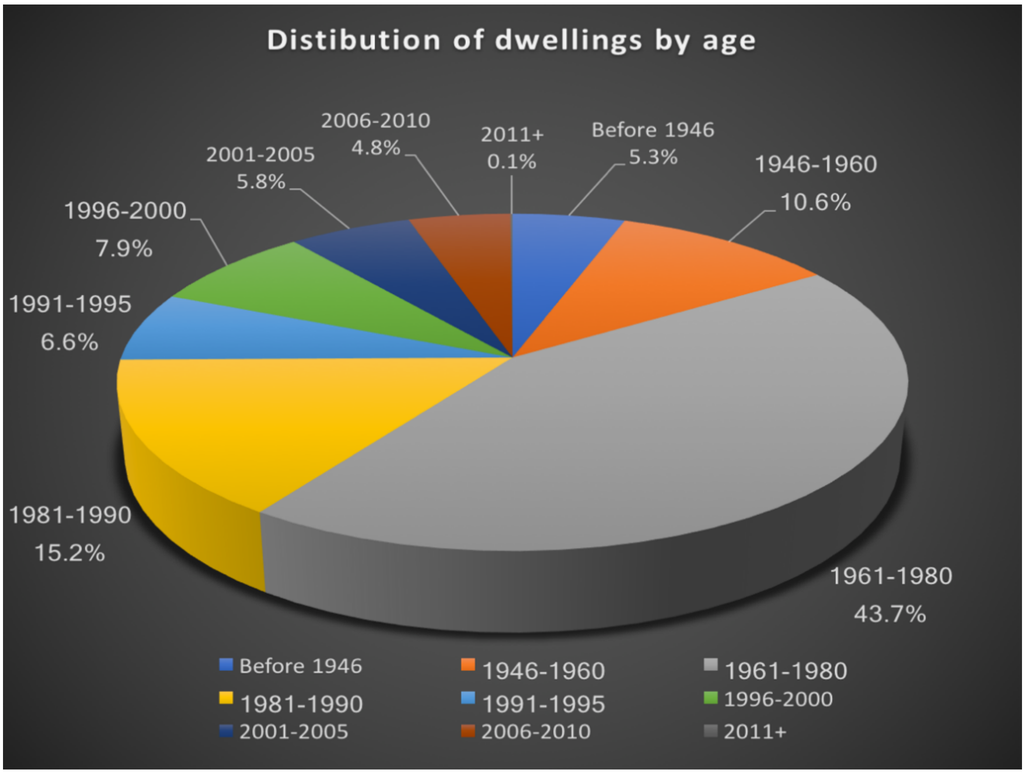


Figure 3.4.5-1: Percentage distribution of Greek dwellings by age of construction. [34]

Thermal Insulation. Almost 60% of the Greek residential buildings have been completed before the first Greek regulation for thermal insulation (1979) while until 2012 only 0.1% of the total residential building stock was constructed in compliance with 2002 EPBD. Thus, only about 50% of Greek dwellings have some kind of thermal insulation.

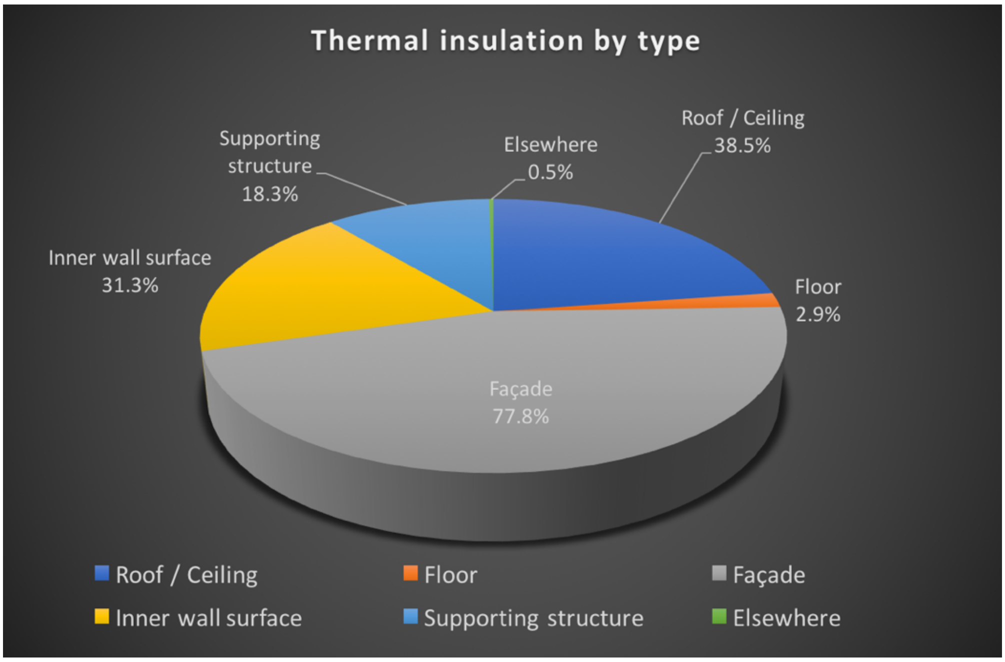


Figure 3.4.5-2: Type of thermal insulation in dwellings. [34]

Space heating. Almost all Greek dwellings use a heating system. In 2011, the systems used were 50.8% central heating system, 48.6% used an autonomous system and 0.6% district heating. 65.3% of the central heating system users, have an autonomous switch.

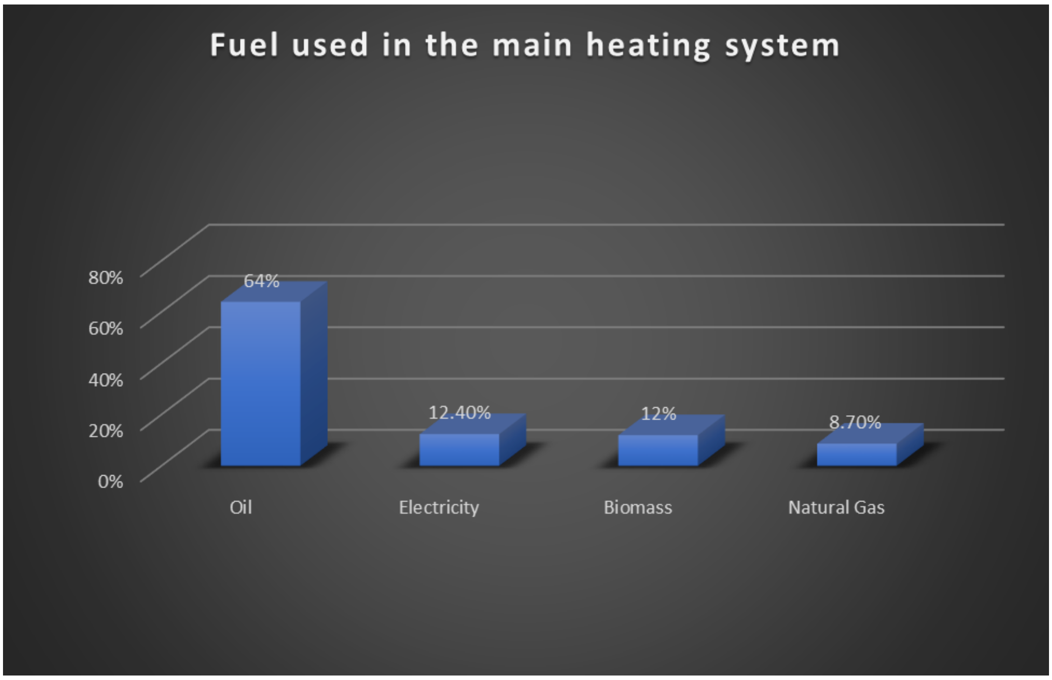


Figure 3.4.5-3: Fuel used in the main heating system in Greek households. [34]

DHW. 98.6% of the dwellings have a DHW production system. Of those users, 74.5% use an electric boiler, 37.6% solar thermal, and 25.2% use the central heating system for DHW production.

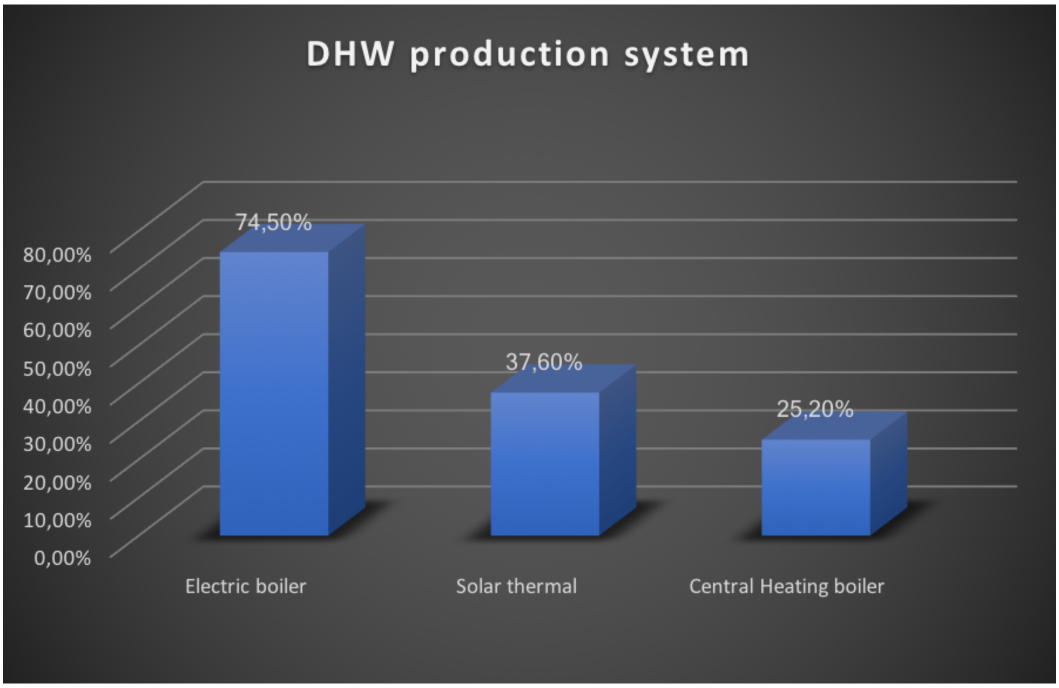


Figure 3.4.5-4: Domestic Hot Water production system usage. [34]

Space Cooling. Almost 60% of the households use a cooling system. Of those systems, 99.7% are split-type air conditioning units with the rest using a central cooling system.

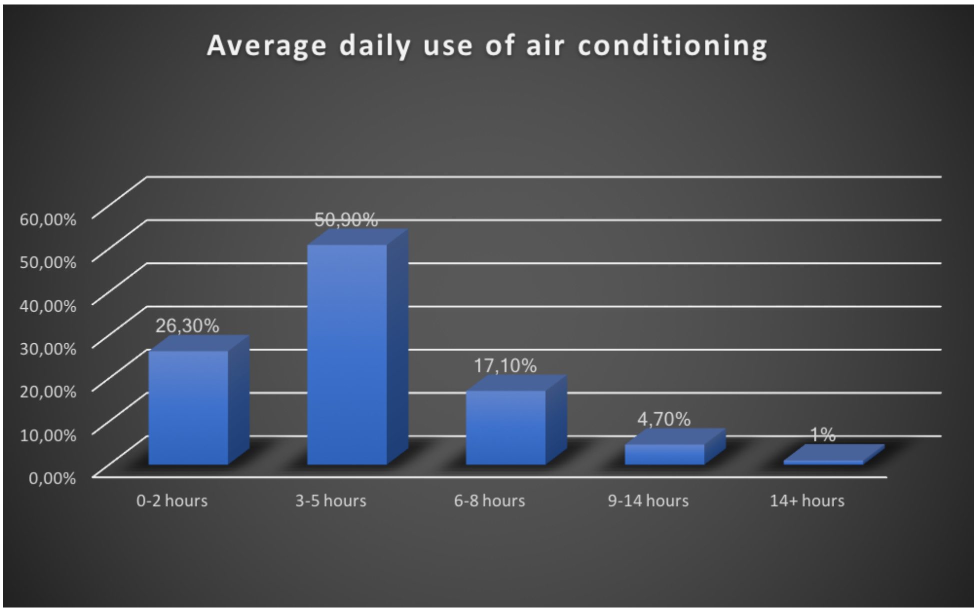


Figure 3.4.5-5: Average daily use of air conditioning in hours. [34]

3.4.6 User's Behaviour

For a building to work efficiently in energy terms, it is essential that the users act towards efficiency with their behaviour. External shading must be used when there is a need for shading, the thermostats must be set appropriately, the lights must be turned off when not needed, etc. A thermostat set in the correct range of temperature (18-20 ^{o}C in winter and 26-28 ^{o}C in summer) may decrease the average thermal energy consumption by 13% for space heating and 15% for space cooling respectively. Natural cooling in summer nights, can reduce the electricity consumption for cooling by 21%, while households washing their clothes or dishes only when they are full (according to the appliance capacity), end up with a consumption reduction of 17% for washing.

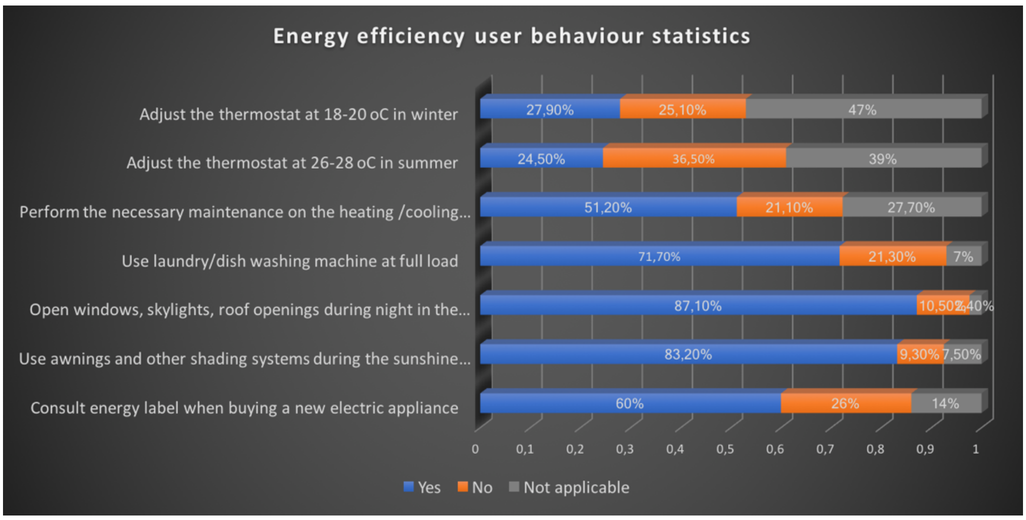


Figure 3.4.5-5: Average daily use of air conditioning in hours. [34]

3.5 Greek Residential Building stock - Energy Certificates data

3.5.1 Compliance of Greek legislation with the European directives

With the regulation for the energy performance of buildings in 2010, the Greek parliament introduced the register of energy inspectors of buildings. This regulation was a result of L.3661/2008 and was created in compliance of the Greek legislation with the European directive 2002/91/EC [35]. The Register of Energy Inspectors and Energy Inspection archive was created under the Greek ministry for Environment and Energy.

3.5.2 Energy Certificates results and statistics for Greece

The Greek ministry of Environment and Energy, is publishing statistics on its website, extracted from the Energy Certification of Greek buildings. For the Greek residential building stock, the last update on the data was on the 30th of September 2017. Those data are presented below in the Figure 3.5.2-1 to Figure 3.5.2-10.

Figure 3.5.2-1: Number of Energy certificates per construction decade and energy category plot (residential buildings). [36]

Number of Energy Certificates (residential buildings)										
	A+	**A**	**B+**	**B**	**C**	**D**	**E**	**Z**	**H**	**Total**
<1960			1	31	135	467	1265	2848	6962	**11709**
1960-1970	3	4	81	539	3366	9844	24352	49907	121829	**209925**
1970-1980	3	9	158	1002	6916	19985	42498	69892	121201	**261664**
1980-1990	1	15	204	1739	15287	31270	34842	22123	32109	**137590**
1990-2000	3	19	218	2553	23781	42125	25330	8648	7446	**110123**
2000-2010	17	74	966	10755	65386	71312	25394	6129	4188	**184221**
2010<	49	125	1467	6264	5592	2648	708	201	193	**17247**
Total	**76**	**246**	**3095**	**22883**	**120463**	**177651**	**154389**	**159748**	**293928**	**932479**

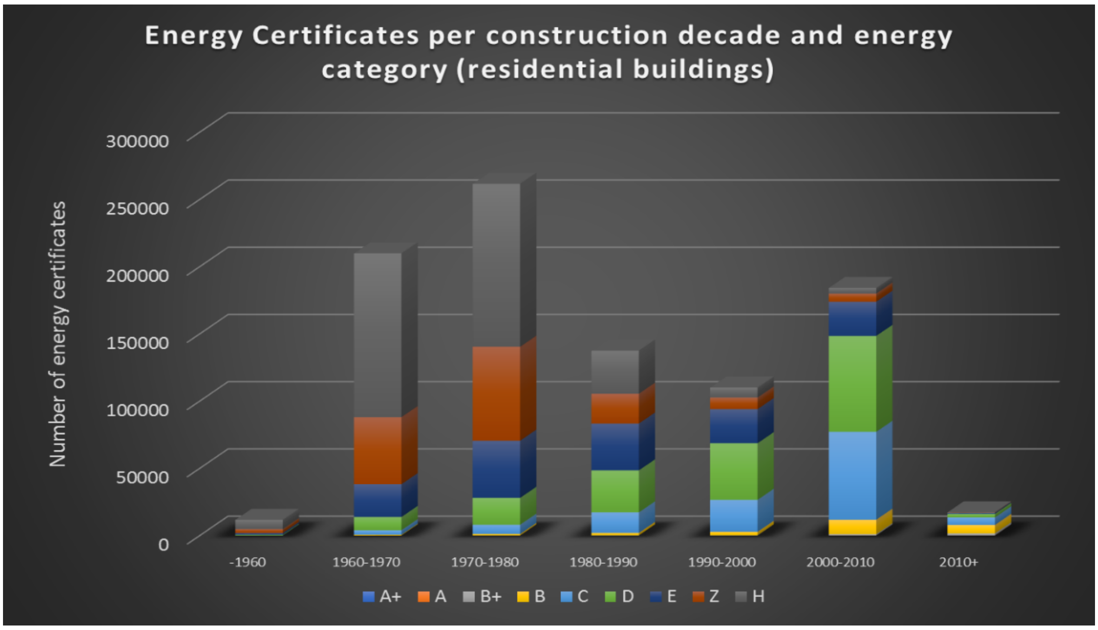


Figure 3.5.2-2: Number of Energy certificates per construction decade and energy category plot. [36]

Figure 3.5.2-3: Number of Energy certificates per construction decade and use (residential buildings). [36]

Number of Energy Certificates per construction decade and use (residential buildings)								
USE	**<1960**	**1960-1970**	**1970-1980**	**1980-1990**	**1990-2000**	**2000-2010**	**2010<**	**Total**
Single-Family House (SFH)	2622	53123	25804	22980	13791	20501	4623	**143444**
Multi-Family House (MFH)	9087	156802	235860	114610	96332	163720	12624	**789035**
Total	**11709**	**209925**	**261664**	**137590**	**110123**	**184221**	**17247**	**932479**

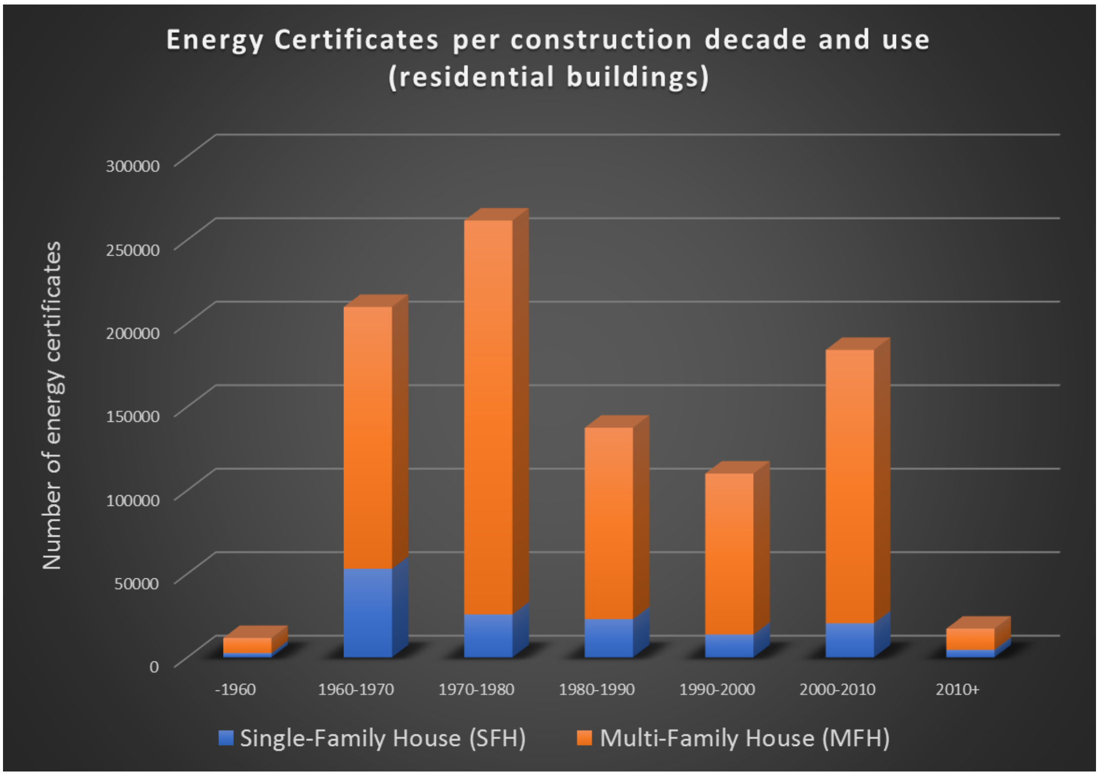


Figure 3.5.2-4: Number of Energy certificates per construction decade and use (residential buildings). [36]

Figure 3.5.2-5: Number of Energy certificates per use and energy category (residential buildings). [36]

Number of energy certificates per use and energy category										
USE	**A+**	**A**	**B+**	**B**	**C**	**D**	**E**	**Z**	**H**	**Total**
Single-Family House (SFH)	33	105	804	4024	12590	20323	18211	16640	70714	**143444**
Multi-Family House (MFH)	43	141	2291	18859	107873	157328	136178	143108	223214	**789035**
Total	**76**	**246**	**3095**	**22883**	**120463**	**177651**	**154389**	**159748**	**293928**	**932479**

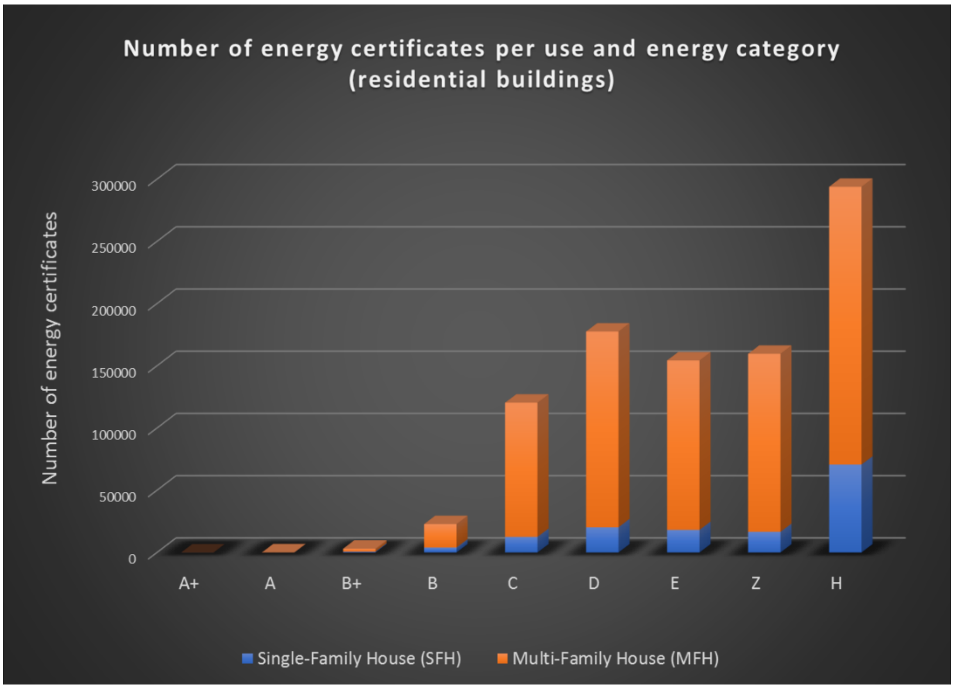


Figure 3.5.2-6: Number of Energy certificates per use and energy category plot (residential buildings). [36]

Figure 3.5.2-7: Average Primary Energy Consumption (residential buildings). [36]

Year/Use	A.P.E.C. for Heating	A.P.E.C. for Cooling	A.P.E.C. for Light-ing	A.P.E.C. for DHW	A.P.E.C. for RES & CEH	Total APEC
Total 2011	187.27	43.64	0	60.95	0.11	291,97
SFH 2011	275.07	51.9	0	58.09	0.42	385.48
MFH 2011	156.8	40.78	0	61.94	0	259.52
Total 2012	161.33	33.52	0	56.18	0.07	251.1
SFH 2012	251.47	45.21	0	53.28	0.43	350.39
MFH 2012	148.53	31.86	0	56.59	0.02	237
Total 2013	178.12	30.4	0	47.93	0.04	256.49
SFH 2013	281.28	41.42	0	42.94	0.06	365.7
MFH 2013	157.65	28.21	0	48.91	0.04	234.81
Total 2014	193.57	31.52	0	47.09	0.04	272.22
SFH 2014	292.66	41.27	0	42.93	0.12	376.98
MFH 2014	166.85	28.89	0	48.21	0.02	243.97
Total 2015	171.4	30.61	0	47.53	0.02	249.56
SFH 2015	254.17	40.7	0	42.55	0.07	337.49
MFH 2015	150.56	28.07	0	48.78	0.01	227.42
Total 2016	164.96	29.86	0	57.52	0.02	252.36
SFH 2016	241.93	43.06	0	47.95	0.09	333.03
MFH 2016	154.96	28.15	0	58.76	0.01	241.88
Total 2017	169.16	30.65	0	56	0.02	255.83
SFH 2017	248.95	43.44	0	48.83	0.07	341.29
MFH 2017	156.08	28.55	0	57.18	0.01	241.82

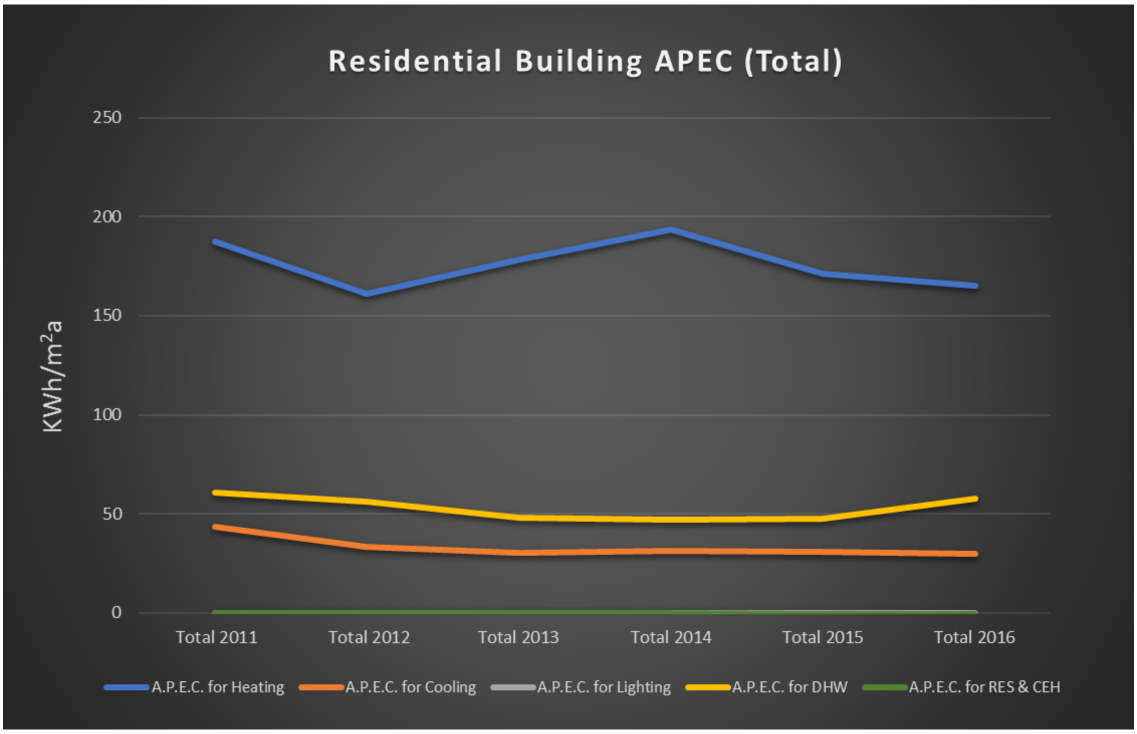


Figure 3.5.2-8: Total Average Primary Energy Consumption plot (residential buildings). [36]

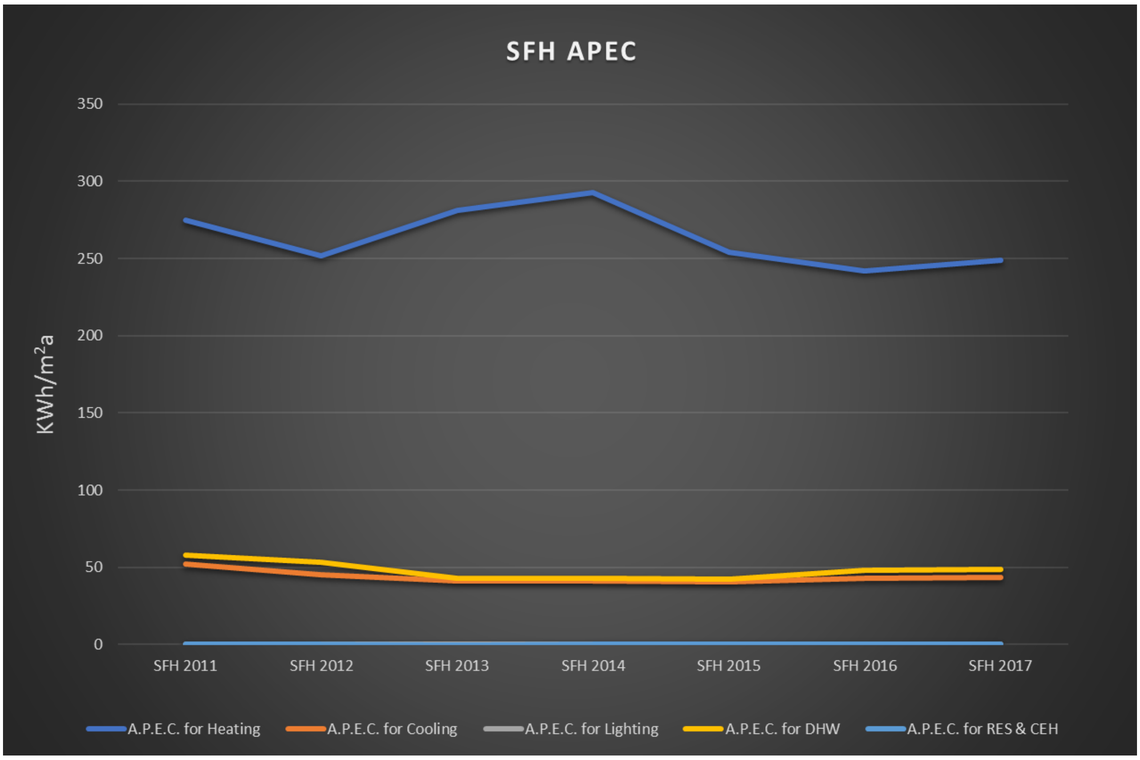


Figure 3.5.2-9: Average Primary Energy Consumption plot (SFH). [36]

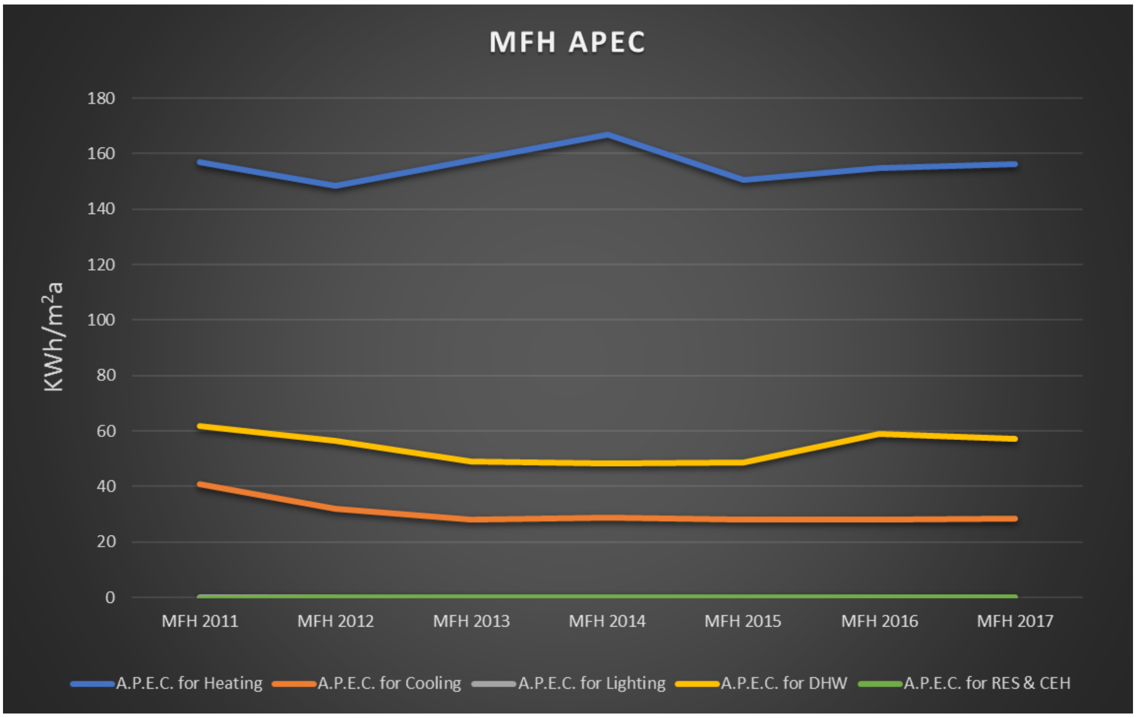


Figure 3.5.2-10: Average Primary Energy Consumption plot (MFH). [36]

3.5.3 Results and Statistics for Central Macedonia - Prefecture of Thessaloniki

The statistics and data from energy certificates, provided by the Greek Ministry for Environment and Energy, are also available for the different prefectures of Greece. In this section, the results for Central Macedonia, prefecture of Thessaloniki will be presented, to compare them in the next chapter with the total National results.

Figure 3.5.3-1: Number of Energy certificates per construction decade and energy category (Central Macedonia – Prefecture of Thessaloniki). [36]

Number of Energy Certificates										
	A+	**A**	**B+**	**B**	**C**	**D**	**E**	**Z**	**H**	**Total**
<1960	0	0	0	2	30	154	287	360	929	**1762**
1960-1970	2	0	15	98	577	2775	5500	6288	13577	**28832**
1970-1980	0	1	41	162	1111	3967	6623	5897	9894	**27696**
1980-1990	0	1	61	333	3105	3915	2843	1551	2715	**14524**
1990-2000	0	1	53	457	4798	6117	2890	660	489	**15465**
2000-2010	0	3	57	1090	10269	9789	2592	447	324	**24571**
2010<	3	17	125	559	744	265	43	5	3	**1764**
Total	**5**	**23**	**352**	**2701**	**20634**	**26982**	**20778**	**15208**	**27931**	**114614**

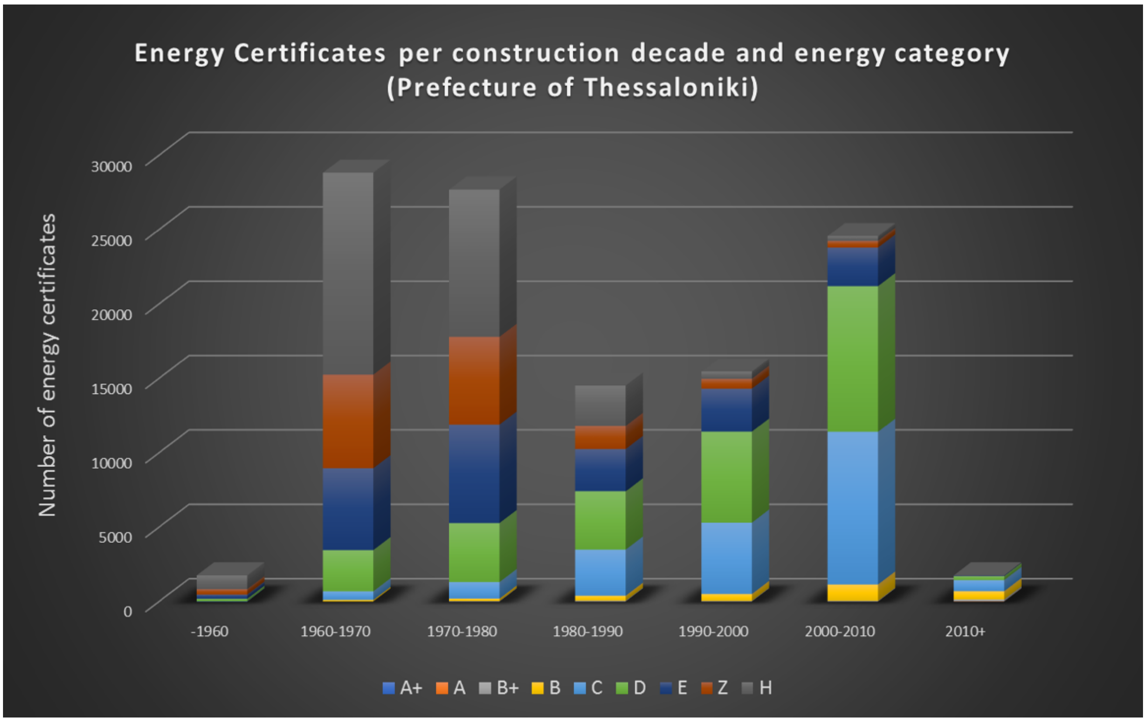


Figure 3.5.3-2: Number of Energy certificates per construction decade and energy category plot (Central Macedonia – Prefecture of Thessaloniki). [36]

Figure 3.5.3-3: Number of Energy certificates per construction decade and use (Central Macedonia – Prefecture of Thessaloniki). [36]

Number of Energy Certificates per construction decade and use (residential buildings)								
	<1960	**1960-1970**	**1970-1980**	**1980-1990**	**1990-2000**	**2000-2010**	**2010<**	**Total**
Single-Family House (SFH)	114	1570	1142	1050	1097	1857	334	**7164**
Multi-Family House (MFH)	1648	27262	26554	13474	14368	22714	1430	**107450**
Total	**1762**	**28832**	**27696**	**14524**	**15465**	**24571**	**1764**	**114614**

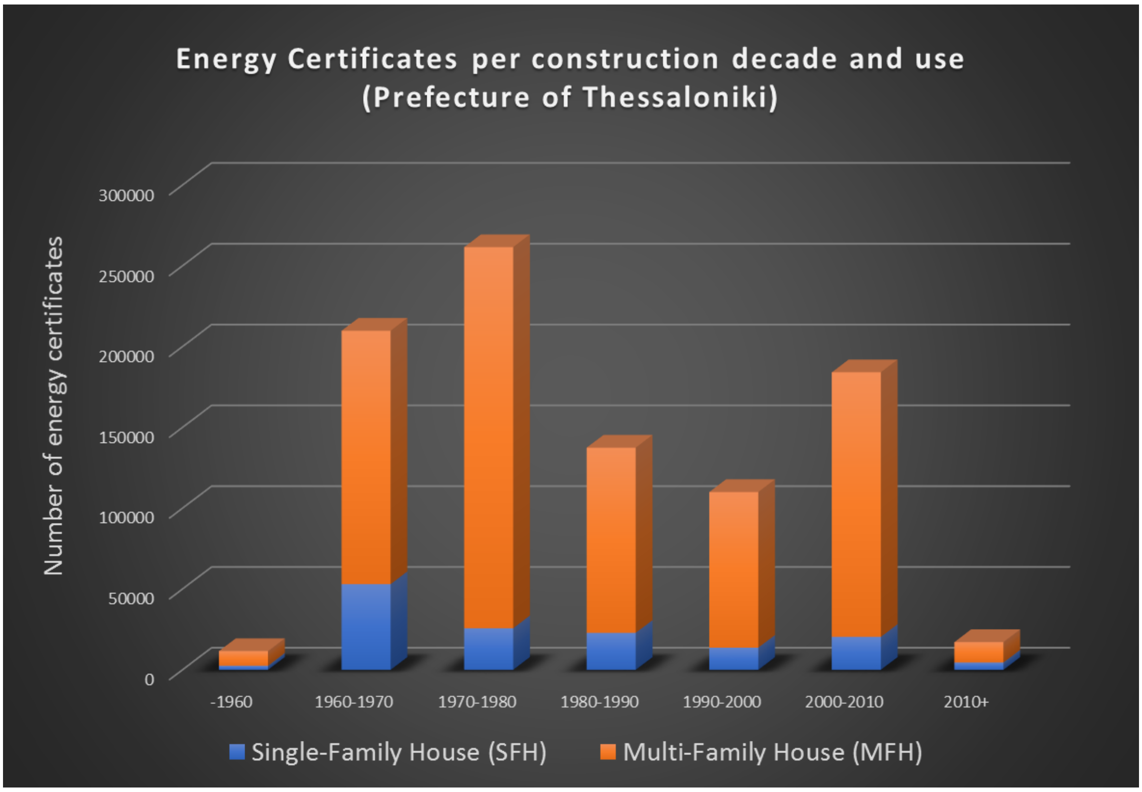


Figure 3.5.3-4: Number of Energy certificates per construction decade and use plot (Central Macedonia – Prefecture of Thessaloniki). [36]

Figure 3.5.3-5: Number of Energy certificates per use and energy category (Central Macedonia – Prefecture of Thessaloniki). [36]

Number of energy certificates per use and energy category										
	A+	**A**	**B+**	**B**	**C**	**D**	**E**	**Z**	**H**	**Total**
Single-Family House (SFH)	**2**	**14**	**69**	**271**	**1248**	**1637**	**890**	**518**	**2515**	**7164**
Multi-Family House (MFH)	**3**	**9**	**283**	**2430**	**19386**	**25345**	**19888**	**14690**	**25416**	**107450**
Total	**5**	**23**	**352**	**2701**	**20634**	**26982**	**20778**	**15208**	**27931**	**114614**

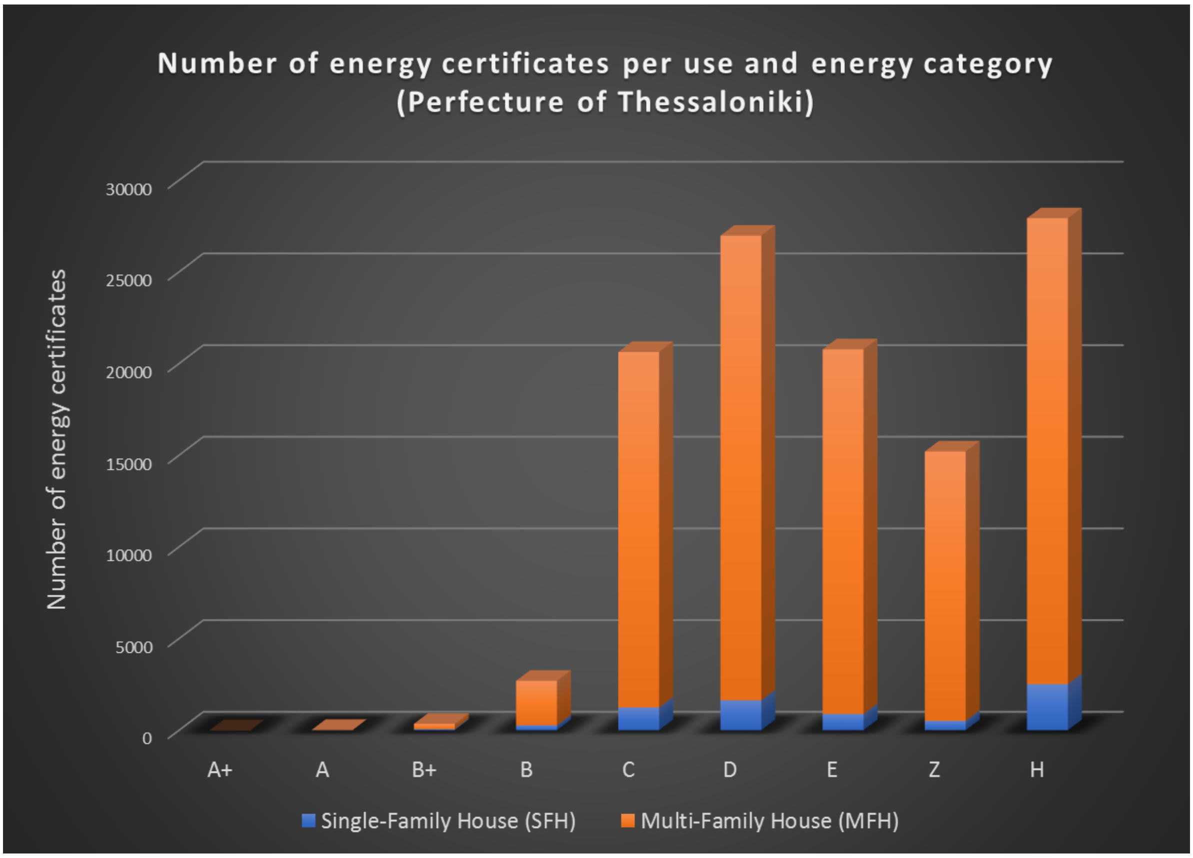


Figure 3.5.3-6: Number of Energy certificates per use and energy category plot (Central Macedonia – Prefecture of Thessaloniki). [36]

Figure 3.5.3-7: Average Primary Energy Consumption (Central Macedonia – Prefecture of Thessaloniki). [36]

Average primary energy consumption (Prefecture of Thessaloniki)						
Year/Use	**A.P.E.C. for Heating**	**A.P.E.C. for Cooling**	**A.P.E.C. for Lighting**	**A.P.E.C. for DHW**	**A.P.E.C. for RES & CEH**	**Total APEC**
Avg Total	195.78	22.7	0	56.15	0.01	274.64
Avg SFH	271.75	30.31	0	48.08	0.09	350.23
Avg MFH	190.72	22.19	0	56.69	0.01	269.61

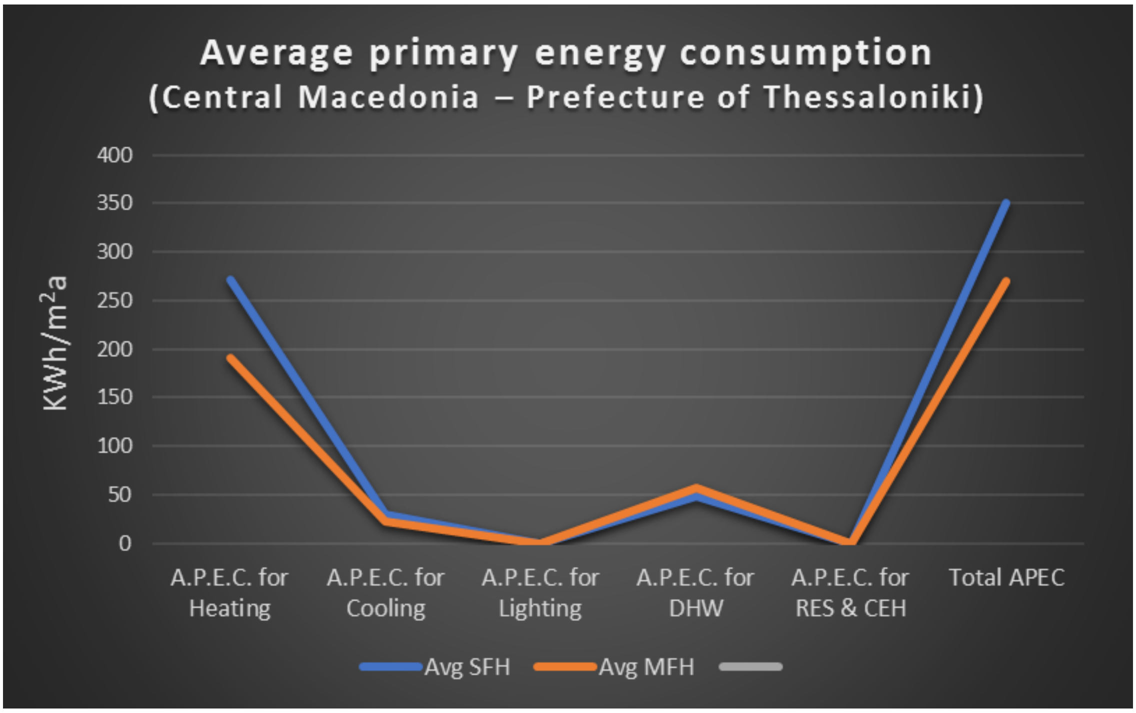


Figure 3.5.3-8: Average Primary Energy Consumption plot (Central Macedonia – Prefecture of Thessaloniki). [36]

3.5.4 Comparing the Energy certificates results for Greece with those for Thessaloniki

The prefecture of Thessaloniki is the second largest prefecture in Greece, and the largest in Macedonia and Northern Greece. It is located in Central Macedonia, and belongs to the Third Climatic Zone of Greece (Climatic Zone A being the hottest and D the coolest) [30]. To understand the difference in the energy needs for heating for the Greek climatic zones, assuming an internal temperature of 18 ^{o}C, the Heating Degree Days in Thessaloniki per year are on average 1756 HDD, while in Crete, Chania are 924 HDD (Climatic Zone A), in Athens 1253 HDD (Climatic Zone B) and in Florina 2584 HDD (Climatic Zone D) [37].

Because of the difference in HDD and considering that the climatic zone D is the smallest in area and the less dense built than the other three zones (A, B, C), it is expected for prefecture of Thessaloniki to have more insulation on the envelope of the residential buildings, higher efficiency heating systems and installations and generally to appear better overall energy performance comparing to the total of the Greek buildings.

The diagrams of comparison of Greek and Thessaloniki prefecture percentages of buildings constructed per decade and category [Figure 3.4.5-1], show that:

- It is expected that the newer a residential building is, it appears to have better energy performance than the older ones, both on national level and in the Thessaloniki prefecture.
- The majority of the buildings constructed between 1990 - 2010 have an energy efficiency rating of the class C and D, while the ones constructed from 2010 onwards belong mostly to classes B and C.
- Overall the prevailing energy efficiency rating classes are the ones from C to H. The percentage of buildings belonging to ratings from B to A+ is negligible.
- The trends per decade of the energy efficiency rating both on the National level and in the prefecture of Thessaloniki, are similar.
- The residential buildings of the Thessaloniki prefecture, appear to have better energy efficiency statistics in all decades and overall, excluding the 2010< constructed residences. This might have happened because of the Greek regulation for the energy performance of building introduction in 2010.

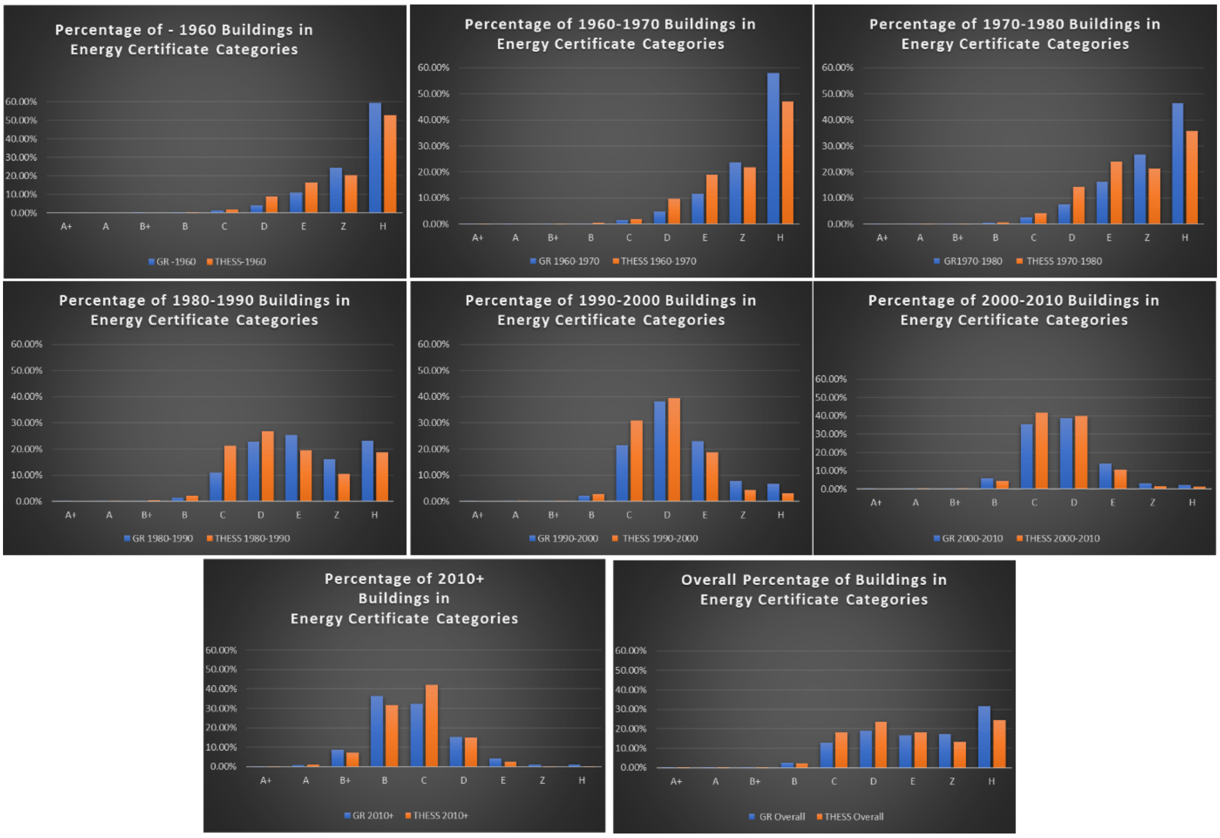


Figure 3.5.4-1: Percentage of Buildings per construction decade and category. [36]

In Figure 3.5.4-2 the percentages of the energy certificates per construction and decade are presented. Although by decade the difference in percentage of certificates for SFH and MFH is relatively small, overall the great majority of energy certificates has been issued for MFH. In the prefecture of Thessaloniki, the difference is even wider.

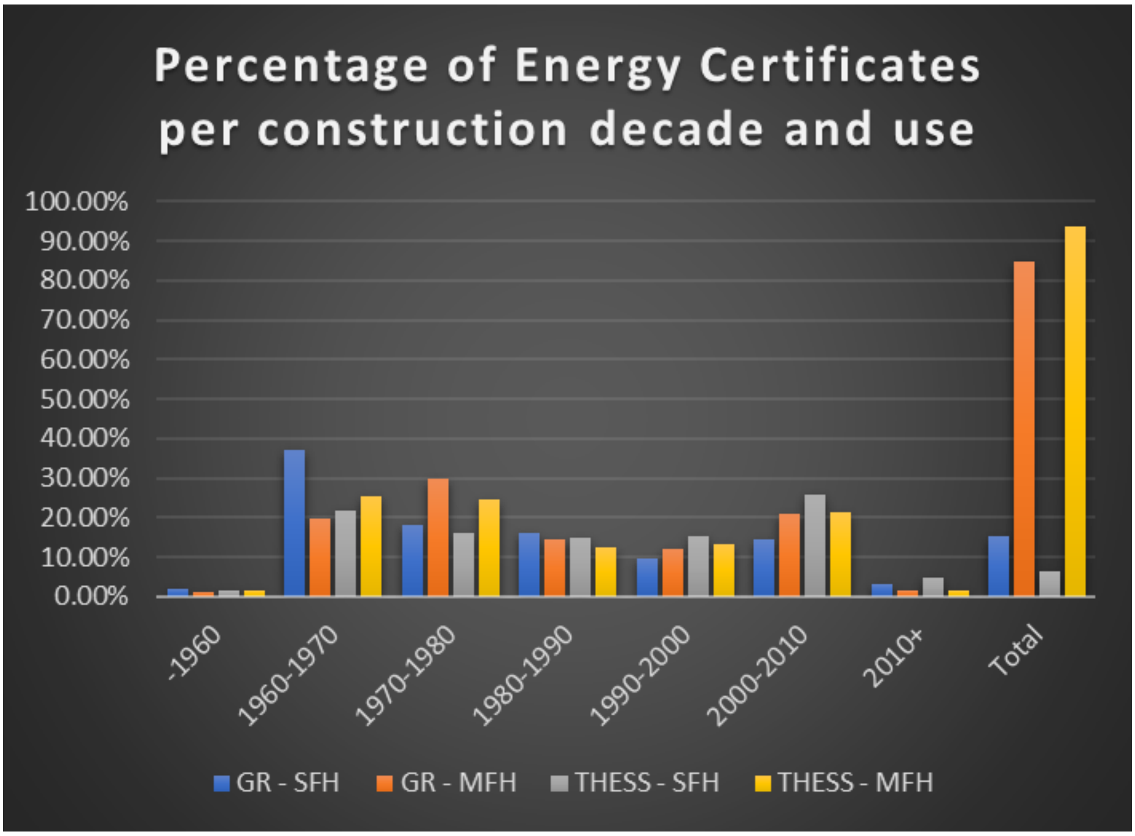


Figure 3.5.4-2: Percentage of energy certificates issued per decade and use (residential buildings). [36]

Comparing the energy certificates rating of the Greek residential building stock with the residential building stock of the Thessaloniki prefecture [Figure 3.5.4-3], it is observed that the Thessaloniki prefecture buildings have better energy efficiency statistics, both in the single-family and the multi-family houses.
The difference of the energy rating in the single-family buildings is huge, with almost half (49.3%) of the Greek national stock residential buildings, belonging to the last energy efficiency rating category. On the other hand, only 35.11% of the Thessaloniki prefecture SFH belongs to this last category and the rest perform better.
The gap between the National and Thessaloniki data sets is narrower when comparing the building stocks of the multi-family houses, with the percentages being significantly smaller than the single-family houses as well. Only 28.29% of the National and 23.65% of Thessaloniki building stock belong to the last rating class. An important observation that can be made is that the trends of the diagrams for the MFH and the total building stock are similar with the percentages of buildings belonging to each energy rating category, being very close as well [Figure 3.5.4-3].

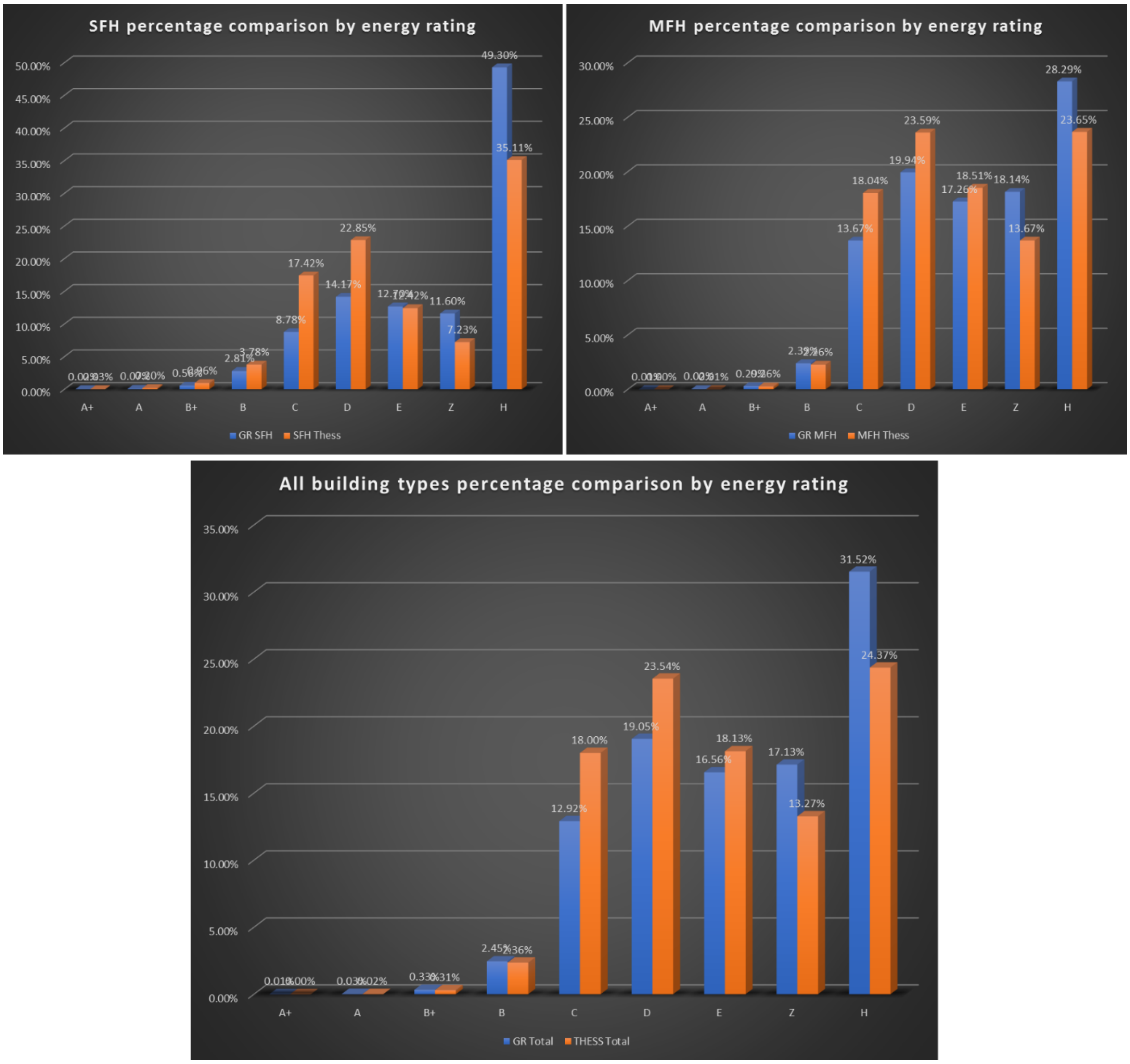


Figure 3.5.4-3: Percentage of energy certificates rating comparison per use (residential buildings). [36]

Figure 3.5.4-4 presents the Average Primary Energy Consumption (APEC) for the Single-Family houses, the Multi-Family houses and for the total residential building stock. Once again, it is clear that the trend of the Multi-Family houses and the total residential building stock are similar. The increase of the average primary energy consumption in the prefecture of Thessaloniki compared to the national residential building stock is expected because of the increased HDD of the climatic zone C comparedg to the average national HDD [38] and verified by the diagram. The reduced primary energy consumption for air conditioning was also expected. Climatic zone C may have increased needs for heating, but it also has lower needs for cooling than zones A and B, adding the fact that the residential buildings located in the Thessaloniki prefecture have better energy efficiency ratings compared to the total of the National residential building stock as it has been shown earlier in Figure 3.5.4-1. It is also clear that at least for the Thessaloniki prefecture, the average primary energy consumption of the Multi-Family houses is very close to the Total residential Thessaloniki building stock APEC.

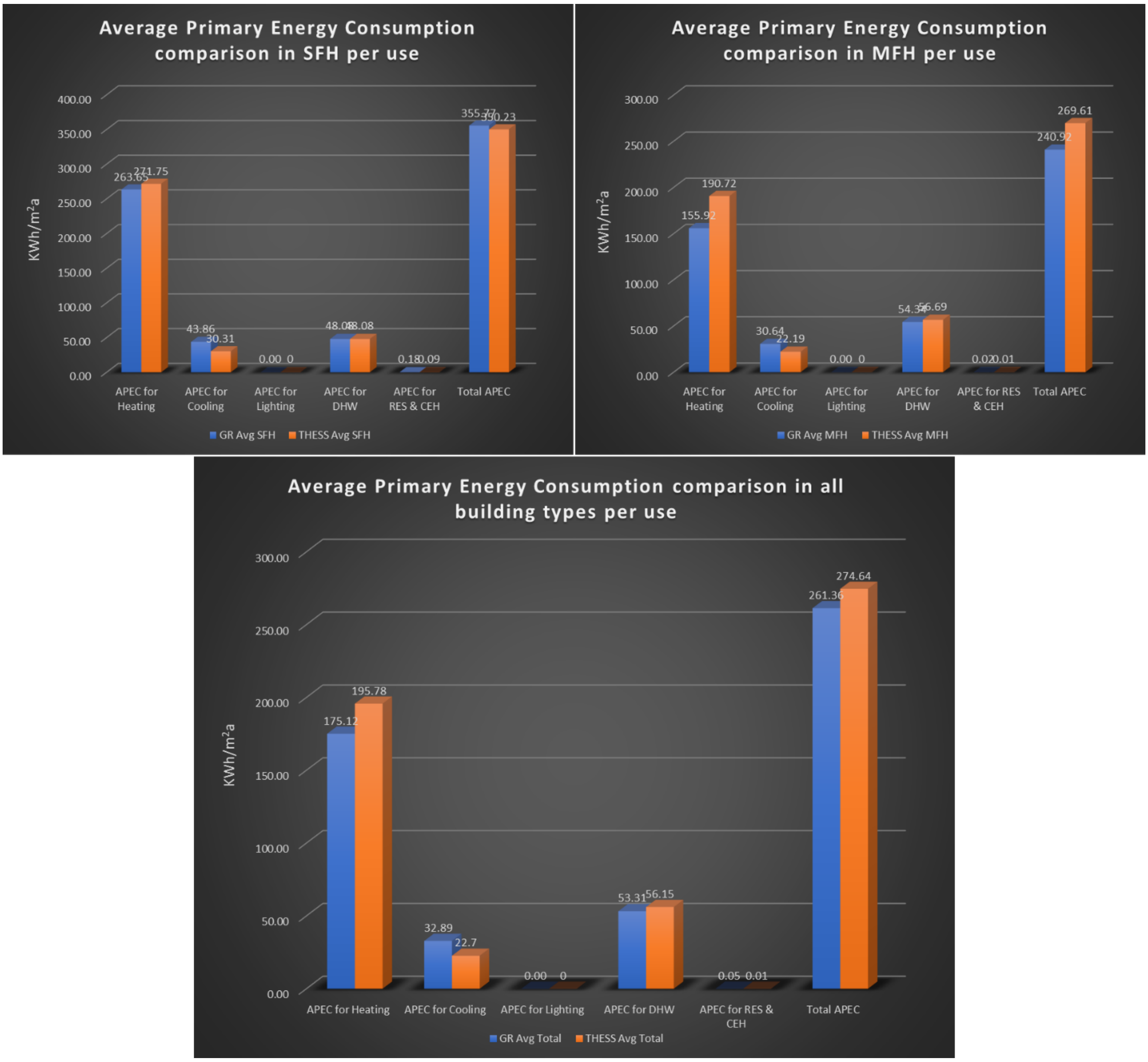


Figure 3.5.4-4: Average Primary Energy Consumption comparison per use (residential buildings). [36]

4 Contribution

4.1 Scope of the study

In this study, thirty case studies of Multi-Family building apartments will be in depth and detailed examined regarding their energy efficiency characteristics. All the cases encountered belong to the Climatic Zone C. The target is to identify and evaluate the results for the prefecture of Thessaloniki. The scope is to obtain information about the effectiveness of nationally suggested measures and scenarios on a prefecture level. In addition, it is a chance to confirm that the methodology suggested for the energy efficiency upgrade of whole buildings, will be also effective when applied in parts of buildings (apartments) renovations as well.

The base of the simulation and scenarios model structure will be the GRBT report. The software used is TEE-KENAK (version 1.29.1.19), as it is the last updated patch of the software available by TCG and NOA-IERSD. The buildings studied will be MFH as they seem to represent more efficiently the national building stock characteristics according to the data described earlier.

4.2 Scenarios applied

For the purposes of this study, the methodology described earlier has been applied in thirty case studies of apartments and buildings located in the prefecture of Thessaloniki. Taking into consideration that in the summer of 2016 the new updated KENAK has been endorsed by the Hellenic parliament and it will be completely applied as soon as the new TOTEE and the new TEE-KENAK software become available by TCG and NOA, the two scenarios related to the application of the 2010 KENAK legislation will be integrated into one. Three scenarios in total are applied in all case studies. The building characteristics and information for each one of the case studies will be presented similarly to the TABULA building information two-page brochures.

Figure 4.2-1: KENAK 2010 maximum thermal conductivity restriction for climatic zone C. [32]

Building Element	Roofs	Pilotis	Floors in contact with non-heated space or ground	Walls	Walls in contact with non-heated space or ground	Openings (windows, doors)	Fixed glazing (cannot be opened)
$\mathbf{U_{value}}$ **(W/m^2K)**	0.40	0.40	0.75	0.45	0.80	2.80	1.80

Figure 4.2-2: KENAK 2010 maximum mean thermal conductivity U_m for climatic zone C. [32]

A/V (m^{-1})	- 0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0+
Um (W/m^2K)	1.05	1.00	0.95	0.90	0.86	0.81	0.76	0.71	0.66

The scenarios idea is based in the typology of Greek buildings brochure methodology described in paragraph 2.7.2, but will differ on the approach and the scale of the interventions. The scenarios are transformed according to usual renovation energy measures taken in Thessaloniki apartment refurbishment, improving the overall efficiency by implementing envelope insulation, automation and HVAC systems as detailed below:

- ***Scenario No1:***
  - ***Envelope**:* Application of thermal insulation on the walls (U_{value}=0.4 W/m^2K), roof (U_{value}=0.35 W/m^2K) and pilotis if applicable (U_{value}=0.35 W/m^2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (U_{value}=2.4 W/m^2K, g=0.45).

- *Systems:* Installation of new condensing gas boiler (η=0.95), low temperature heating radiators, one thermostat per property. New heating and DHW distribution systems if none are installed or when the efficiency of the distribution system is low.
- *RES:* Installation of 3 m^2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 3 m^2.

- ***Scenario No2:***
  - ***Envelope**:* Application of thermal insulation on the walls (U_{value}=0.30 W/m^2K), roof (U_{value}=0.25 W/m^2K) and pilotis if applicable (U_{value}=0.25 W/m^2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (U_{value}=1.7 W/m^2K, g=0.45).
  - *Systems:* Installation of new condensing gas boiler (η=0.95) with weather compensation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW distribution systems if there aren't any installed or when the efficiency of the distribution system is low.
  - *RES:* Installation 5 m^2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m^2.
- ***Scenario No3:***
  - ***Envelope**:* Application of thermal insulation on the walls (U_{value}=0.30 W/m^2K), roof (U_{value}=0.25 W/m^2K) and pilotis if applicable (U_{value}=0.25 W/m^2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (U_{value}=1.7 W/m^2K, g=0.45).
  - ***Systems:*** Installation of low temperatures heat pump (COP:4.65, EER: 4.11) with weather compensation and underfloor heating. Installation of thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the distribution system is low.
  - ***RES:*** Installation of 7 m^2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. If a residence has a

different number of bedrooms, the surface of the solar collector is respectively adjusted with a minimum of 7 m^2. Installation of 2 m^2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W) for partially covering the electricity needs.

The interventions were chosen so they are applicable in practice in existing city apartments, without the need for all the owners of the building to agree in renovating their properties. The purpose for this is to study the most usual case in Greece of an owner that wants to refurbish his apartment without being obliged to cooperate with the rest of the building owners, to do so.

The cost of the interventions has been calculated using the Greek market prices of 2017 according to the following table [Figure 4.2-2]. The cost includes VAT and is calculated as the final cost of the installed intervention without including any other renovation works that might occur (example new final floor level with ceramic tiles in the case of underfloor heating application).

Figure 4.2-2: Cost of building interventions installation

Application	Specification	Cost	Unit
Thermal Insulation	U value=0.40	€50.00	/m2
Thermal Insulation	Uvalue=0.35	€55.00	/m2
Thermal Insulation	Uvalue=0.30	€60.00	/m2
Thermal Insulation	Uvalue=0.25	€65.00	/m2
Thermal Insulation walls 3rd period building (Uvalue=0.7) Scnario No1	U value=0.40	€35.00	/m2
Thermal Insulation roof/pilotis 3rd period building (Uvalue=0.7) Scnario No1	Uvalue=0.35	€35.00	/m2
Thermal Insulation walls 3rd period building (Uvalue=0.7) Scnario No2, No3	Uvalue=0.30	€40.00	/m2
Thermal Insulation roof/pilotis 3rd period building (Uvalue=0.7) Scnario No2, No3	Uvalue=0.25	€40.00	/m2
Condensing Gas boiler	24KW	€1,200.00	/application
Thermostat installation		€200.00	/application
Thermostatic valves installation		€300.00	/ apartment
Low temperature radiators installation		€900.00	/100m2 apartment
Heating distribution system installation		€3,000.00	/100m2 apartment
DHW distribution system installation		€400.00	/apartment
Low temperature air to water Heat Pump installed with thermostat in every heating space	8KW / COP 4.65	€6,500.00	/apartment

Underfloor heating		€5,000.00	/100m2 apartment
Solar Thermal Cost Installed and connected	Selective	€300.00	/m2 Solar
Polycrystalline Photovoltaic Panels installed and connected	n=16.9%, Nominal output 0.26 KW	€400.00	/m2 PV
Window aluminium, thermal break 4-12-4 low-e glazing, noble gas Uvalue=2.4, g=0.45		€550.00	/m2 Window
Window aluminium, thermal break 4-12-4 low-e glazing, noble gas Uvalue=1.7, g=0.45		€800.00	/m2 Window

4.3 Case studies characteristics

The residences studied, are part of Multi-Family buildings. Twenty of the cases belong to the first building age period (<1980), six in the second period (1981-2000) and two in the third period (2001-2010).

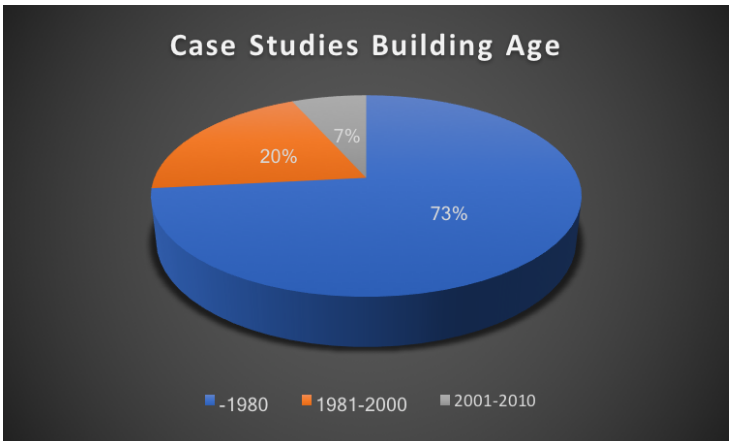


Figure 4.3-1: Building age period percentages of the thirty case studies

Six of the buildings have been certificated asn class H, six as class Z, five as class E, nine as class D and three as class C, while there aren't any certified as class B and above.

The residences are located mostly in the municipality of Thessaloniki while some are in the municipalities of Kalamaria, Neapoli and Stavroupoli. All the municipalities are part of the broader urban area of Thessaloniki.

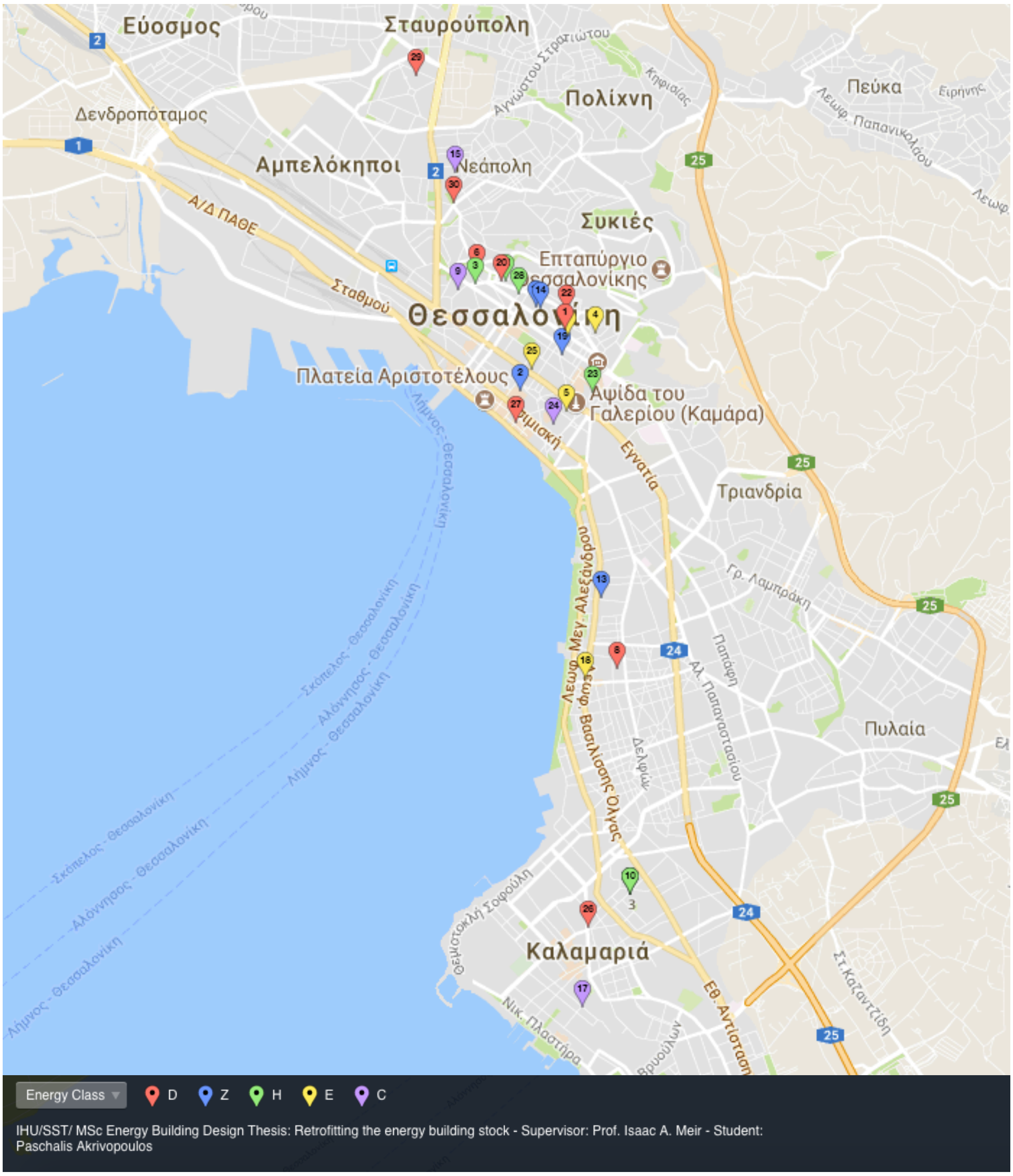


Figure 4.3-2: Location of the case studies by address, coloured by energy certification class. [39]

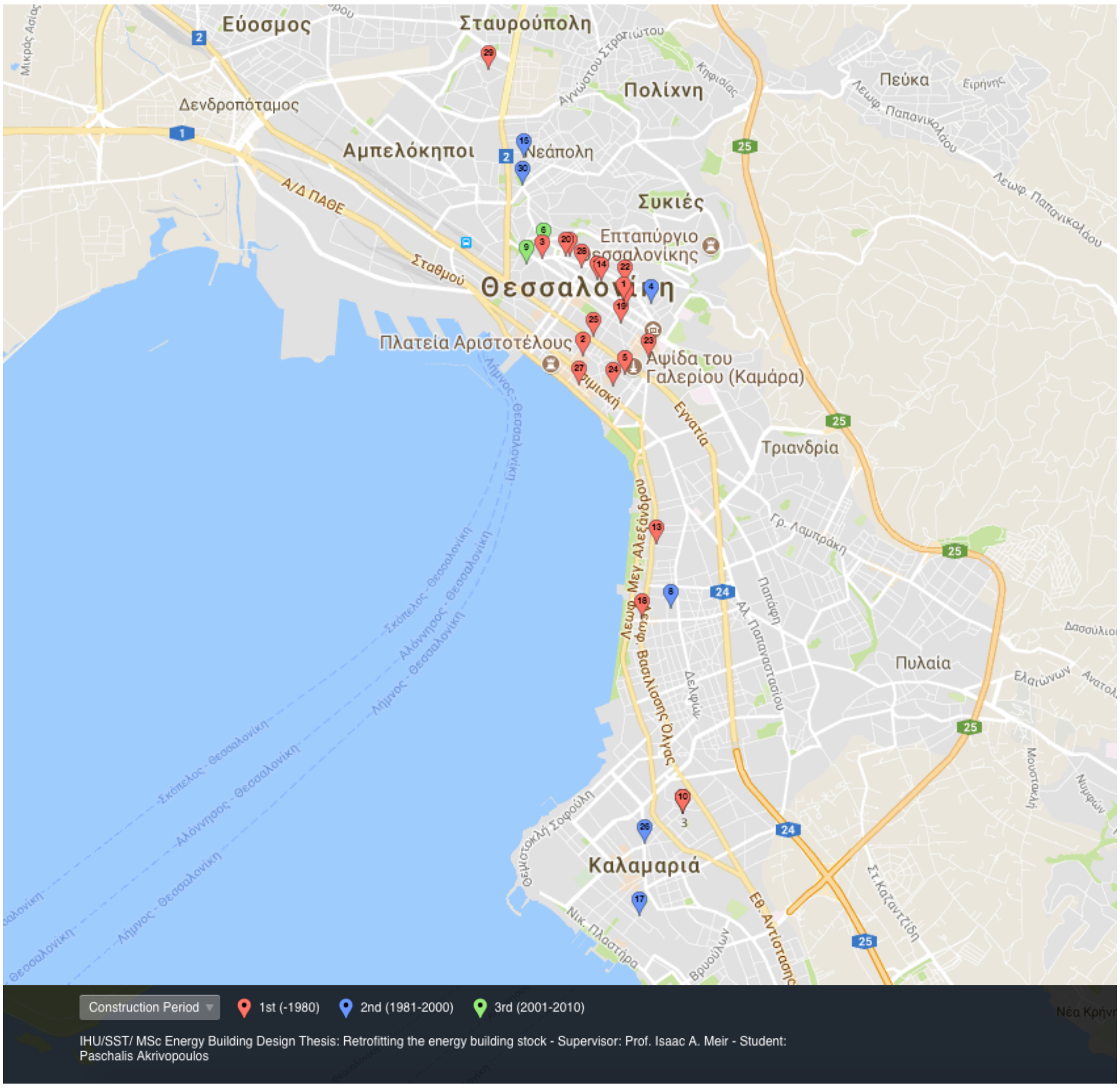


Figure 4.3-3: Location of the case studies by address, coloured by construction period. [39]

The map is interactive and accessible in the “batchgeo” website which was used to create it. The link is sited in the references.

A summary of the most important general building characteristics is presented in the figure 4.3-4.

Figure 4.3-4: Case studies building characteristics.

Building Case studies	Construction Period	PEC	Area m2	Energy Class	Operating cost /a	CO2 Emissions (Kg/m2/a)
Agias Sofias 73, Thessaloniki	1	295.6	48.6	D	€868.90	69.2
Agias Theodoras 13, Thessaloniki	1	221.2	83.3	Z	€1,217.60	44.9
Agiou Dimitriou 23, Thessaloniki	1	697.1	27	H	€715.20	231.8
Dimitriou Gounari 31, Thessaloniki	1	284.3	148.3	E	€2,848.30	55.9
Eurypidou 20, Thessaloniki	1	187	52	E	€510.90	58.1
Kalimnou 6, Kalamaria 1st Floor	1	814.4	45	H	€1,456.20	283.2
Kalimnou 6, Kalamaria 2nd Floor	1	589.5	55.5	H	€1,494.70	235.7
Kalimnou 6, Kalamaria 3rd Floor	1	268.2	41	Z	€782.80	83.8
Karaiskaki 5, Thessaloniki	1	236.9	56.2	Z	€843.30	70.6
Lapithon 6, Thessaloniki	1	255.6	44	Z	€439.60	87.4
Makedonikis Amynis 28, Thessaloniki	1	474.4	57	Z	€2,013.60	123.8
Markou Mpotsari 7, Thessaloniki	1	331.6	40	E	€851.30	71.7
Olympou 103, Thessaloniki	1	272.8	45.2	Z	€744.40	90.1
Olympiados 7, Thessaloniki	1	188.9	66	D	€819.10	38.4
Olympiados 13, Thessaloniki	1	292.4	48	H	€664.40	94.3
Olympiados 76, Thessaloniki	1	167.7	90.5	D	€1,007.50	33.3
Plateia Ag. Panteleimonos 5, Thessaloniki	1	228.3	92.75	H	€1,313.50	66.7
Plateia Navarinou 3, Thessaloniki	1	105.8	34	C	€224.20	30.7
Platonos 1, Thessaloniki	1	270.6	108.14	E	€2,020.60	58.2
Proksenou Koromila 31, Thessaloniki	1	172.8	79	D	€916.60	34.3
Raktivan 10, Thessaloniki	1	466.6	32.3	H	€672.50	182.2
Rodou 19, Stavroupoli	1	272.1	63	D	€960.80	44.6
Athinas 7, Thessaloniki	2	196.8	42	E	€322.40	67.2
Zanna Iatrou 30, Thessaloniki	2	179.8	115	D	€1,414.60	48.2
Madytou 20, Neapoli	2	222.7	60	C	€827.10	51.2
Metron 24, Kalamaria	2	530.7	57.53	C	€1,192.50	181.4
Pontou 29. Kalamaria	2	363	55	D	€530.10	84.4
Stratigou Sarafi 2, Thessaloniki	2	145.8	40.51	D	€325.00	44.5
Eratous 4A, Thessaloniki	3	284.6	26.91	D	€533.60	94.3
Kalvou Andrea 7, Thessaloniki	3	199.7	21.44	C	€237.20	32.3

4.4 Three-page brochures

To present the results, the idea of the "two-page brochure" method, used in the Greek typology report has been adopted. The brochures presented in this study, use three pages. In the first page, there is information for the case study building as is, such as the age category, the climatic zone, the address and the conditioned space area and volume, followed by a brief description of the building envelope and the HVAC systems with a table containing performance information. Finally, some important annual energy values are presented as the CO_2 emissions, the primary energy consumption and the operational cost.

In the second page the Scenarios No1 and No2 are presented, with the results for Primary Energy Saving, the estimated initial cost for the scenario and the Payback Period. The interventions in each scenario case are briefly described for the envelope, HVAC and RES solutions suggested. Comparative charts are presented between the studied scenario and the initial building state. The third page contains the Scenario No3 and is completed with six charts comparing the three scenarios and the initial state.

The result is relatively different than the initial "two-page" brochure idea but it follows the same principles, adding information needed for the complete information presentation and comparison of the scenarios. The photograph of the building is not indicative, but it is a real picture of the building under study. Thirty "three-page" brochures have been created, one for each case study. An example of the "three-page" brochures is presented in the following figure. All thirty of the three-page brochures are available in the "Appendix".

1	Multi-Family House			
	Apartment			
	Agias Sofias 73, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	48.6			
Heater Volume	145.8			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.5
Roof	A/S
Floor	A/S
Openings	3.8
g-openings	0.52

HVAC systems performance

	Heating	DHW
Production	0.929	0.929
Distribution	0.86	0.72
Terminal Units / Storage	0.87	1

Systems

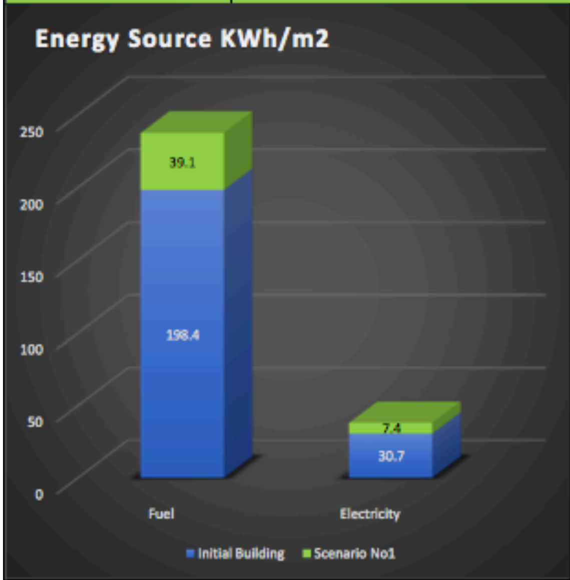
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

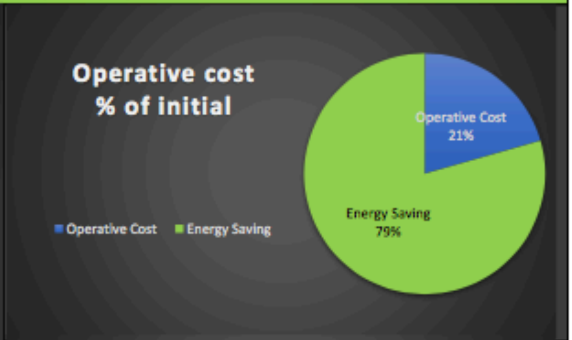
Annual Energy Characteristics

Energy Demand (KWh/m2/a)	180.3
Energy Consumption (KWh/m2/a)	228.4
Thermal Energy (KWh/m2/a)	198.4
Electricity (KWh/m2/a)	30.7
Primary Energy (KWh/m2/a)	295.4
CO2 Emissions (Kg/m2/a)	69.2
Total Final Thermal Energy	9642.24
Total Electricity Consumption	1492.02
Operating cost	€868.90

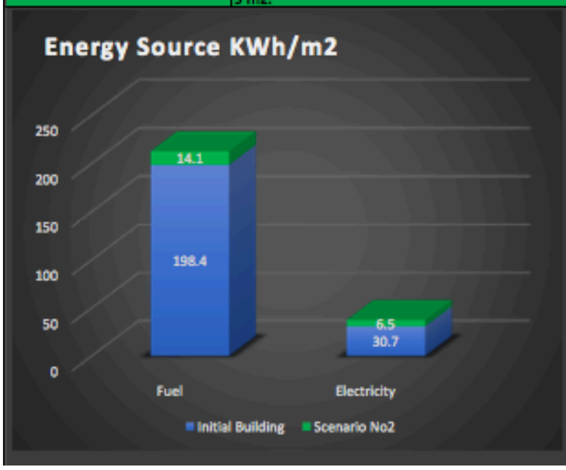
Energy Saving Interventions

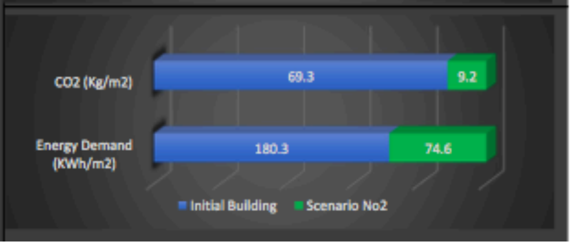
Scenario No1	P.E.S.	79.70%	Initial cost	€11,322.00	P.P. (Years)	16.4
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					





Scenario No2	P.E.S.	89.30%	Initial cost	€14,677.20	P.P. (Years)	18.7
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	New condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					





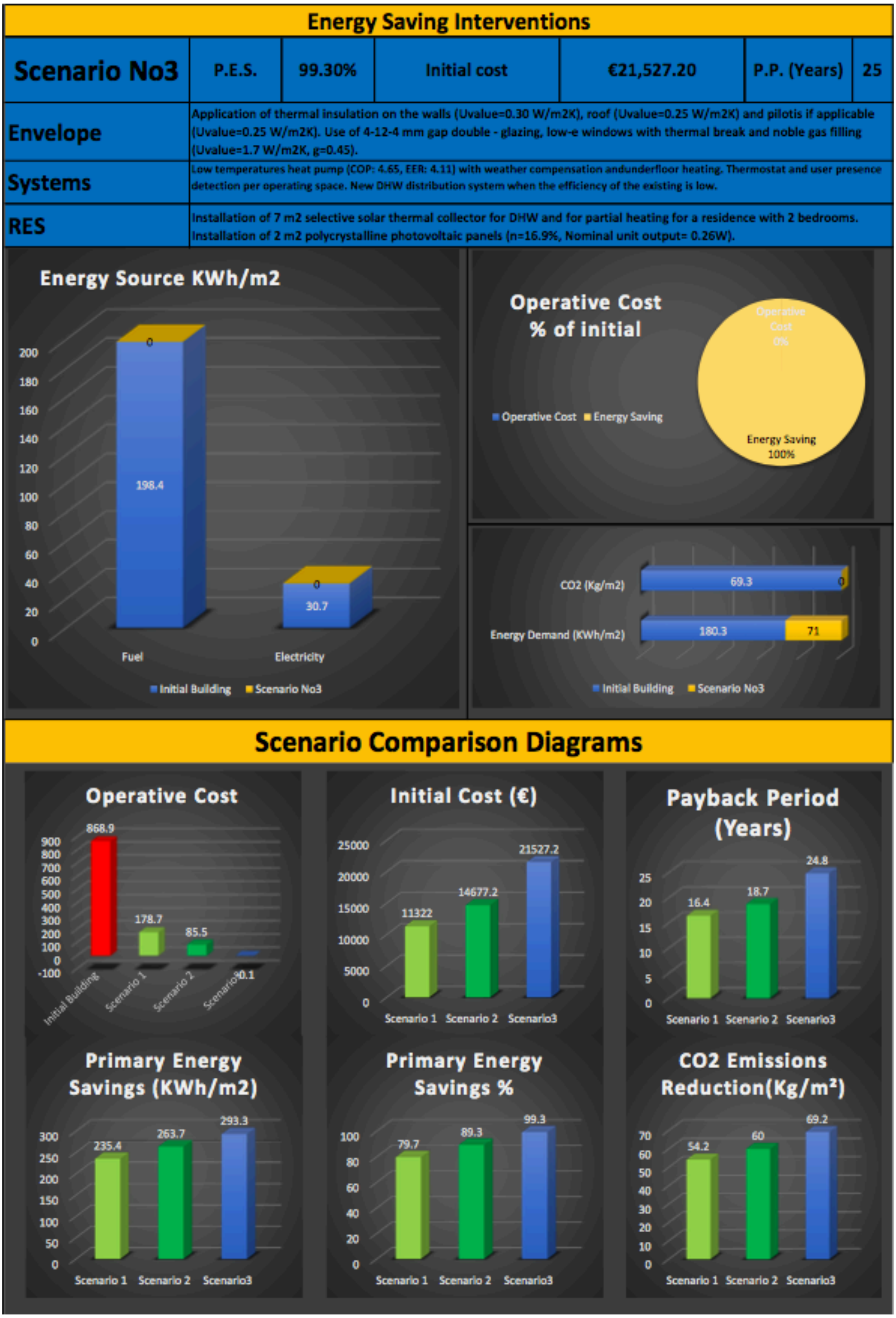


Figure 4.4-1: Three-page brochure example.

A summary of the results from the simulation of three scenarios for each of the case studies is presented in the tables of the figures 4.4-2 to 4.4-4.

Figure 4.4-2: Summary results for Scenario No1.

Building Case studies	PEC	Operating cost /a	Scenario No1 PES	Scenario No1 Cost	Scenario No1 SRP
Agias Sofias 73, Thessaloniki	295.6	€868.90	79.70%	€11,322.00	16.4
Agias Theodoras 13, Thessaloniki	221.2	€1,217.60	78.50%	€17,239.00	17.7
Agiou Dimitriou 23, Thessaloniki	697.1	€715.20	88.60%	€8,024.50	13.8
Dimitriou Gounari 31, Thessaloniki	284.3	€2,848.30	71.90%	€38,259.00	18.4
Eurypidou 20, Thessaloniki	187	€510.90	73.30%	€11,169.50	32
Kalimnou 6, Kalamaria 1st Floor	814.4	€1,456.20	90.50%	€14,395.00	11.7
Kalimnou 6, Kalamaria 2nd Floor	589.5	€1,494.70	89.20%	€14,214.00	11.5
Kalimnou 6, Kalamaria 3rd Floor	268.2	€782.80	79.70%	€9,886.00	15.6
Karaiskaki 5, Thessaloniki	236.9	€843.30	73.80%	€12,825.00	20.6
Lapithon 6, Thessaloniki	255.6	€439.60	75.10%	€11,591.50	44.3
Makedonikis Amynis 28, Thessaloniki	474.4	€2,013.60	82.40%	€15,458.50	9
Markou Mpotsari 7, Thessaloniki	331.6	€851.30	76.80%	€7,775.50	11.7
Olympou 103, Thessaloniki	272.8	€744.40	80.30%	€11,312.10	19.6
Olympiados 7, Thessaloniki	188.9	€819.10	70.10%	€12,255.00	20.7
Olympiados 13, Thessaloniki	292.4	€664.40	87.80%	€9,521.50	17.1
Olympiados 76, Thessaloniki	167.7	€1,007.50	74.00%	€14,670.00	18
Plateia Ag. Panteleimonos 5, Thessaloniki	228.3	€1,313.50	80.00%	€17,170.80	16.2
Plateia Navarinou 3, Thessaloniki	105.8	€224.20	52.90%	€6,992.00	60.5
Platonos 1, Thessaloniki	270.6	€2,020.60	76.20%	€20,773.50	12.7
Proksenou Koromila 31, Thessaloniki	172.8	€916.60	69.50%	€12,409.50	19.1
Raktivan 10, Thessaloniki	466.6	€672.50	89.10%	€8,634.00	15.6
Rodou 19, Stavroupoli	272.1	€960.80	73.70%	€15,101.50	21
Athinas 7, Thessaloniki	196.8	€322.40	70.40%	€8,238.00	50.6
Zanna Iatrou 30, Thessaloniki	179.8	€1,414.60	50.00%	€20,725.90	27.1
Madytou 20, Neapoli	222.7	€827.10	63.20%	€14,622.30	28.5
Metron 24, Kalamaria	530.7	€1,192.50	87.60%	€13,554.40	14.3
Pontou 29. Kalamaria	363	€530.10	85.50%	€8,450.50	20.5
Stratigou Sarafi 2, Thessaloniki	145.8	€325.00	71.30%	€6,885.00	31.6
Eratous 4A, Thessaloniki	284.6	€533.60	64.20%	€7,807.80	23.7
Kalvou Andrea 7, Thessaloniki	199.7	€237.20	50.30%	€5,600.10	45.3

Figure 4.4-3: Summary results for Scenario No2.

Building Case studies	PEC	Operating cost /a	Scenario No2 PES	Scenario No2 Cost	Scenario No2 SRP
Agias Sofias 73, Thessaloniki	295.6	€868.90	89.30%	€14,677.20	18.7
Agias Theodoras 13, Thessaloniki	221.2	€1,217.60	89.20%	€22,334.20	20.2
Agiou Dimitriou 23, Thessaloniki	697.1	€715.20	96.00%	€10,197.40	15.1
Dimitriou Gounari 31, Thessaloniki	284.3	€2,848.30	85.40%	€49,730.80	20.2
Eurypidou 20, Thessaloniki	187	€510.90	88.70%	€14,448.80	32.1
Kalimnou 6, Kalamaria 1st Floor	814.4	€1,456.20	95.40%	€18,132.80	13.4
Kalimnou 6, Kalamaria 2nd Floor	589.5	€1,494.70	94.80%	€18,362.40	13.3
Kalimnou 6, Kalamaria 3rd Floor	268.2	€782.80	91.10%	€13,026.00	18
Karaiskaki 5, Thessaloniki	236.9	€843.30	87.00%	€16,701.60	22.5
Lapithon 6, Thessaloniki	255.6	€439.60	89.30%	€14,888.80	40.4
Makedonikis Amynis 28, Thessaloniki	474.4	€2,013.60	92.70%	€19,927.50	10.5
Markou Mpotsari 7, Thessaloniki	331.6	€851.30	89.20%	€10,419.40	13.4
Olympou 103, Thessaloniki	272.8	€744.40	92.40%	€14,297.20	20.8
Olympiados 7, Thessaloniki	188.9	€819.10	85.60%	€15,961.00	22.1
Olympiados 13, Thessaloniki	292.4	€664.40	95.80%	€12,110.20	19.1
Olympiados 76, Thessaloniki	167.7	€1,007.50	88.30%	€17,435.00	19.2
Plateia Ag. Panteleimonos 5, Thessaloniki	228.3	€1,313.50	89.60%	€22,245.80	18.7
Plateia Navarinou 3, Thessaloniki	105.8	€224.20	85.30%	€9,316.60	47.8
Platonos 1, Thessaloniki	270.6	€2,020.60	87.30%	€28,067.80	15.4
Proksenou Koromila 31, Thessaloniki	172.8	€916.60	85.50%	€16,989.40	21.3
Raktivan 10, Thessaloniki	466.6	€672.50	96.00%	€11,116.40	17.5
Rodou 19, Stavroupoli	272.1	€960.80	88.20%	€20,024.20	23.3
Athinas 7, Thessaloniki	196.8	€322.40	88.40%	€11,576.40	43.8
Zanna Iatrou 30, Thessaloniki	179.8	€1,414.60	71.30%	€28,317.60	26.8
Madytou 20, Neapoli	222.7	€827.10	80.90%	€20,231.60	30.1
Metron 24, Kalamaria	530.7	€1,192.50	93.40%	€17,857.60	16.7
Pontou 29. Kalamaria	363	€530.10	93.90%	€11,658.40	23.9
Stratigou Sarafi 2, Thessaloniki	145.8	€325.00	90.00%	€9,723.60	33.2
Eratous 4A, Thessaloniki	284.6	€533.60	83.60%	€11,475.20	25.8
Kalvou Andrea 7, Thessaloniki	199.7	€237.20	84.10%	€7,762.80	37.9

Figure 4.4-4: Summary results for Scenario No3.

Building Case studies	PEC	Operating cost /a	Scenario No3 PES	Scenario No3 Cost	Scenario No3 SRP
Agias Sofias 73, Thessaloniki	295.6	€868.90	99.30%	€21,527.20	24.8
Agias Theodoras 13, Thessaloniki	221.2	€1,217.60	98.30%	€29,514.20	24.2
Agiou Dimitriou 23, Thessaloniki	697.1	€715.20	100.10%	€16,897.40	23.6
Dimitriou Gounari 31, Thessaloniki	284.3	€2,848.30	94.90%	€58,930.80	21.4
Eurypidou 20, Thessaloniki	187	€510.90	100.20%	€21,148.80	41.4
Kalimnou 6, Kalamaria 1st Floor	814.4	€1,456.20	99.50%	€25,482.80	17.5
Kalimnou 6, Kalamaria 2nd Floor	589.5	€1,494.70	99.40%	€25,262.40	16.9
Kalimnou 6, Kalamaria 3rd Floor	268.2	€782.80	100.40%	€21,426.00	27.4
Karaiskaki 5, Thessaloniki	236.9	€843.30	98.20%	€23,701.60	28.1
Lapithon 6, Thessaloniki	255.6	€439.60	99.90%	€21,588.80	49.1
Makedonikis Amynis 28, Thessaloniki	474.4	€2,013.60	99.20%	€26,827.50	13.3
Markou Mpotsari 7, Thessaloniki	331.6	€851.30	98.90%	€20,069.40	23.6
Olympou 103, Thessaloniki	272.8	€744.40	99.90%	€21,329.20	28.6
Olympiados 7, Thessaloniki	188.9	€819.10	97.60%	€24,561.00	30
Olympiados 13, Thessaloniki	292.4	€664.40	100.40%	€18,960.20	28.5
Olympiados 76, Thessaloniki	167.7	€1,007.50	99.00%	€27,735.00	27.5
Plateia Ag. Panteleimonos 5, Thessaloniki	228.3	€1,313.50	97.20%	€29,545.80	23
Plateia Navarinou 3, Thessaloniki	105.8	€224.20	101.20%	€15,616.60	69.6
Platonos 1, Thessaloniki	270.6	€2,020.60	96.50%	€38,867.80	19.6
Proksenou Koromila 31, Thessaloniki	172.8	€916.60	98.50%	€21,489.40	23.4
Raktivan 10, Thessaloniki	466.6	€672.50	100.30%	€17,616.40	26.2
Rodou 19, Stavroupoli	272.1	€960.80	99.10%	€27,024.20	28.1
Athinas 7, Thessaloniki	196.8	€322.40	99.60%	€18,326.40	56.8
Zanna Iatrou 30, Thessaloniki	179.8	€1,414.60	88.90%	€39,817.60	30.1
Madytou 20, Neapoli	222.7	€827.10	96.50%	€27,131.60	32.8
Metron 24, Kalamaria	530.7	€1,192.50	99.40%	€24,657.60	20.7
Pontou 29. Kalamaria	363	€530.10	100.50%	€18,658.40	35.2
Stratigou Sarafi 2, Thessaloniki	145.8	€325.00	100.50%	€16,323.60	50.5
Eratous 4A, Thessaloniki	284.6	€533.60	98.50%	€18,575.20	34.8
Kalvou Andrea 7, Thessaloniki	199.7	€237.20	100.50%	€15,062.80	63.5

5 Conclusions

5.1 Existing state trends

During the procedure of applying the intervention scenarios, several recordings have been made on the energy characteristics of the existing buildings state for each one of the case studies. It is interesting to compare those trends observations and draw the picture of their relative behaviour. Those recordings have been made for all the building case studies and they seem to apply in a similar way to all of them regardless of the construction period of each case study building. The observations for each of the case studies have been transformed into graphs.

5.1.1 Energy efficiency of a building approach

A building's energy efficiency is often approached differently. An efficient building can be characterized by the low CO_2 emissions, the low Primary Energy consumption or the low operational cost for energy. Diagrams have been exported from the case studies energy certificates to compare those three characteristics. The observations made indicate that those three characteristics are correlated, one with each of the other two. The graphs are not a secure way to conclude if there is a correlation or not between the variables, as only data analysis can verify it, but it is a first optical way to see if it is possible that those variables may be correlated.

5.1.2 Primary Energy Consumption vs CO_2 Emissions

In the Figure 5.1.2-1, the PEC characteristic seems to be correlated with the CO_2 Emissions. The values seem to move together as well. This observation was expected. In the procedure of the energy certification, the energy values and characteristics of the conditioned space, translate in primary energy. No matter what the system or the fuel used for the heating of a conditioned space or the DHW, the transformation includes all the necessary parameters for exporting the final energy to primary (such as national electricity distribution system coefficient). Primary energy consumption is totally correlated with the CO_2 emissions.

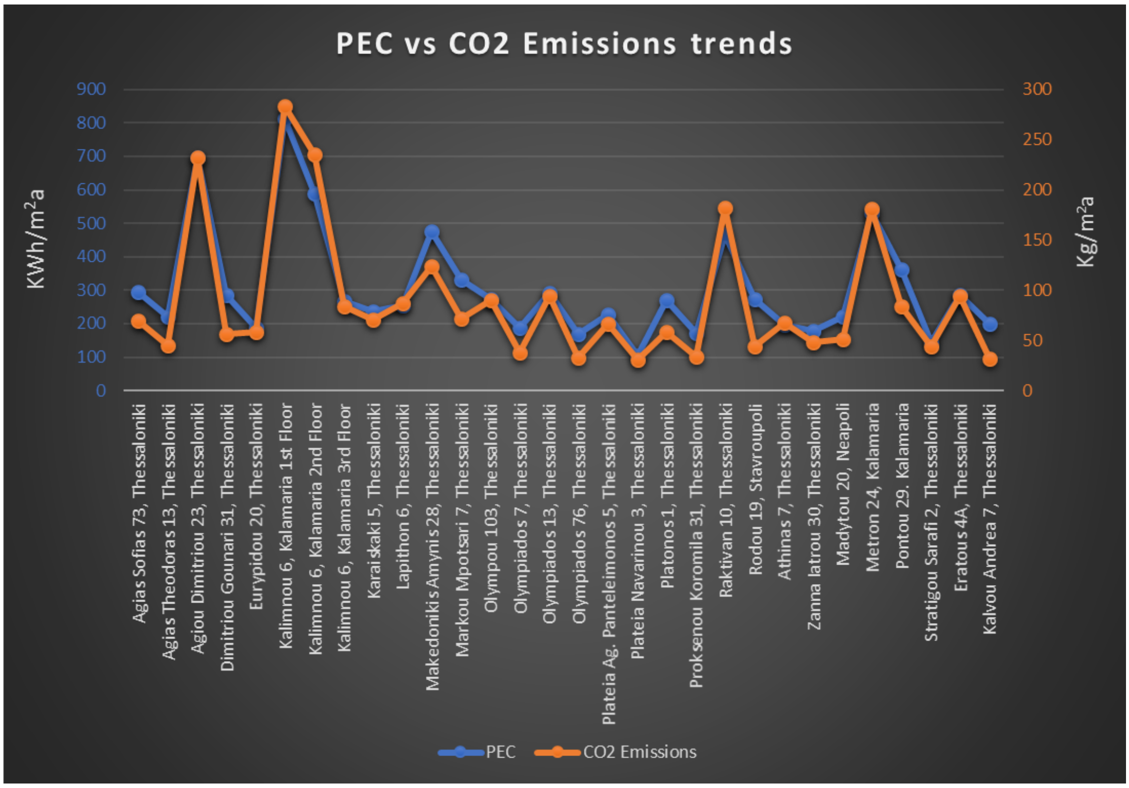


Figure 5.1.2-1: Primary Energy Consumption vs CO_2 Emissions trends graph.

5.1.3 PEC vs Operating Cost

It is expected that a building with low primary energy consumption, will also have a low operating cost. The assumption for the relation of those two characteristics seems to be verified for the case studies. The characteristics seem to be correlated. The correlation level though, seems to be lower than in the previous case of the PEC with the CO_2 emissions comparison. This is expected since the operating cost is also related with the market price of the fuel used.

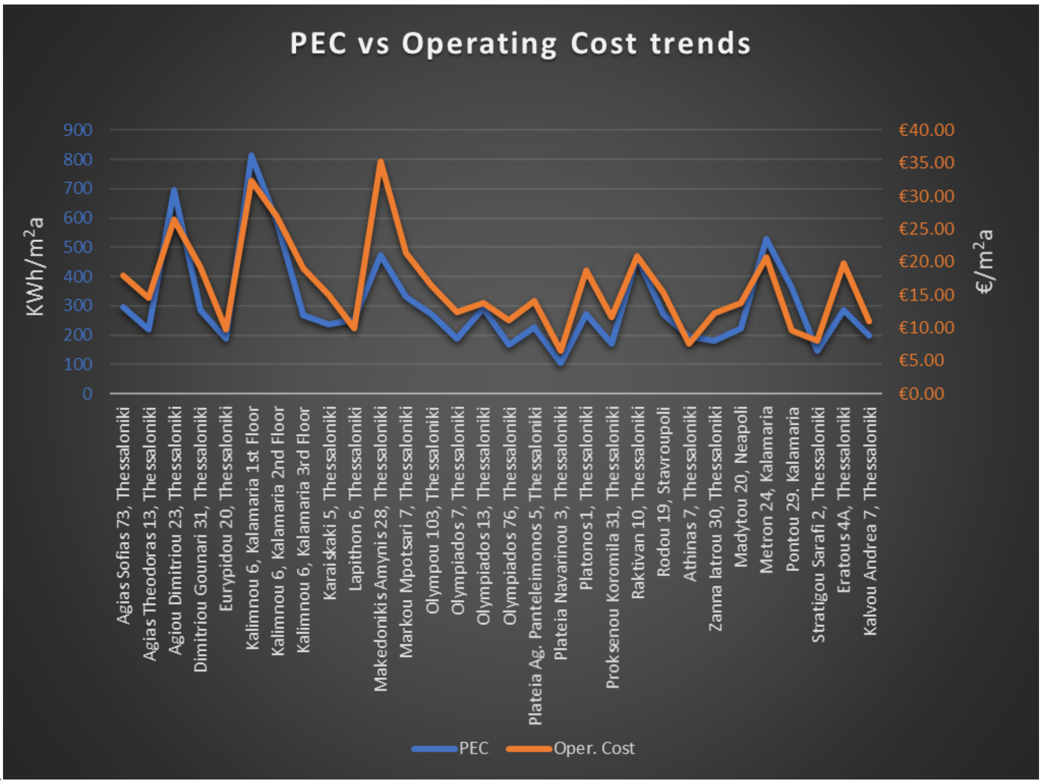


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Figure 5.1.3-1: Primary Energy Consumption vs Operating Cost.

5.1.4 CO_2 Emissions vs Operating Cost

The observations extracted from the Figure 5.1.2-1 and Figure 5.1.3-1 seem to be verified by the third graph. The CO_2 emissions seem to be as well correlated with the operating cost with the second appearing to have a deviation from the first.

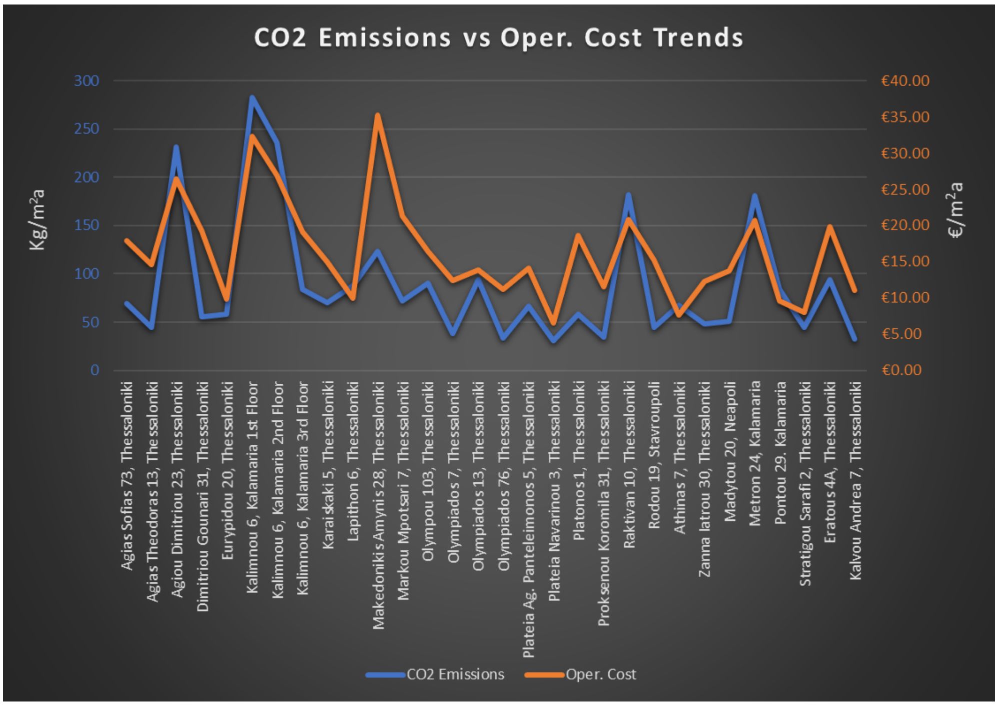


Figure 5.1.4-1: CO_2 emissions vs Operating Cost.

5.1.5 Energy Certification vs Construction Period

It is expected that the older a building is, the less energy efficient it will be. This is verified for the case studies as well. The median of energy class for the 1st period buildings appears being energy class No6 which accounts for energy class Z, the median for the 2nd period is energy class No4 which accounts for energy class D and the median value for the 3rd period is 3.5 which is higher than class D. The fluctuations are related in energy interventions made in the residences by the owners, before the production of the Energy Certificate and in the building positioning and surroundings as well. For example, in the case of building No 16, (Olympiados 76) the owner already installed new openable metal frame windows with 12mm double glazing and an individual gas boiler. Those interventions updated the energy certification rating to class D. In the case of building No18 (Plateia Navarinou 3), the replacement of the windows with openable synthetic frame double glazing 12mm and an individual gas boiler resulted in energy certification class C. For calculation reasons the certification rating classes (A,B,C,D,E,Z,H) have been replaced with numbers (1,2,3,4,5,6,7,8).

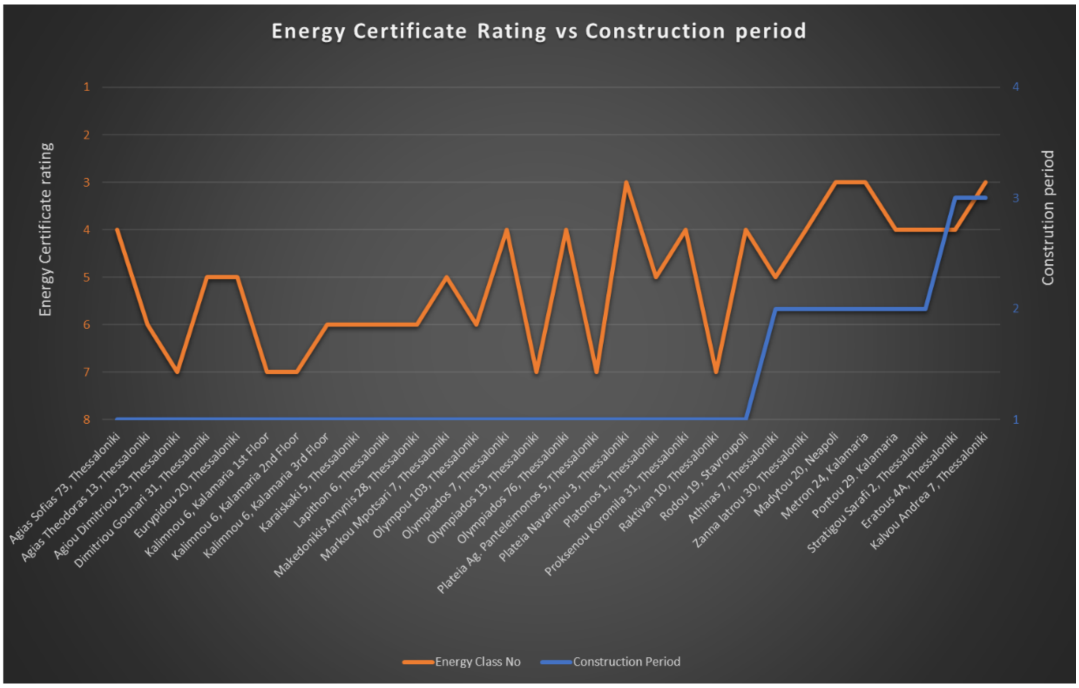


Figure 5.1.5-1: Energy certificate rating vs construction period.

5.2 Scenarios No1, No2, No3

All the scenarios No1, No2, No3 have been applied in case studies regardless of the construction period. The reason for this is that the purpose of the study is to achieve the same goals in energy efficiency retrofitting of the final product in absolute terms of energy consumption rather than relative. The effect of the building construction period has been noted in all the results: the energy saving percentage, the investment cost and the payback period. The interventions simulated for each scenario are described in paragraph 4.2.

5.2.1 Energy saving percentage

The scenarios simulated the energy consumption for each case study after the interventions applied. It is expected that every scenario will make a significant difference comparing to the other two scenarios and the initial case.

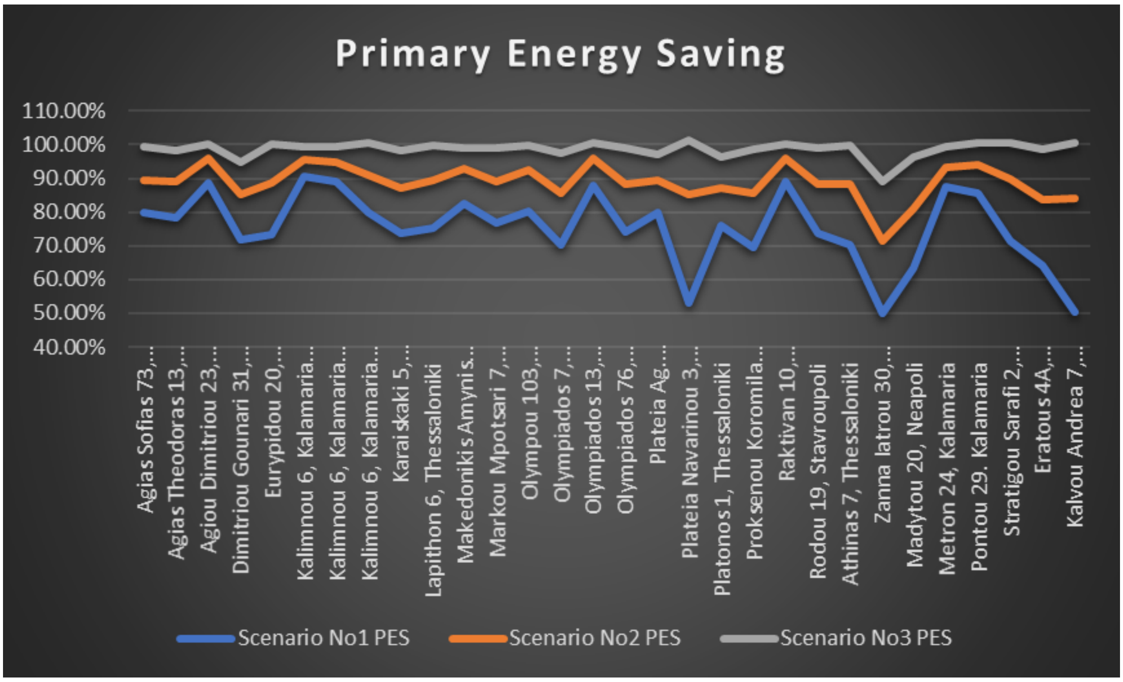


Figure 5.2.1-1: Scenario No1,2,3 Primary Energy Saving percentage.

In Figure 5.2.1-1, the behavior of each case in the intervention scenarios has been plotted for comparison. All scenarios seem to have a significant effect on the primary energy savings. Scenario No1 mean PES has the value of 75% while scenarios No2 and No3 achieve 89% and 99% PES respectively. This means that the application of the minimum interventions simulated, can offer an exciting potential to drastically reduce the CO_2 emissions of a building. This potential can be maximized in every type of building achieving a Net Zero Energy Building, no matter the energy category it belonged to before the retrofitting or no matter the construction period.

Comparing the energy saving potential for the case studies per period of construction, the values for each scenario show that the same interventions appear to have a higher impact on buildings that are constructed in an older period with less energy saving measures taken [Figure 5.2.1-2], as could be expected.

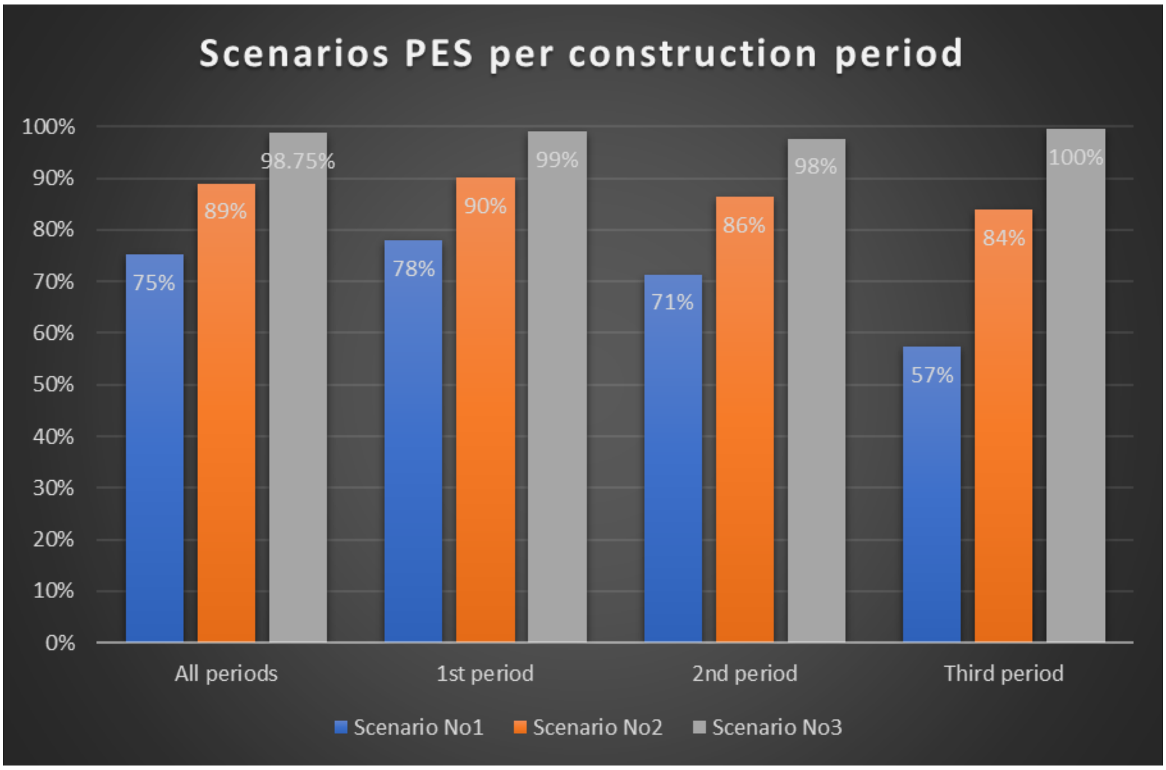


Figure 5.2.1-2: Plot of Primary Energy Saving potential per scenario and construction period.

5.2.2 Initial cost of energy renovation measures

It is expected that the initial cost for the energy renovation measures will be higher for the scenarios No2 and No3. To be comparable, the initial investment costs have been transformed in initial costs per square meter. The results received for all the building case studies are presented in Figure 5.2.2-1. The mean values for all periods and for each scenario are approximately Scenario No1: €225, Scenario No2: €297 and Scenario No3: €446.

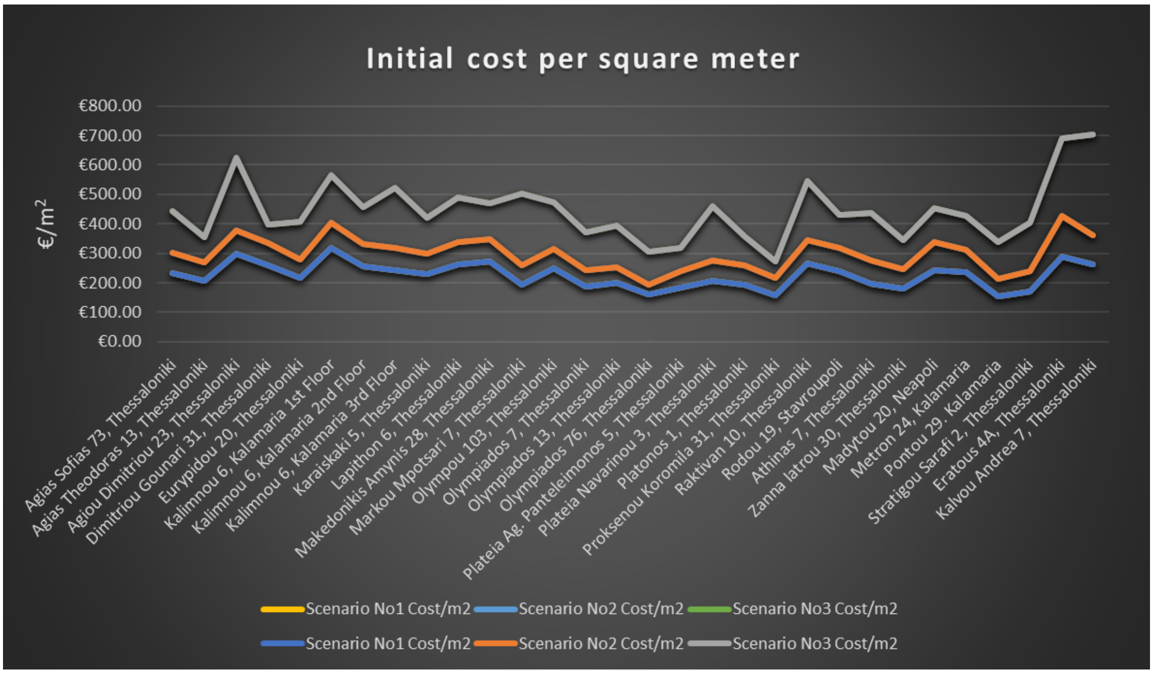


Figure 5.2.2-1: Initial cost per square meter for Scenarios No1,2,3.

Comparing the case studies results for the initial cost depending on the construction period is expected that the initial cost will decrease, the newest a building is. The results observed in Figure 5.2.2-2, indicate that this is true for the buildings of the second period, but it cannot be verified for those of the third period.

The cost in the cases of the scenarios No1 and No2 seems to differ only slightly in a percentage of approximately 10%. This is logical as the application of certain measures, implies that only a few items can be kept from the old building (as the distribution system or an existing gas boiler) and only if those items' performance has acceptable values.

The failure of verification of the cost mitigation in the third period building category lies ino the fact that only two of the case studies belong to the third period and although the mean area values for the buildings of the first and second period are approximately 62m2 for both of the periods, the mean area value for the third period is only 24m2. The problem occurred by the difference in the mean floor area is that in the case of small apartments, some absolute and invariable costs like the cost of a new gas boiler or a heat pump, may increase disproportionately the final cost per square meter.

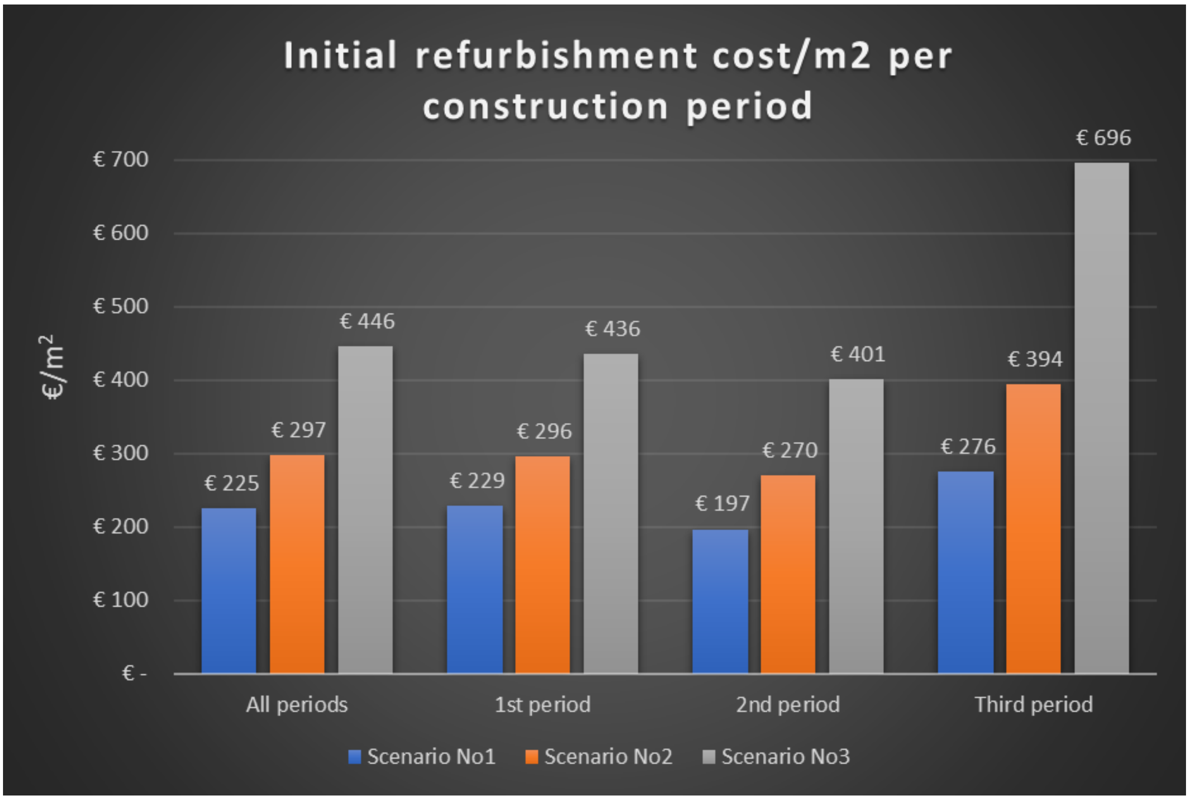


Figure 5.2.2-2: Initial cost per square meter per construction period mean values

5.2.3 Payback period

The payback period of the investment is significant in the decision-making process for every investment. The payback periods for all the case studies are presented in Figure 5.2.3-1.

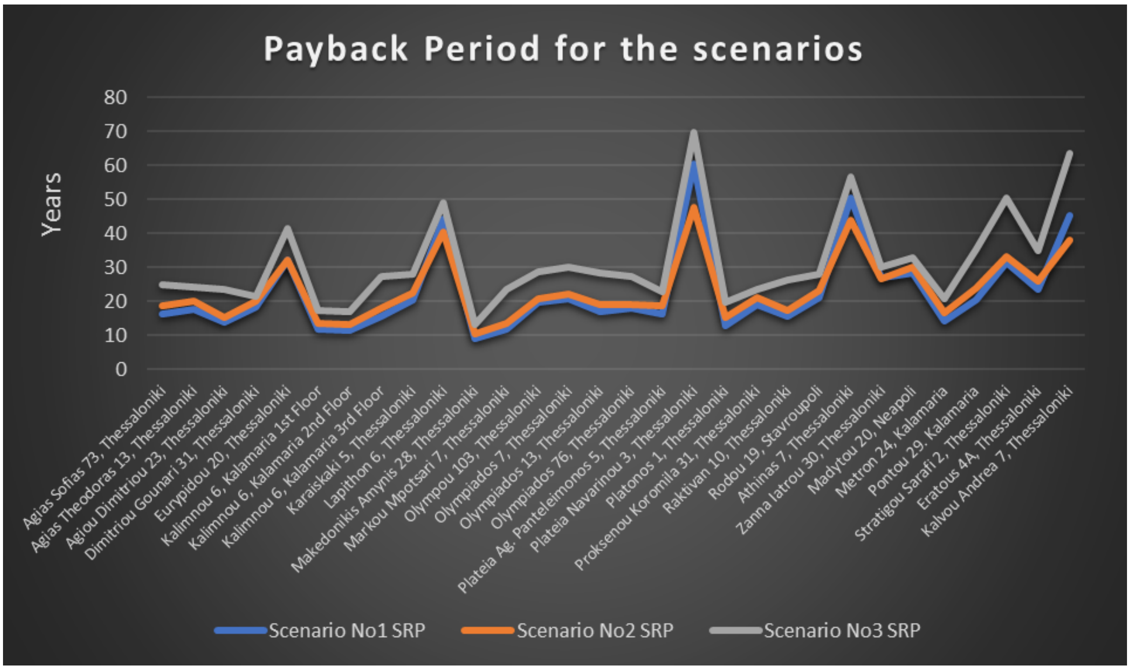


Figure: 5.2.3-1: Payback period for each scenario, all case studies.

It is observed that in most of the cases the payback period of the Scenarios No1 and No2 are very close to each other for the same case study. This is observed for all the construction periods. The mean values for each construction period are plotted in Figure 5.2.3-2.

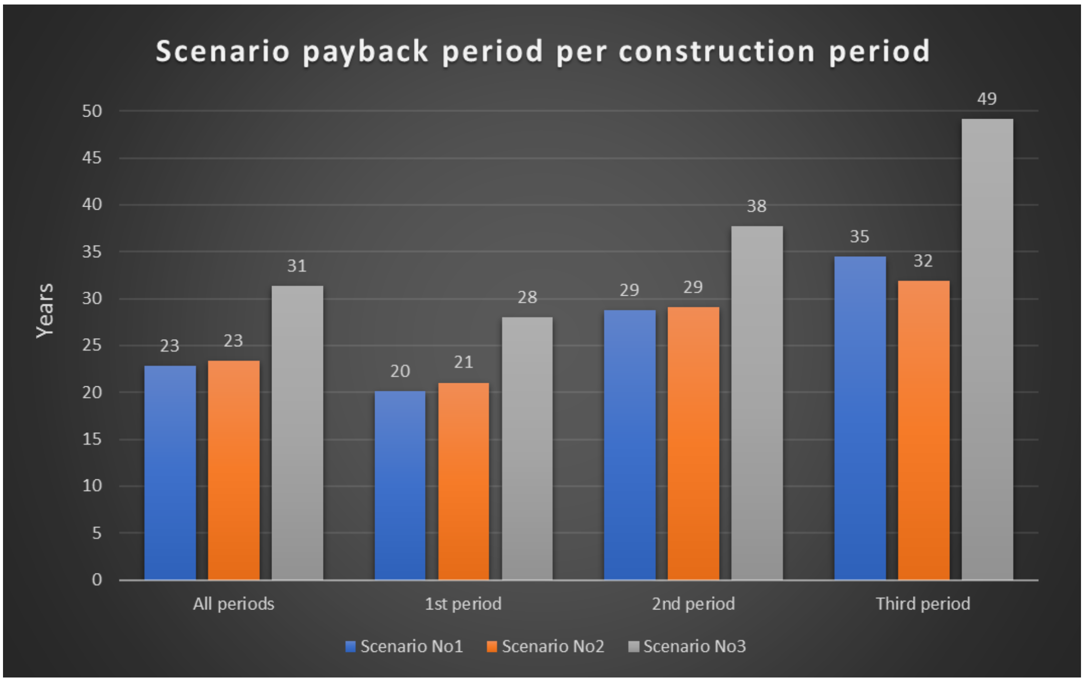


Figure 5.2.3-2: Payback Period per case study and Scenario plot

5.2.4 Operational cost

Although the operational cost is not a variable affecting directly the investment decision process, it is a significant factor affecting the residents of a building. In that sense, it is interesting to observe the difference in the costs occurring from each energy refurbishment scenarios.

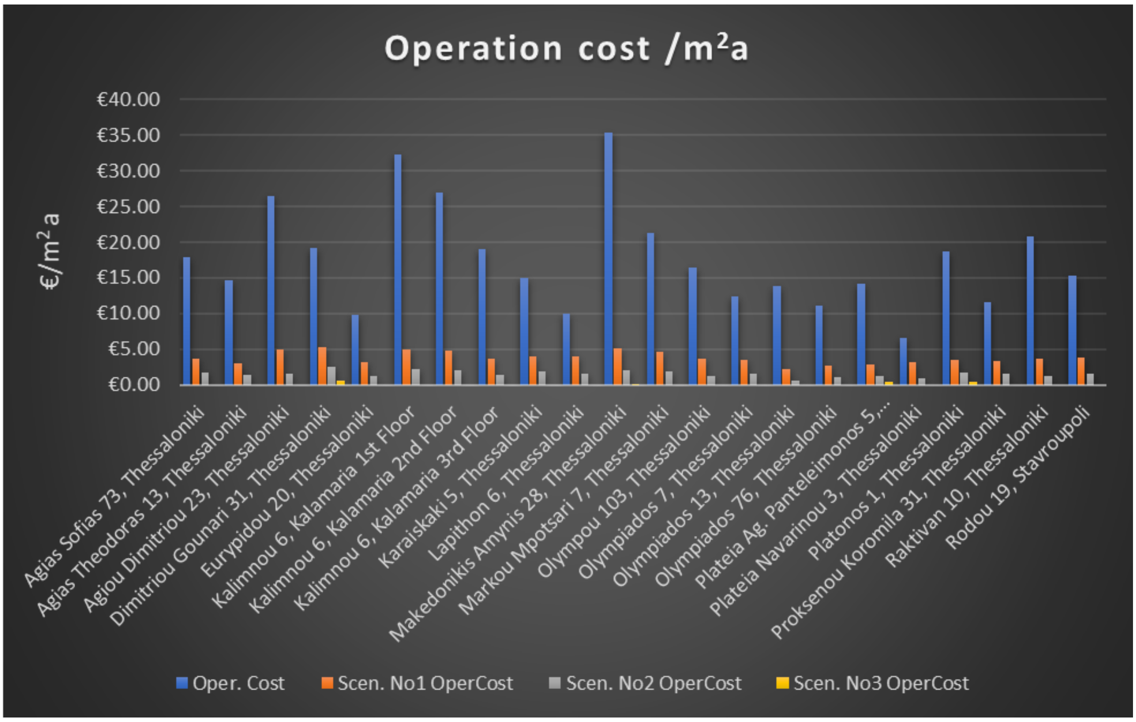


Figure 5.2.4-1: Operational cost for each of the case studies and scenario

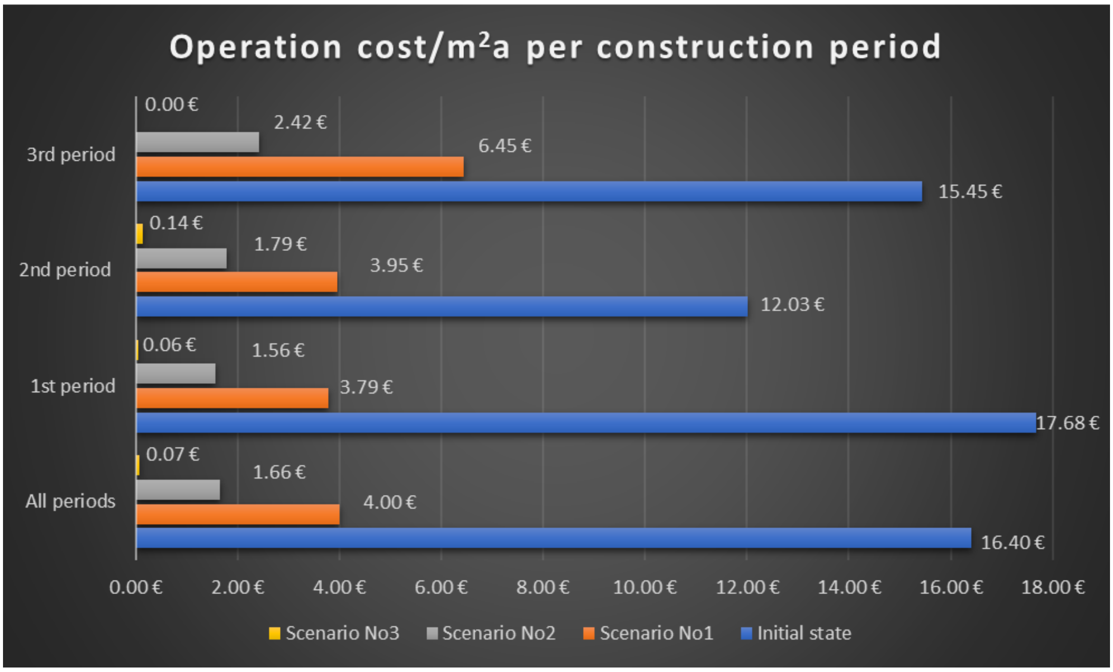


Figure 5.2.4-2: Mean operational cost per period and scenario applied

The energy refurbishment measures appear to have a significant impact on the operational cost of all the case studies even for the minimum interventions of the Scenario No1 [Figure 5.2.4-1] [Figure 5.2.4-2].

5.3 Overview

The research has given information for the energy behavior of the thirty case studies, all located in Greece – prefecture of Thessaloniki [Figure 4.3-2], after the application of three individual energy saving scenarios described in paragraph 4.2. The buildings chosen were all multi-family houses, as shown in paragraph 3.5.4 that the multi-family buildings energy characteristics represent better the building stock characteristics. The methodology used was based in the TABULA – EPISCOPE projects and the relative report of the Greek Energy Saving Team of the Institute for Environmental Research and Sustainable Development of NOA "Greek residential Buildings Typology" [27]. The scenario results have been plotted separately for each case study in three-page brochures presenting comparative diagrams between each scenario and the initial state of the building and between the individual scenarios.

The material produced offered the opportunity to observe the reaction of the thirty case studies and through the procedure and the numerical results to obtain useful policy-making information. In general, it has been clear that the energy saving interventions applied in the form of scenarios, had similar final absolute results no matter the construction period of the building. Approached from a percentage point of view though, a significant difference in the impact of the measures has been observed, both in the energy saving potential and in the payback period of the investment. The percentage of energy saving potential difference between the scenarios was decreasing from the first scenario to the third [Figure 5.2.1-2] while on the contrary the payback period was increasing [Figure 5.2.3-2]. What is extremely interesting is that for all construction periods, the payback period for the first and the second scenario are very close [Figure 5.2.3-2], while the respective PES potential difference is as high as 12% for the first period buildings and 15% for the second period buildings [Figure 5.2.1-2] with the initial cost for scenario No2 being 30% and 38% higher for the 1^{st} and the 2^{nd} construction period respectively. In almost all case studies the third scenario application resulted in net zero energy buildings with the PES being from 98-100%. The initial cost is generally almost double of the first scenario [Figure 5.2.2-2] with the mean payback period increasing for approximately 8, 9, 14 years, respectively for each of the three periods and 8 years for the whole building stock of the case studies [Figure 5.2.3-2].

Summarizing the observations obtained through this research:

- For an existing building the higher the primary energy consumption, the higher the CO_2 emissions and the operating cost.
- The older buildings have a higher potential for energy saving.
- Even the minimum efficiency measures have a great impact on the mitigation of primary energy consumption.
- Applying increased measures can result in higher efficiency with the same PP.

- With the appropriate measures, all the construction periods buildings have the ability to achieve net zero state.
- It is impossible to achieve NZEB renovation without the use of heat pumps and RES as photovoltaics and solar thermal.
- The distribution systems may greatly affect the efficiency of new installations.
- Small buildings / apartments have an increased cost for energy saving retrofitting interventions and a long payback period because of the invariable costs of systems installations.
- In policy making, no matter if the decision makers’ approach is financial, environmental, social or a mixture of all three, it is more effective to renovate old and buildings with high Primary Energy Consumption.

6 Appendix

1	Multi-Family House			
	Apartment			
	Agias Sofias 73, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	48.6			
Heater Volume	145.8			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.5
Roof	A/S
Floor	A/S
Openings	3.8
g-openings	0.52

HVAC systems performance

	Heating	DHW
Production	0.929	0.929
Distribution	0.86	0.72
Terminal Units / Storage	0.87	1

Systems

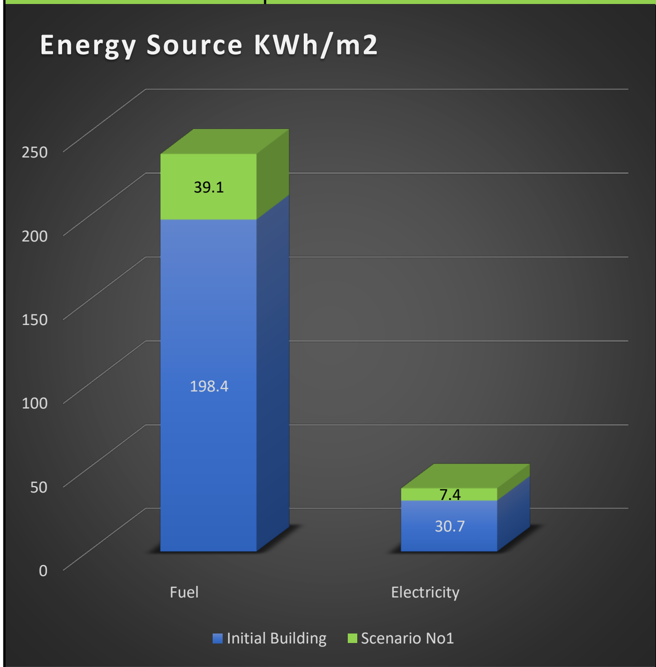
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

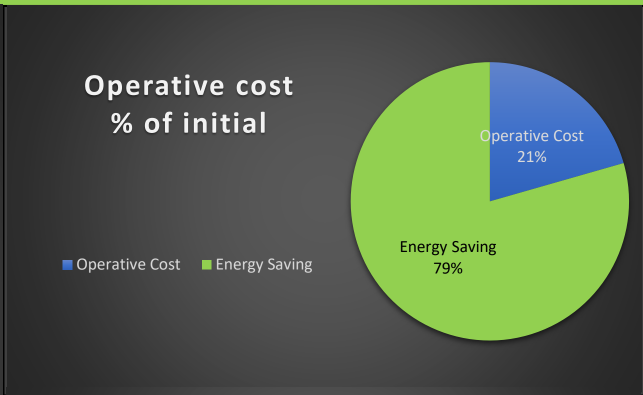
Annual Energy Characteristics

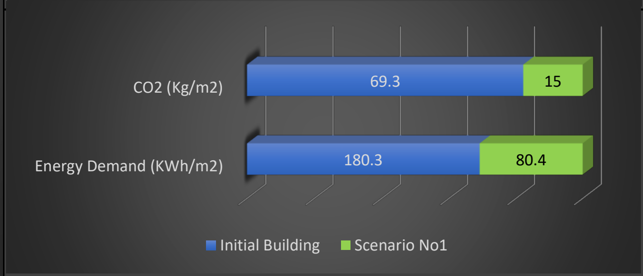
Energy Demand (KWh/m2/a)	180.3
Energy Consumption (KWh/m2/a)	228.4
Thermal Energy (KWh/m2/a)	198.4
Electricity (KWh/m2/a)	30.7
Primary Energy (KWh/m2/a)	295.4
CO2 Emissions (Kg/m2/a)	69.2
Total Final Thermal Energy	9642.24
Total Electricity Consumption	1492.02
Operating cost	€868.90

Energy Saving Interventions

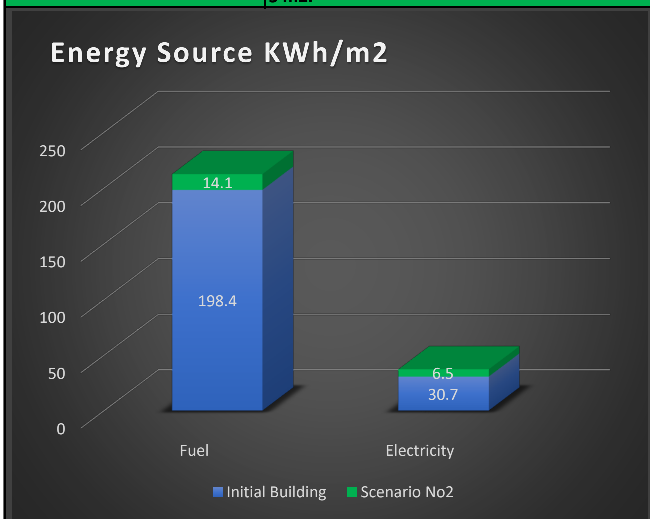
Scenario No1	P.E.S.	79.70%	Initial cost	€11,322.00	P.P. (Years)	16.4
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

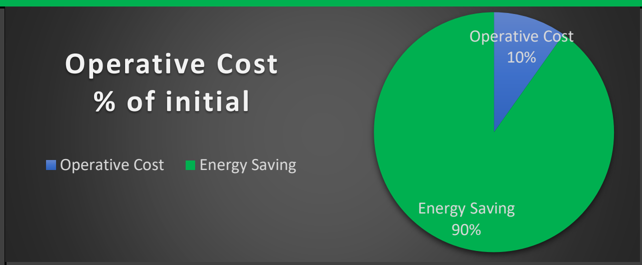


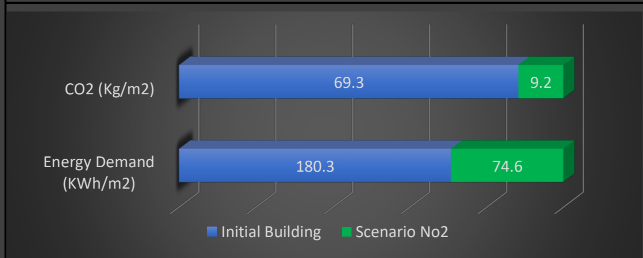




Scenario No2	P.E.S.	89.30%	Initial cost	€14,677.20	P.P. (Years)	18.7
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	New condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

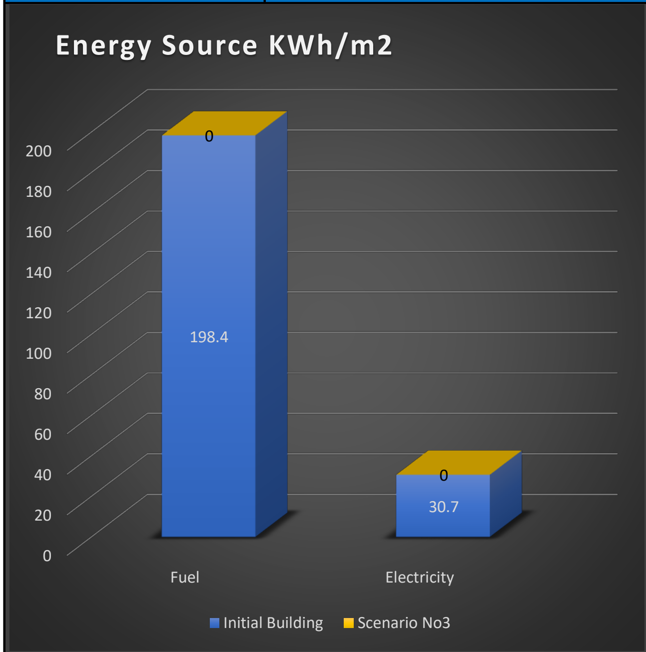


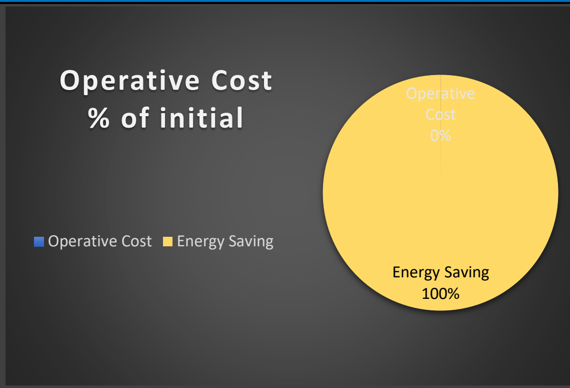


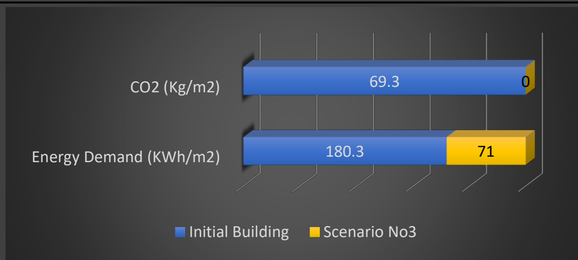


Energy Saving Interventions

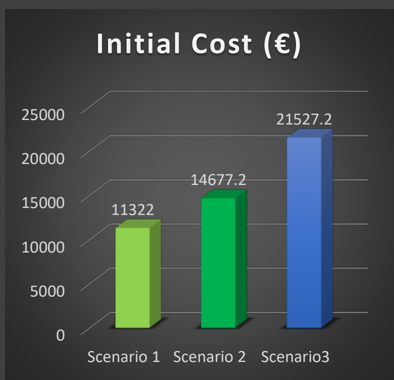
Scenario No3	P.E.S.	99.30%	Initial cost	€21,527.20	P.P. (Years)	25
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

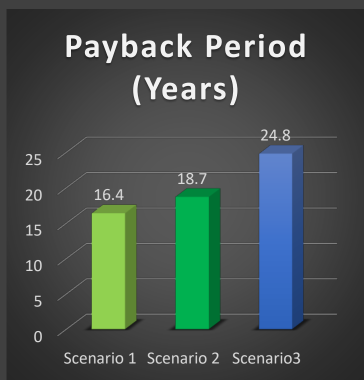


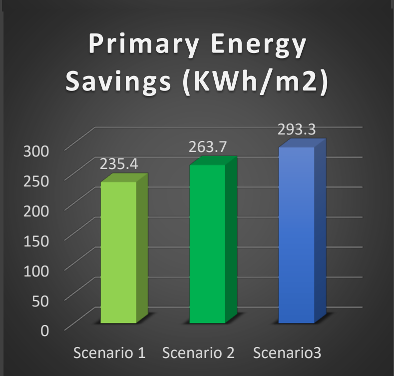


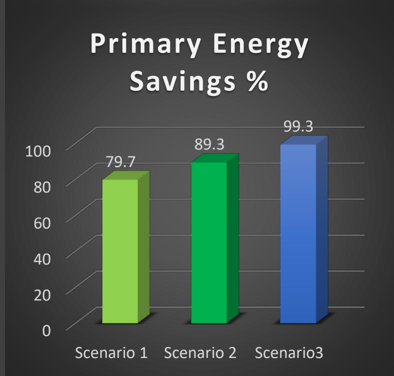


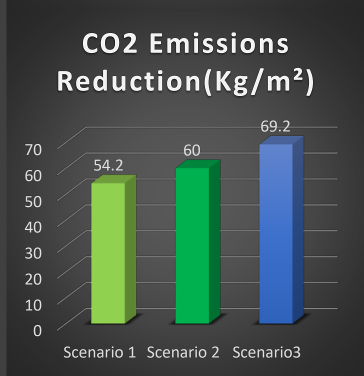
Scenario Comparison Diagrams











2	Multi-Family House			
	Apartment			
	Agias Theodoras 13 Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	83.3			
Heater Volume	245.74			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable wooden frame single glazing
Blinds	Wooden blinds
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.6
Roof	A/S
Floor	A/S
Openings	5.99
g-openings	0.63

HVAC systems performance

	Heating	DHW
Production	0.896	0.896
Distribution	0.89	0.72
Terminal Units / Storage	0.87	1

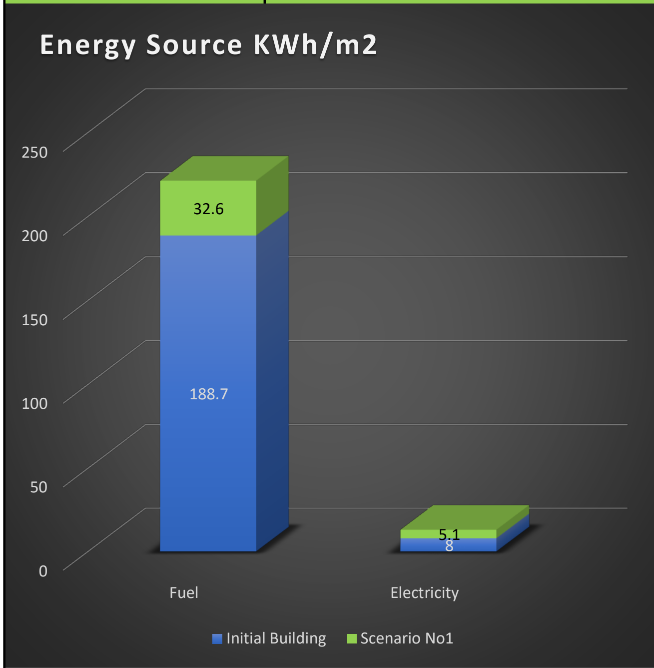
Systems

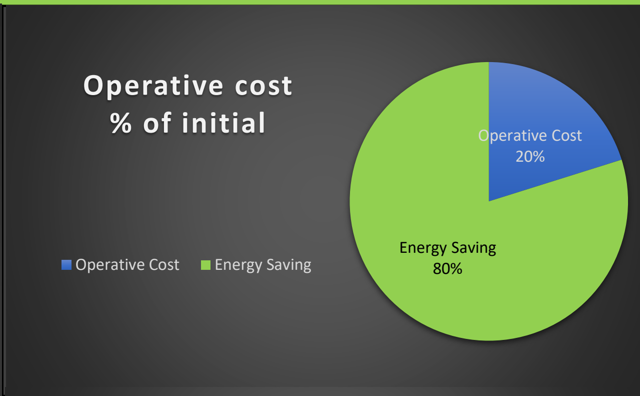
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

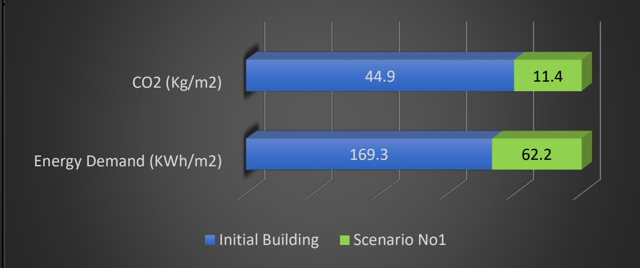
Annual Energy Characteristics

Energy Demand (KWh/m2/a)	169.3
Energy Consumption (KWh/m2/a)	196.1
Thermal Energy (KWh/m2/a)	188.7
Electricity (KWh/m2/a)	8
Primary Energy (KWh/m2/a)	219.5
CO2 Emissions (Kg/m2/a)	44.9
Total Final Thermal Energy	15718.71
Total Electricity Consumption	666.4
Operating cost	€1,217.60

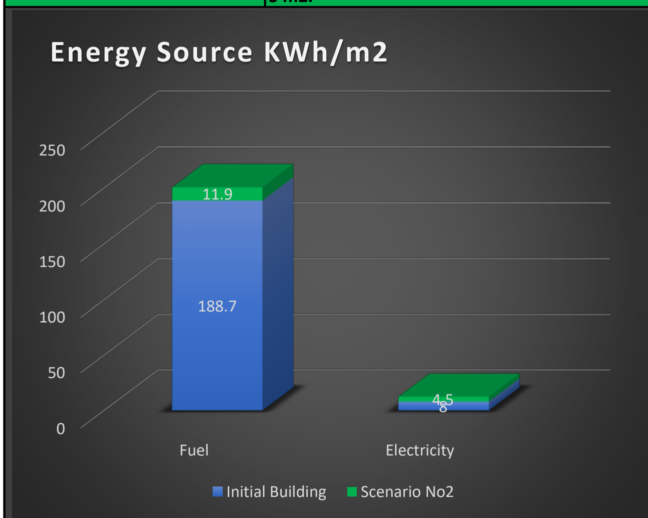
Energy Saving Interventions						
Scenario No1	P.E.S.	78.50%	Initial cost	€17,239.00	P.P. (Years)	17.7
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

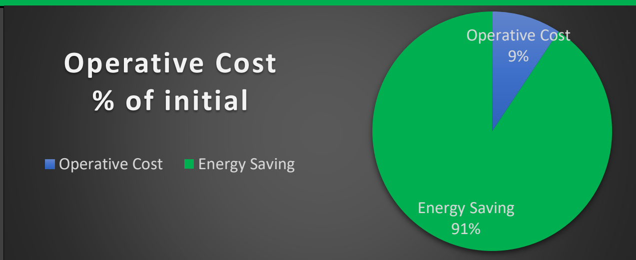


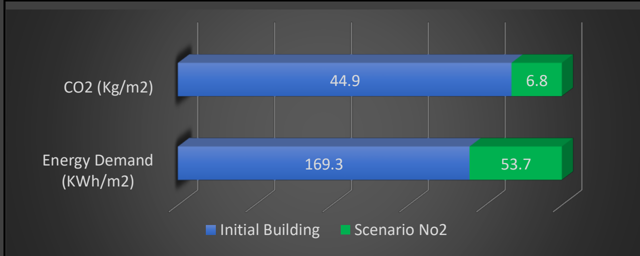




Scenario No2	P.E.S.	89.20%	Initial cost	€22,334.20	P.P. (Years)	20.2
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

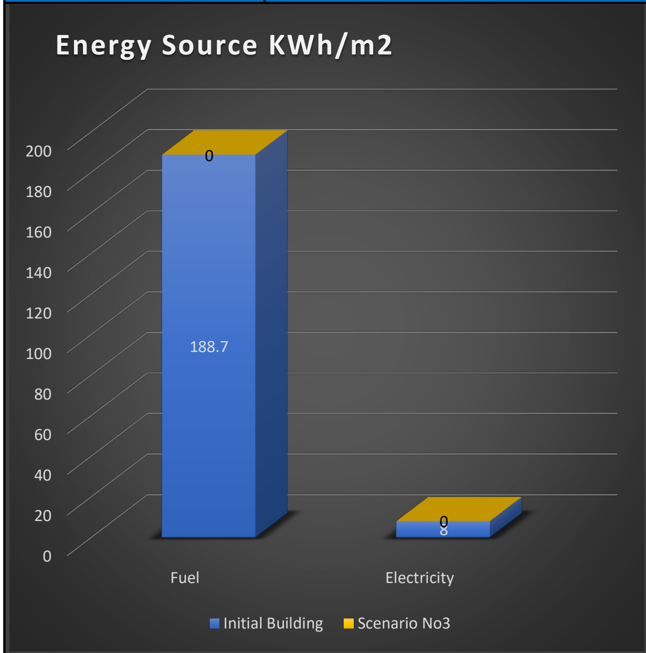


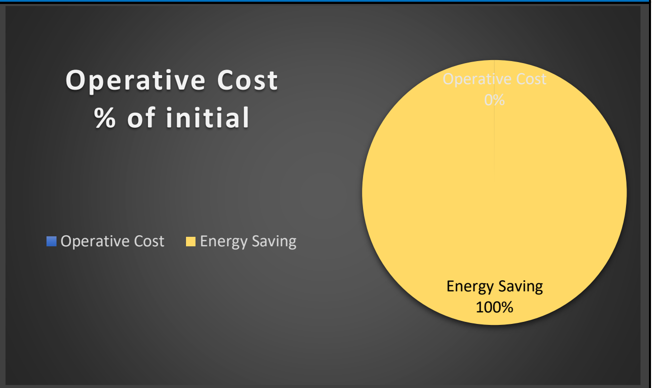


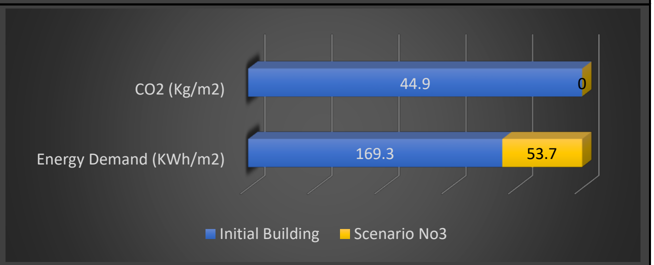


Energy Saving Interventions

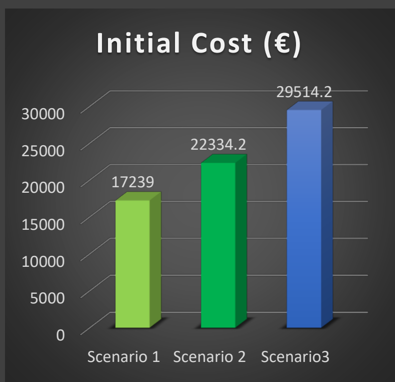
Scenario No3	P.E.S.	98.30%	Initial cost	€29,514.20	P.P. (Years)	24.2
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

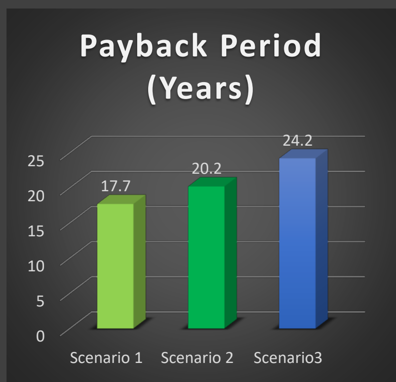


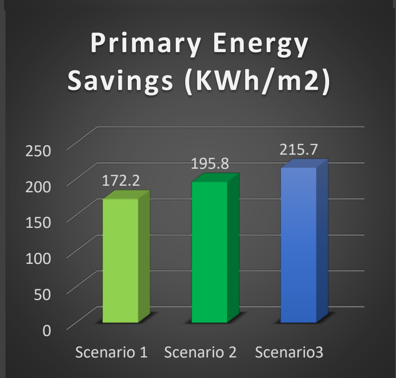


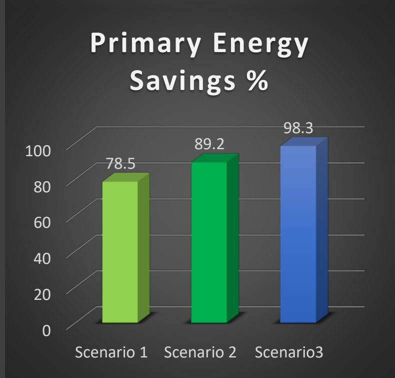


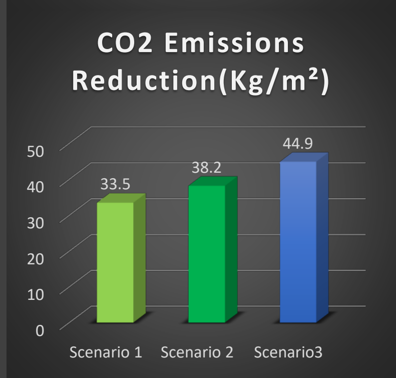
Scenario Comparison Diagrams











3	Multi-Family House			
	Apartment			
	Agiou Dimitriou 23, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	27			
Heater Volume	83.7			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable wooden frame single glazing
Blinds	Wooden blinds
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.5
Roof	A/S
Floor	A/S
Openings	4.9
g-openings	0.55

HVAC systems performance

	Heating	DHW
Production	1	1
Distribution	1	0.72
Terminal Units / Storage	0.938	0.98

Systems

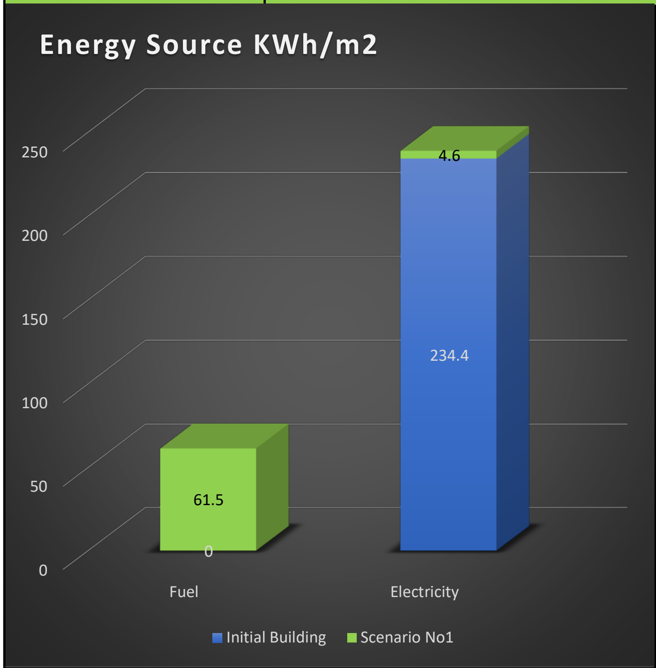
Production	Local electrical radiators
Distribution	Non applicable
Solar thermal	Non applicable
DHW	Local electrical boiler

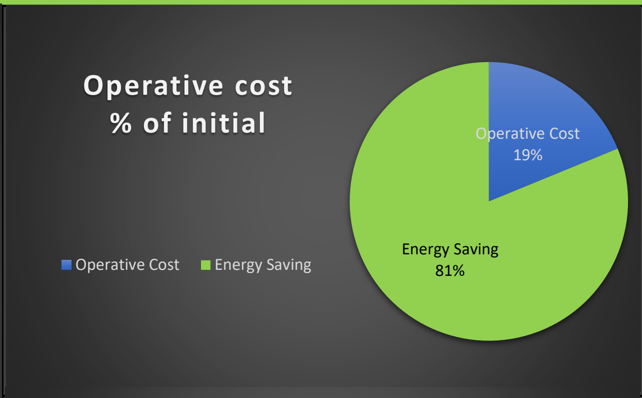
Annual Energy Characteristics

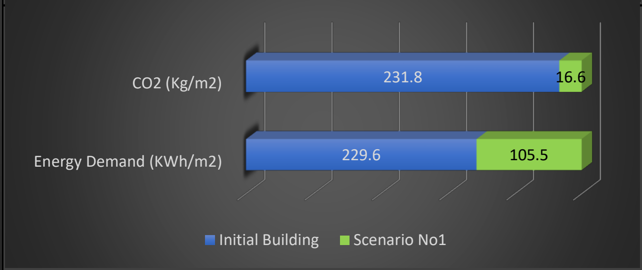
Energy Demand (KWh/m2/a)	229.6
Energy Consumption (KWh/m2/a)	234.2
Thermal Energy (KWh/m2/a)	0
Electricity (KWh/m2/a)	234.4
Primary Energy (KWh/m2/a)	679.2
CO2 Emissions (Kg/m2/a)	231.8
Total Final Thermal Energy	0
Total Electricity Consumption	6328.8
Operating cost	€715.20

Energy Saving Interventions

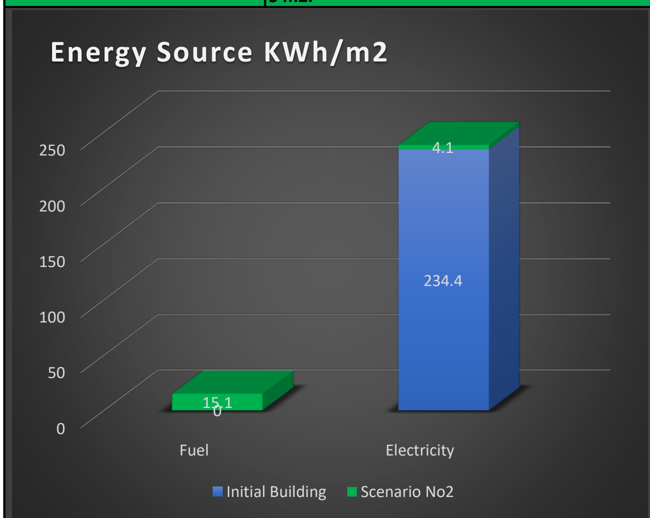
Scenario No1	P.E.S.	88.60%	Initial cost	€8,024.50	P.P. (Years)	13.8
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

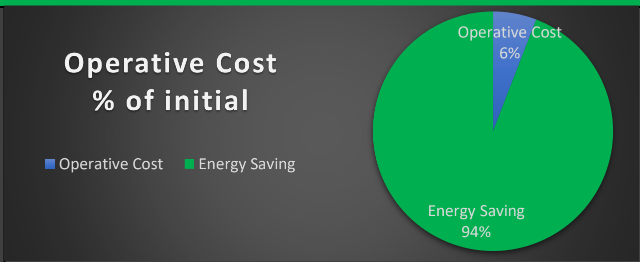


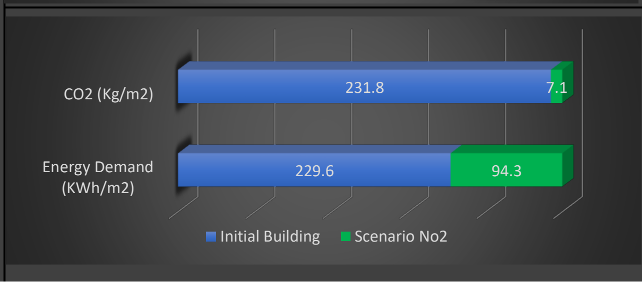




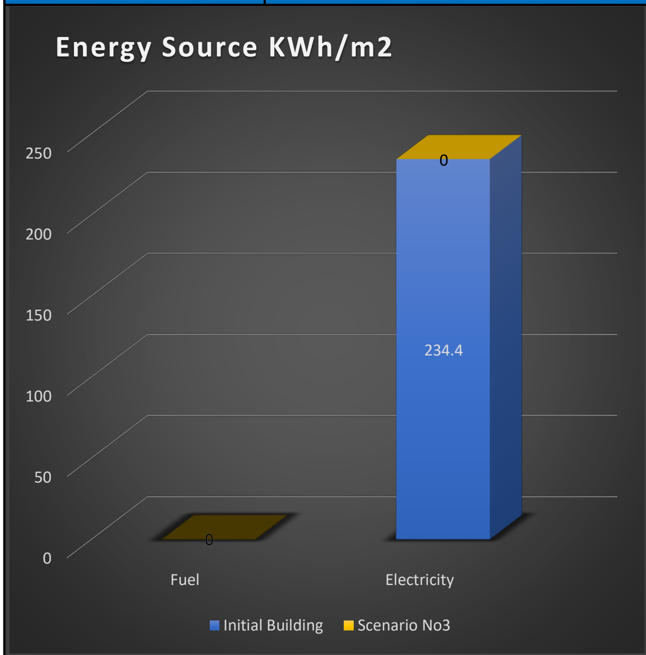
Scenario No2	P.E.S.	96.00%	Initial cost	€10,197.40	P.P. (Years)	15.1
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

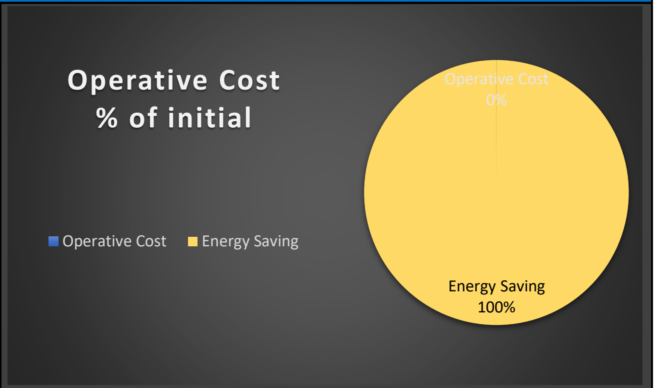


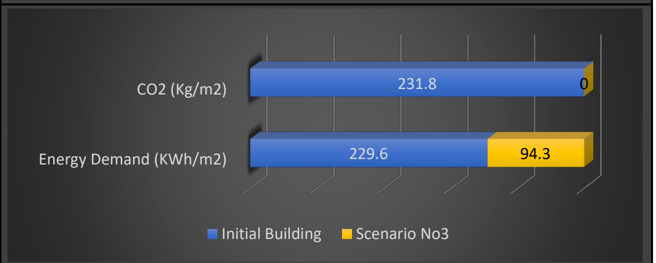




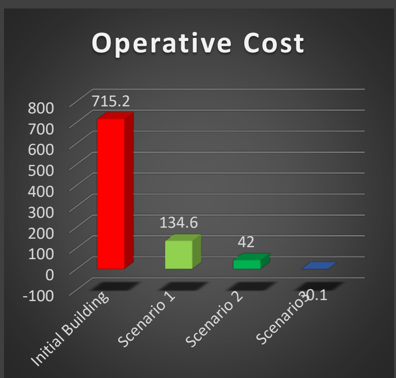
Energy Saving Interventions						
Scenario No3	P.E.S.	100.10%	Initial cost	€16,897.40	P.P. (Years)	23.6
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

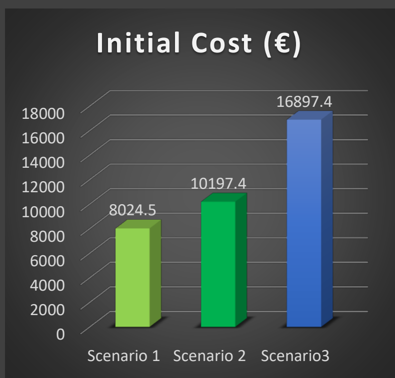


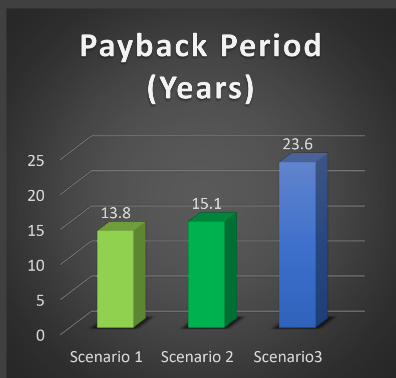


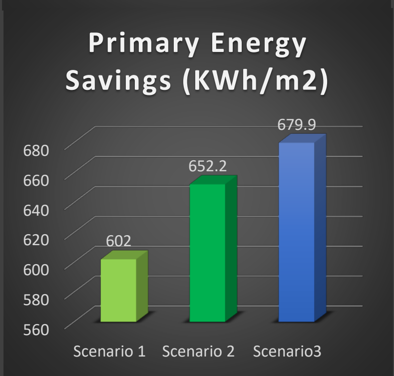


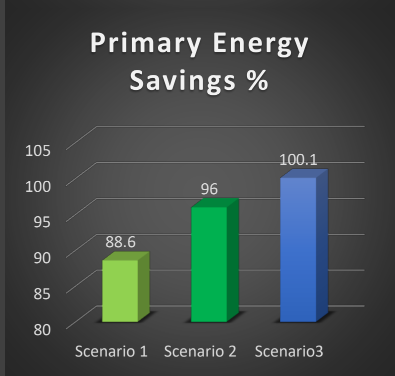
Scenario Comparison Diagrams

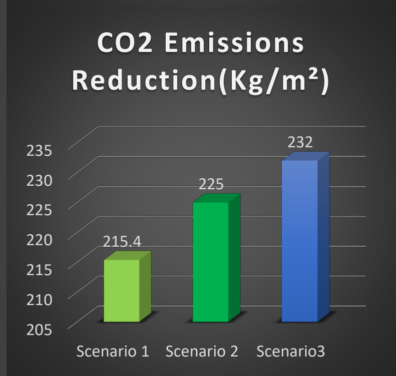












4	**Multi-Family House**			
	Apartment			
	Dimitriou Gounari 31, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	148.3			
Heater Volume	467.15			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic frame double glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.56
Roof	A/S
Floor	A/S
Openings	3
g-openings	0.5

HVAC systems performance

	Heating	DHW
Production	0.935	0.935
Distribution	0.89	0.846
Terminal Units / Storage	0.938	1

Systems

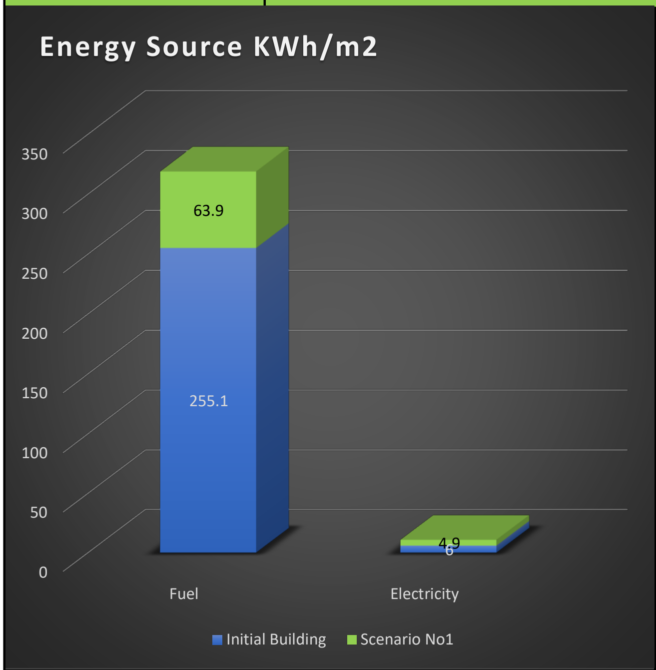
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

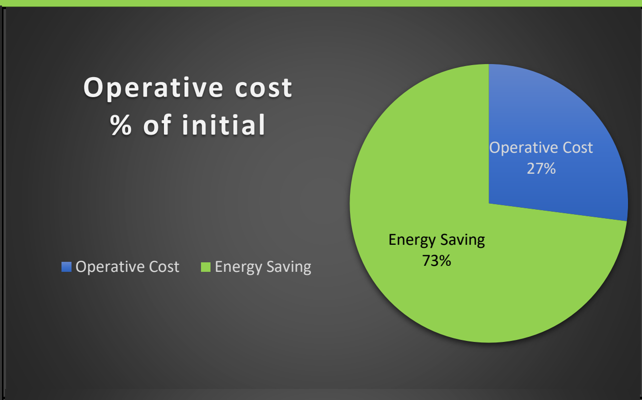
Annual Energy Characteristics

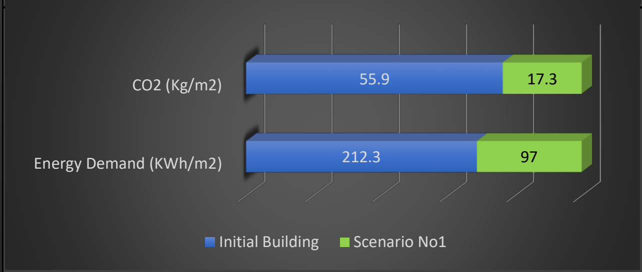
Energy Demand (KWh/m2/a)	212.3
Energy Consumption (KWh/m2/a)	260.7
Thermal Energy (KWh/m2/a)	255.1
Electricity (KWh/m2/a)	6
Primary Energy (KWh/m2/a)	284.2
CO2 Emissions (Kg/m2/a)	55.9
Total Final Thermal Energy	37831.33
Total Electricity Consumption	889.8
Operating cost	€2,848.30

Energy Saving Interventions

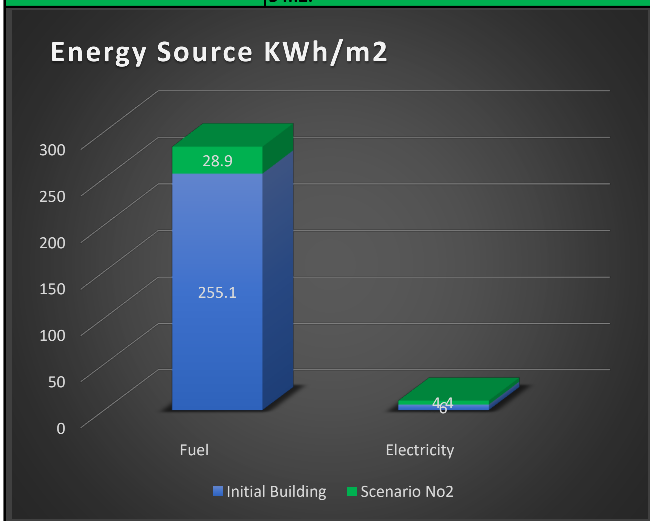
Scenario No1	P.E.S.	71.90%	Initial cost	€38,259.00	P.P. (Years)	18.4
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

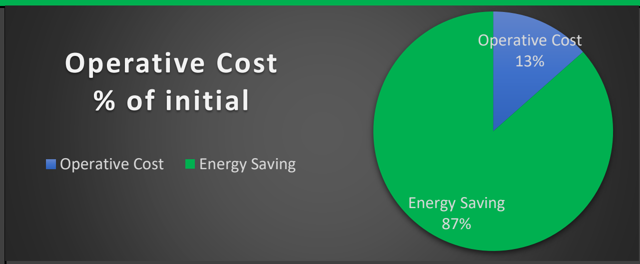


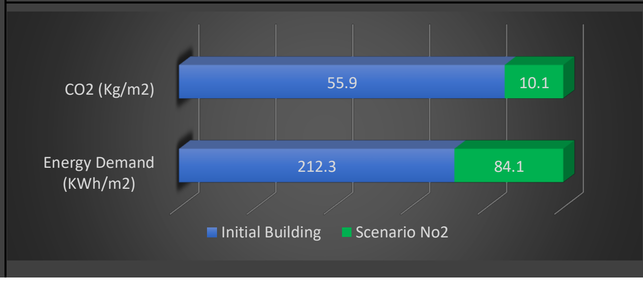




Scenario No2	P.E.S.	85.40%	Initial cost	€49,730.80	P.P. (Years)	20.2
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

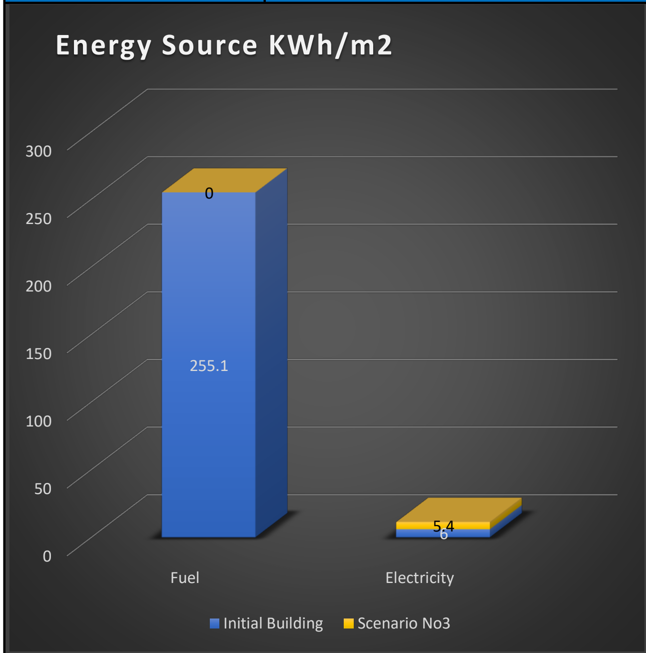


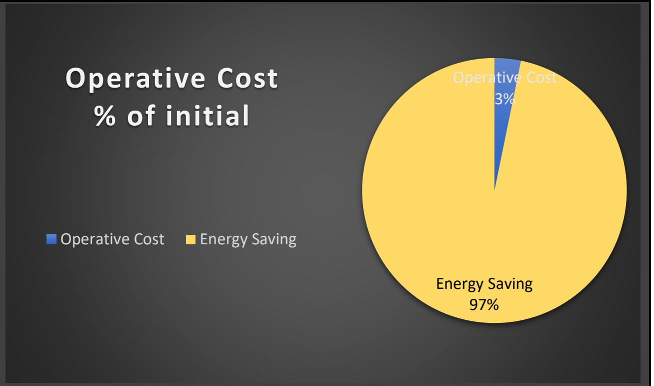


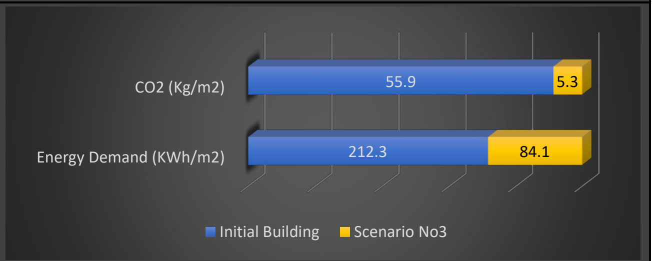


Energy Saving Interventions

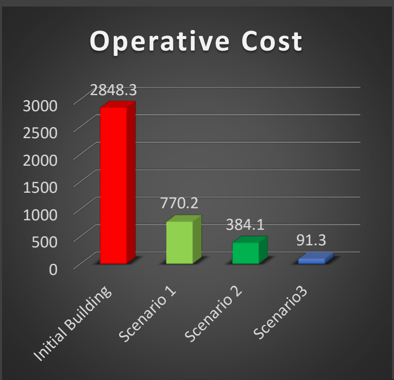
Scenario No3	P.E.S.	94.90%	Initial cost	€58,930.80	P.P. (Years)	21.4
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

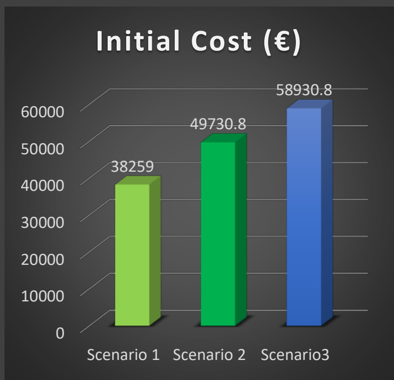


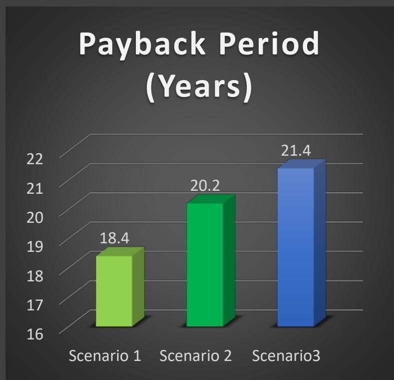


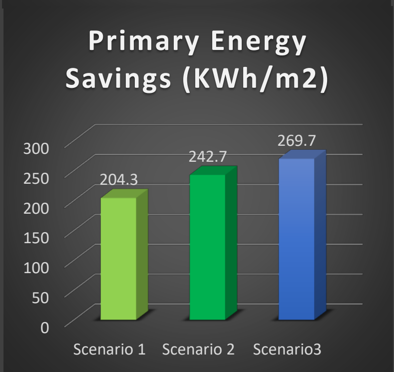


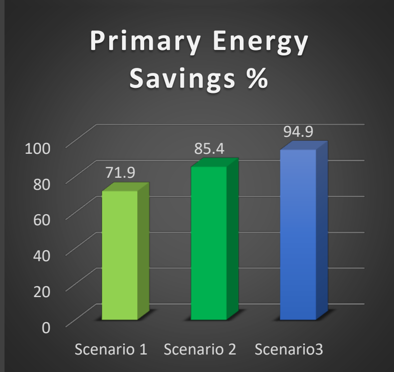
Scenario Comparison Diagrams

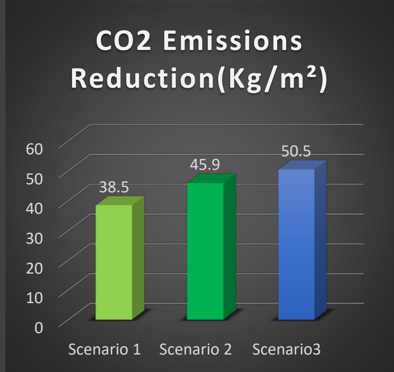




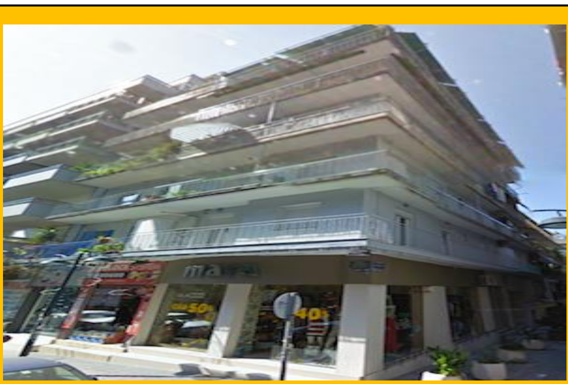








5	Multi-Family House			
	Apartment			
	Eyrypidou 20, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	52			
Heater Volume	156			



Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.56
Roof	A/S
Floor	A/S
Openings	3.8
g-openings	0.52

HVAC systems performance

	Heating	DHW
Production	0.935	1
Distribution	0.95	0.72
Terminal Units / Storage	0.93	0.98

Systems

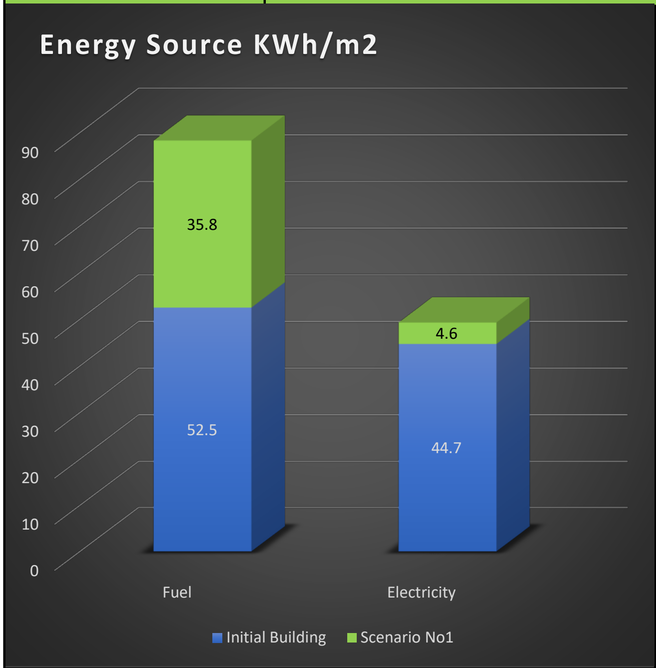
Production	Oil boiler, local A/C
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Local electric boiler

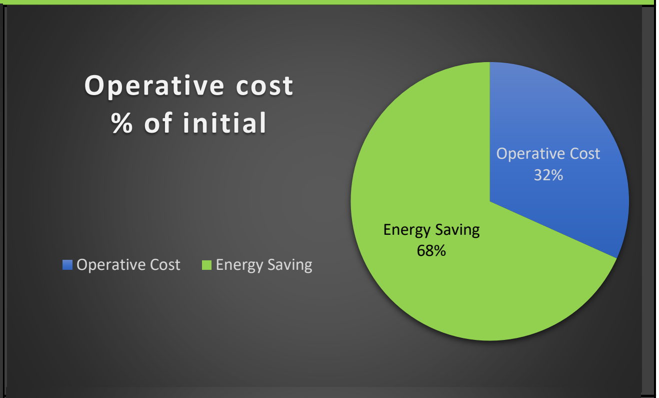
Annual Energy Characteristics

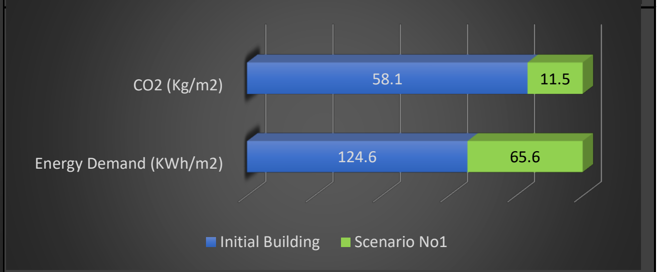
Energy Demand (KWh/m2/a)	124.6
Energy Consumption (KWh/m2/a)	97.1
Thermal Energy (KWh/m2/a)	52.5
Electricity (KWh/m2/a)	44.7
Primary Energy (KWh/m2/a)	187
CO2 Emissions (Kg/m2/a)	58.1
Total Final Thermal Energy	2730
Total Electricity Consumption	2324.4
Operating cost	€510.90

Energy Saving Interventions

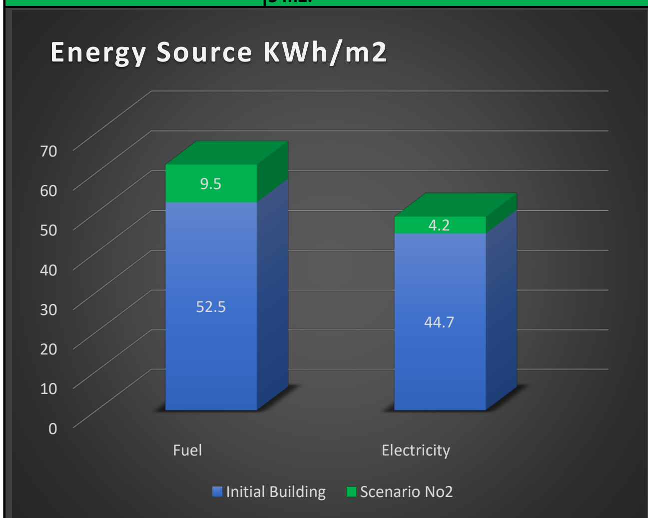
Scenario No1	P.E.S.	73.30%	Initial cost	€11,169.50	P.P. (Years)	32
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

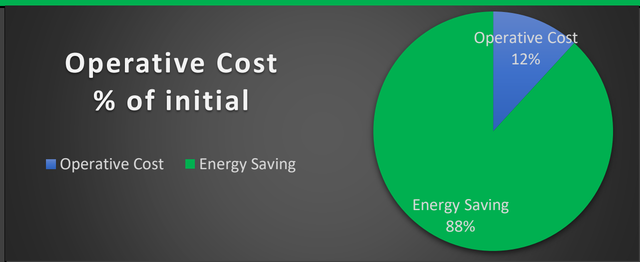


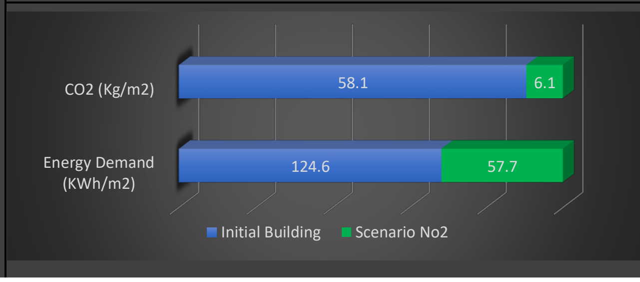




Scenario No2	P.E.S.	88.70%	Initial cost	€14,448.80	P.P. (Years)	32.1
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

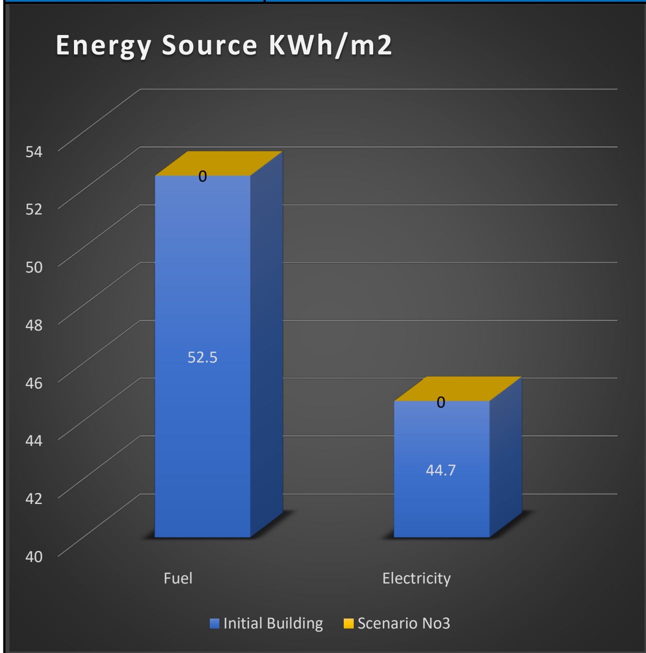


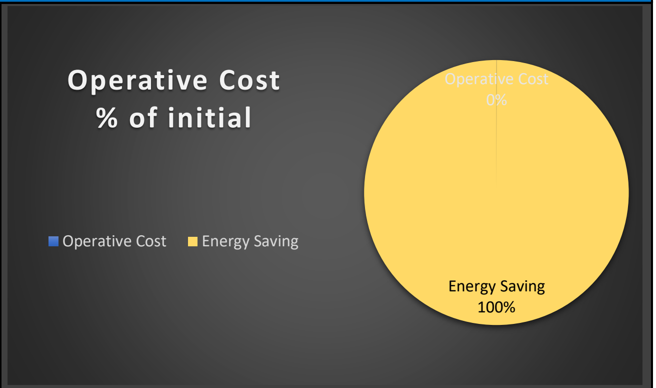


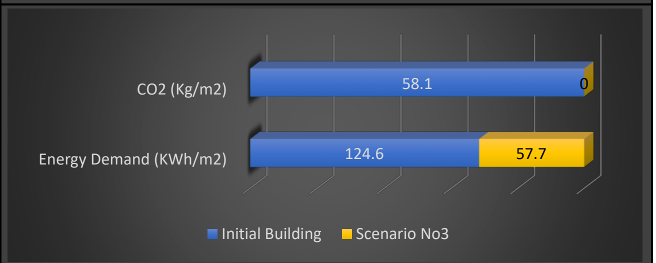


Energy Saving Interventions

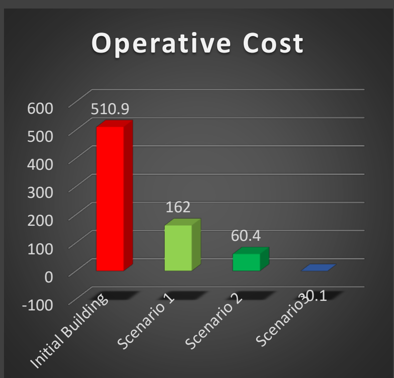
Scenario No3	P.E.S.	100.20%	Initial cost	€21,148.80	P.P. (Years)	41.4
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

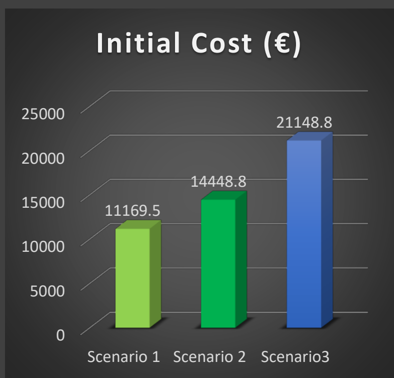


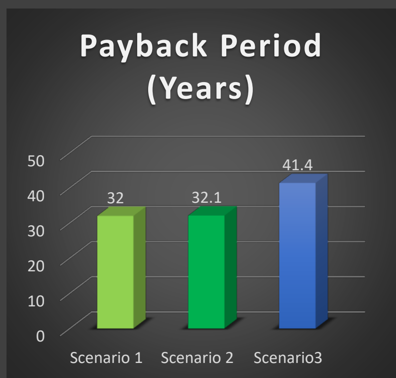


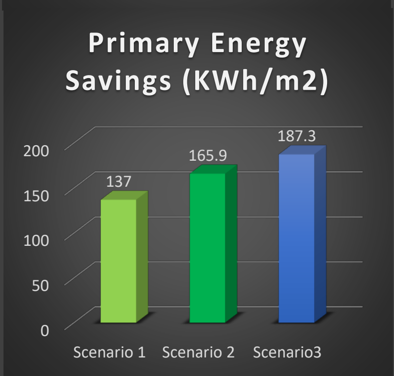


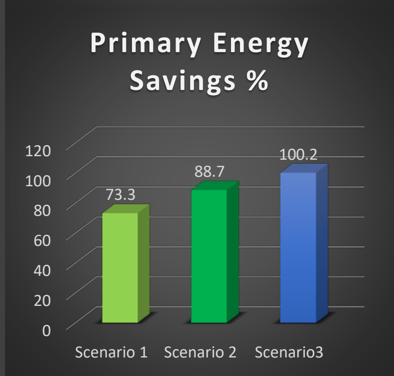
Scenario Comparison Diagrams

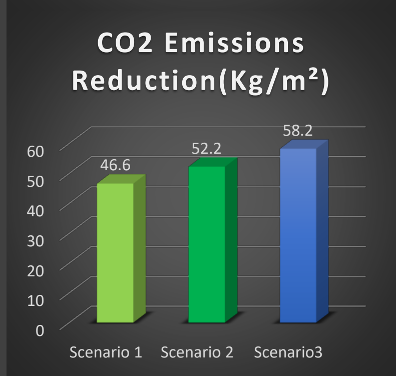












6	Multi-Family House			
	Apartment			
	Kalymnou 6 Kalamaria (1st floor)			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	45			
Heater Volume	135			

Building Description

First floor apartment in Kalamaria over pilotis. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic frame double glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.6
Roof	A/S
Floor	2.75
Openings	2.7
g-openings	0.53

HVAC systems performance

	Heating	DHW
Production	0.8	1
Distribution	1	0.72
Terminal Units / Storage	1	0.98

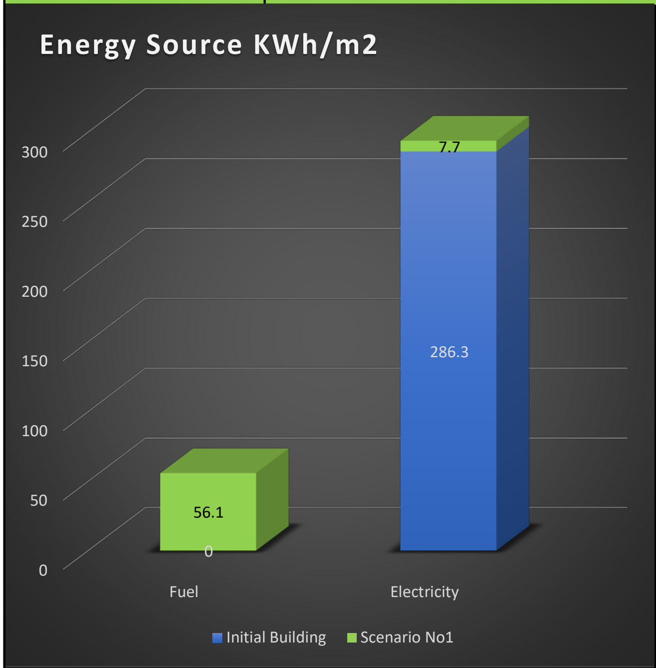
Systems

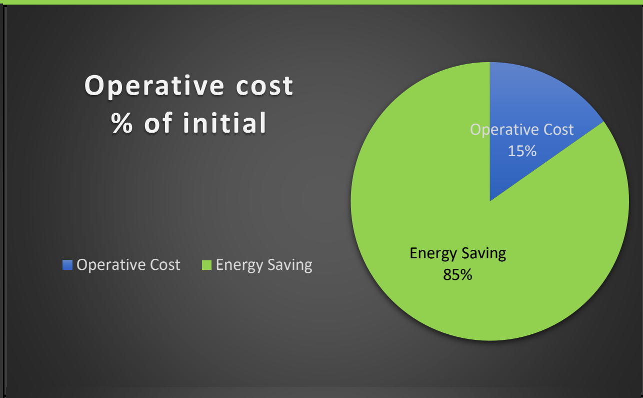
Production	Local electric radiators
Distribution	Non applicable
Solar thermal	Non applicable
DHW	Local electric boiler

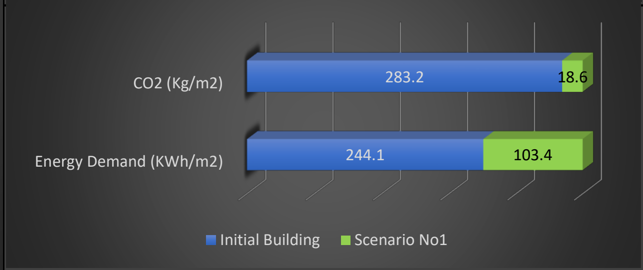
Annual Energy Characteristics

Energy Demand (KWh/m2/a)	244.1
Energy Consumption (KWh/m2/a)	285.7
Thermal Energy (KWh/m2/a)	0
Electricity (KWh/m2/a)	286.3
Primary Energy (KWh/m2/a)	828.4
CO2 Emissions (Kg/m2/a)	283.2
Total Final Thermal Energy	0
Total Electricity Consumption	12883.5
Operating cost	€1,456.20

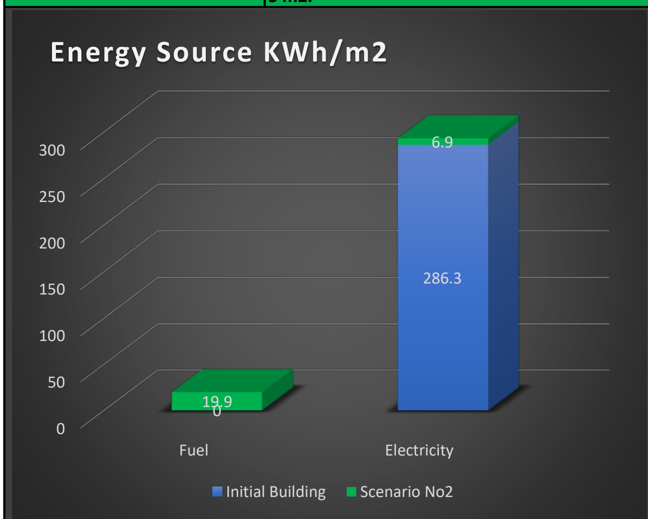
Energy Saving Interventions						
Scenario No1	P.E.S.	90.50%	Initial cost	€14,395.00	P.P. (Years)	11.7
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

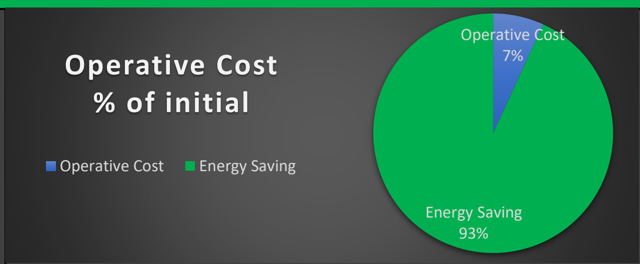


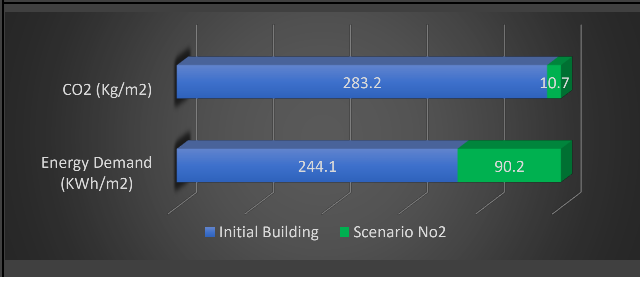




Scenario No2	P.E.S.	95.40%	Initial cost	€18,132.80	P.P. (Years)	13.4
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

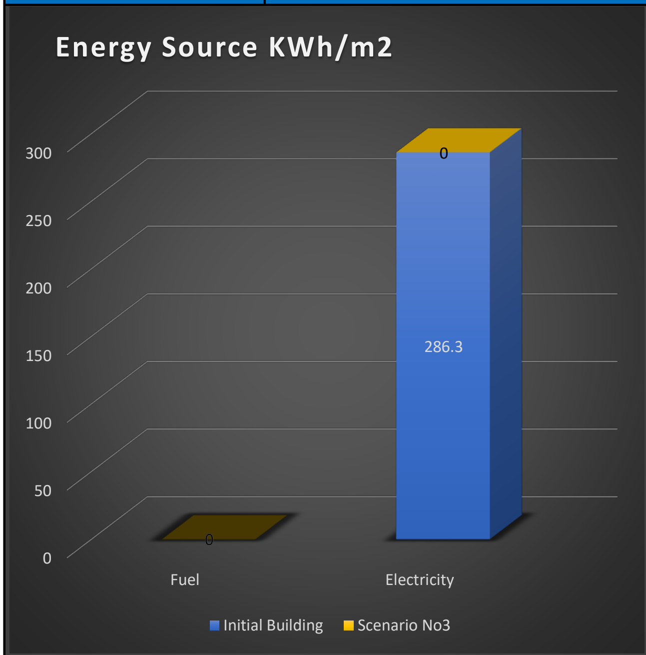


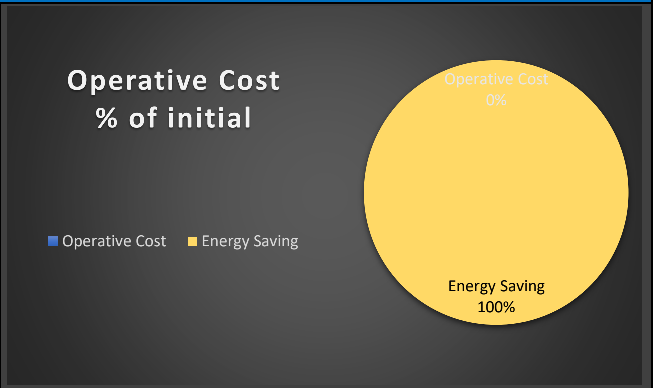


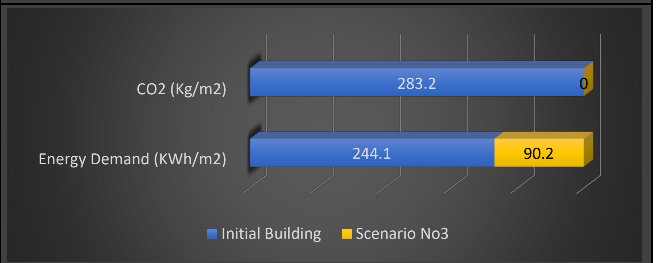


Energy Saving Interventions

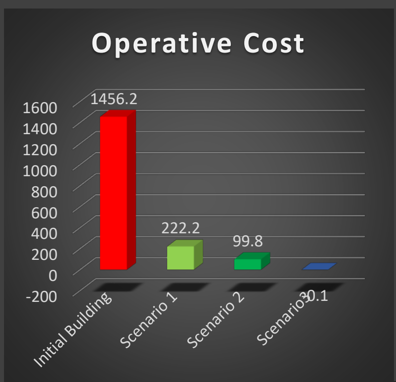
Scenario No3	P.E.S.	99.50%	Initial cost	€25,482.80	P.P. (Years)	17.5
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

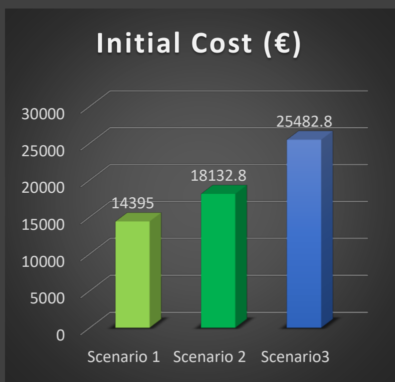


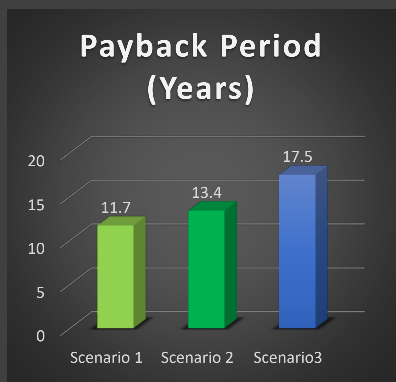


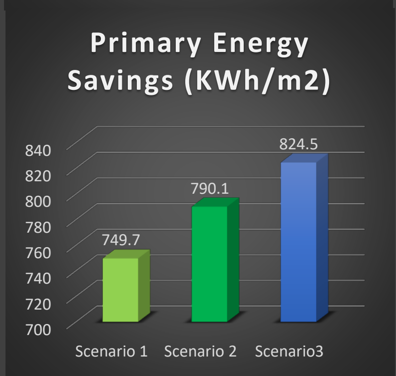


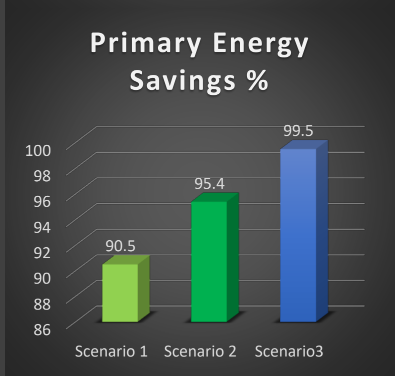
Scenario Comparison Diagrams

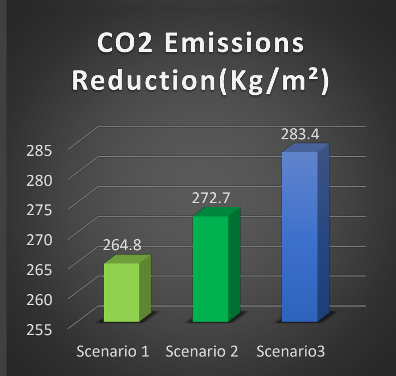












7	Multi-Family House Apartment Kalymnou 6 Kalamaria (2nd floor)			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	55.5			
Heater Volume	166.5			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic frame double glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.6
Roof	A/S
Floor	A/S
Openings	3
g-openings	0.48

HVAC systems performance

	Heating	DHW
Production	0.8	1
Distribution	0.95	0.72
Terminal Units / Storage	1	0.98

Systems

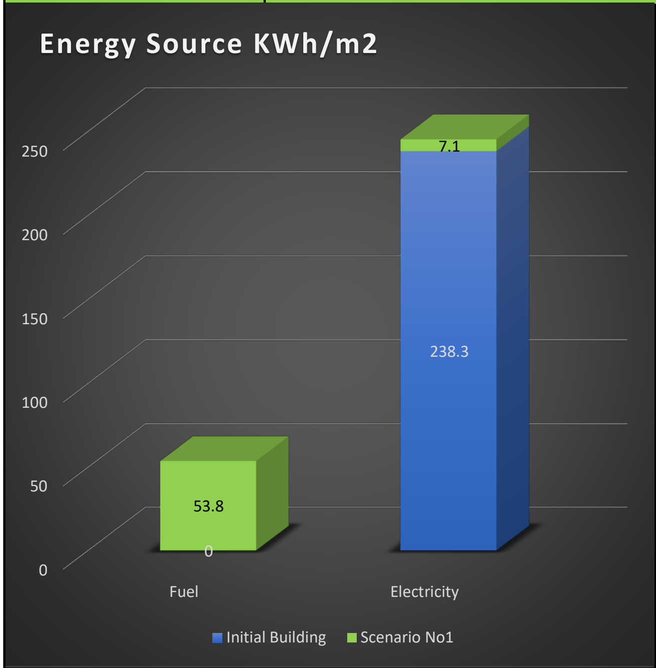
Production	Local electric radiators
Distribution	Non applicable
Solar thermal	Non applicable
DHW	Local electric boiler

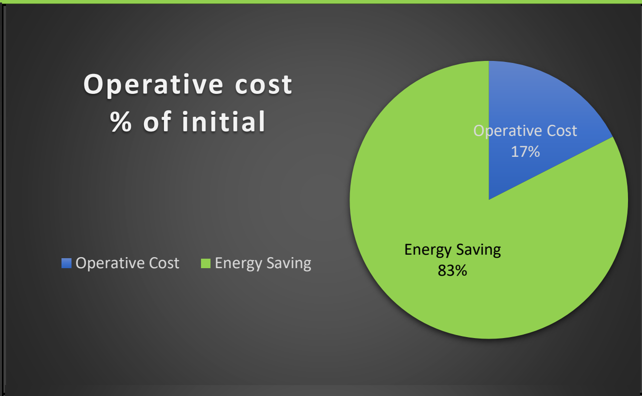
Annual Energy Characteristics

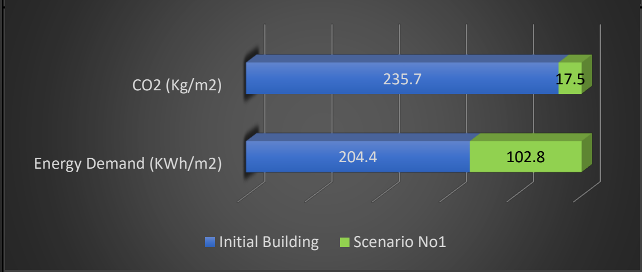
Energy Demand (KWh/m2/a)	204.4
Energy Consumption (KWh/m2/a)	237.4
Thermal Energy (KWh/m2/a)	0
Electricity (KWh/m2/a)	238.3
Primary Energy (KWh/m2/a)	688.3
CO2 Emissions (Kg/m2/a)	235.7
Total Final Thermal Energy	0
Total Electricity Consumption	13225.65
Operating cost	€1,494.70

Energy Saving Interventions

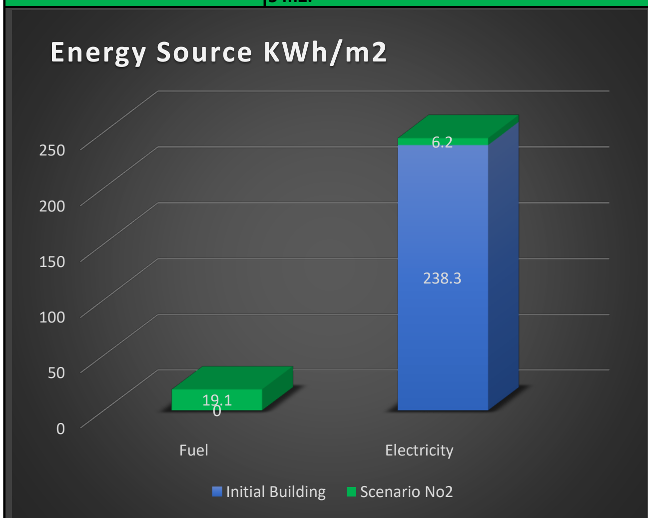
Scenario No1	P.E.S.	89.20%	Initial cost	€14,214.00	P.P. (Years)	11.5
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

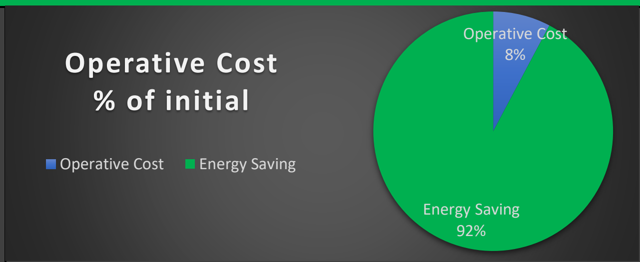


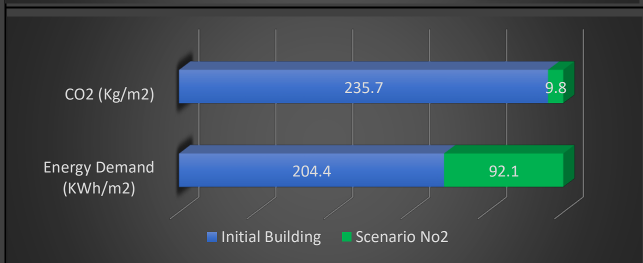




Scenario No2	P.E.S.	94.80%	Initial cost	€18,362.40	P.P. (Years)	13.3
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

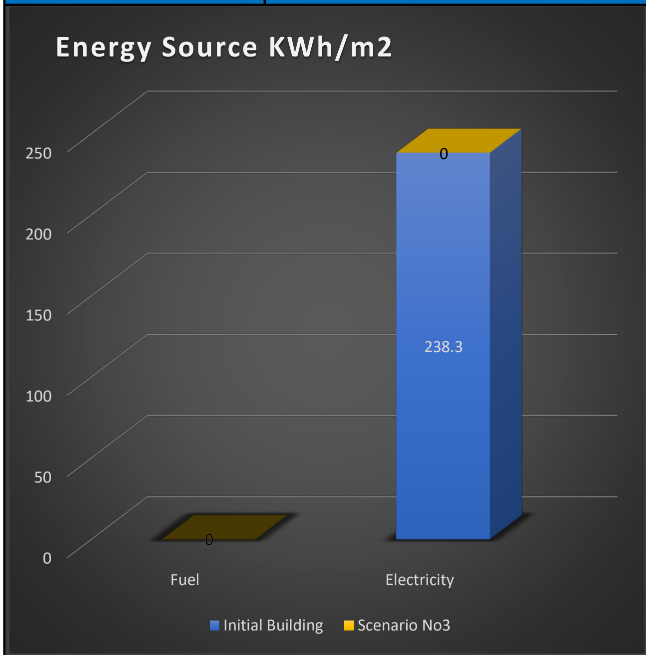


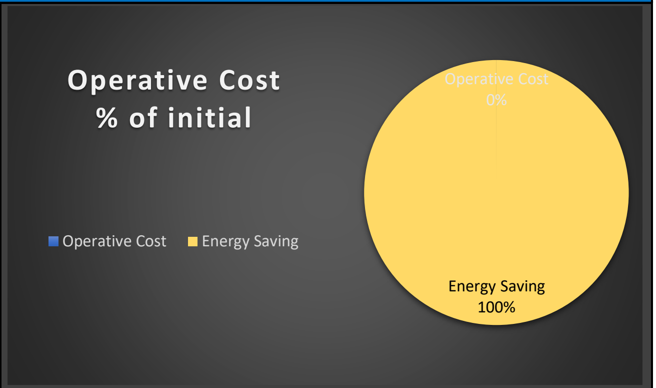


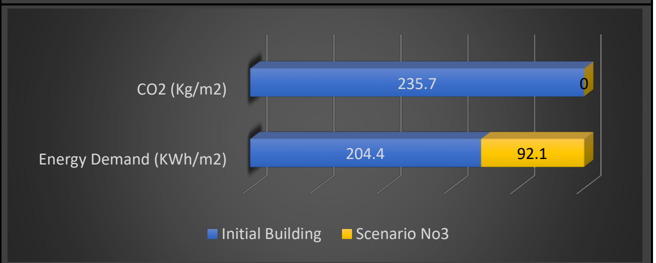


Energy Saving Interventions

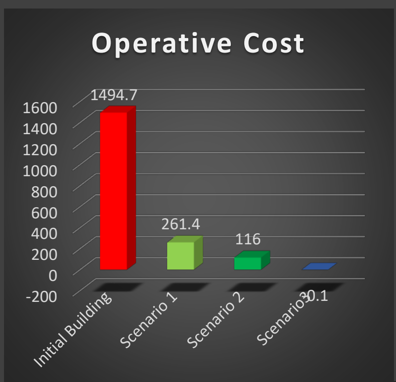
Scenario No3	P.E.S.	99.40%	Initial cost	€25,262.40	P.P. (Years)	16.9
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

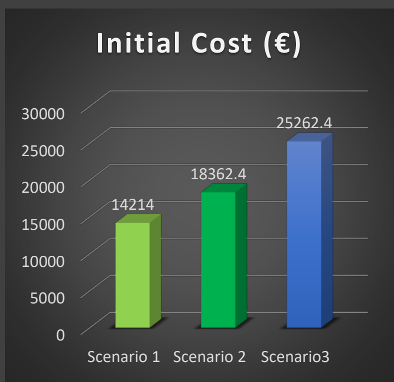


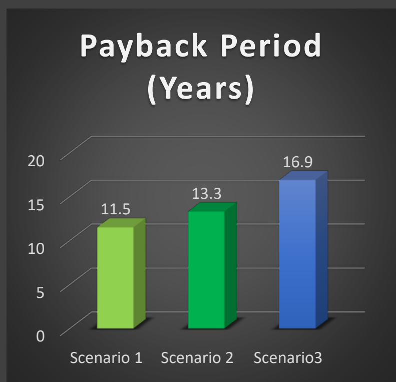


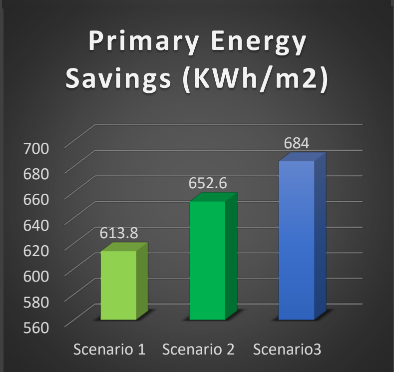


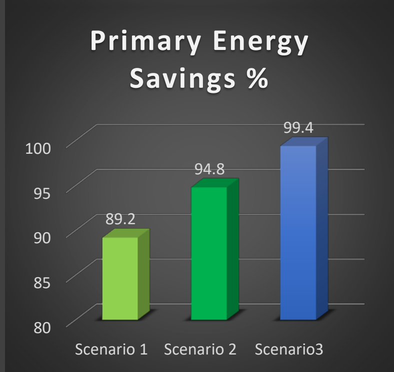
Scenario Comparison Diagrams

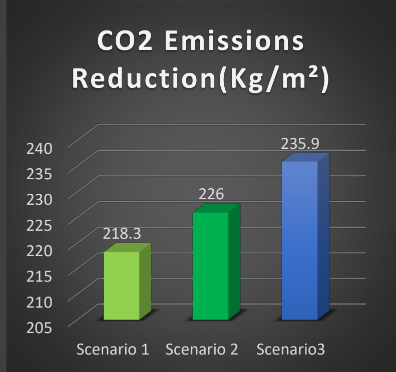












8	Multi-Family House			
	Apartment			
	Kalymnou 6 Kalamaria (3rd floor)			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	41			
Heater Volume	123			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic frame double glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.6
Roof	A/S
Floor	A/S
Openings	3
g-openings	0.48

HVAC systems performance

	Heating	DHW
Production	0.935	1
Distribution	0.95	0.72
Terminal Units / Storage	0.93	0.98

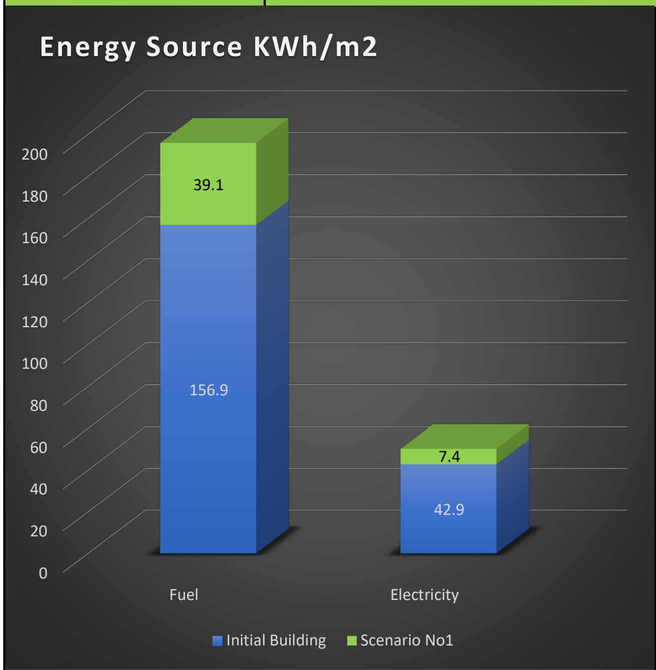
Systems

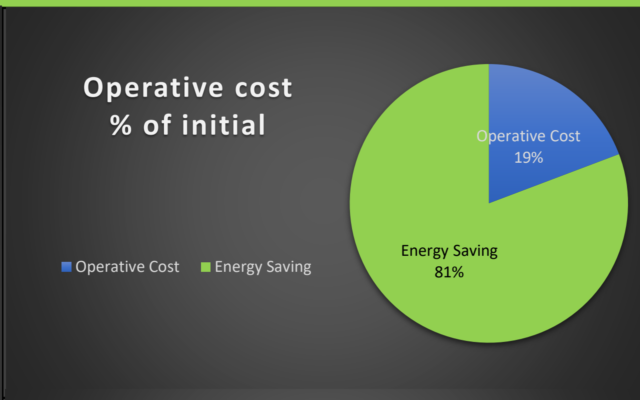
Production	Oil boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Local electric boiler

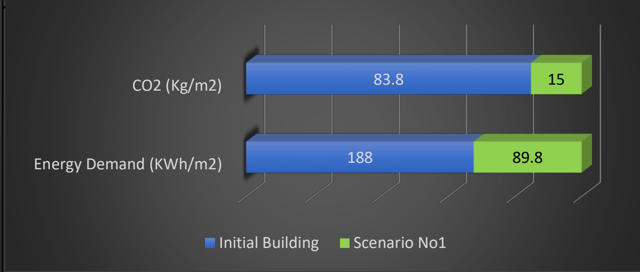
Annual Energy Characteristics

Energy Demand (KWh/m2/a)	188
Energy Consumption (KWh/m2/a)	198.9
Thermal Energy (KWh/m2/a)	156.9
Electricity (KWh/m2/a)	42.9
Primary Energy (KWh/m2/a)	294.4
CO2 Emissions (Kg/m2/a)	83.8
Total Final Thermal Energy	6432.9
Total Electricity Consumption	1758.9
Operating cost	€782.80

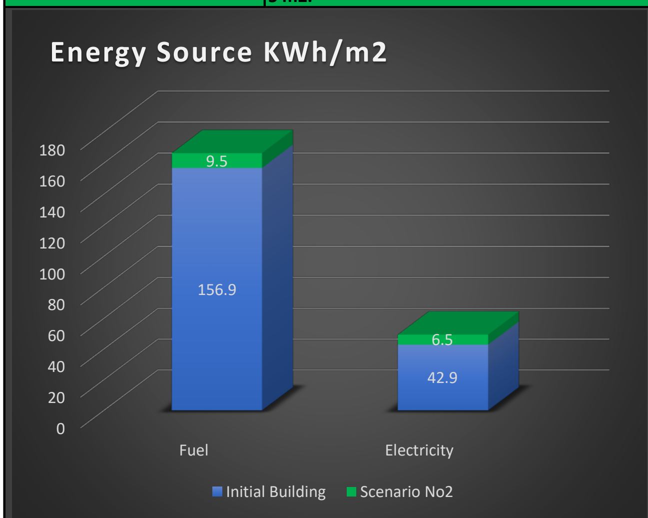
Energy Saving Interventions						
Scenario No1	P.E.S.	79.70%	Initial cost	€9,886.00	P.P. (Years)	15.6
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

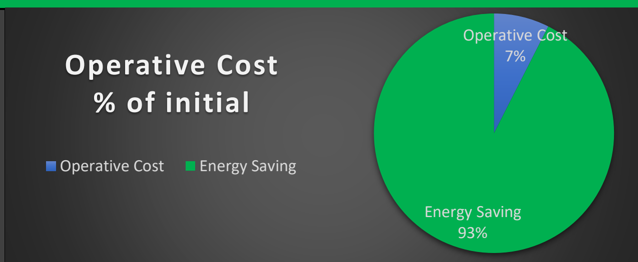


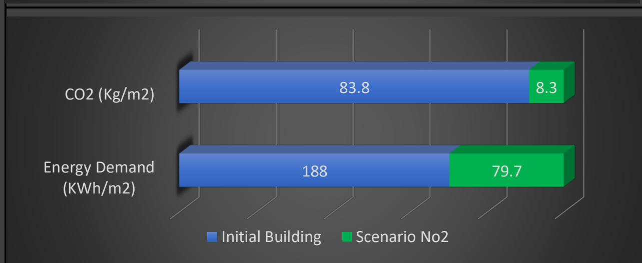




Scenario No2	P.E.S.	91.10%	Initial cost	€13,026.00	P.P. (Years)	18
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

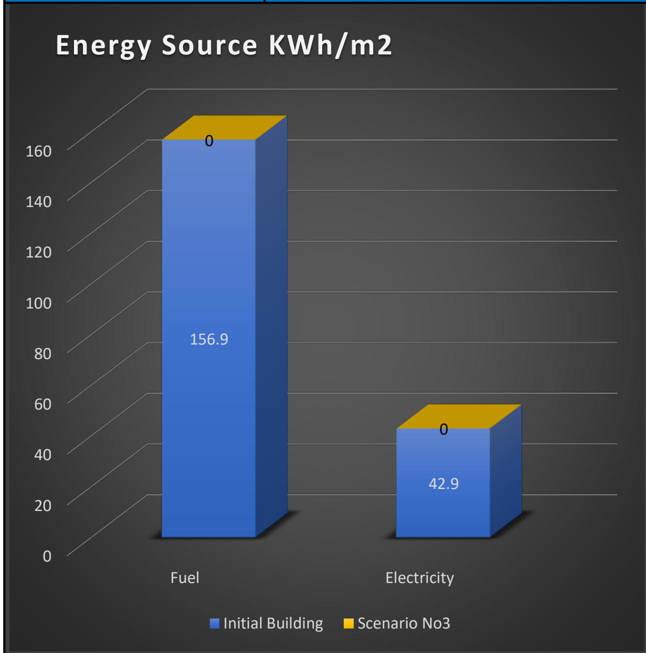


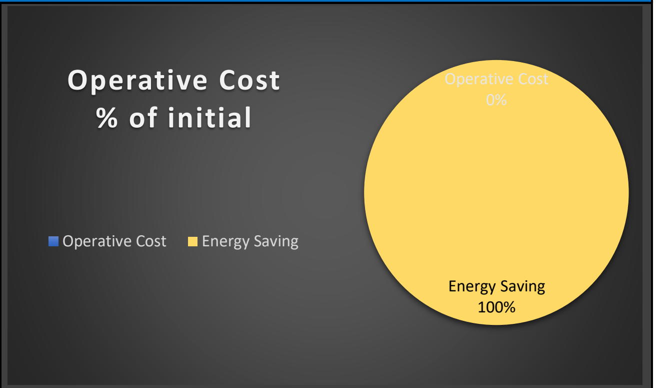


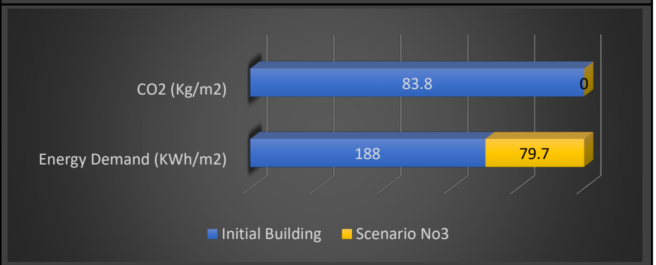


Energy Saving Interventions

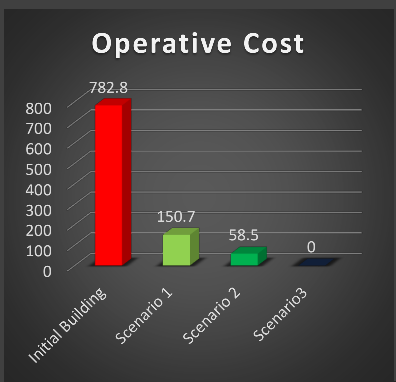
Scenario No3	P.E.S.	100.40%	Initial cost	€21,426.00	P.P. (Years)	27.4
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

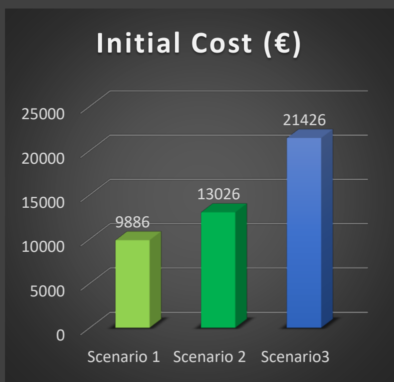


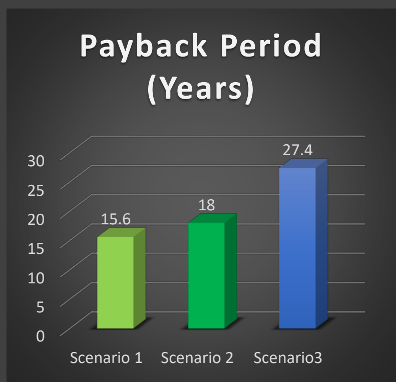


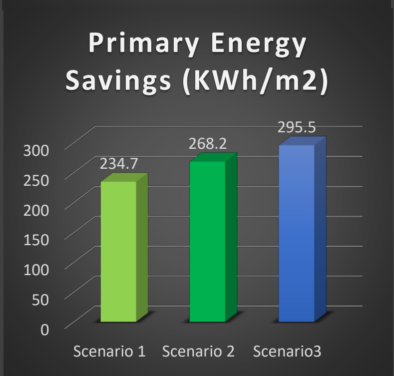


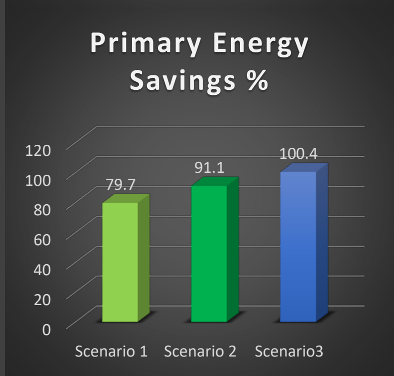
Scenario Comparison Diagrams

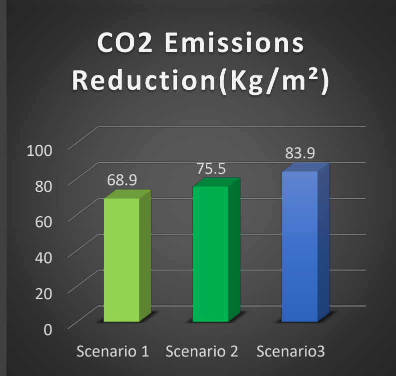












9	Multi-Family House			
	Apartment			
	Karaiskaki 5, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	56.2			
Heater Volume	174.22			

Building Description

Indermediate floor apartment in the center of Thessaloniki. 10 m2 roof exposed. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable wooden frame single glazing
Blinds	Wooden blinds
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.4
Roof	3.05
Floor	A/S
Openings	5
g-openings	0.56

HVAC systems performance

	Heating	DHW
Production	0.935	0.935
Distribution	0.95	0.72
Terminal Units / Storage	0.959	1

Systems

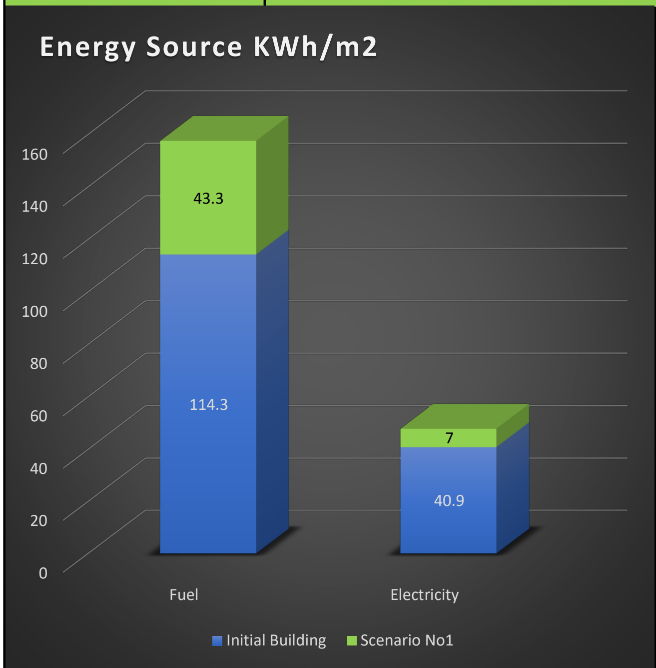
Production	Oil boiler, local A/C
Distribution	Pipes inside the building at least 80% of their length
Solar thermal	Non applicable
DHW	Oil boiler

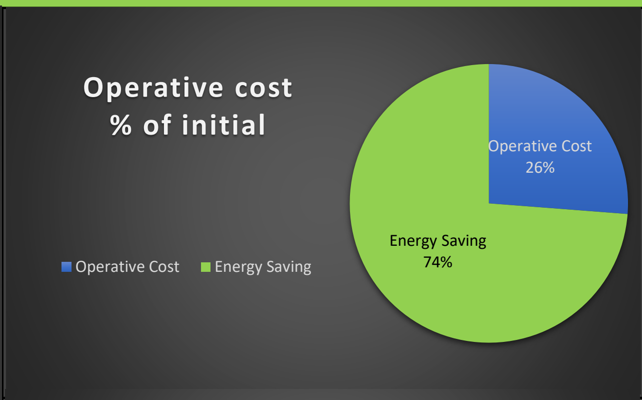
Annual Energy Characteristics

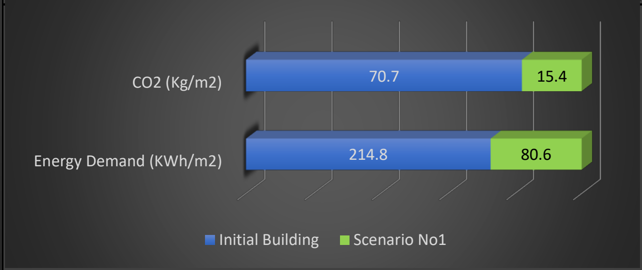
Energy Demand (KWh/m2/a)	214.8
Energy Consumption (KWh/m2/a)	154.4
Thermal Energy (KWh/m2/a)	114.3
Electricity (KWh/m2/a)	40.9
Primary Energy (KWh/m2/a)	242.1
CO2 Emissions (Kg/m2/a)	70.6
Total Final Thermal Energy	6423.66
Total Electricity Consumption	2298.58
Operating cost	€843.30

Energy Saving Interventions

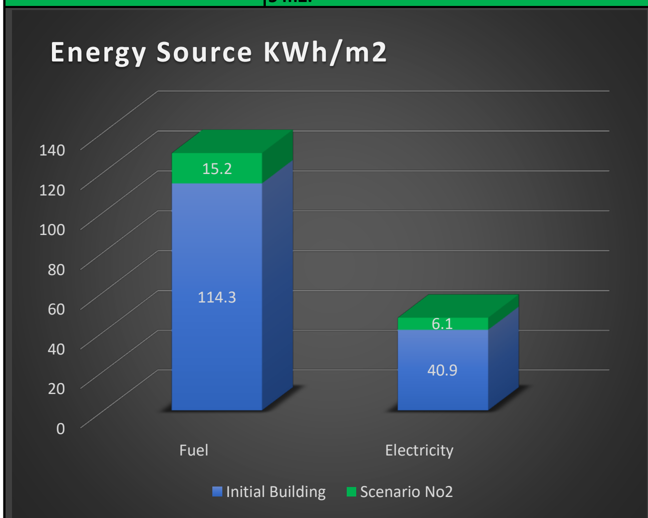
Scenario No1	P.E.S.	73.80%	Initial cost	€12,825.00	P.P. (Years)	20.6
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

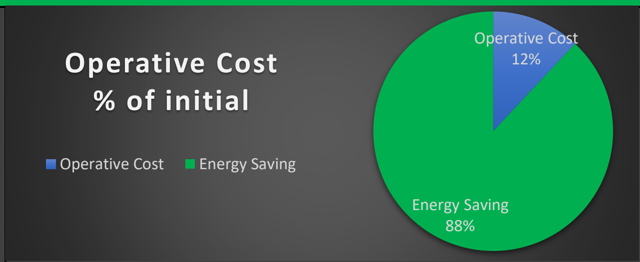


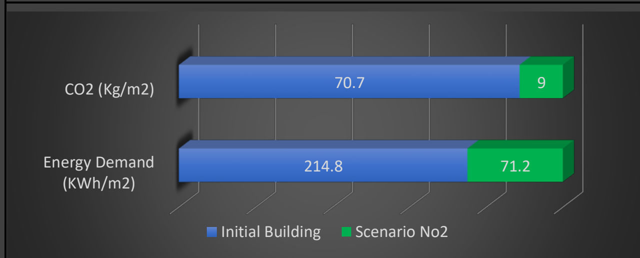




Scenario No2	P.E.S.	87.00%	Initial cost	€16,701.60	P.P. (Years)	22.5
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

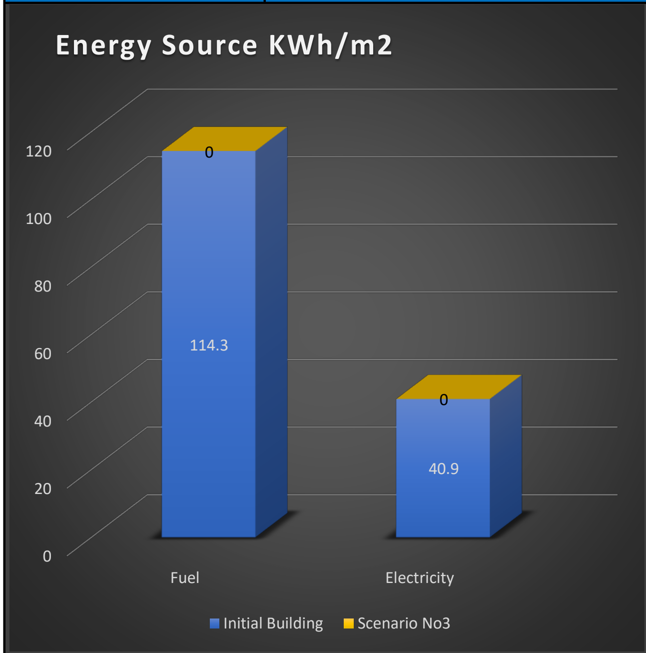


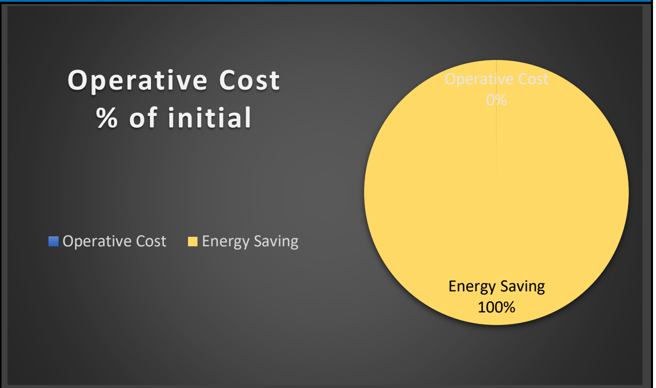


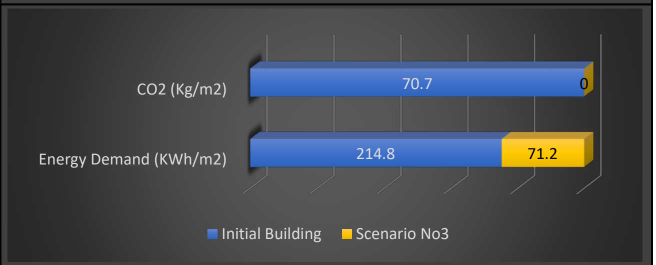


Energy Saving Interventions

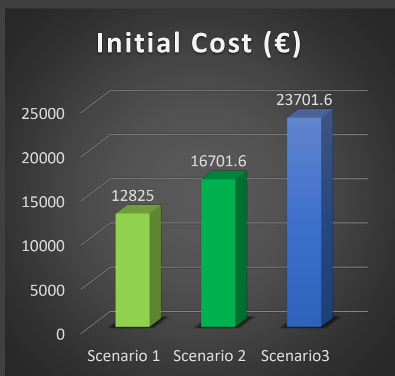
Scenario No3	P.E.S.	98.20%	Initial cost	€23,701.60	P.P. (Years)	28.1
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

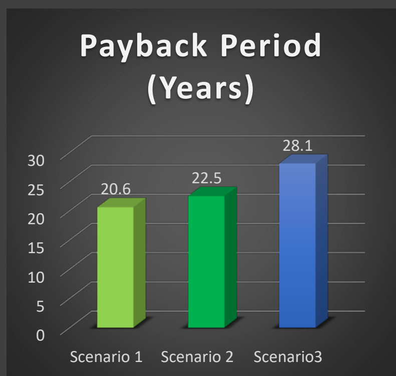


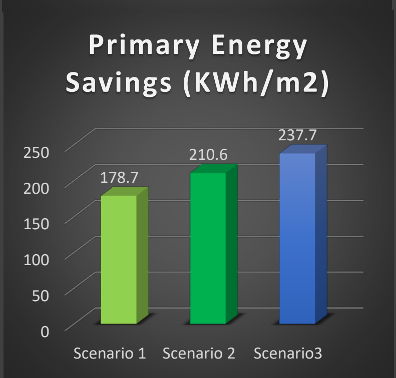


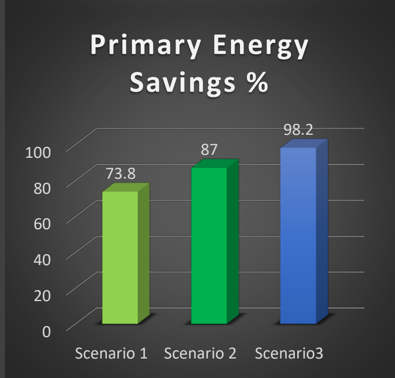


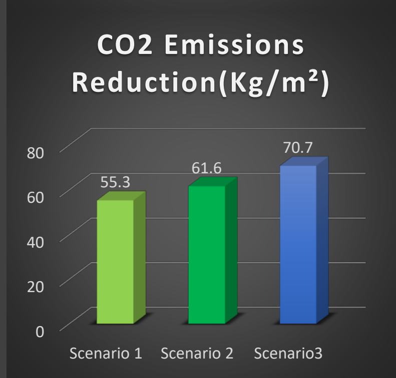
Scenario Comparison Diagrams











10	Multi-Family House			
	Apartment			
	Lapithon 6,Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	44			
Heater Volume	132			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic frame double glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.55
Roof	A/S
Floor	A/S
Openings	3.2
g-openings	0.46

HVAC systems performance

	Heating	DHW
Production	2.9	1
Distribution	1	0.72
Terminal Units / Storage	0.93	0.98

Systems

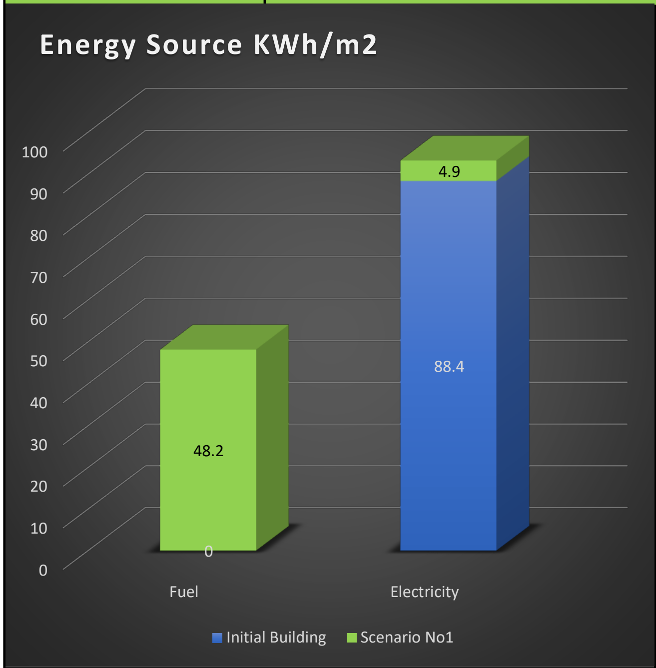
Production	Local A/C
Distribution	Non applicable
Solar thermal	Non applicable
DHW	Local electric boiler

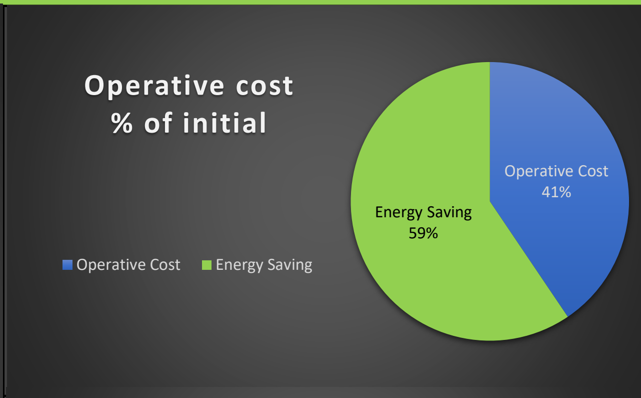
Annual Energy Characteristics

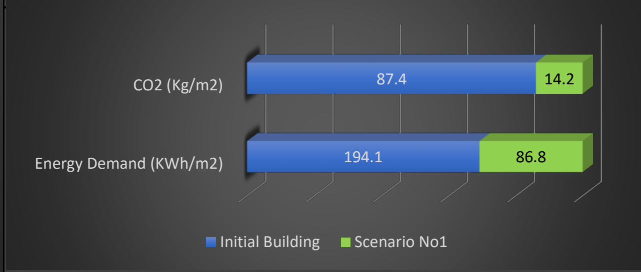
Energy Demand (KWh/m2/a)	194.1
Energy Consumption (KWh/m2/a)	88.1
Thermal Energy (KWh/m2/a)	0
Electricity (KWh/m2/a)	88.4
Primary Energy (KWh/m2/a)	255.5
CO2 Emissions (Kg/m2/a)	87.4
Total Final Thermal Energy	0
Total Electricity Consumption	3889.6
Operating cost	€439.60

Energy Saving Interventions

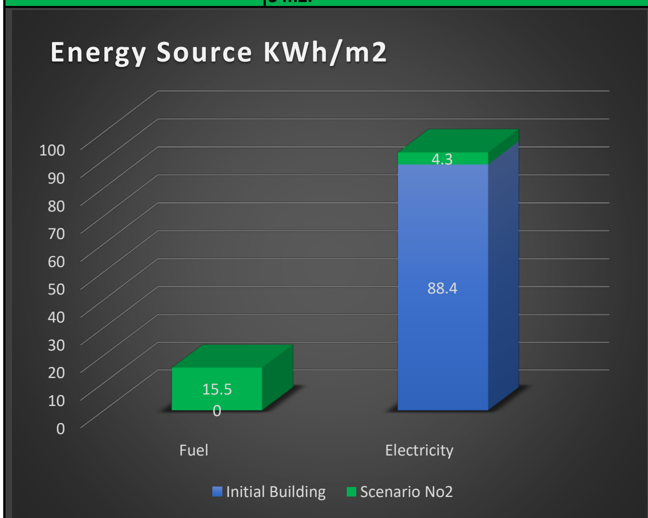
Scenario No1	P.E.S.	75.10%	Initial cost	€11,591.50	P.P. (Years)	44.3
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

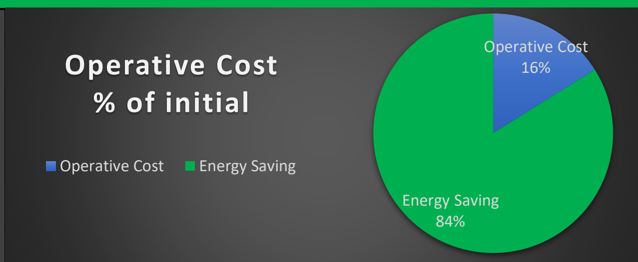


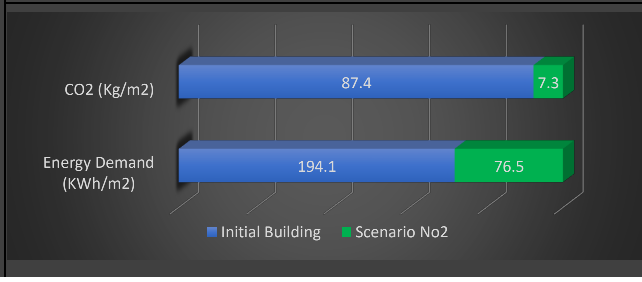




Scenario No2	P.E.S.	89.30%	Initial cost	€14,888.80	P.P. (Years)	40.4
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

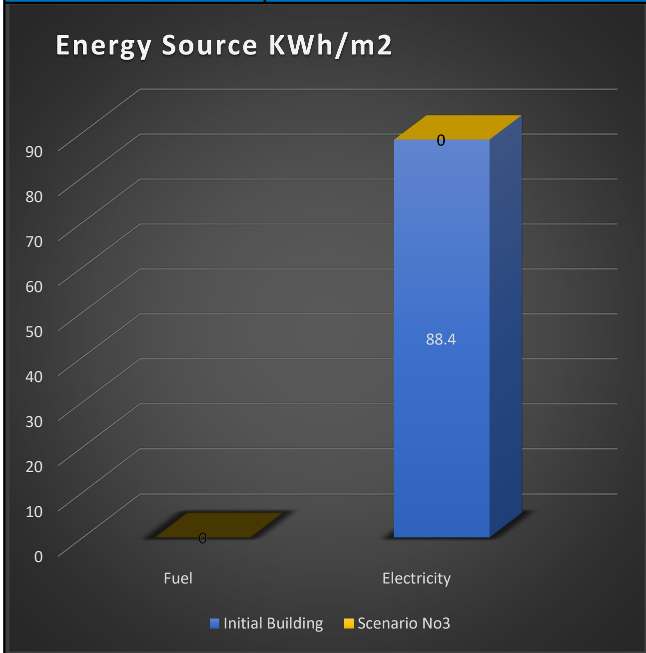


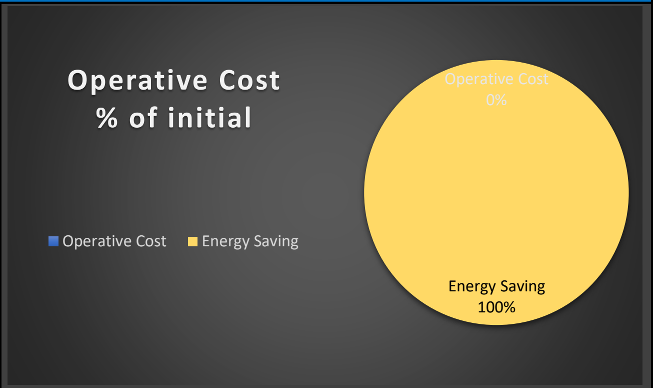


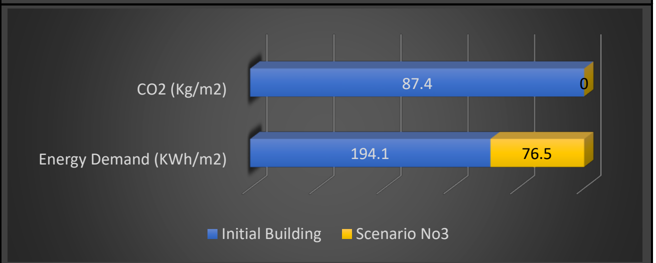


Energy Saving Interventions

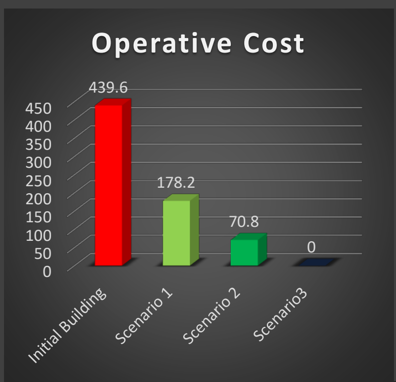
Scenario No3	P.E.S.	99.90%	Initial cost	€21,588.80	P.P. (Years)	49.1
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

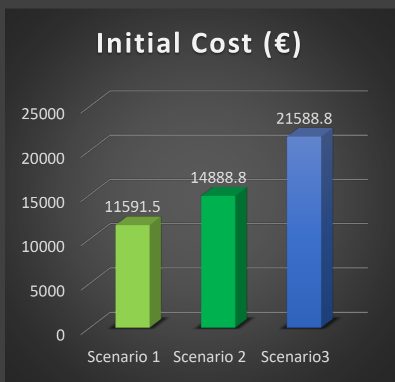


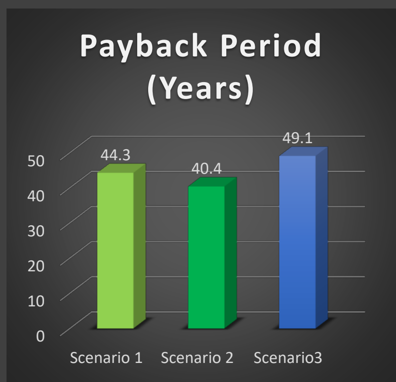


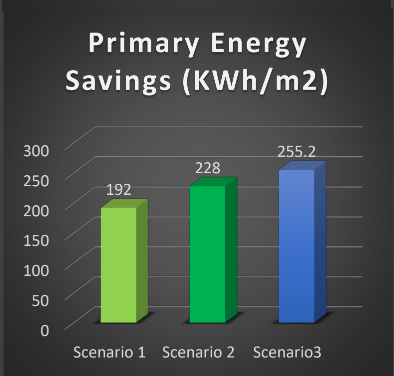


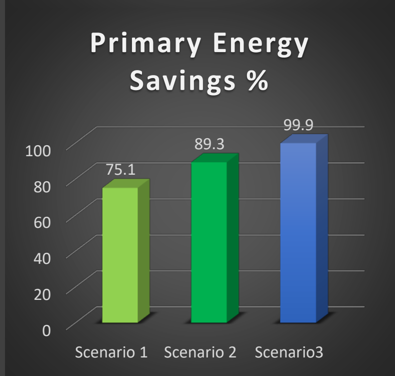
Scenario Comparison Diagrams

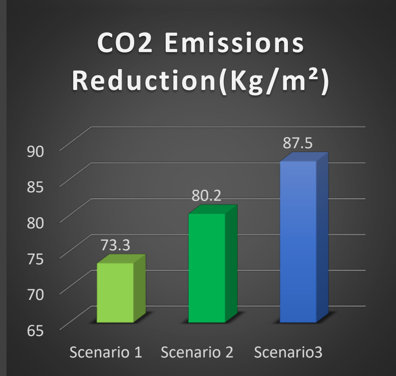












11	Multi-Family House			
	Apartment			
	Makedonikis Amynis 28, Thessalonik			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	57			
Heater Volume	171			

Building Description

Indermediate floor apartment in the center of Thessaloniki. 6,5m2 roof in contact with external air. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface & without insulation
Openings	Openable wooden frame single glazing
Blinds	Wooden blinds
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.5
Roof	A/S
Floor	A/S
Openings	5
g-openings	0.56

HVAC systems performance

	Heating	DHW
Production	0.811	0.811
Distribution	0.86	0.72
Terminal Units / Storage	0.845	0.93

Systems

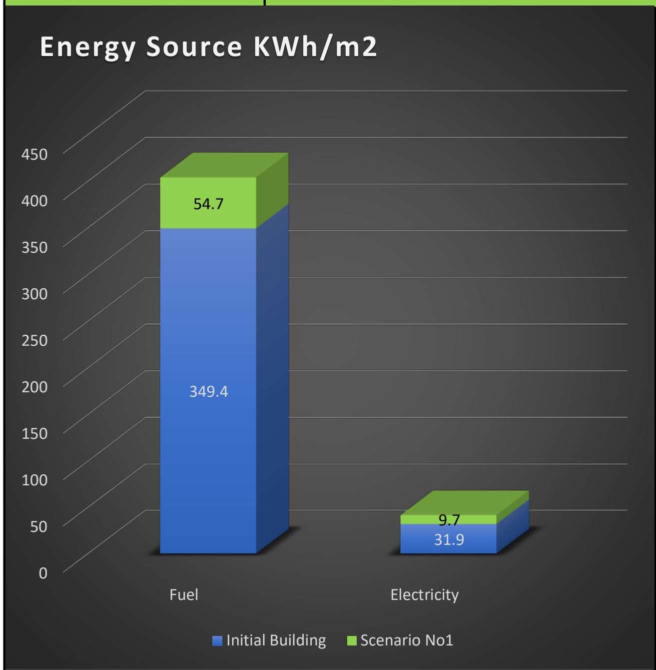
Production	Individual oil boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual oil boiler

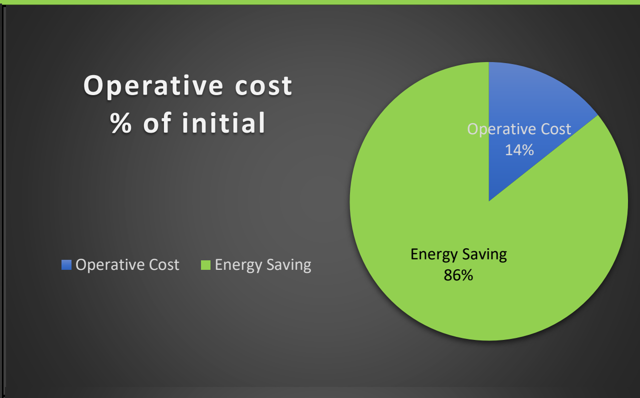
Annual Energy Characteristics

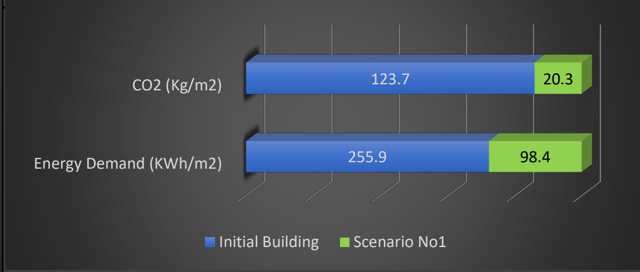
Energy Demand (KWh/m2/a)	255.9
Energy Consumption (KWh/m2/a)	380.4
Thermal Energy (KWh/m2/a)	349.4
Electricity (KWh/m2/a)	31.9
Primary Energy (KWh/m2/a)	474.2
CO2 Emissions (Kg/m2/a)	123.8
Total Final Thermal Energy	19915.8
Total Electricity Consumption	1818.3
Operating cost	€2,013.60

Energy Saving Interventions

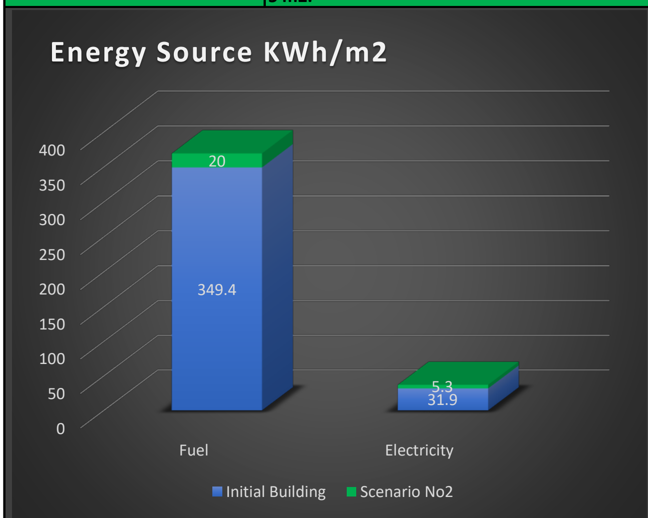
Scenario No1	P.E.S.	82.40%	Initial cost	€15,458.50	P.P. (Years)	9
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

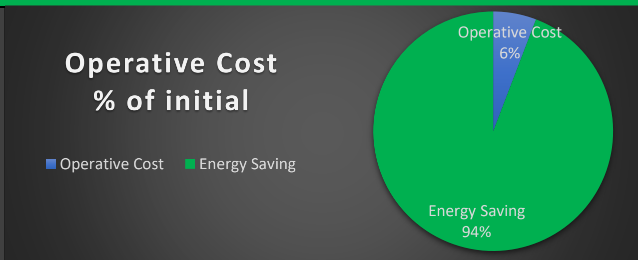


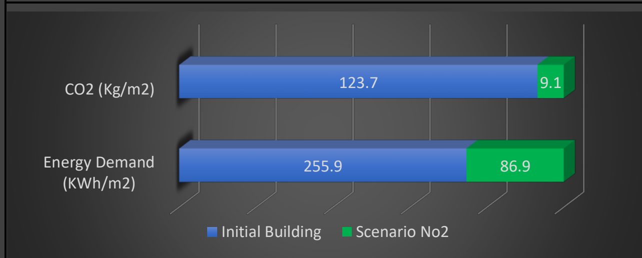




Scenario No2	P.E.S.	92.70%	Initial cost	€19,927.50	P.P. (Years)	10.5
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

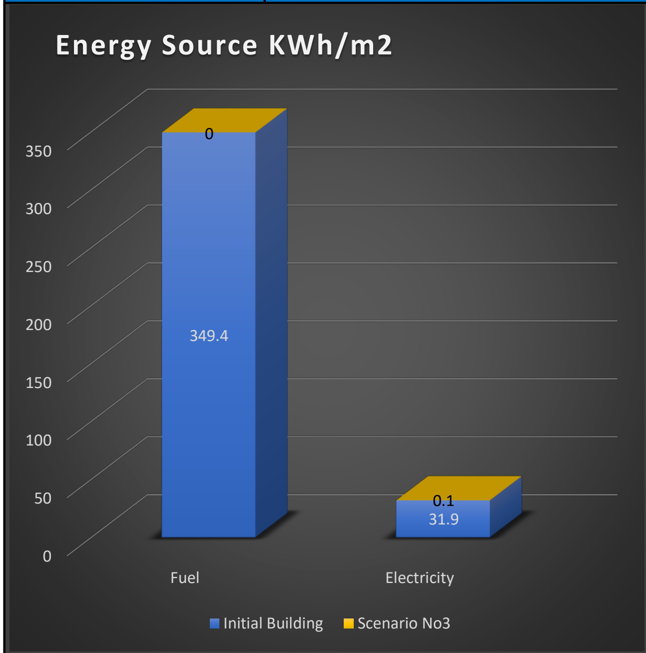


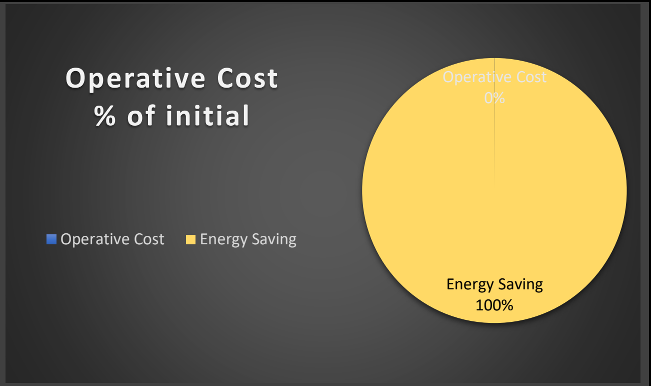


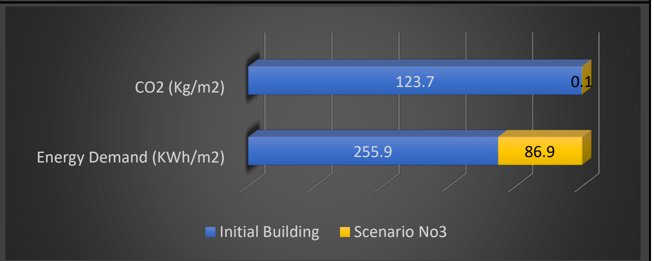


Energy Saving Interventions

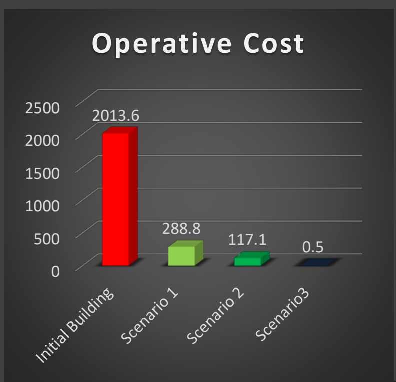
Scenario No3	P.E.S.	99.20%	Initial cost	€26,827.50	P.P. (Years)	13.3
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

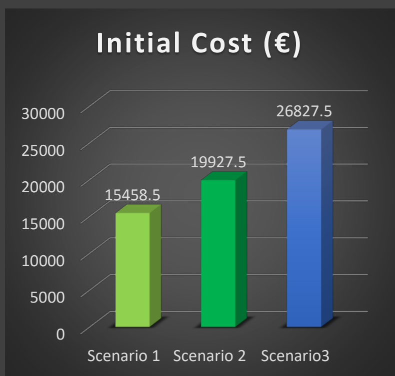


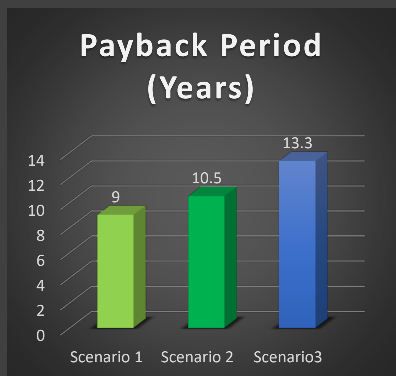


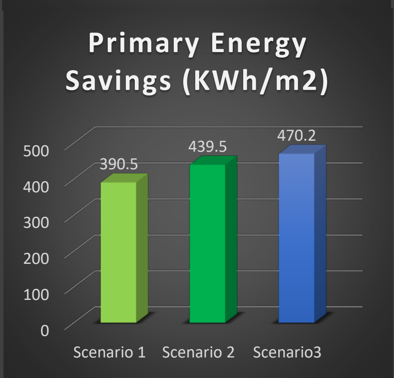


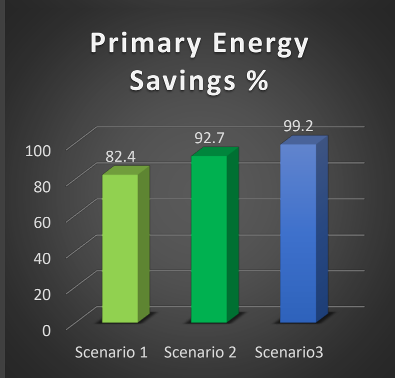
Scenario Comparison Diagrams

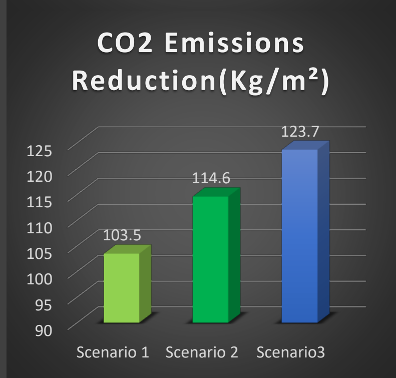












12	Multi-Family House			
	Apartment			
	Markou Mpotsari 7, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	40			
Heater Volume	120			

Building Description

Top floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Without insulation
Openings	Openable metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.55
Roof	3.05
Floor	A/S
Openings	3.92
g-openings	0.51

HVAC systems performance

	Heating	DHW
Production	0.95	0.95
Distribution	0.945	0.92
Terminal Units / Storage	0.89	1

Systems

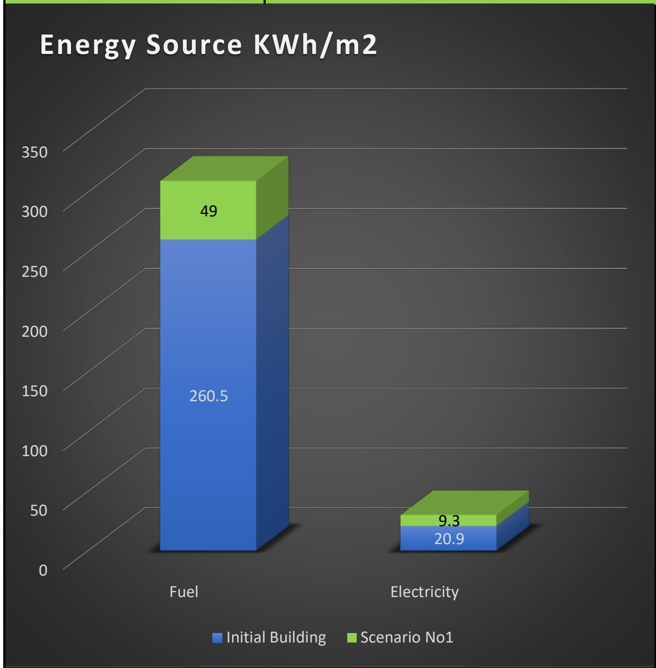
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

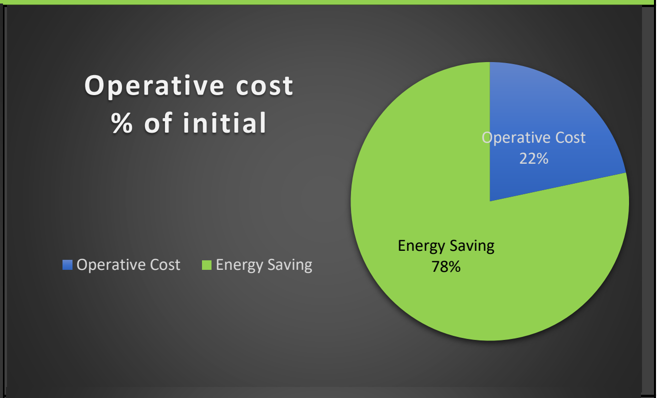
Annual Energy Characteristics

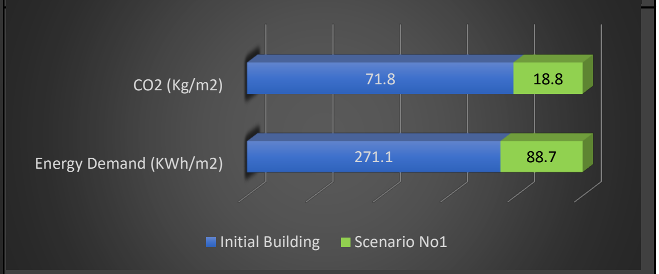
Energy Demand (KWh/m2/a)	271.1
Energy Consumption (KWh/m2/a)	280
Thermal Energy (KWh/m2/a)	260.5
Electricity (KWh/m2/a)	20.9
Primary Energy (KWh/m2/a)	330.1
CO2 Emissions (Kg/m2/a)	71.7
Total Final Thermal Energy	10420
Total Electricity Consumption	836
Operating cost	€851.30

Energy Saving Interventions

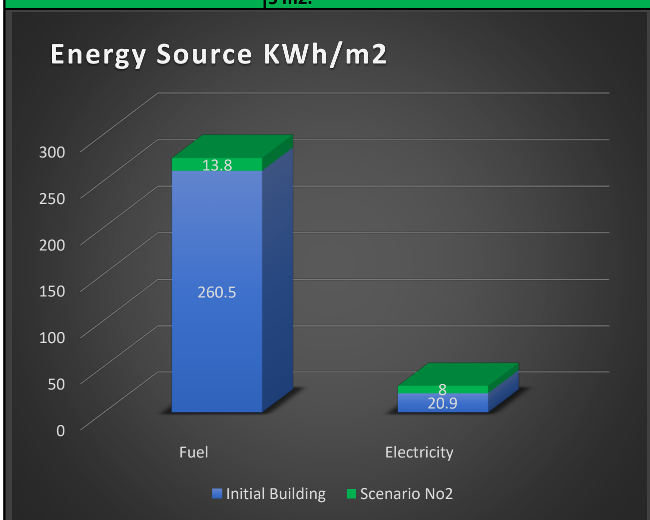
Scenario No1	P.E.S.	76.80%	Initial cost	€7,775.50	P.P. (Years)	11.7
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

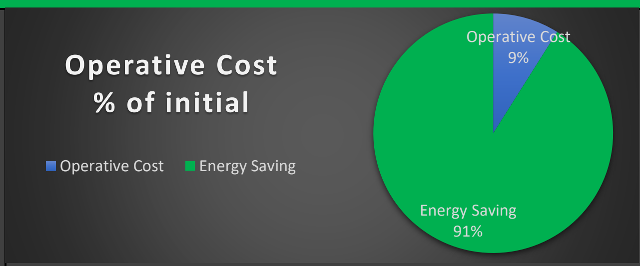


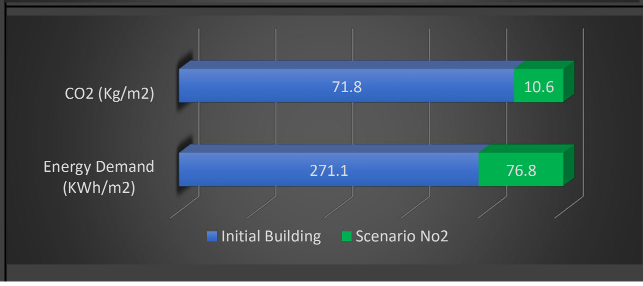




Scenario No2	P.E.S.	89.20%	Initial cost	€10,419.40	P.P. (Years)	13.4
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

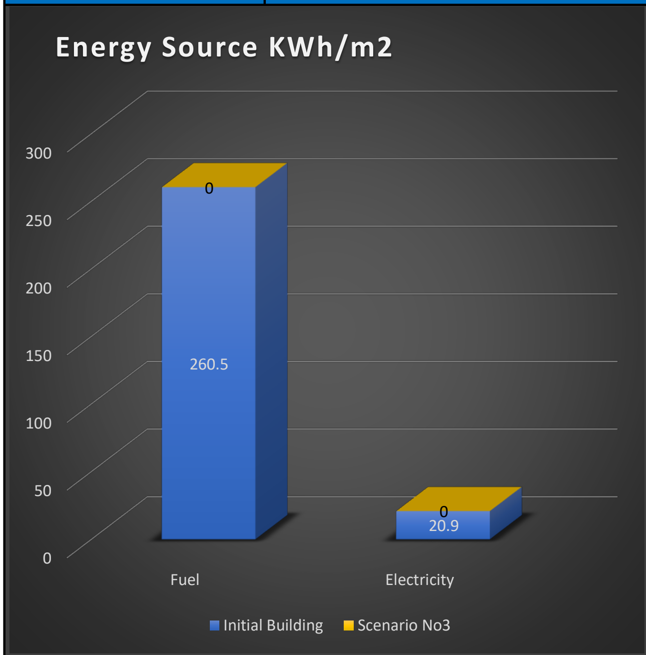


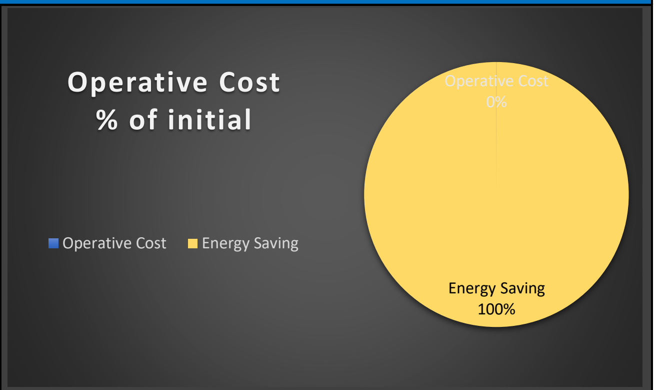


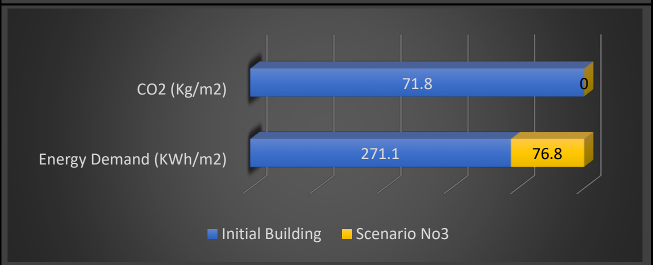


Energy Saving Interventions

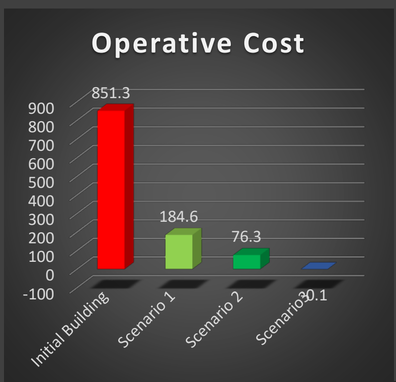
Scenario No3	P.E.S.	98.90%	Initial cost	€20,069.40	P.P. (Years)	23.6
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

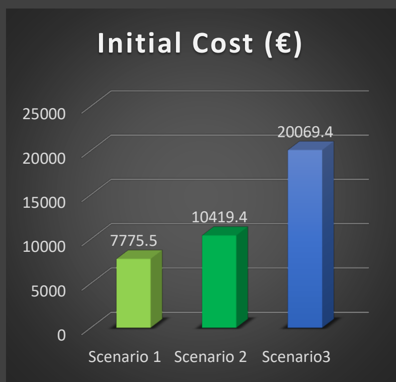


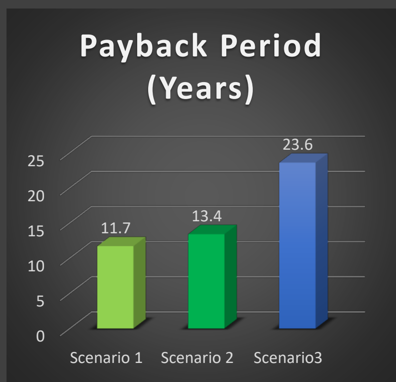


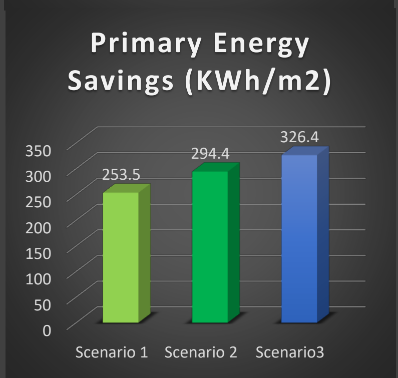


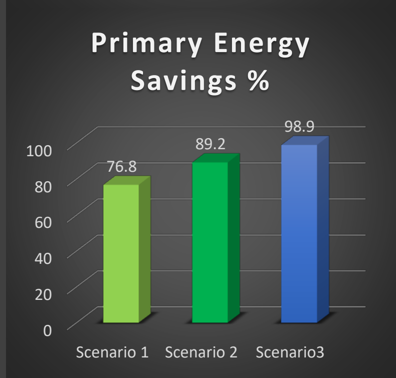
Scenario Comparison Diagrams

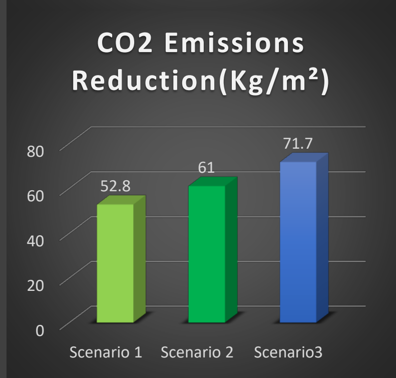












13	Multi-Family House			
	Apartment			
	Olympou 103, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	45.2			
Heater Volume	142.38			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable metal Frame Double Glazing 12mm with thermal brake
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.5
Roof	A/S
Floor	A/S
Openings	3.25
g-openings	0.46

HVAC systems performance

	Heating	DHW
Production	0.967	1
Distribution	0.95	0.72
Terminal Units / Storage	0.959	0.98

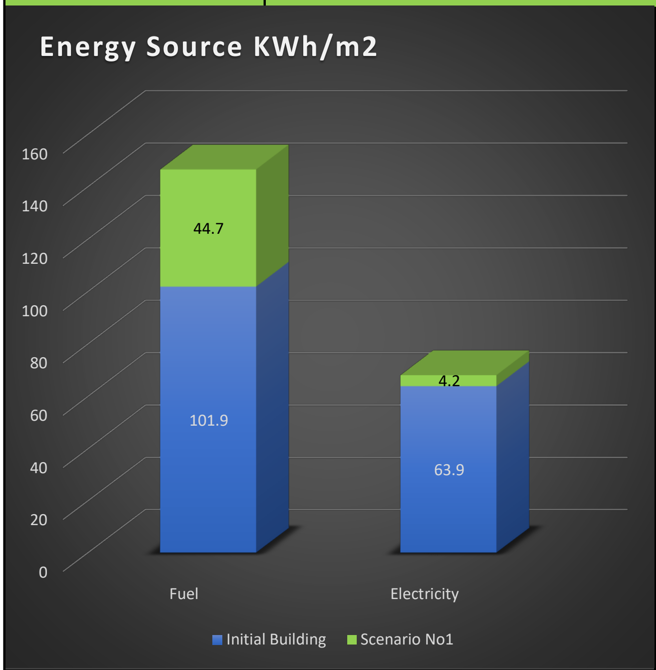
Systems

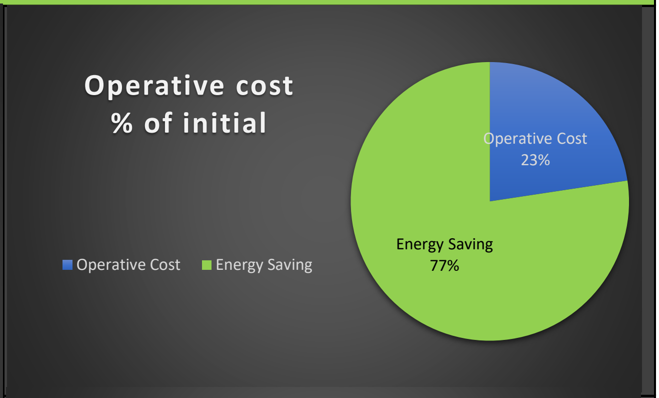
Production	Oil boiler, local A/C
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Local electric boiler

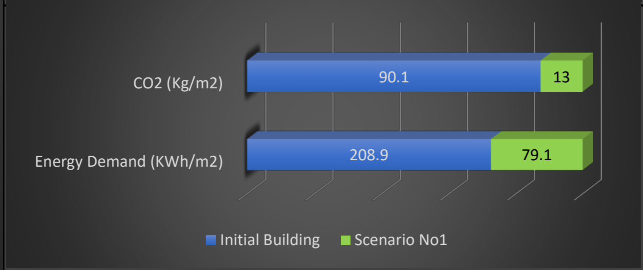
Annual Energy Characteristics

Energy Demand (KWh/m2/a)	208.9
Energy Consumption (KWh/m2/a)	165.5
Thermal Energy (KWh/m2/a)	101.9
Electricity (KWh/m2/a)	63.9
Primary Energy (KWh/m2/a)	296.6
CO2 Emissions (Kg/m2/a)	90.1
Total Final Thermal Energy	4605.88
Total Electricity Consumption	2888.28
Operating cost	€744.40

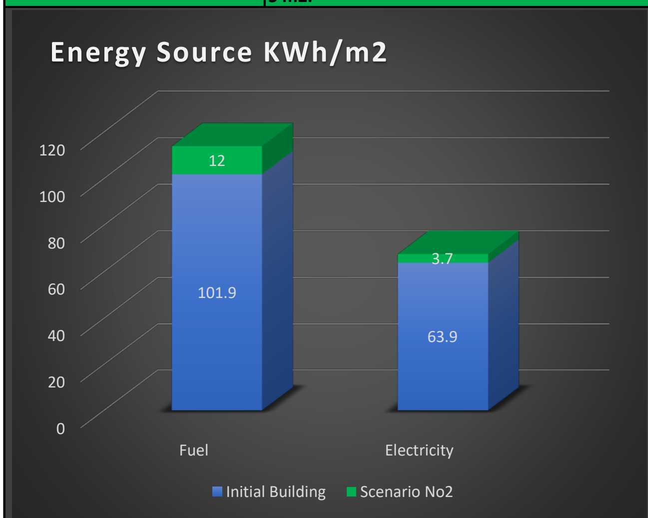
Energy Saving Interventions						
Scenario No1	P.E.S.	80.30%	Initial cost	€11,312.10	P.P. (Years)	19.6
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

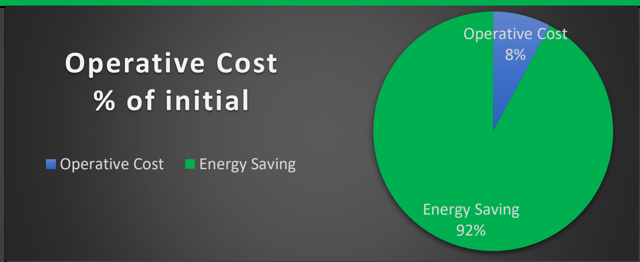


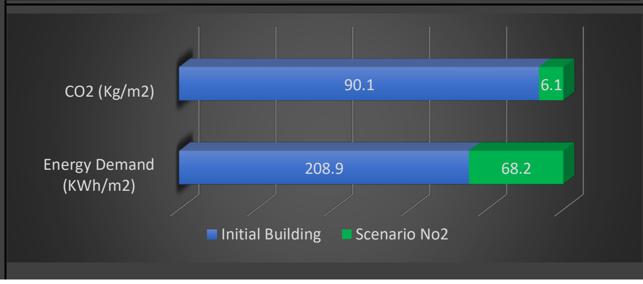




Scenario No2	P.E.S.	92.40%	Initial cost	€14,297.20	P.P. (Years)	20.8
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

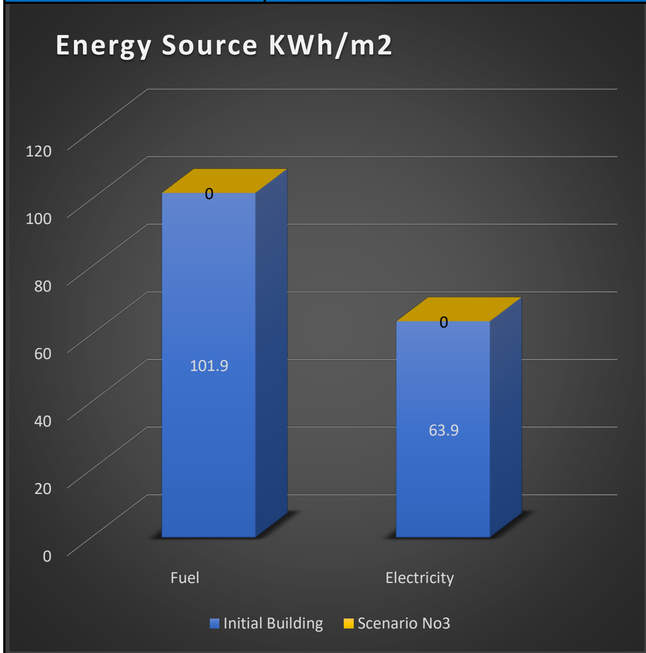


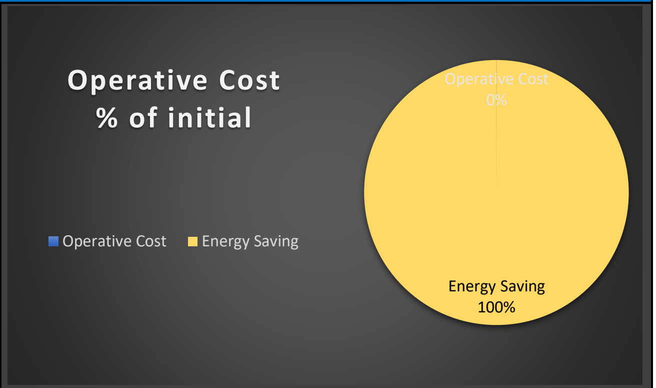


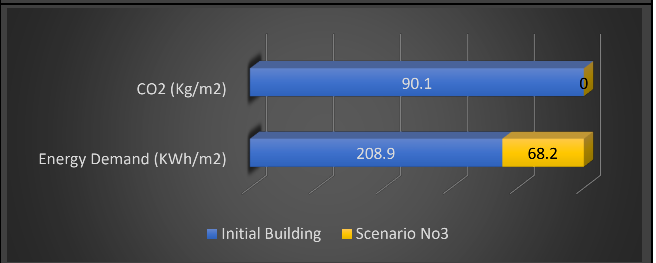


Energy Saving Interventions

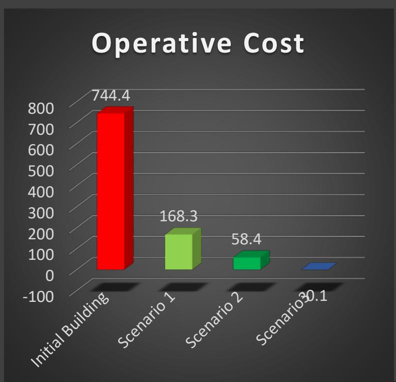
Scenario No3	P.E.S.	99.90%	Initial cost	€21,329.20	P.P. (Years)	28.6
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

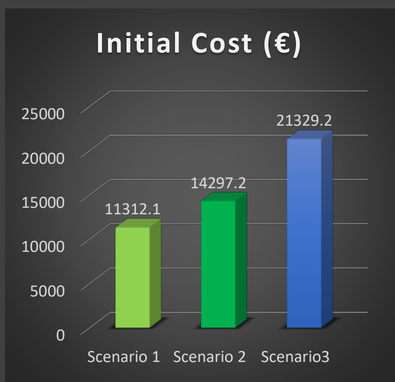


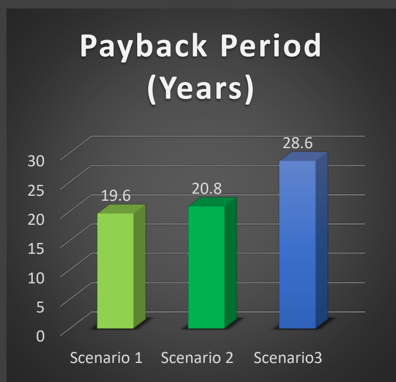


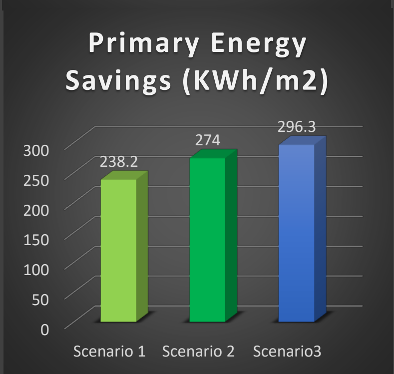


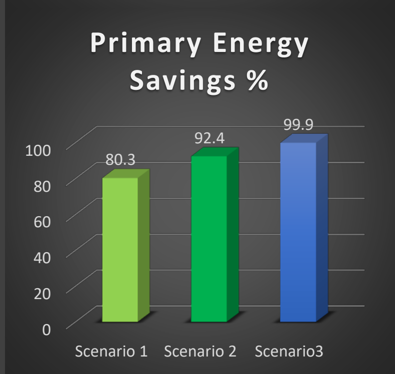
Scenario Comparison Diagrams

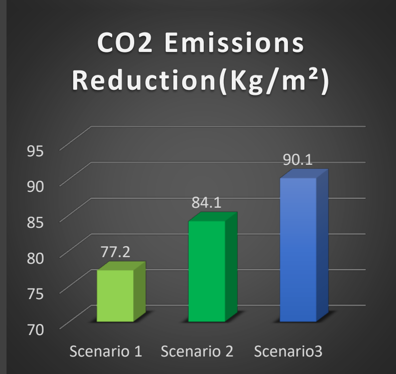












14	Multi-Family House			
	Apartment			
	Olympiados 7, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	66			
Heater Volume	207.9			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.6
Roof	A/S
Floor	A/S
Openings	3.8
g-openings	0.52

HVAC systems performance

	Heating	DHW
Production	0.95	0.95
Distribution	0.89	0.72
Terminal Units / Storage	0.883	1

Systems

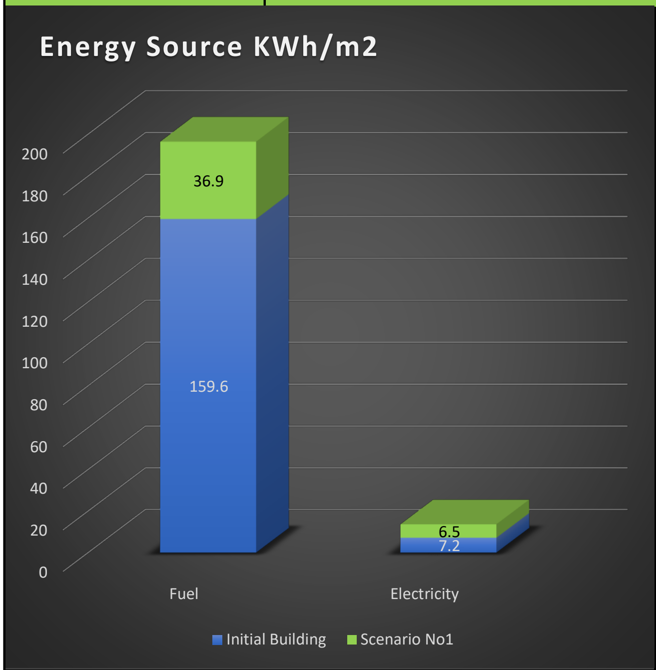
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

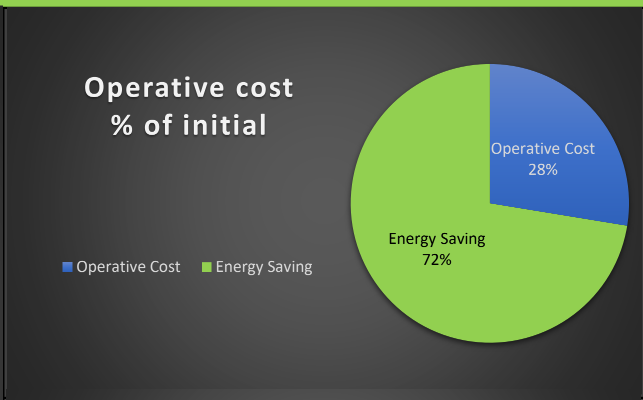
Annual Energy Characteristics

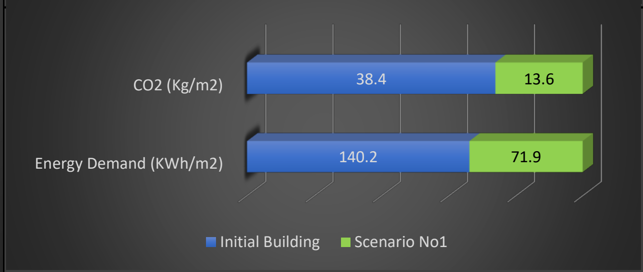
Energy Demand (KWh/m2/a)	140.2
Energy Consumption (KWh/m2/a)	166.5
Thermal Energy (KWh/m2/a)	159.6
Electricity (KWh/m2/a)	7.2
Primary Energy (KWh/m2/a)	187.5
CO2 Emissions (Kg/m2/a)	38.4
Total Final Thermal Energy	10533.6
Total Electricity Consumption	475.2
Operating cost	€819.10

Energy Saving Interventions

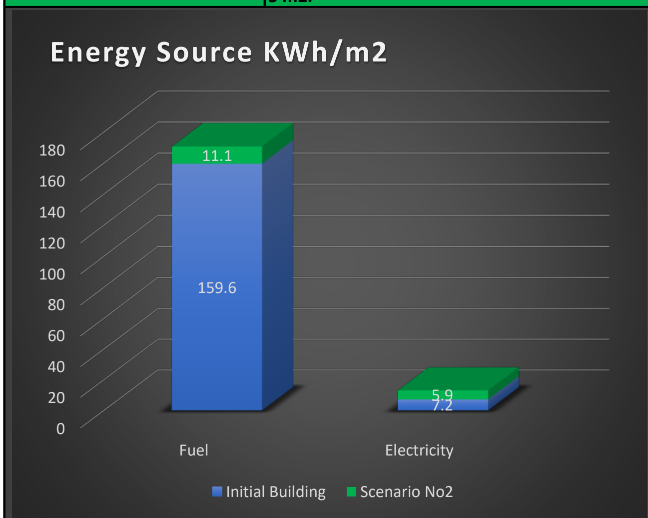
Scenario No1	P.E.S.	70.10%	Initial cost	€12,255.00	P.P. (Years)	20.7
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

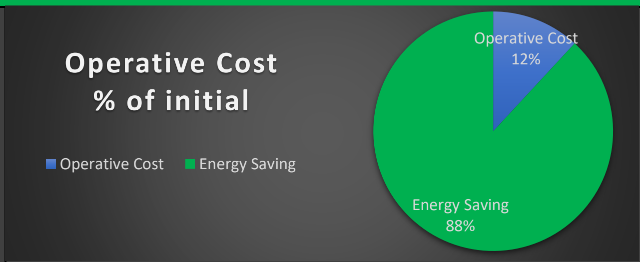


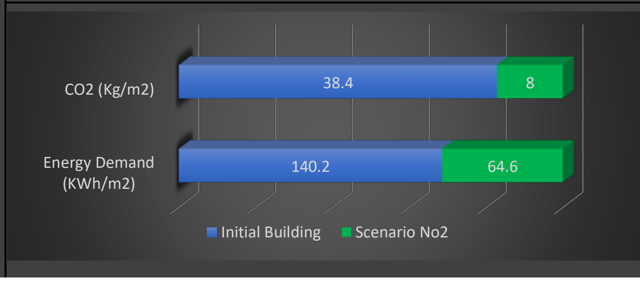




Scenario No2	P.E.S.	85.60%	Initial cost	€15,961.00	P.P. (Years)	22.1
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

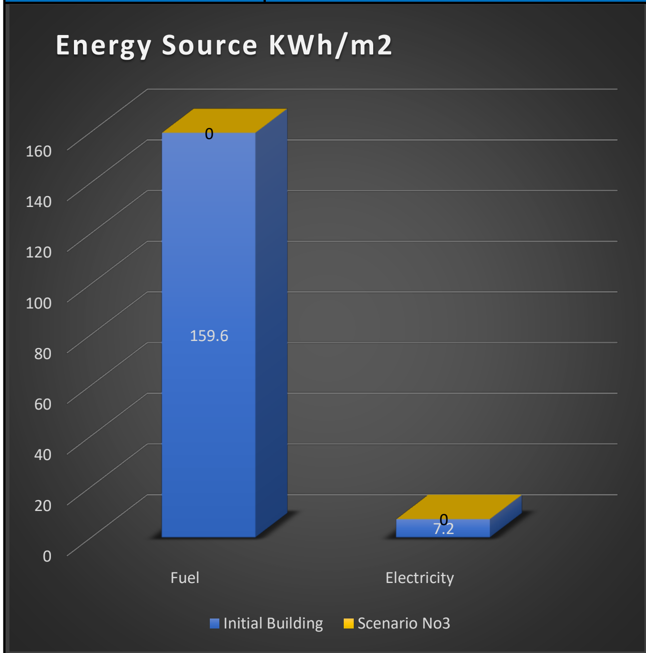


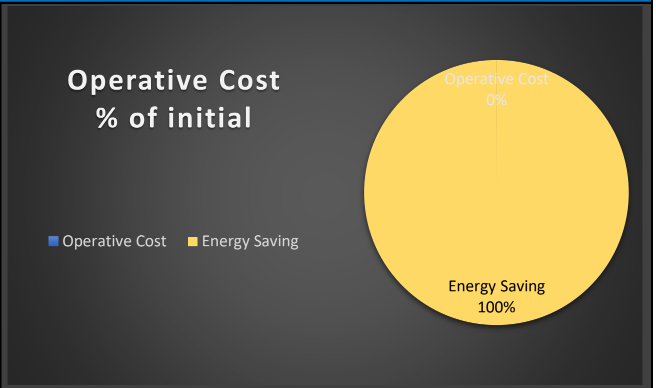


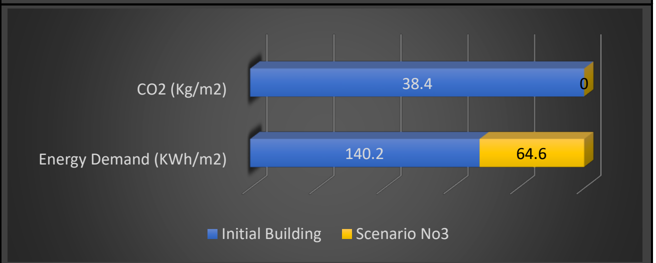


Energy Saving Interventions

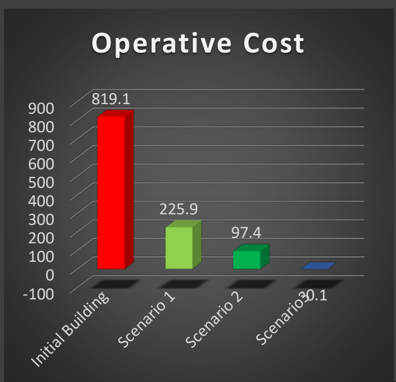
Scenario No3	P.E.S.	97.60%	Initial cost	€24,561.00	P.P. (Years))	30
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

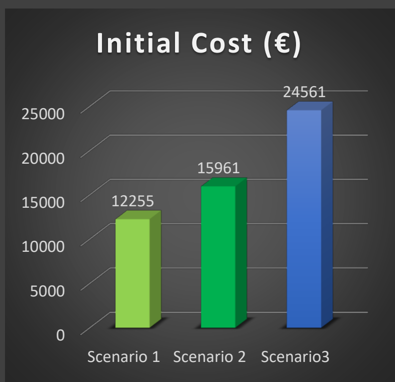


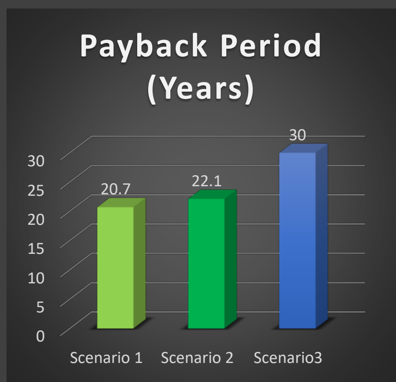


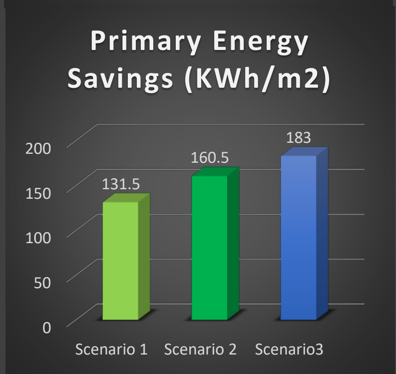


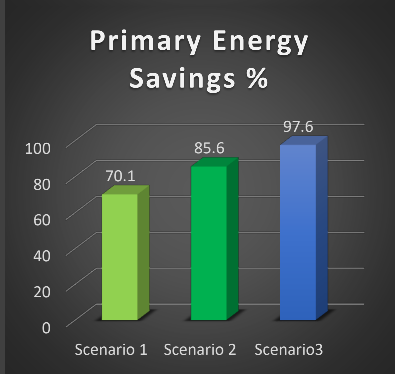
Scenario Comparison Diagrams

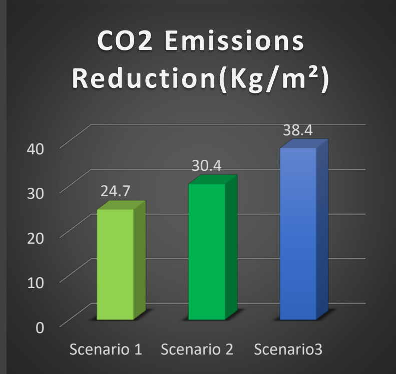












15	Multi-Family House			
	Apartment			
	Olympiados 13, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	48.6			
Heater Volume	145.8			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable wooden frame single glazing
Blinds	Wooden blinds
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.55
Roof	A/S
Floor	A/S
Openings	4.9
g-openings	0.52

HVAC systems performance

	Heating	DHW
Production	0.94	1
Distribution	0.95	0.72
Terminal Units / Storage	0.91	0.98

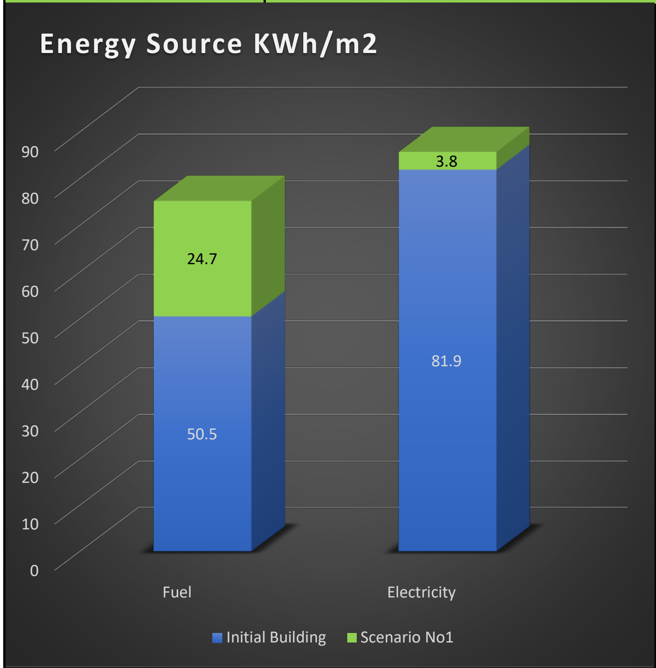
Systems

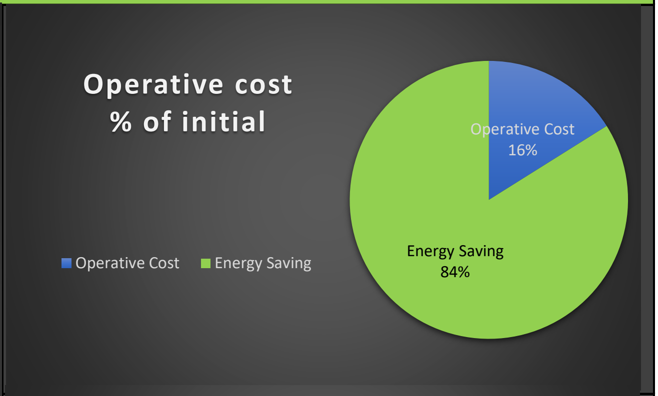
Production	Oil boiler, local A/C
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Local elecric boiler

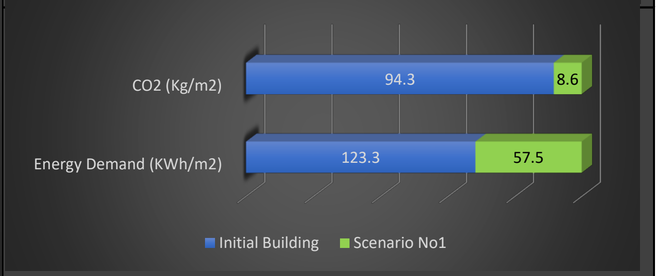
Annual Energy Characteristics

Energy Demand (KWh/m2/a)	123.3
Energy Consumption (KWh/m2/a)	132.1
Thermal Energy (KWh/m2/a)	50.5
Electricity (KWh/m2/a)	81.9
Primary Energy (KWh/m2/a)	292.2
CO2 Emissions (Kg/m2/a)	94.3
Total Final Thermal Energy	2454.3
Total Electricity Consumption	3980.34
Operating cost	€664.40

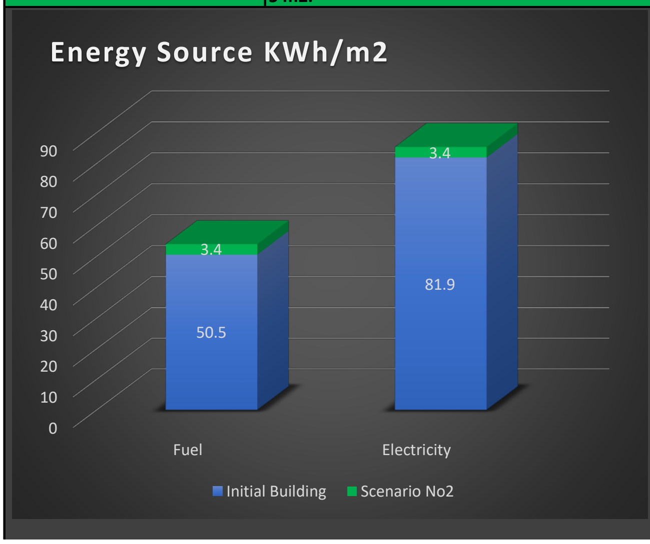
Energy Saving Interventions						
Scenario No1	P.E.S.	87.80%	Initial cost	€9,521.50	P.P. (Years)	17.1
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

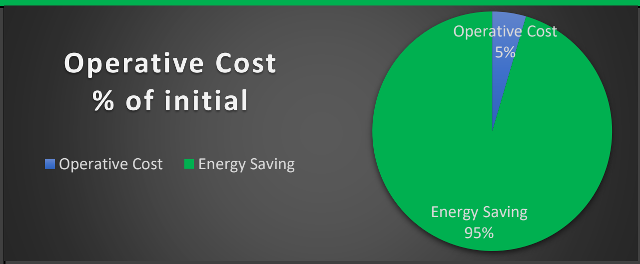


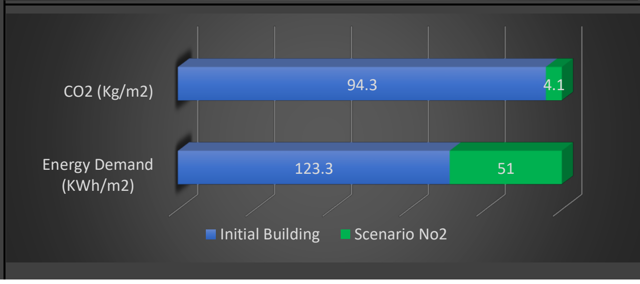




Scenario No2	P.E.S.	95.80%	Initial cost	€12,110.20	P.P. (Years)	19.1
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

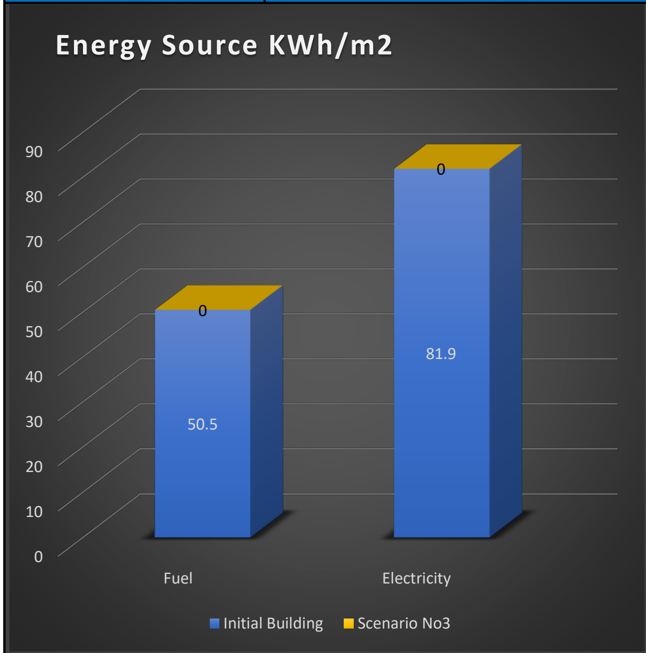


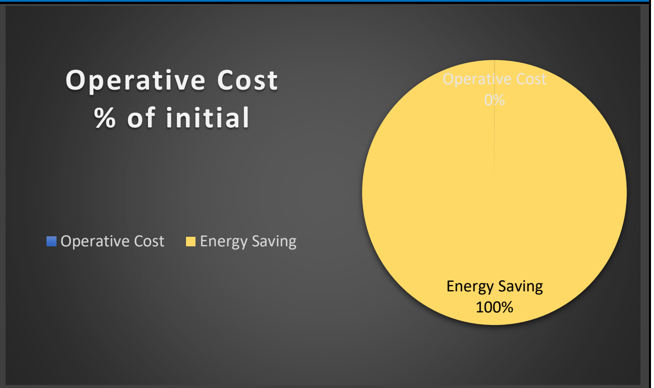


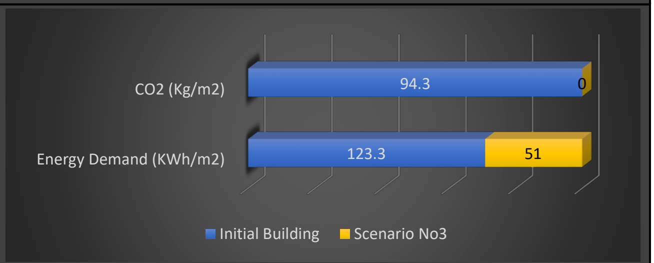


Energy Saving Interventions

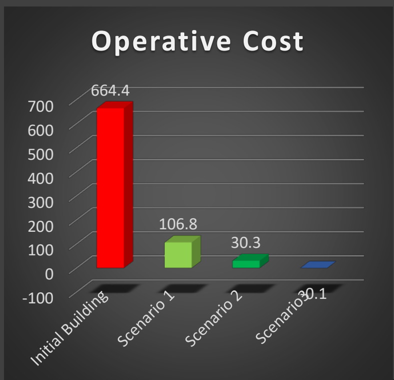
Scenario No3	P.E.S.	100.40%	Initial cost	€18,960.20	P.P. (Years)	28.5
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

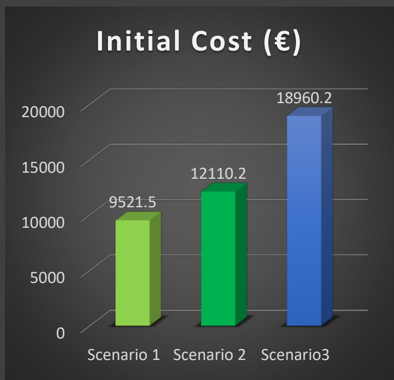


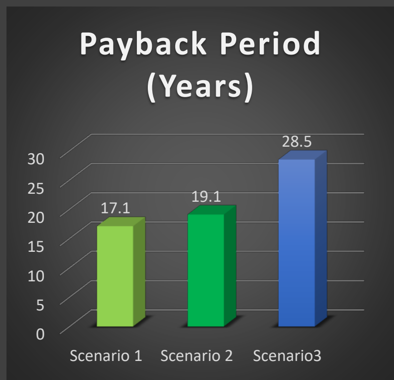


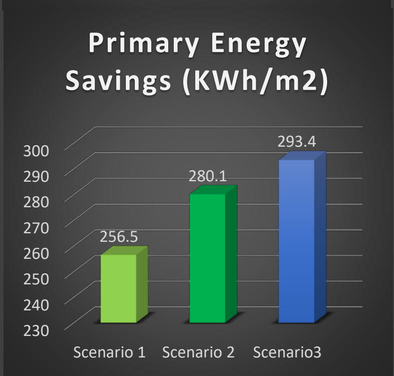


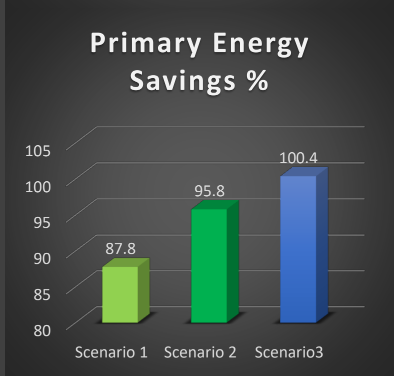
Scenario Comparison Diagrams

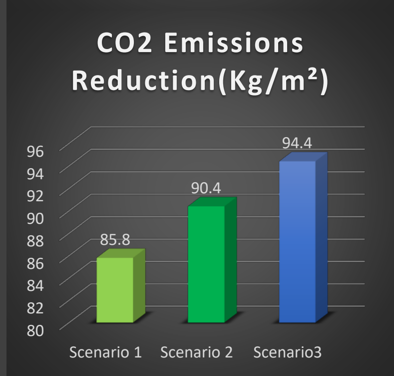




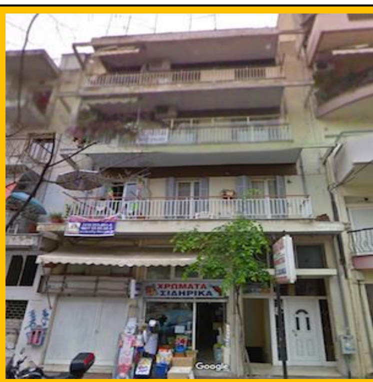








16	Multi-Family House			
	Apartment			
	Olympiados 76, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	90.5			
Heater Volume	271.5			



Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.7
Roof	A/S
Floor	A/S
Openings	3.8
g-openings	0.52

HVAC systems performance

	Heating	DHW
Production	0.95	1
Distribution	0.945	0.72
Terminal Units / Storage	0.87	1

Systems

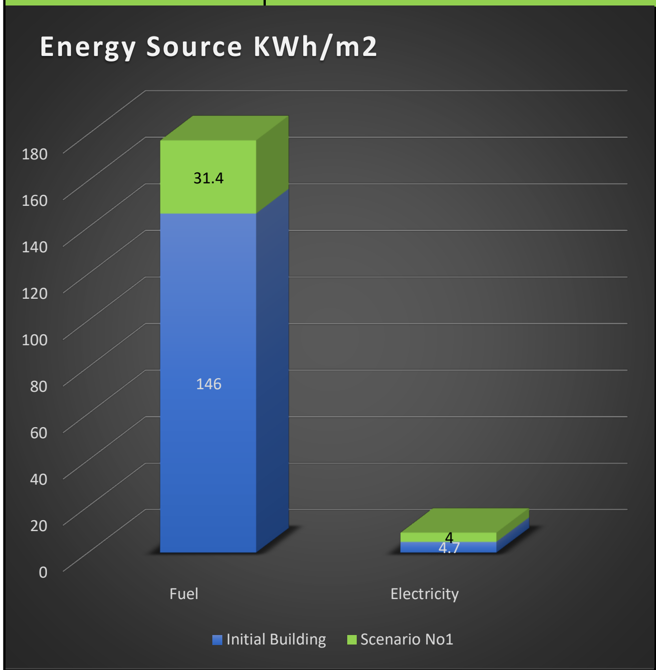
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

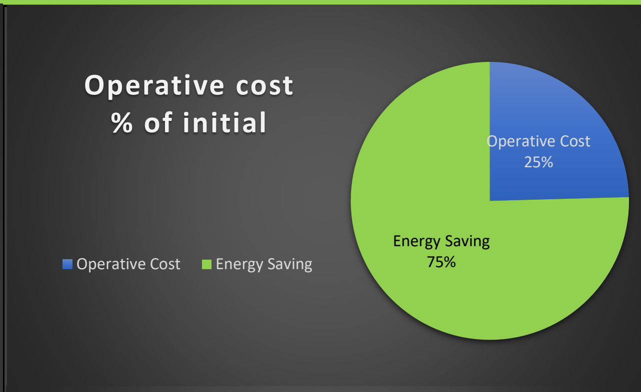
Annual Energy Characteristics

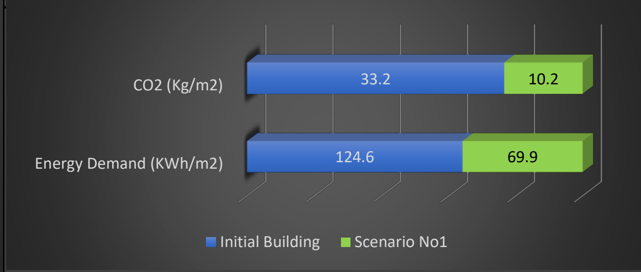
Energy Demand (KWh/m2/a)	124.6
Energy Consumption (KWh/m2/a)	150.3
Thermal Energy (KWh/m2/a)	146
Electricity (KWh/m2/a)	4.7
Primary Energy (KWh/m2/a)	165.9
CO2 Emissions (Kg/m2/a)	33.3
Total Final Thermal Energy	13213
Total Electricity Consumption	425.35
Operating cost	€1,007.50

Energy Saving Interventions

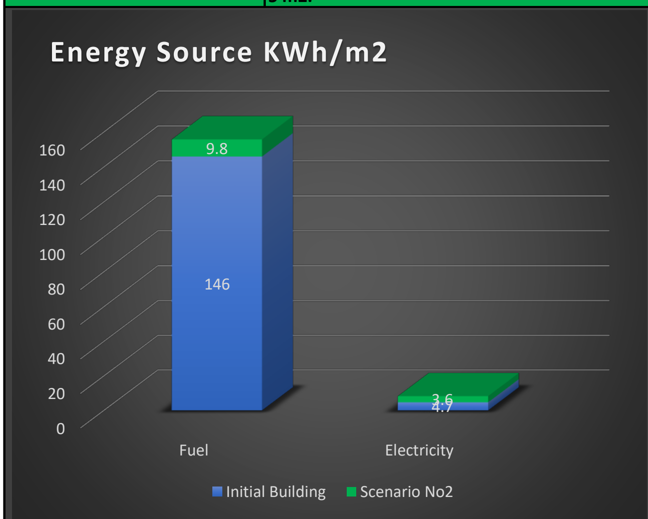
Scenario No1	P.E.S.	74.00%	Initial cost	€13,670.00	P.P. (Years)	18
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

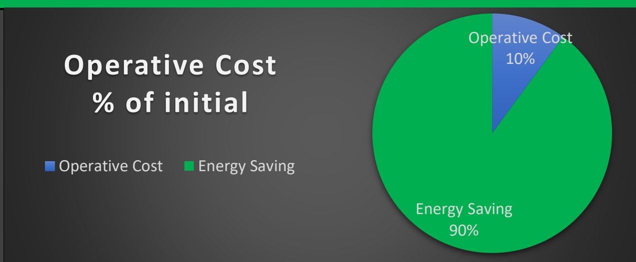


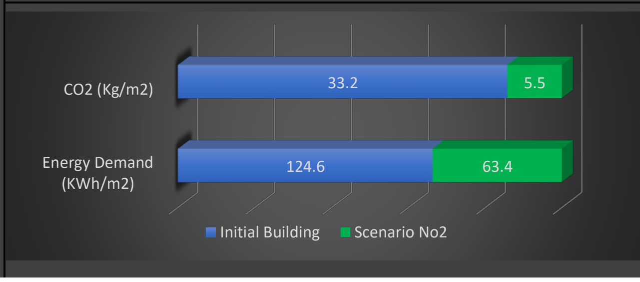




Scenario No2	P.E.S.	88.30%	Initial cost	€17,435.00	P.P. (Years)	19.2
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

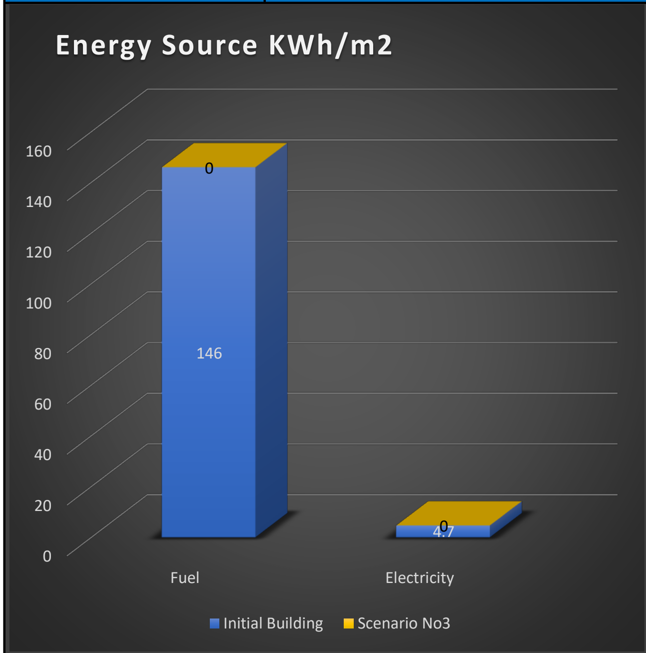


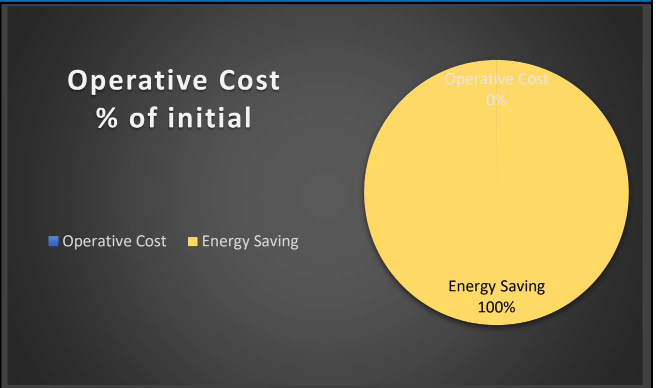


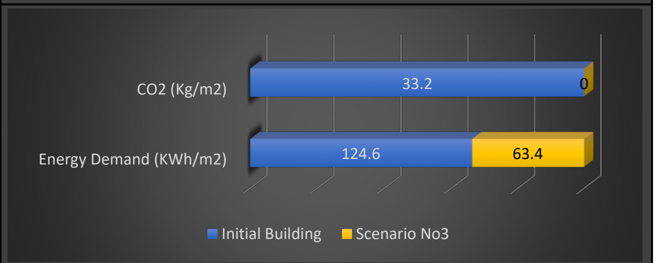


Energy Saving Interventions

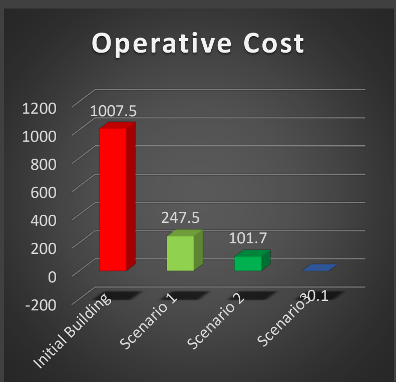
Scenario No3	P.E.S.	99.00%	Initial cost	€27,735.00	P.P. (Years)	27.5
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

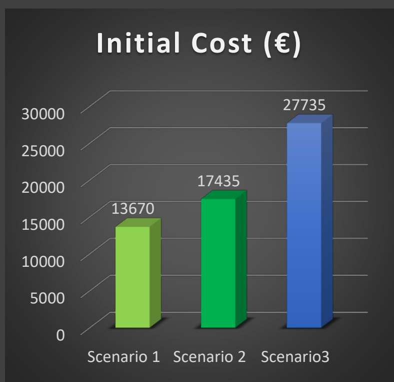


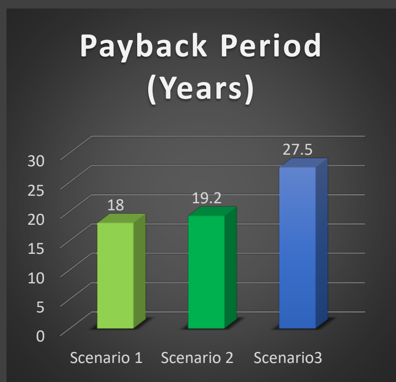


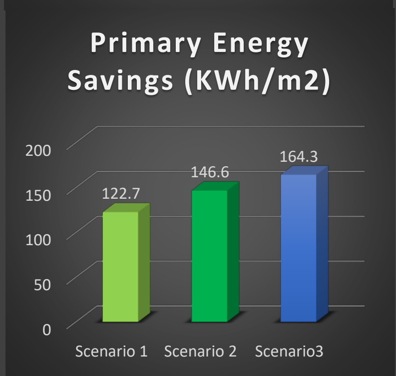


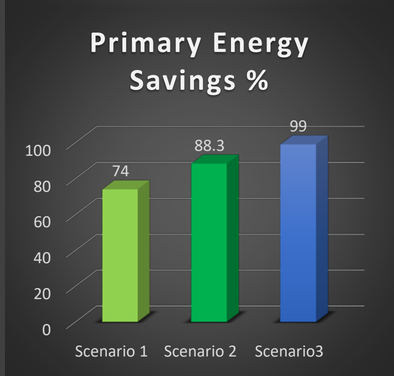
Scenario Comparison Diagrams

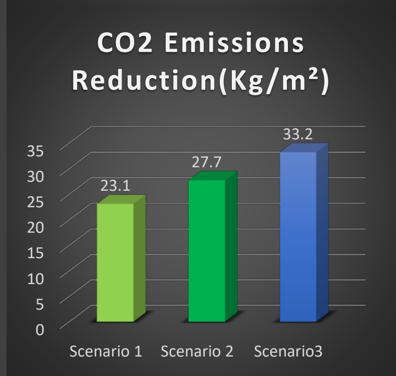




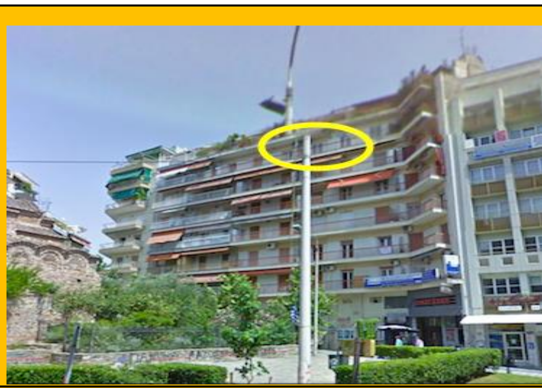








17	Multi-Family House			
	Apartment			
	ting. Thermostat and user presence dete			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	92.75			
Heater Volume	278.25			



Building Description

Indermediate floor apartment in the center of Thessaloniki. 25,75m2 roof in contact with external air. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface, without inulation
Openings	Openable synthtic frame double glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.7
Roof	3.05
Floor	A/S
Openings	3.02
g-openings	0.48

HVAC systems performance

	Heating	DHW
Production	0.935	1
Distribution	0.95	0.72
Terminal Units / Storage	0.93	0.98

Systems

Production	Oil boiler
Distribution	Pipes inside the building at least 80% of their length
Solar thermal	Non applicable
DHW	Local electric boiler

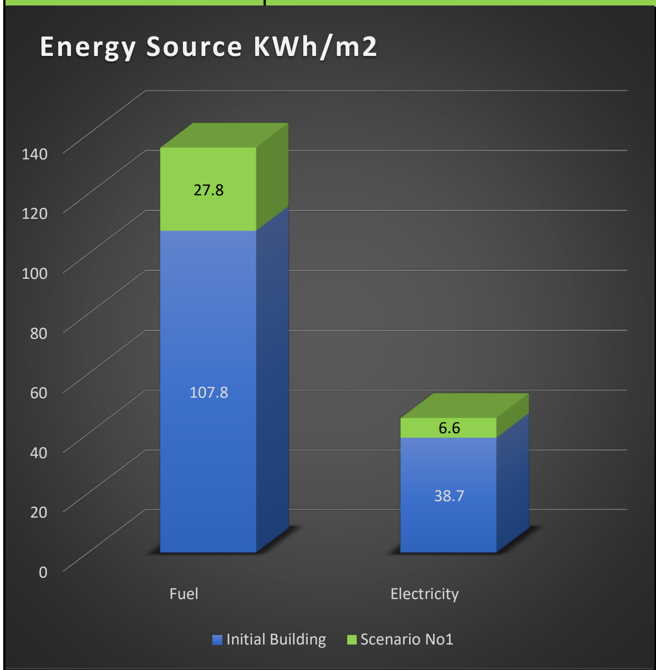
Annual Energy Characteristics

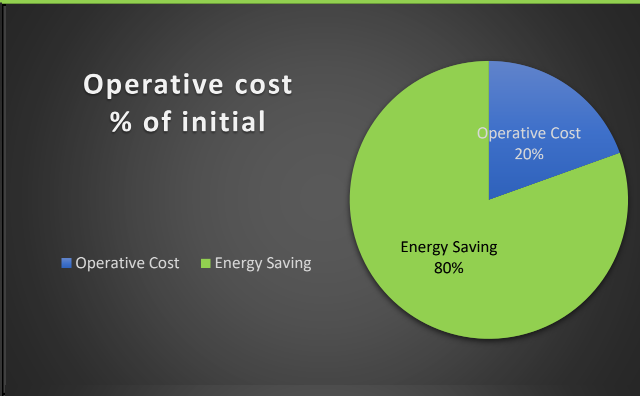
Energy Demand (KWh/m2/a)	146.3
Energy Consumption (KWh/m2/a)	145.6
Thermal Energy (KWh/m2/a)	107.8
Electricity (KWh/m2/a)	38.7
Primary Energy (KWh/m2/a)	228.2
CO2 Emissions (Kg/m2/a)	66.7
Total Final Thermal Energy	9998.45
Total Electricity Consumption	3589.425
Operating cost	€1,313.50

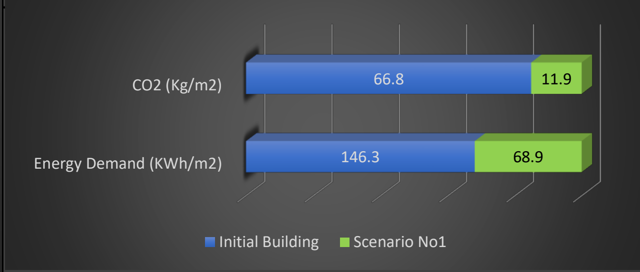
Energy Saving Interventions

Scenario No1	P.E.S.	80.00%	Initial cost	€17,170.80	P.P. (Years)	16.2

Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.

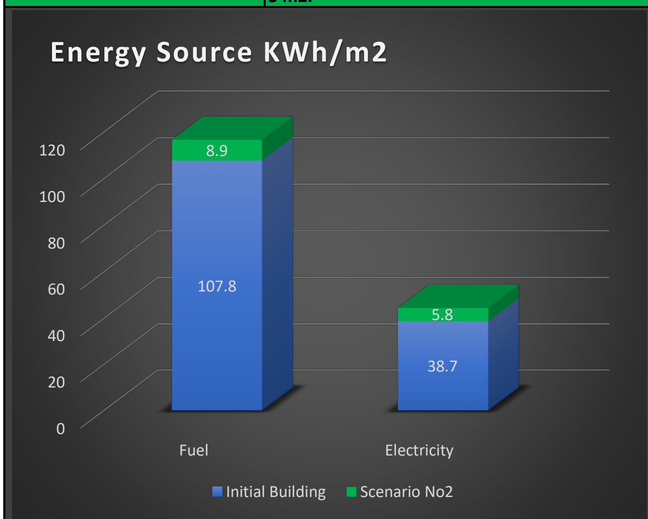


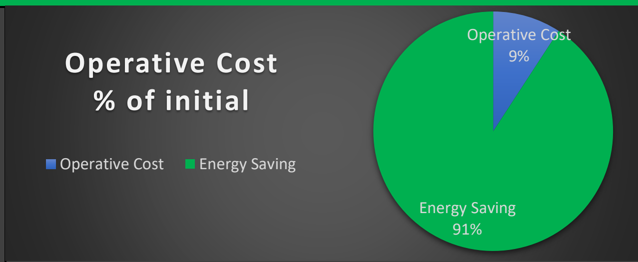


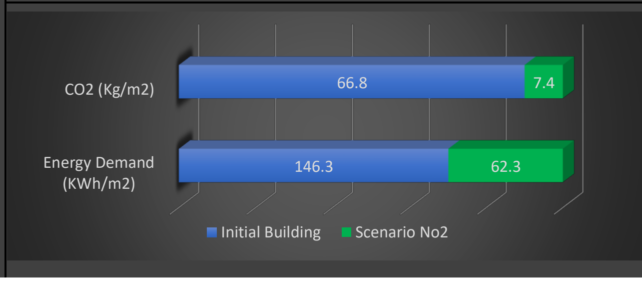


Scenario No2	P.E.S.	89.60%	Initial cost	€22,245.80	P.P. (Years)	18.7

Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.

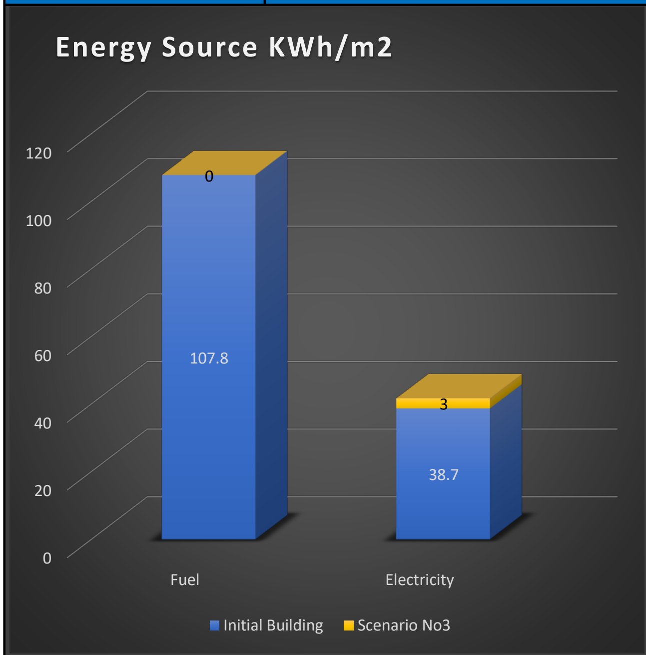


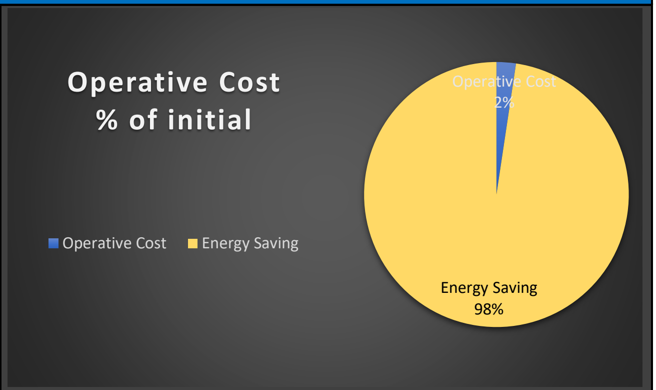


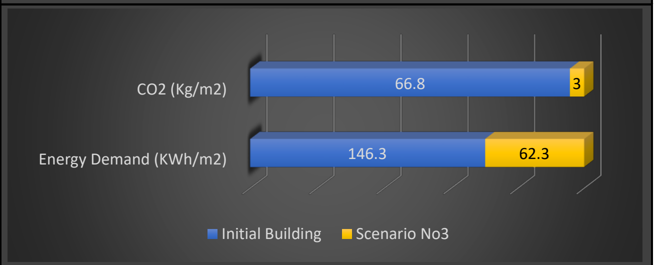


Energy Saving Interventions

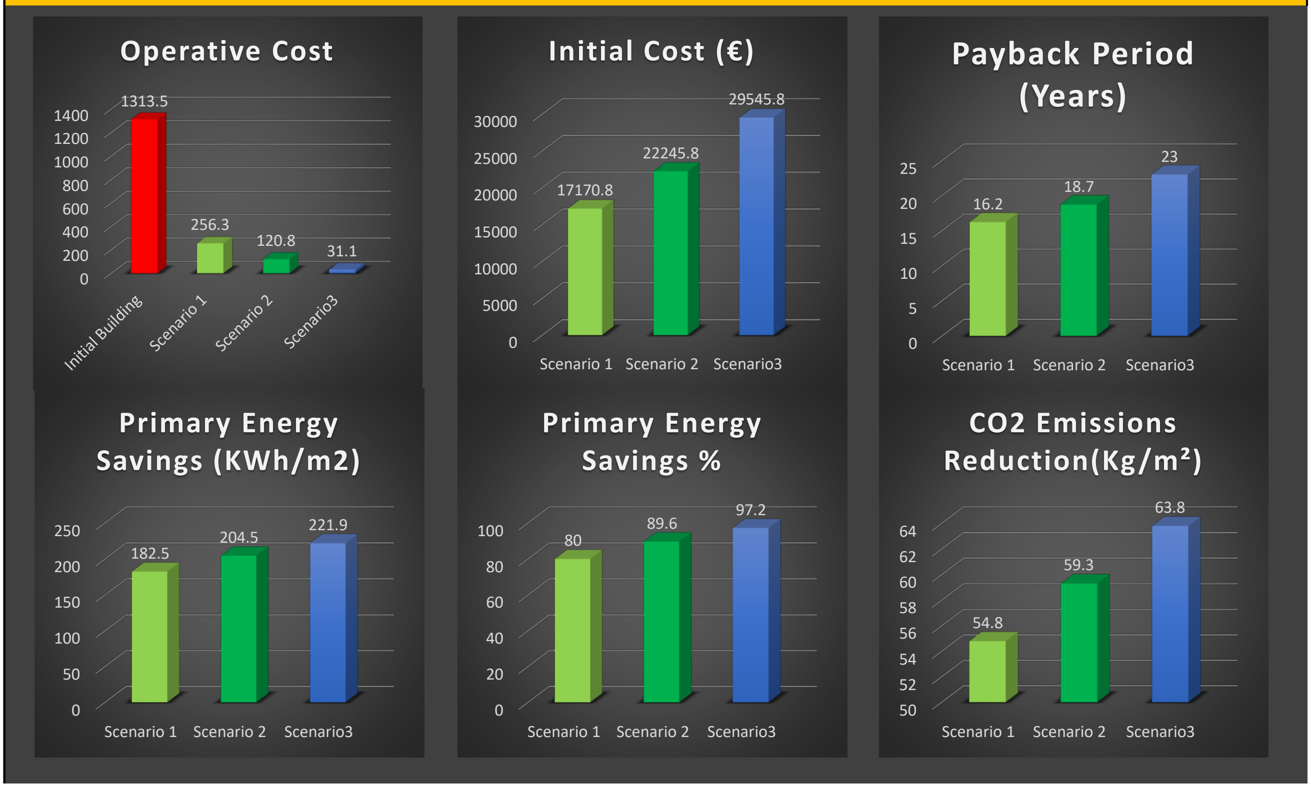
Scenario No3	P.E.S.	97.20%	Initial cost	€29,545.80	P.P. (Years)	23
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					







Scenario Comparison Diagrams



18	Multi-Family House			
	Apartment			
	Plateia Navarinou 3, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	34			
Heater Volume	108.8			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic Frame Double Glazing 12mm
Blinds	Wooden blinds
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.55
Roof	A/S
Floor	A/S
Openings	3
g-openings	0.49

HVAC systems performance

	Heating	DHW
Production	0.967	1
Distribution	0.95	0.72
Terminal Units / Storage	0.93	0.98

Systems

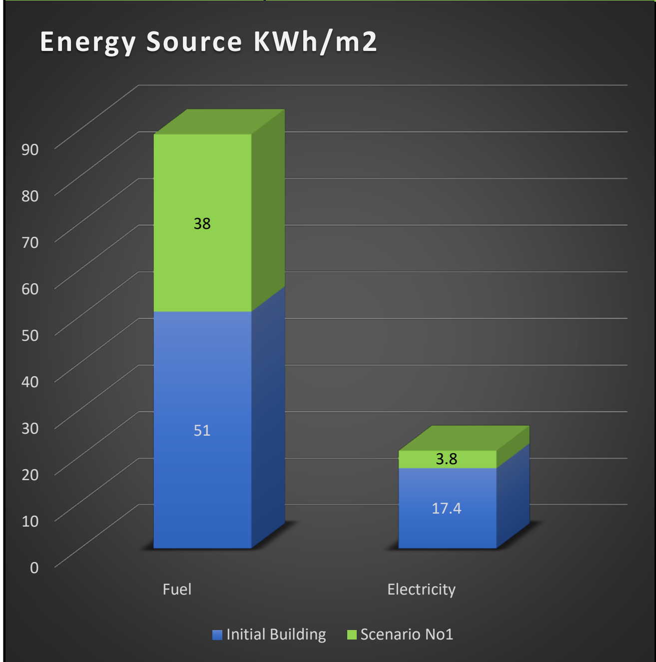
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

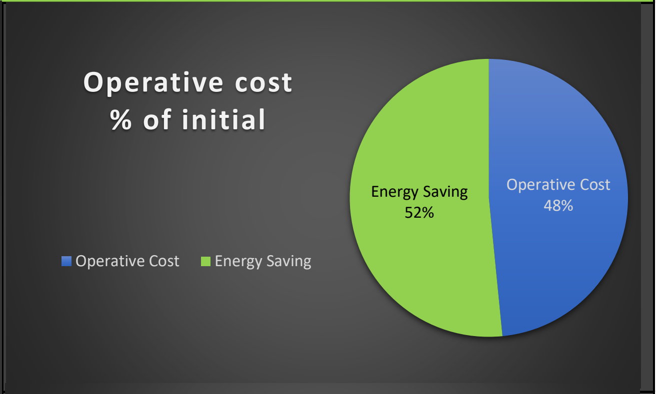
Annual Energy Characteristics

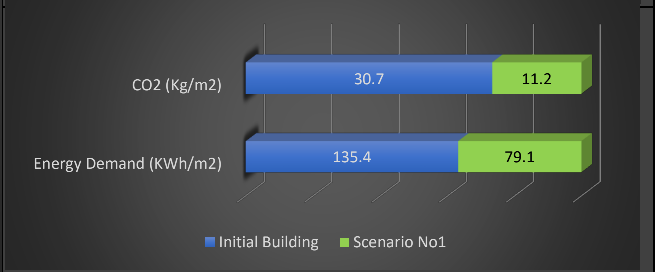
Energy Demand (KWh/m2/a)	135.4
Energy Consumption (KWh/m2/a)	107.1
Thermal Energy (KWh/m2/a)	51
Electricity (KWh/m2/a)	17.4
Primary Energy (KWh/m2/a)	105.6
CO2 Emissions (Kg/m2/a)	30.7
Total Final Thermal Energy	1734
Total Electricity Consumption	591.6
Operating cost	€224.20

Energy Saving Interventions

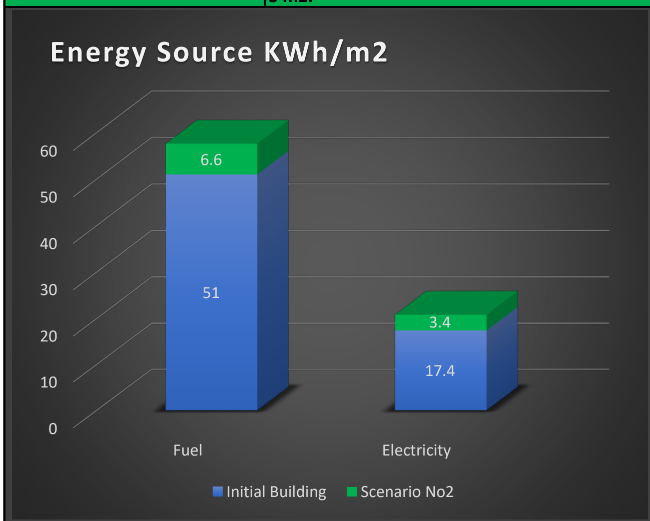
Scenario No1	P.E.S.	52.90%	Initial cost	€6,992.00	P.P. (Years)	60.5
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

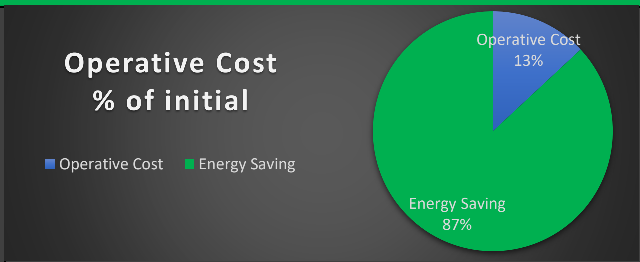


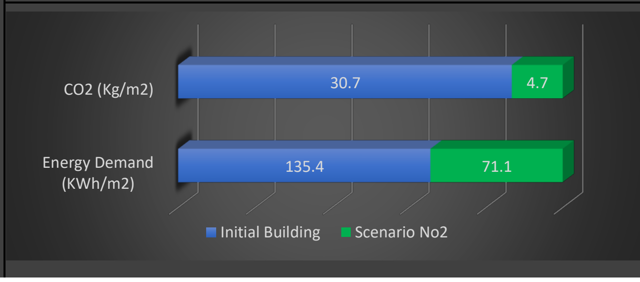




Scenario No2	P.E.S.	85.30%	Initial cost	€9,316.60	P.P. (Years)	47.8
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

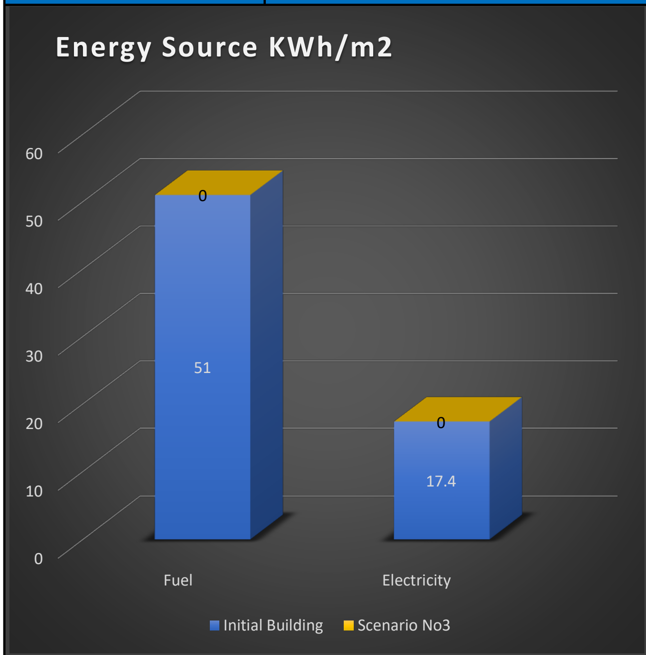


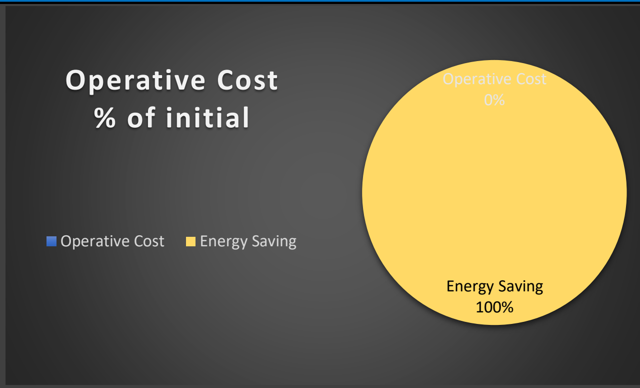


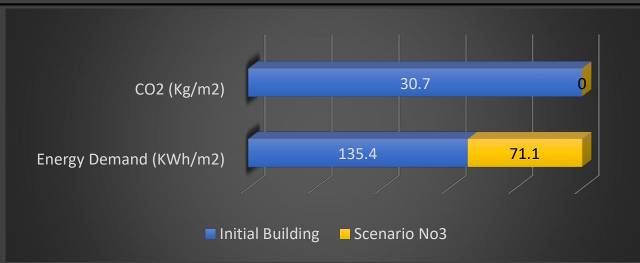


Energy Saving Interventions

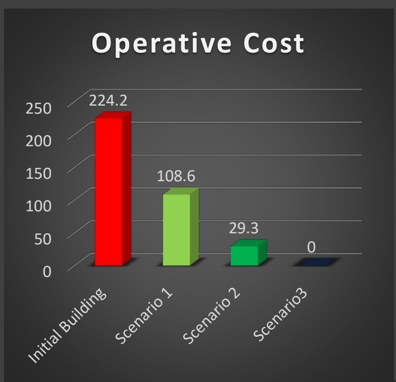
Scenario No3	P.E.S.	101.20%	Initial cost	€15,616.60	P.P. (Years)	69.6
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

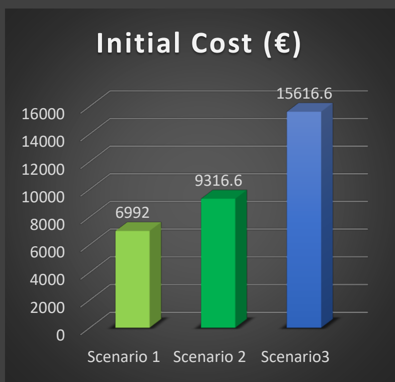


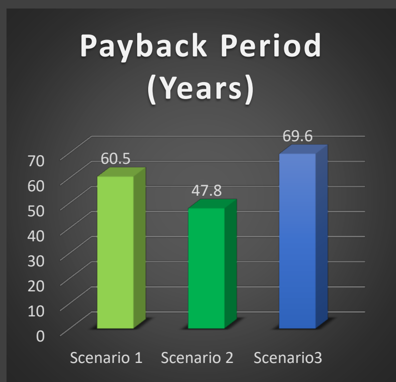


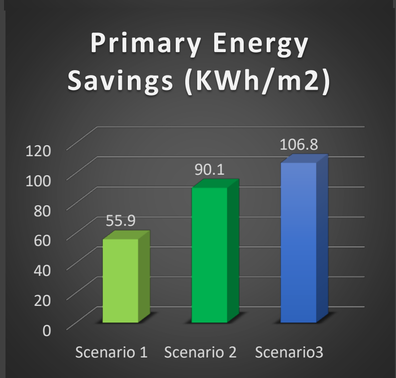


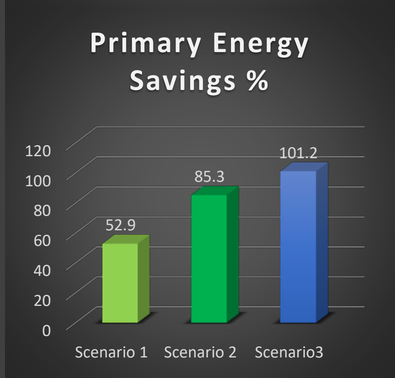
Scenario Comparison Diagrams

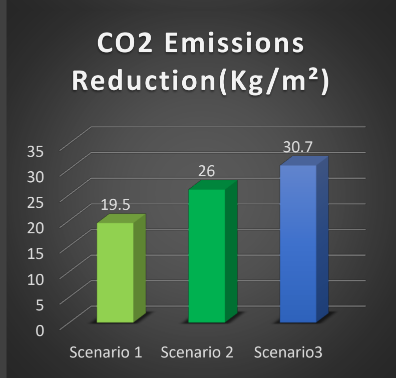












19	Multi-Family House			
	Apartment			
	Platonos 1, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	108.14			
Heater Volume	408.77			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic Frame Double Glazing 12mm
Blinds	Wooden blinds
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.55
Roof	A/S
Floor	A/S
Openings	3.05
g-openings	0.48

HVAC systems performance

	Heating	DHW
Production	0.868	0.868
Distribution	0.945	0.72
Terminal Units / Storage	0.891	0.88

Systems

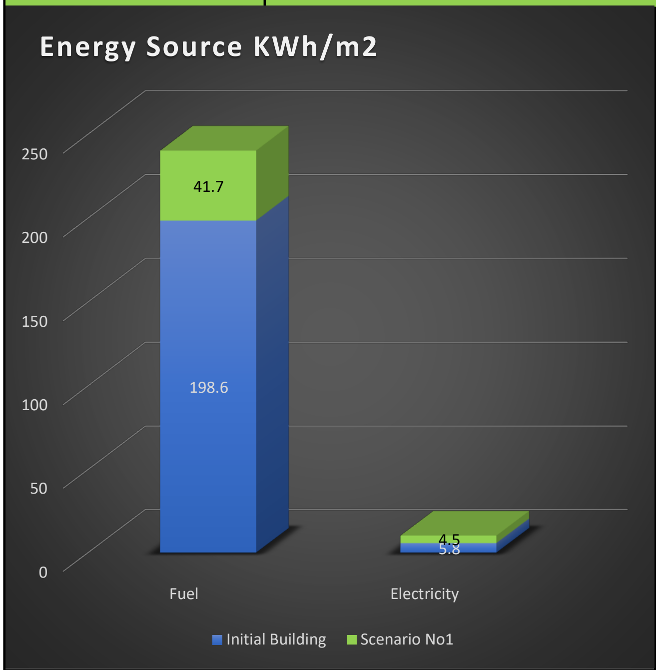
Production	Individual oil Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual oil Boiler

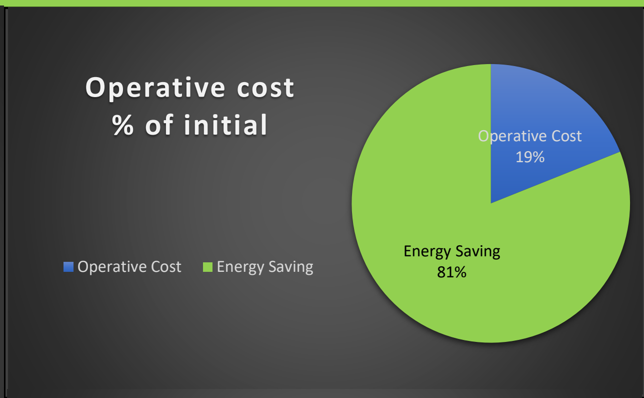
Annual Energy Characteristics

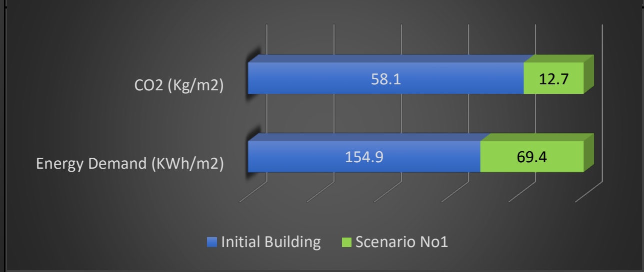
Energy Demand (KWh/m2/a)	154.9
Energy Consumption (KWh/m2/a)	204.1
Thermal Energy (KWh/m2/a)	198.6
Electricity (KWh/m2/a)	5.8
Primary Energy (KWh/m2/a)	234.4
CO2 Emissions (Kg/m2/a)	58.2
Total Final Thermal Energy	21476.604
Total Electricity Consumption	627.212
Operating cost	€2,020.60

Energy Saving Interventions

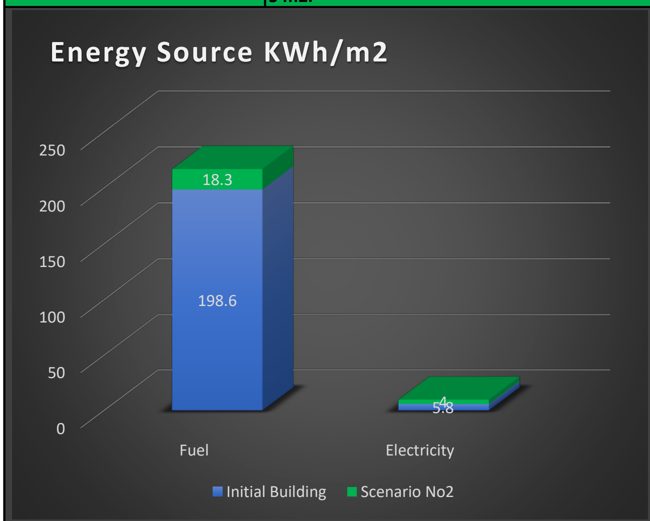
Scenario No1	P.E.S.	76.20%	Initial cost	€20,773.50	P.P. (Years)	12.7
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

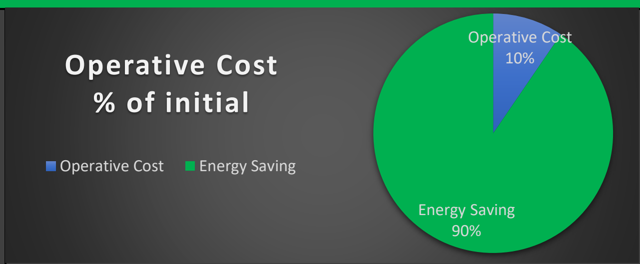


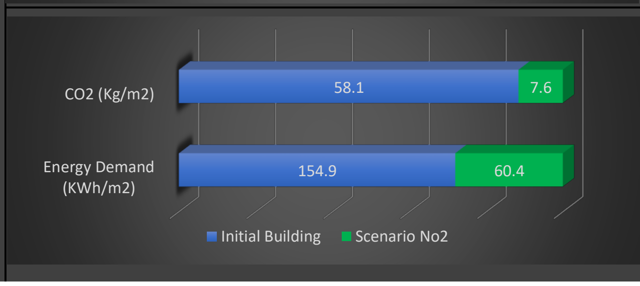




Scenario No2	P.E.S.	87.30%	Initial cost	€28,067.80	P.P. (Years)	15.4
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

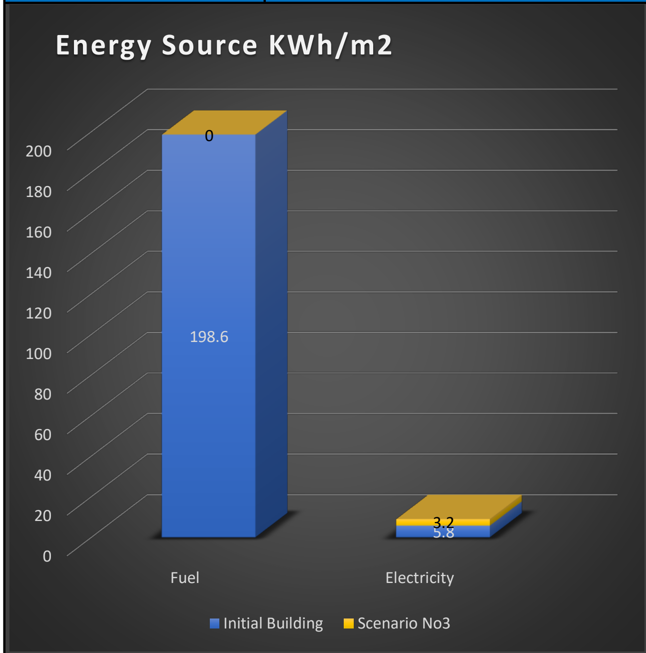


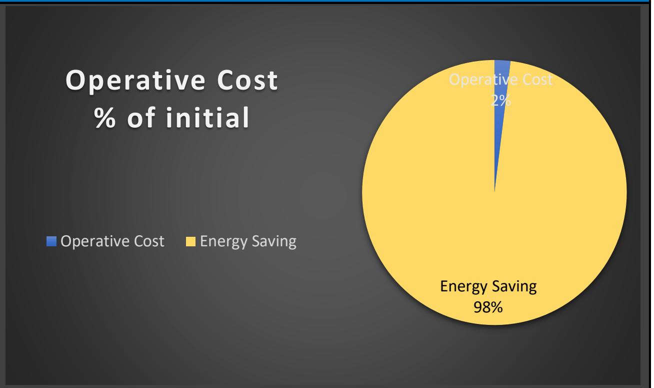


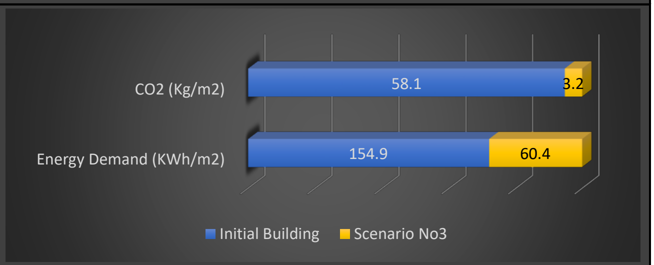


Energy Saving Interventions

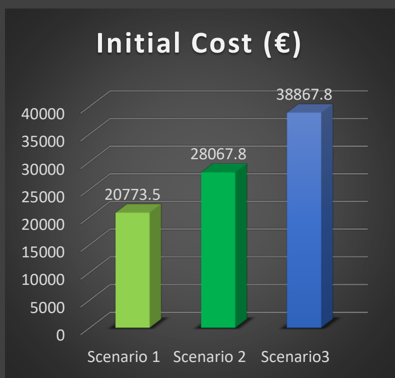
Scenario No3	P.E.S.	96.50%	Initial cost	€38,867.80	P.P. (Years)	19.6
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

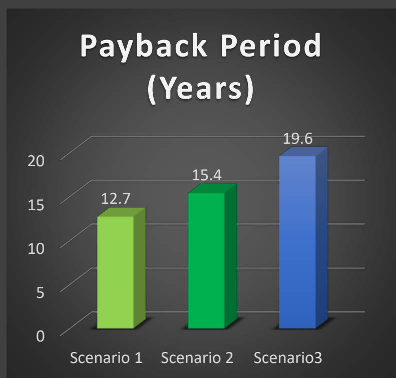


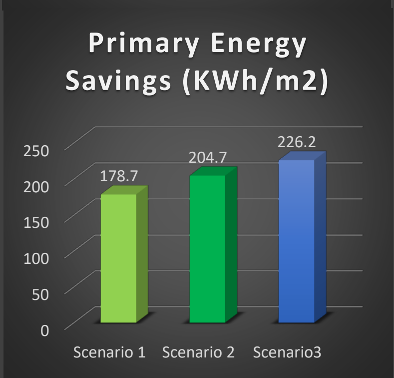


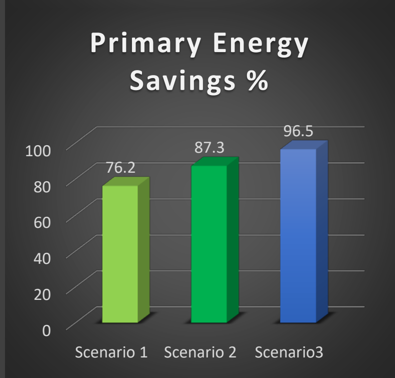


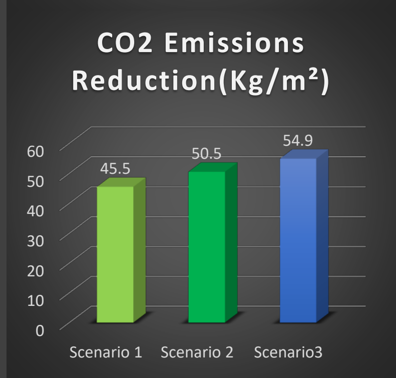
Scenario Comparison Diagrams











20	Multi-Family House			
	Apartment			
	Proksenou Koromila 31, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	79			
Heater Volume	237			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.7
Roof	A/S
Floor	A/S
Openings	3
g-openings	0.5

HVAC systems performance

	Heating	DHW
Production	0.868	0.868
Distribution	0.945	0.92
Terminal Units / Storage	0.89	0.98

Systems

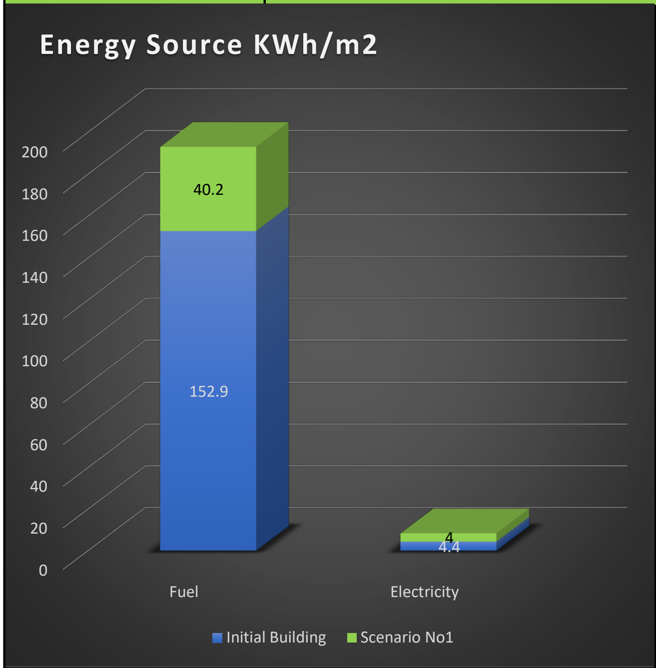
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

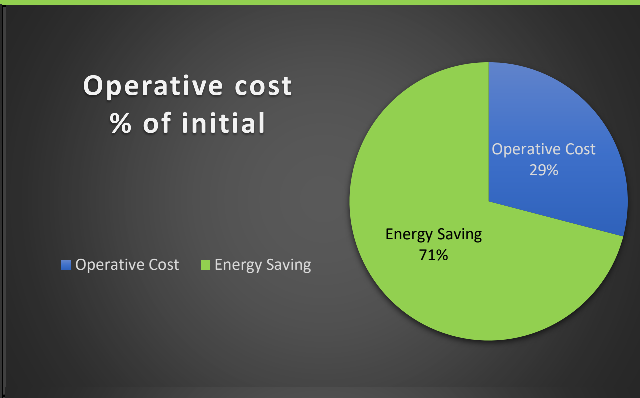
Annual Energy Characteristics

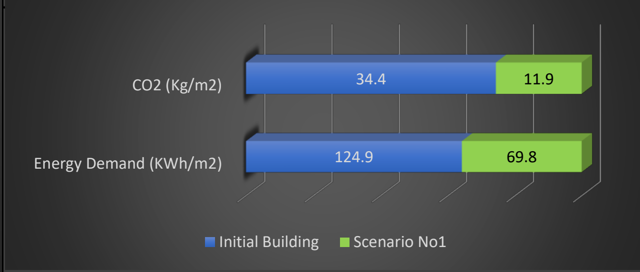
Energy Demand (KWh/m2/a)	124.9
Energy Consumption (KWh/m2/a)	157.1
Thermal Energy (KWh/m2/a)	152.9
Electricity (KWh/m2/a)	4.4
Primary Energy (KWh/m2/a)	172.7
CO2 Emissions (Kg/m2/a)	34.3
Total Final Thermal Energy	12079.1
Total Electricity Consumption	347.6
Operating cost	€916.60

Energy Saving Interventions

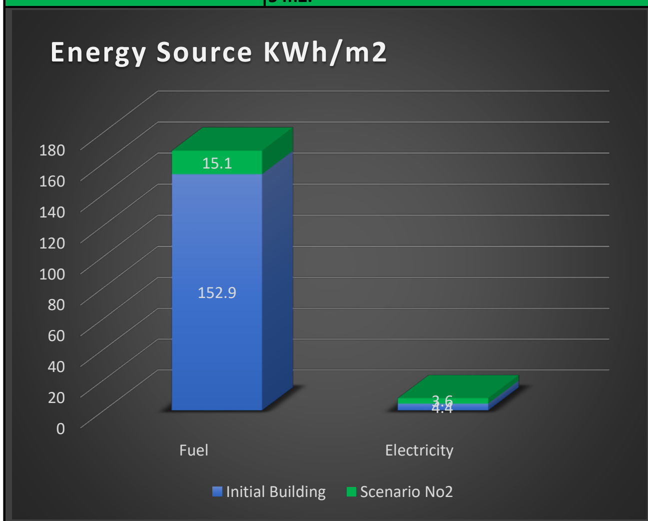
Scenario No1	**P.E.S.**	**69.50%**	**Initial cost**	**€12,409.50**	**P.P. (Years)**	**19.1**
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

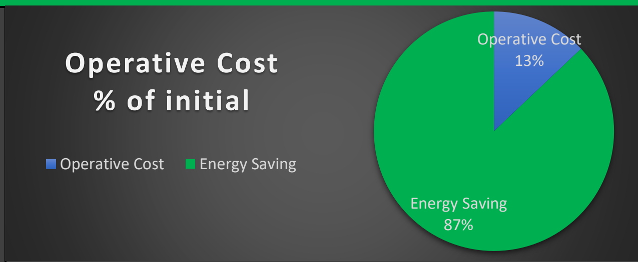


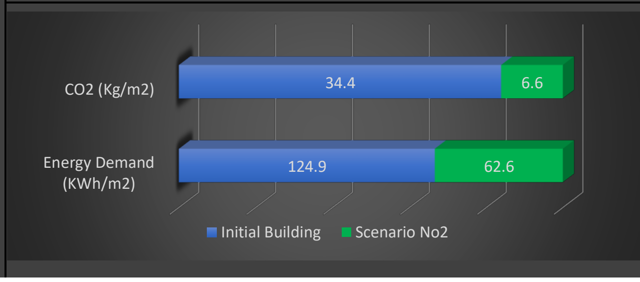




Scenario No2	**P.E.S.**	**85.50%**	**Initial cost**	**€16,989.40**	**P.P. (Years)**	**21.3**
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

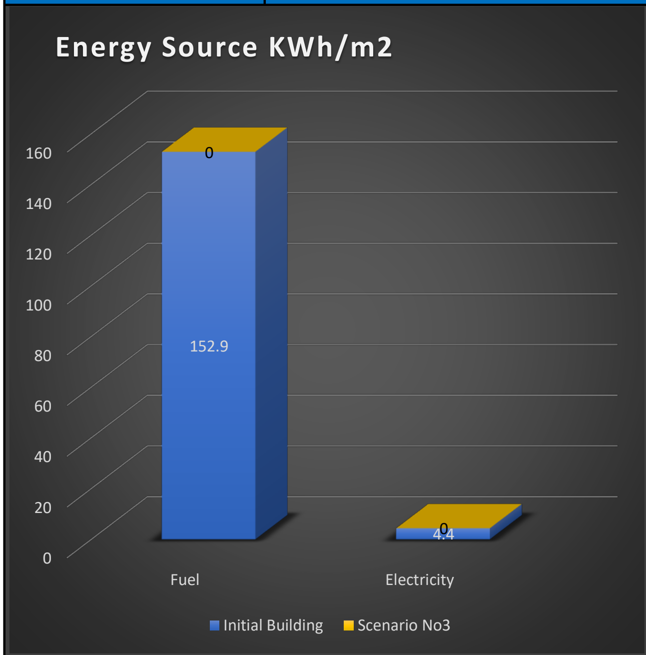


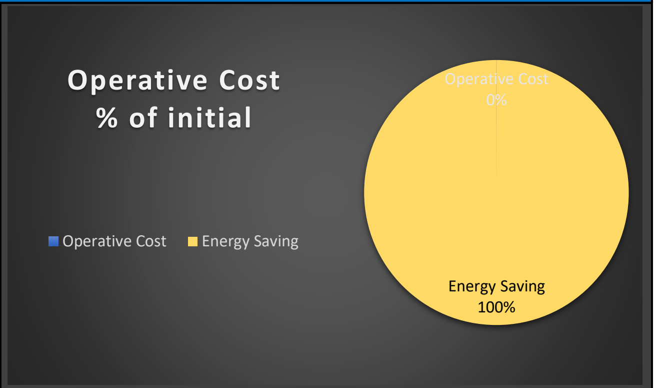


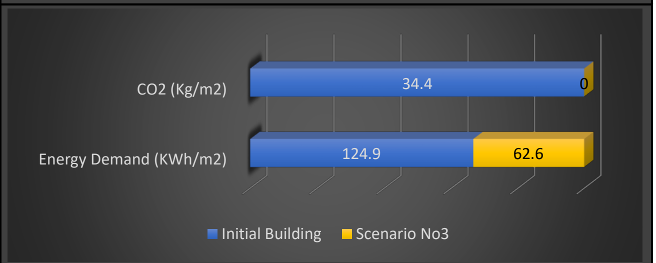


Energy Saving Interventions

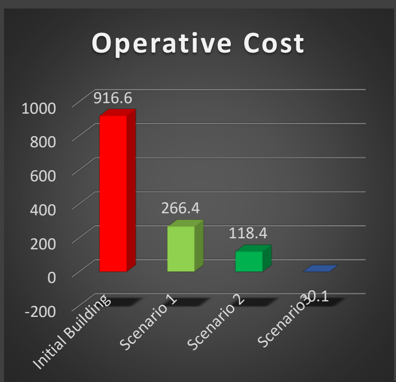
Scenario No3	P.E.S.	98.50%	Initial cost	€21,489.40	P.P. (Years)	23.4
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

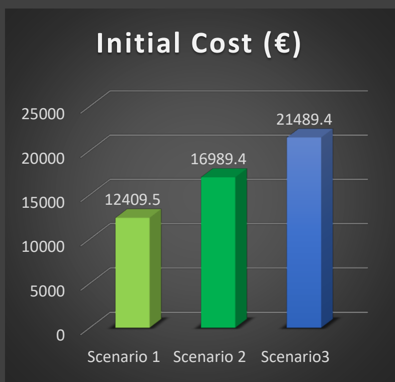


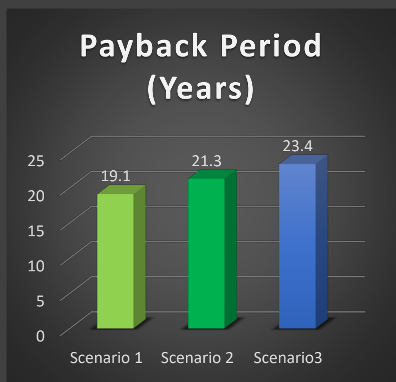


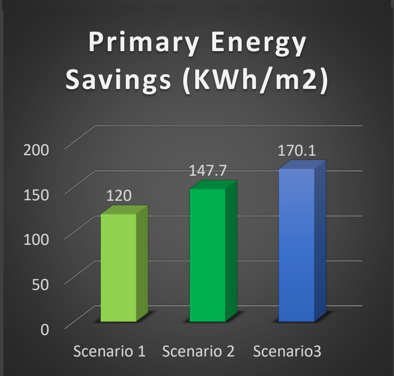


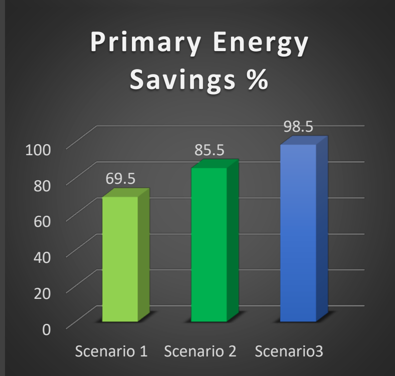
Scenario Comparison Diagrams

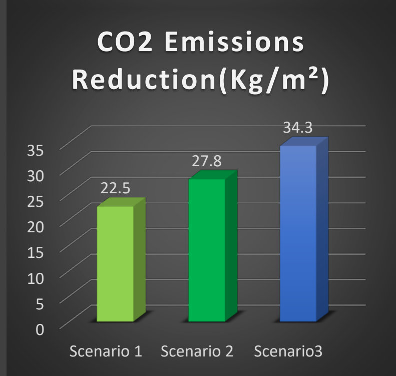




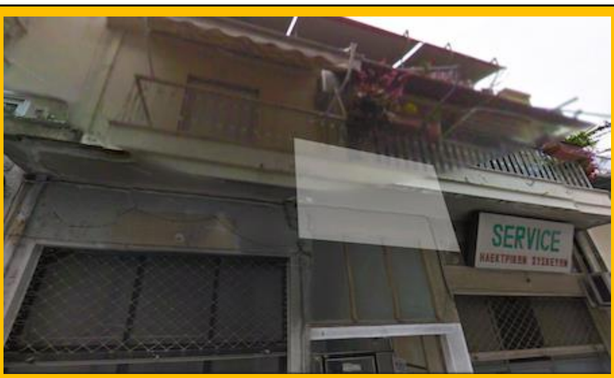








21	Multi-Family House			
	Apartment			
	Raktivan 10, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	32.3			
Heater Volume	96.9			



Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Openable synthetic Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.5
Roof	A/S
Floor	A/S
Openings	3
g-openings	0.48

HVAC systems performance

	Heating	DHW
Production	1	1
Distribution	1	0.72
Terminal Units / Storage	0.91	0.98

Systems

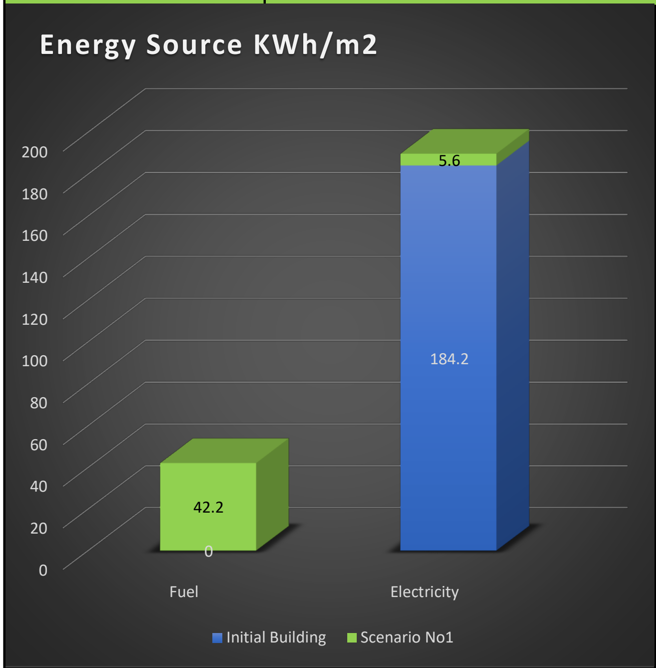
Production	Local electric radiators
Distribution	Non applicable
Solar thermal	Non applicable
DHW	Local electric boiler

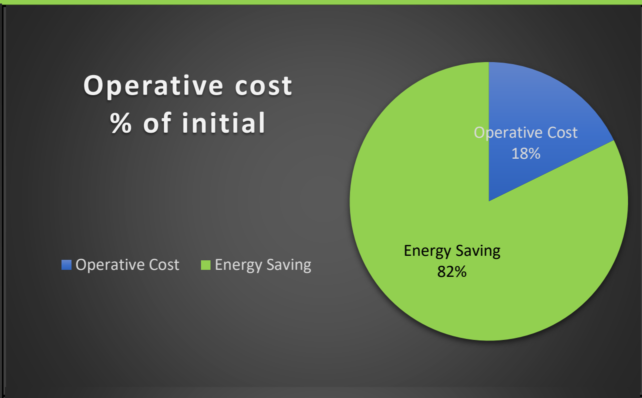
Annual Energy Characteristics

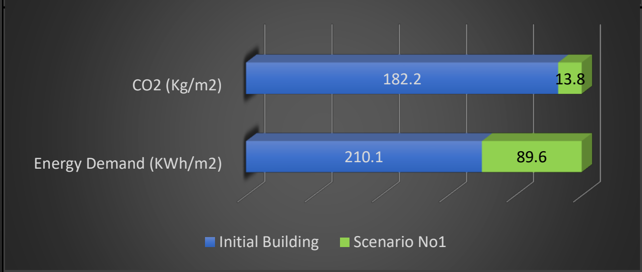
Energy Demand (KWh/m2/a)	210.1
Energy Consumption (KWh/m2/a)	183.8
Thermal Energy (KWh/m2/a)	0
Electricity (KWh/m2/a)	184.2
Primary Energy (KWh/m2/a)	533.1
CO2 Emissions (Kg/m2/a)	182.2
Total Final Thermal Energy	0
Total Electricity Consumption	5949.66
Operating cost	€672.50

Energy Saving Interventions

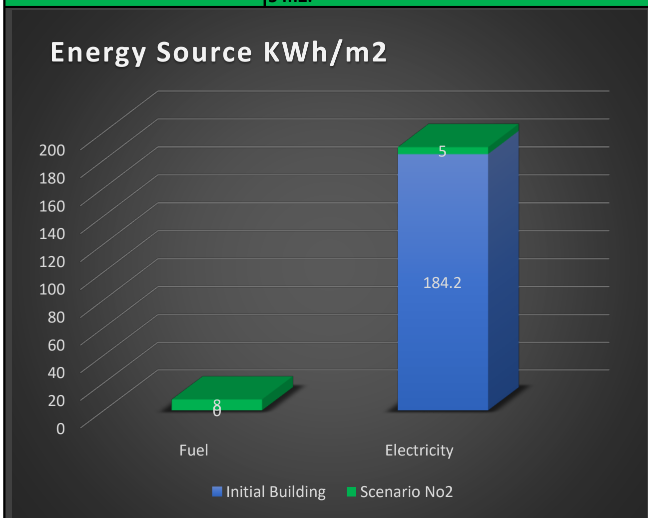
Scenario No1	P.E.S.	89.10%	Initial cost	€8,634.00	P.P. (Years)	15.6
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

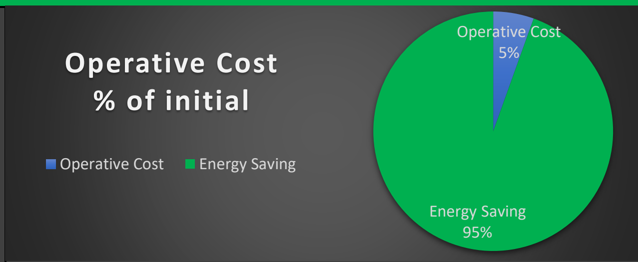


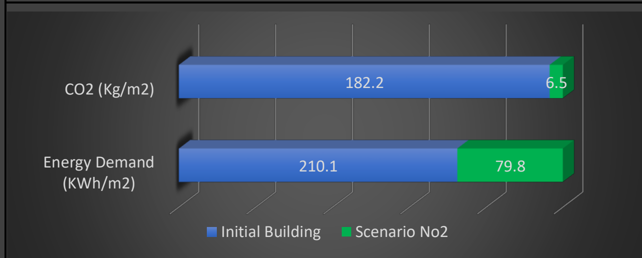




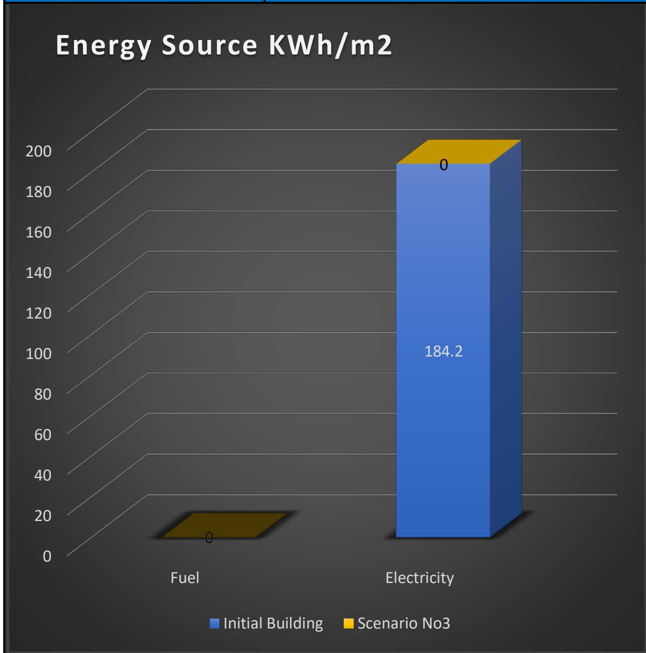
Scenario No2	P.E.S.	96.00%	Initial cost	€11,116.40	P.P. (Years)	17.5
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

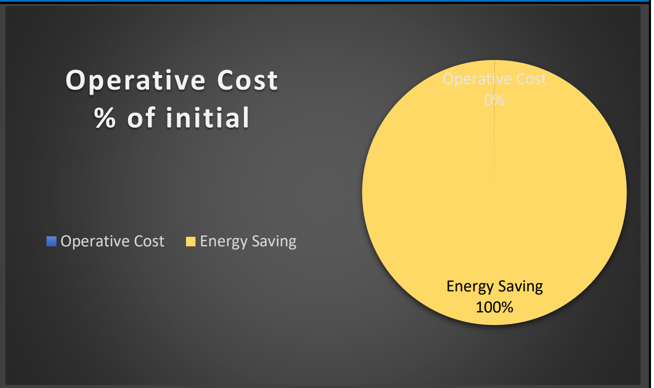


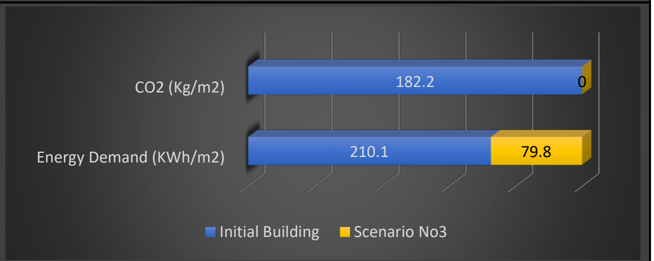




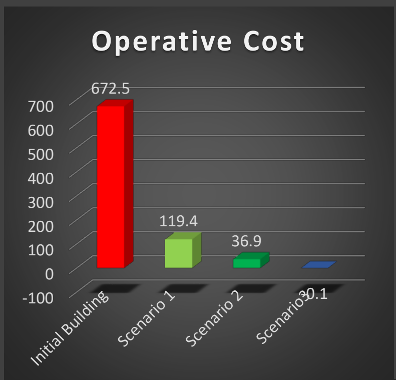
Energy Saving Interventions						
Scenario No3	P.E.S.	100.30%	Initial cost	€17,616.40	P.P. (Years)	26.2
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

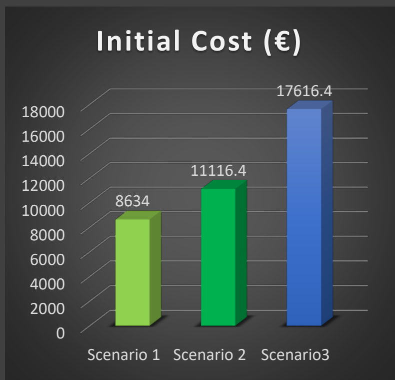


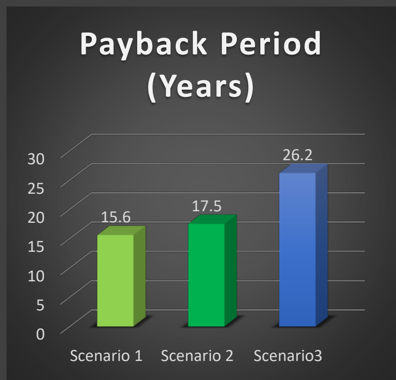


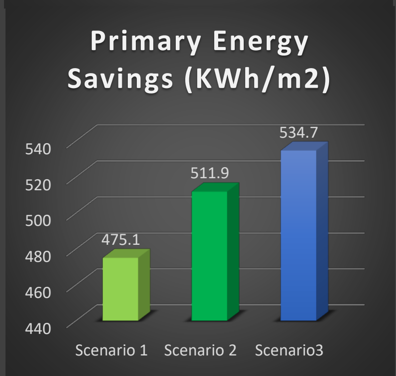


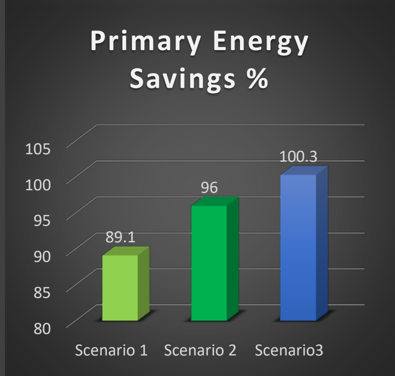
Scenario Comparison Diagrams

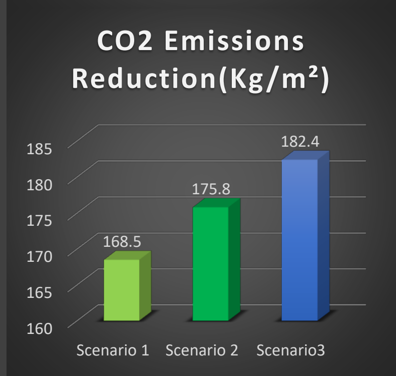












22	Multi-Family House			
	Apartment			
	Rodou 10, Stavroupoli			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	48.6			
Heater Volume	145.8			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall without insulation
Concrete Structure	Without insulation
Roof	Adiabatic surface
Openings	Sliding metal Frame Single Glazing
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	2.5
Roof	A/S
Floor	A/S
Openings	6
g-openings	0.6

HVAC systems performance

	Heating	DHW
Production	0.93	0.93
Distribution	0.86	0.72
Terminal Units / Storage	0.845	1

Systems

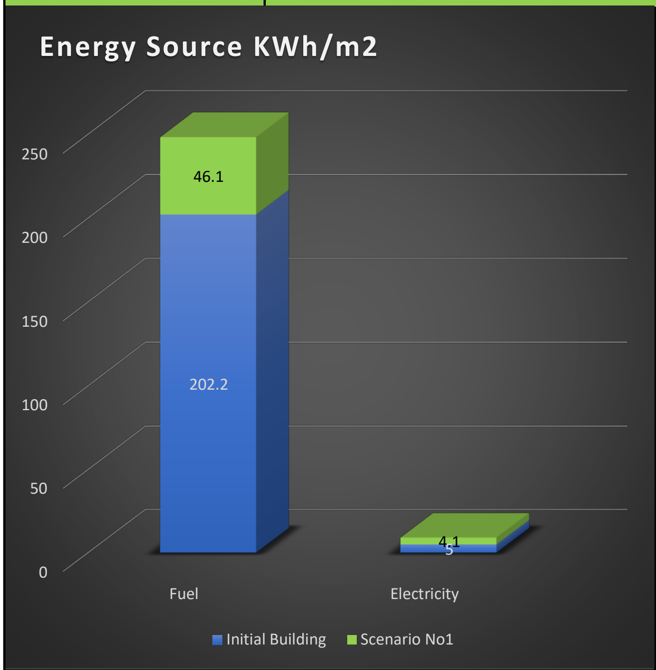
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

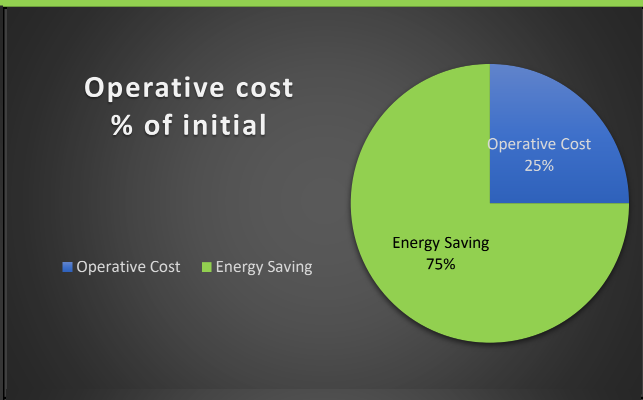
Annual Energy Characteristics

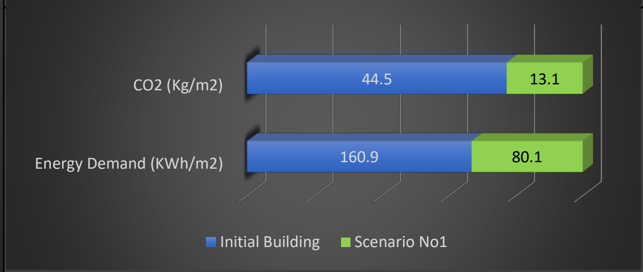
Energy Demand (KWh/m2/a)	160.9
Energy Consumption (KWh/m2/a)	207
Thermal Energy (KWh/m2/a)	202.2
Electricity (KWh/m2/a)	5
Primary Energy (KWh/m2/a)	226.2
CO2 Emissions (Kg/m2/a)	44.6
Total Final Thermal Energy	9826.92
Total Electricity Consumption	243
Operating cost	€960.80

Energy Saving Interventions

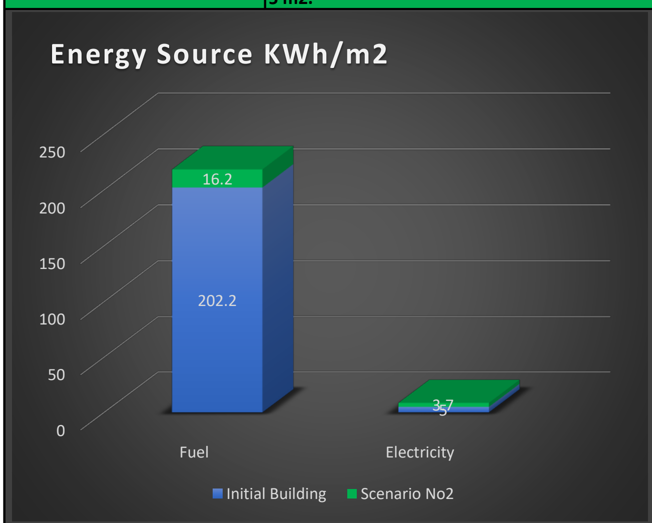
Scenario No1	P.E.S.	73.70%	Initial cost	€15,101.50	P.P. (Years)	21
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

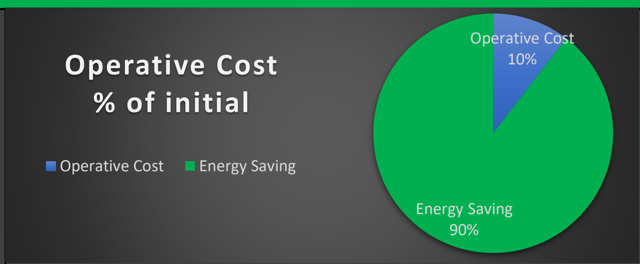


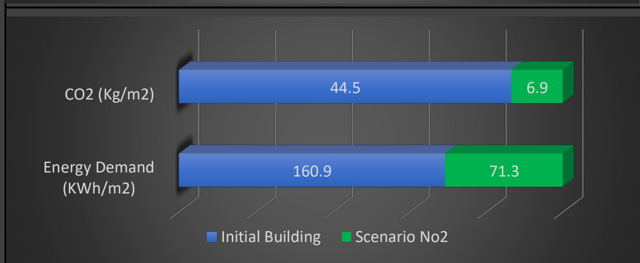




Scenario No2	P.E.S.	88.20%	Initial cost	€20,024.20	P.P. (Years)	23.3
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

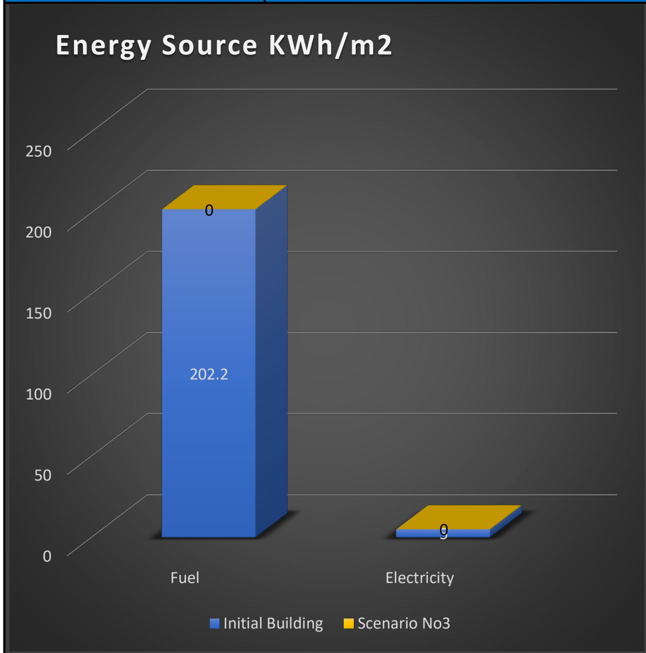


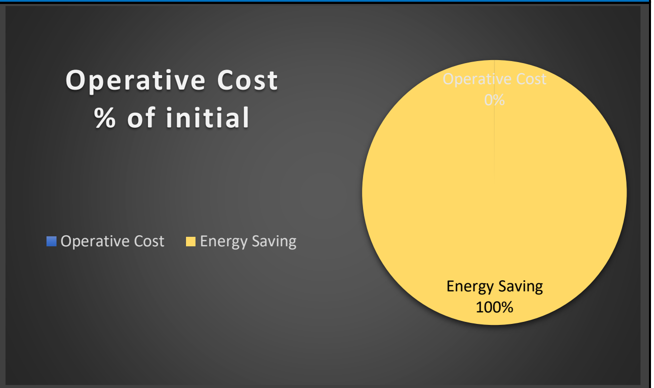


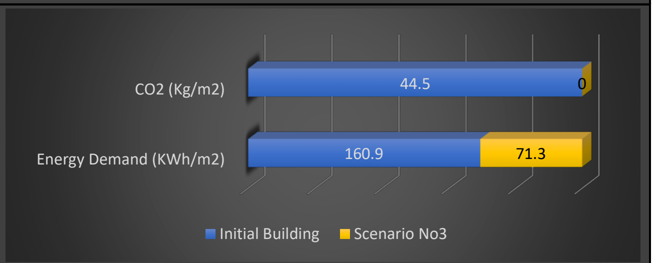


Energy Saving Interventions

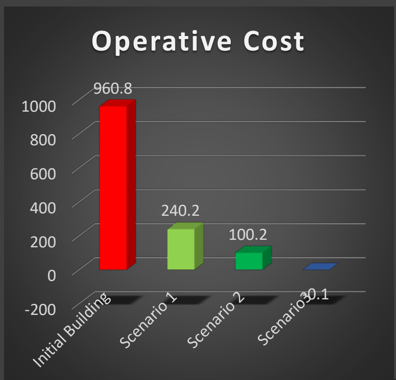
Scenario No3	P.E.S.	99.10%	Initial cost	€27,024.20	P.P. (Years)	28.1
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

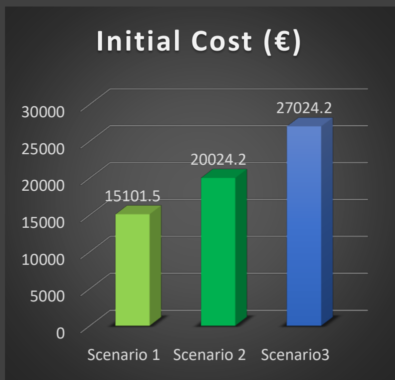


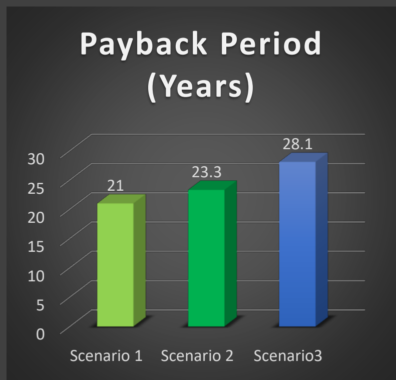


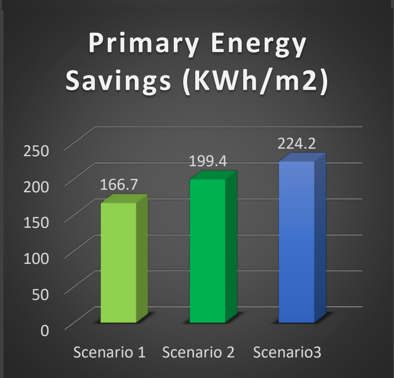


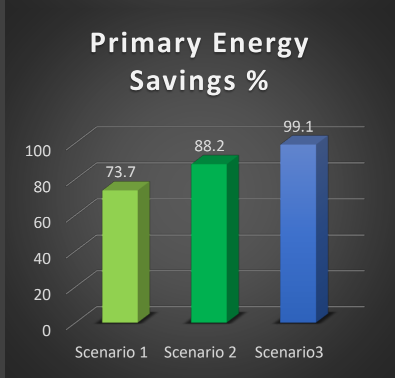
Scenario Comparison Diagrams

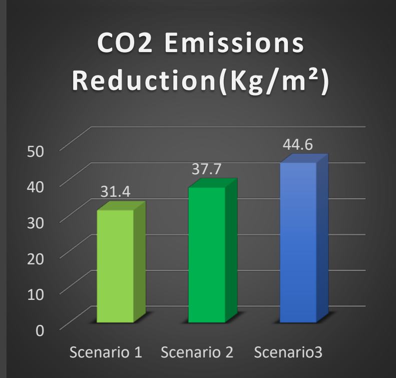












23	Multi-Family House			
	Apartment			
	Athinas 7, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	42			
Heater Volume	126			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall with insulation (RTI1979)
Concrete Structure	With insulation (RTI 1979)
Roof	Adiabatic surface
Openings	Openable wooden frame single glazing
Blinds	Wooden binds
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	0.7
Roof	A/S
Floor	A/S
Openings	4.7
g-openings	0.47

HVAC systems performance

	Heating	DHW
Production	3.63	1
Distribution	1	0.84
Terminal Units / Storage	1	0.98

Systems

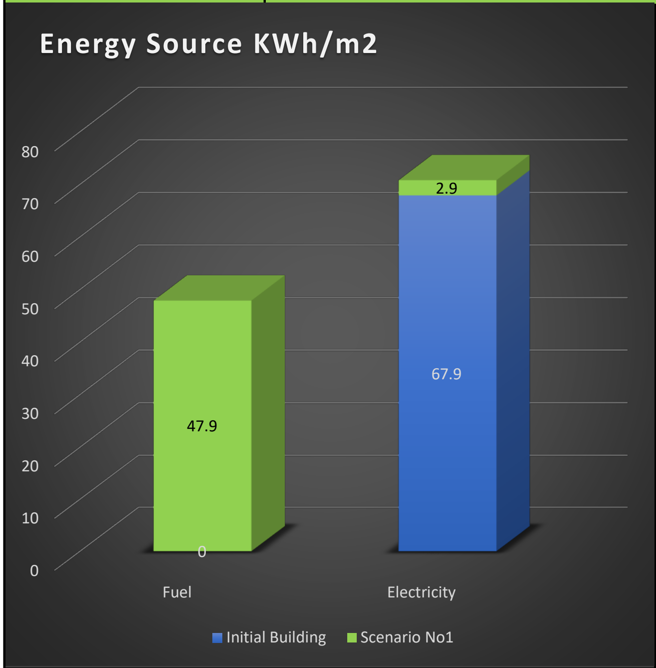
Production	Local A/C, local electric radiator
Distribution	Non applicable
Solar thermal	Non applicable
DHW	Local electric boiler

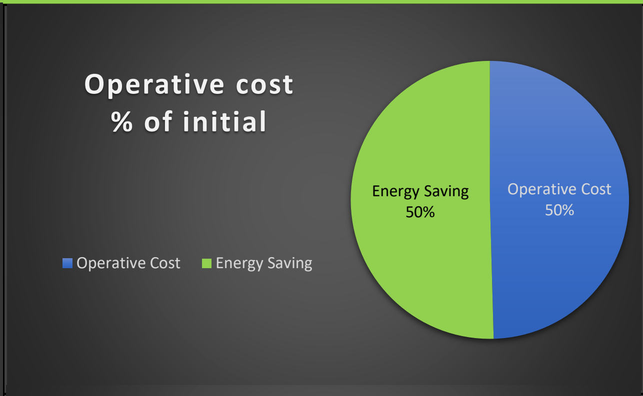
Annual Energy Characteristics

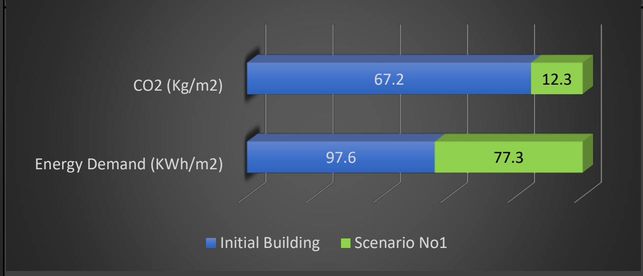
Energy Demand (KWh/m2/a)	97.6
Energy Consumption (KWh/m2/a)	67.8
Thermal Energy (KWh/m2/a)	0
Electricity (KWh/m2/a)	67.9
Primary Energy (KWh/m2/a)	196.7
CO2 Emissions (Kg/m2/a)	67.2
Total Final Thermal Energy	0
Total Electricity Consumption	2851.8
Operating cost	€322.40

Energy Saving Interventions

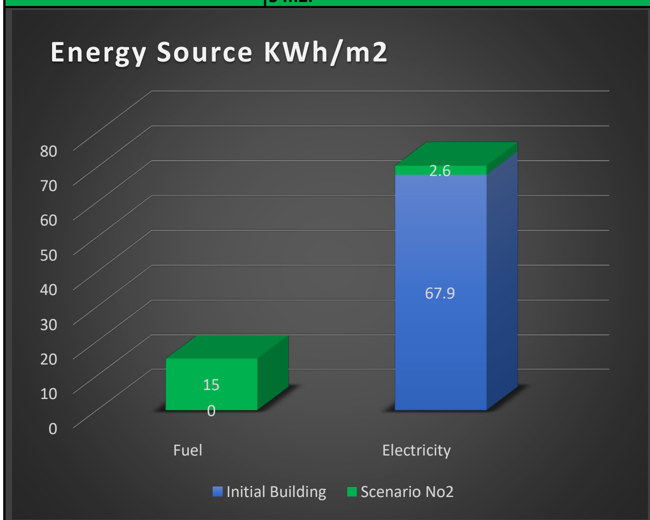
Scenario No1	P.E.S.	70.40%	Initial cost	€8,238.00	P.P. (Years)	50.6
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

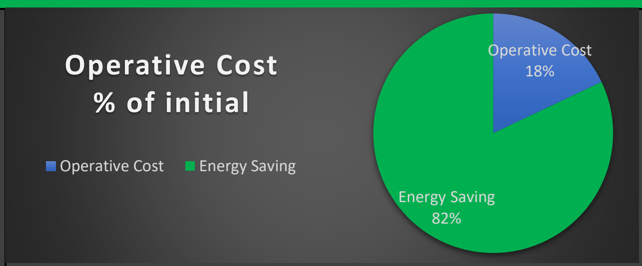


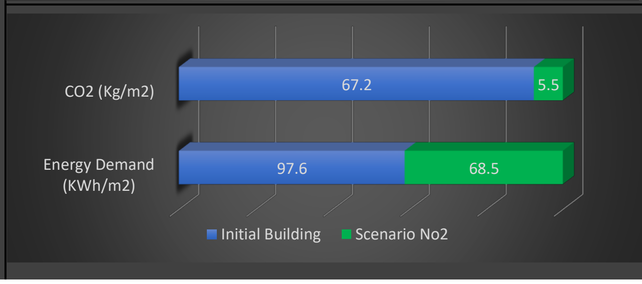




Scenario No2	P.E.S.	88.40%	Initial cost	€11,576.40	P.P. (Years)	43.8
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

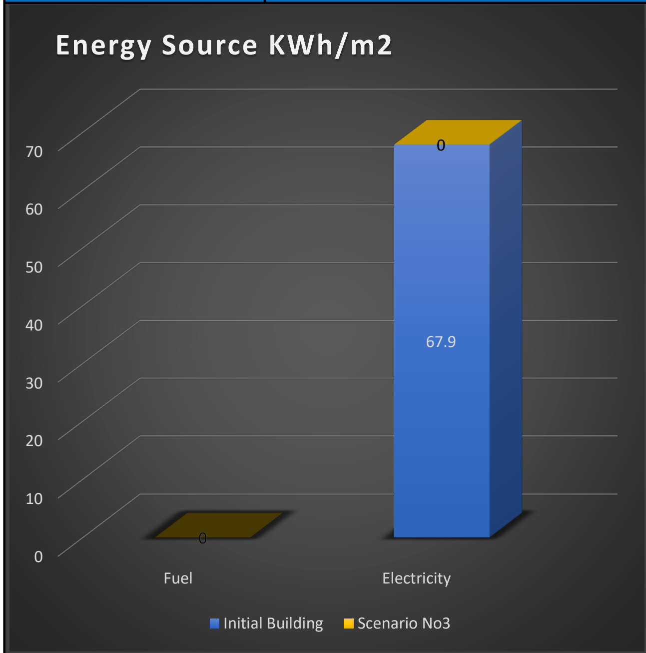


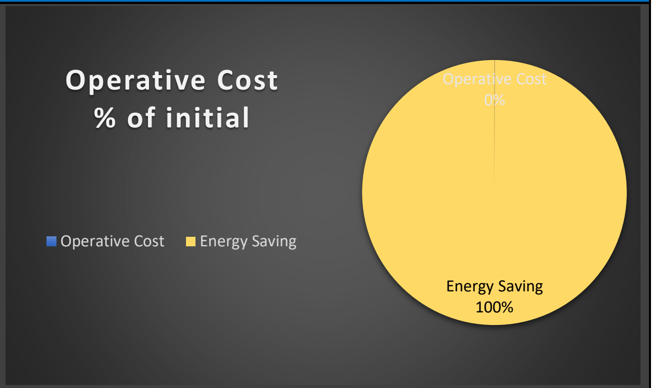


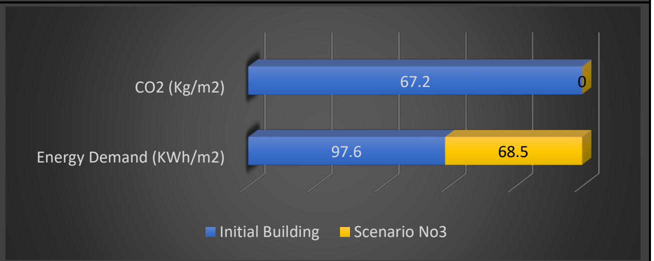


Energy Saving Interventions

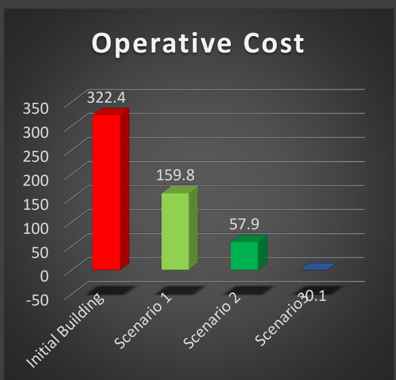
Scenario No3	P.E.S.	99.60%	Initial cost	€18,326.40	P.P. (Years)	56.8
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

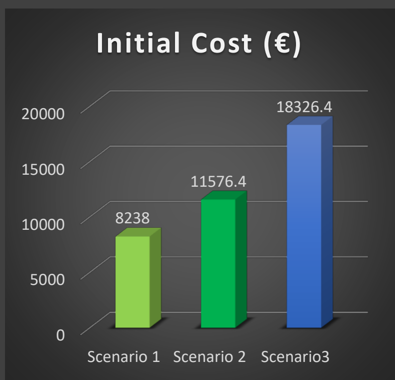


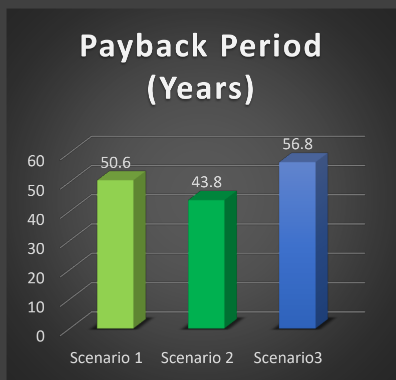


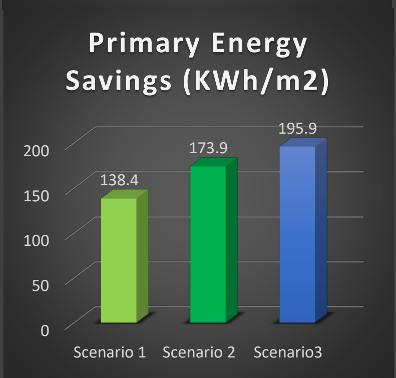


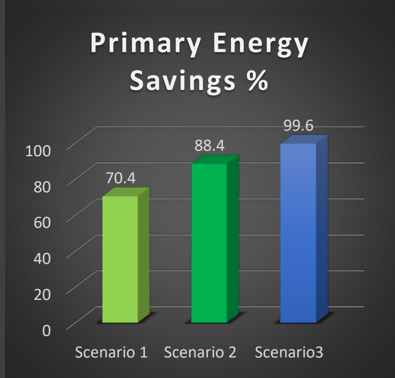
Scenario Comparison Diagrams

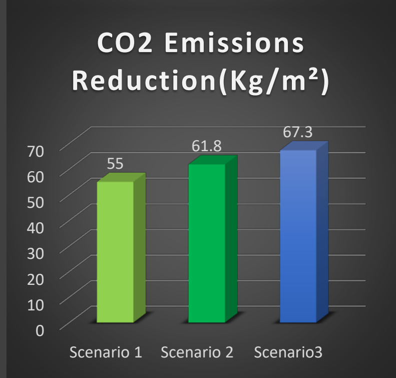












24	Multi-Family House			
	Apartment			
	Iatrou Zanna 30, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	115			
Heater Volume	327.75			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall with insulation (RTI1979)
Concrete Structure	With insulation (RTI 1979)
Roof	Adiabatic surface
Openings	Sliding metal Frame Double Glazing 6mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Insulated pilotis (RTI 1979)

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	0.7
Roof	A/S
Floor	A/S
Openings	4.14
g-openings	0.53

HVAC systems performance

	Heating	DHW
Production	0.935	0.97
Distribution	0.95	0.846
Terminal Units / Storage	0.93	0.98

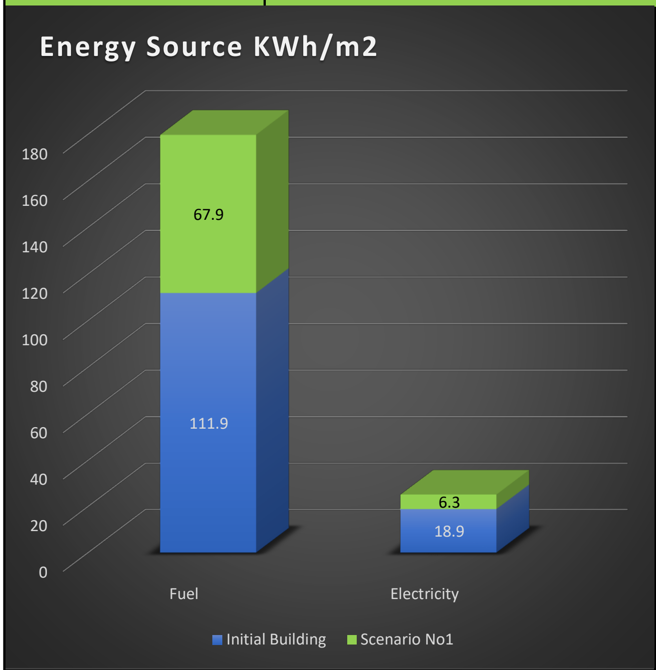
Systems

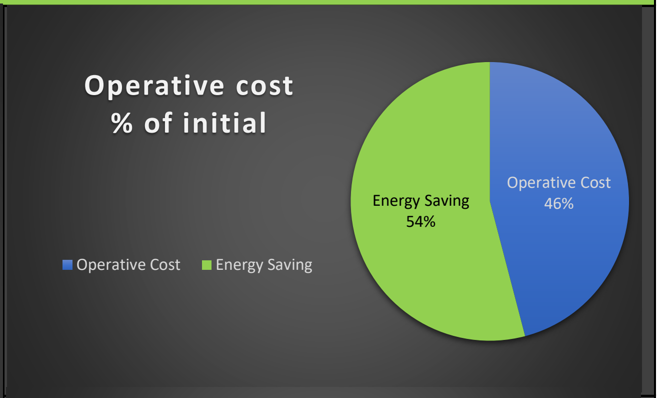
Production	Oil boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Oil boiler, local electric boiler

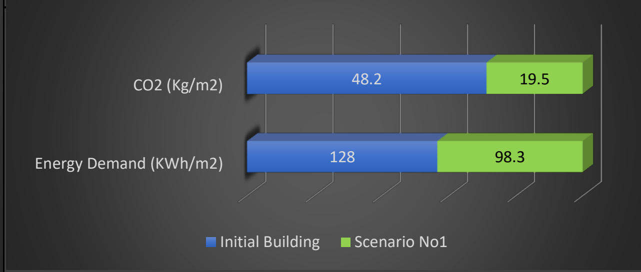
Annual Energy Characteristics

Energy Demand (KWh/m2/a)	128
Energy Consumption (KWh/m2/a)	130.4
Thermal Energy (KWh/m2/a)	111.9
Electricity (KWh/m2/a)	18.9
Primary Energy (KWh/m2/a)	176.7
CO2 Emissions (Kg/m2/a)	48.2
Total Final Thermal Energy	12868.5
Total Electricity Consumption	2173.5
Operating cost	€1,414.60

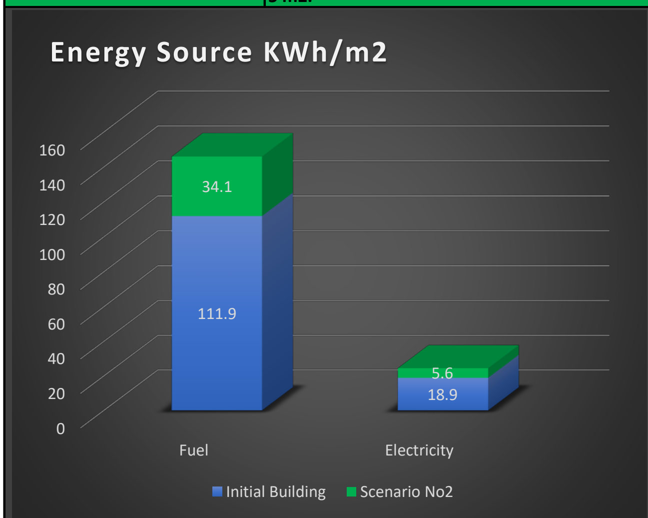
Energy Saving Interventions						
Scenario No1	P.E.S.	50.00%	Initial cost	€20,725.90	P.P. (Years)	27.1
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

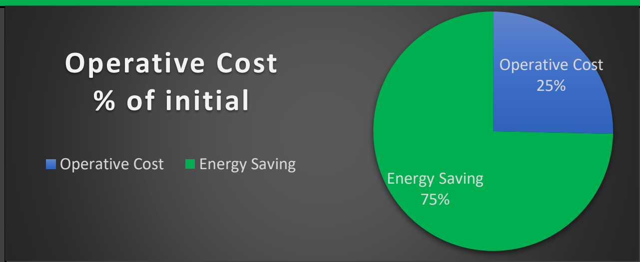


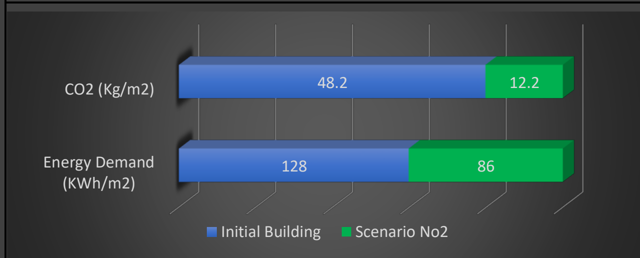




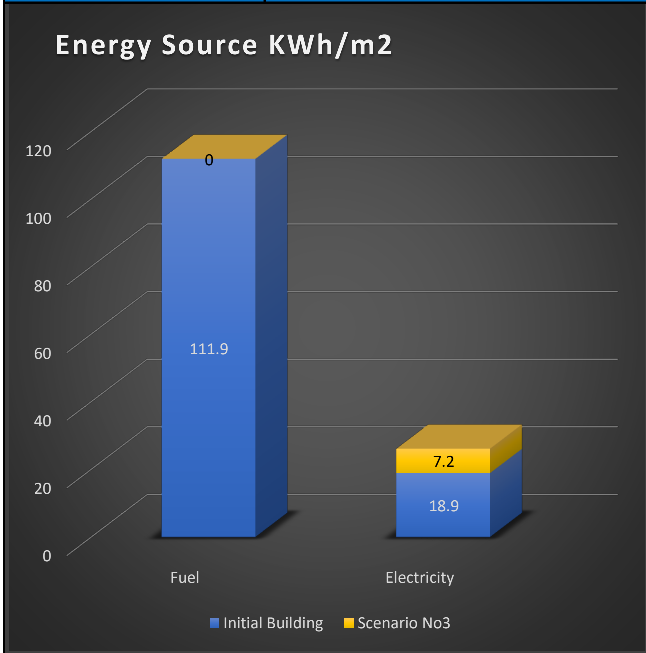
Scenario No2	P.E.S.	71.30%	Initial cost	€28,317.60	P.P. (Years)	26.8
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

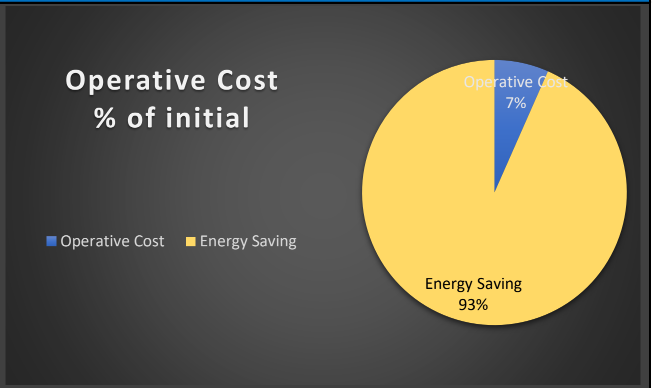


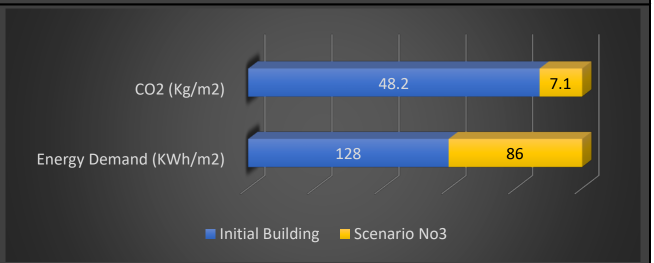




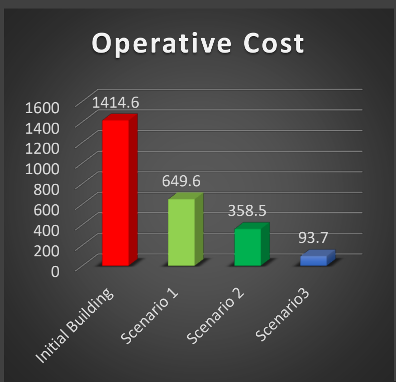
Energy Saving Interventions						
Scenario No3	**P.E.S.**	**88.90%**	**Initial cost**	**€39,817.60**	**P.P. (Years)**	**30.1**
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

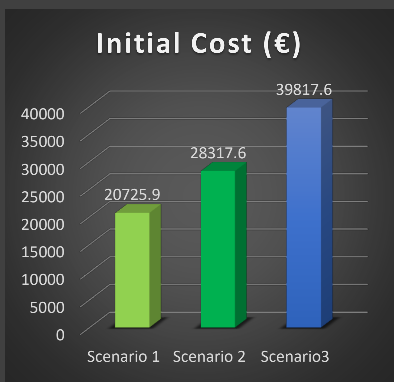


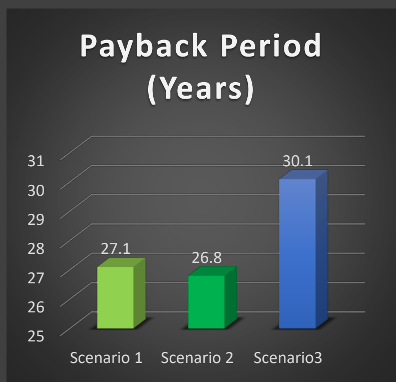


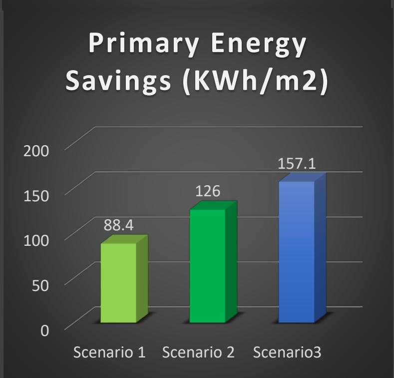


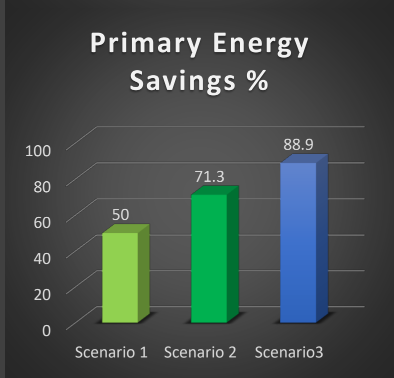
Scenario Comparison Diagrams

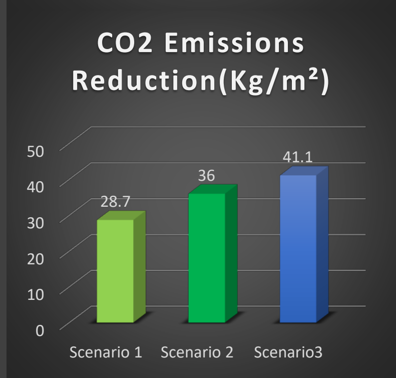












25	Multi-Family House			
	Apartment			
	Madytou 20, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	60			
Heater Volume	171			

Building Description

Indermediate floor apartment in Neapoli, Thessaloniki. 14m2 roof in contact with external air. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall, insufficient insulation (RTI 1979)
Concrete Structure	Insufficient insulation (RTI 1979)
Roof	Adiabatic surface & Insufficient insulation (RTI 1979)
Openings	Sliding metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	0.89
Roof	0.95
Floor	A/S
Openings	3.48
g-openings	0.58

HVAC systems performance

	Heating	DHW
Production	0.929	0.929
Distribution	0.86	0.86
Terminal Units / Storage	0.87	1

Systems

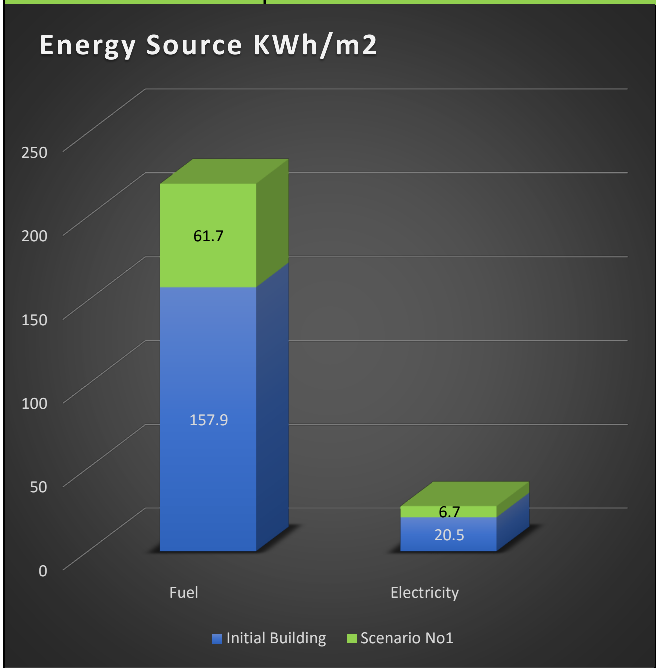
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

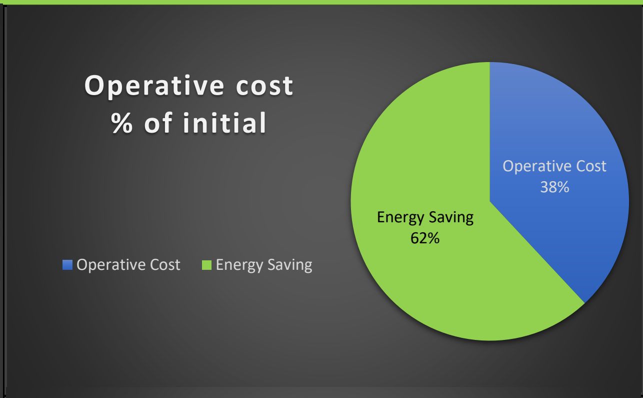
Annual Energy Characteristics

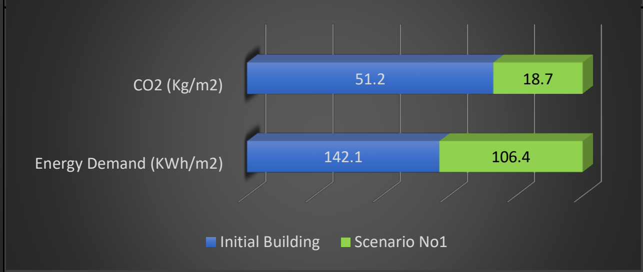
Energy Demand (KWh/m2/a)	142.1
Energy Consumption (KWh/m2/a)	177.5
Thermal Energy (KWh/m2/a)	157.9
Electricity (KWh/m2/a)	20.5
Primary Energy (KWh/m2/a)	222.7
CO2 Emissions (Kg/m2/a)	51.2
Total Final Thermal Energy	9474
Total Electricity Consumption	1230
Operating cost	€827.10

Energy Saving Interventions

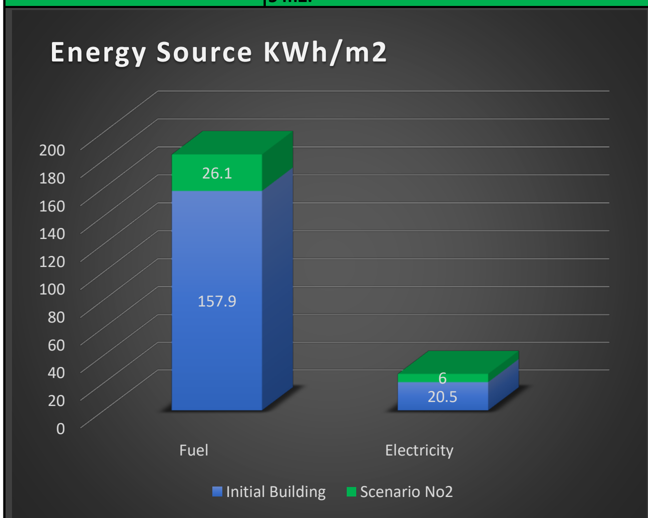
Scenario No1	P.E.S.	63.20%	Initial cost	€14,622.30	P.P. (Years)	28.5
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

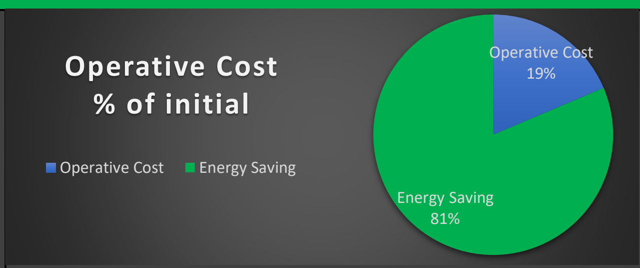


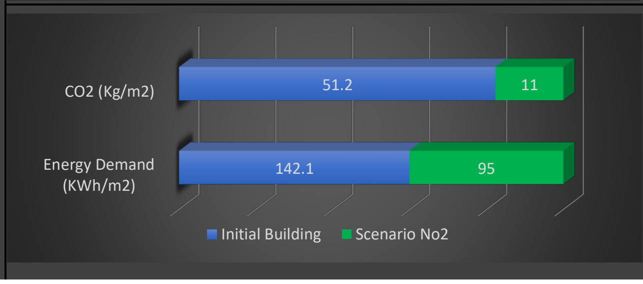




Scenario No2	P.E.S.	80.90%	Initial cost	€20,231.60	P.P. (Years)	30.1
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

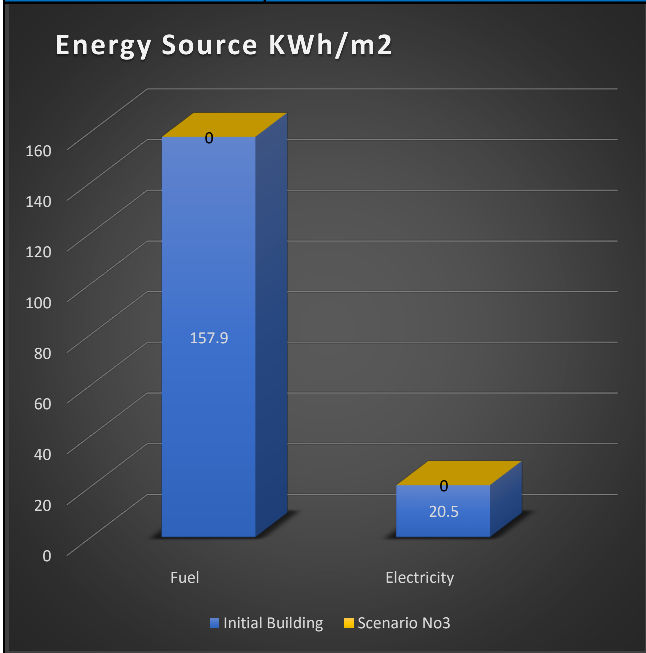


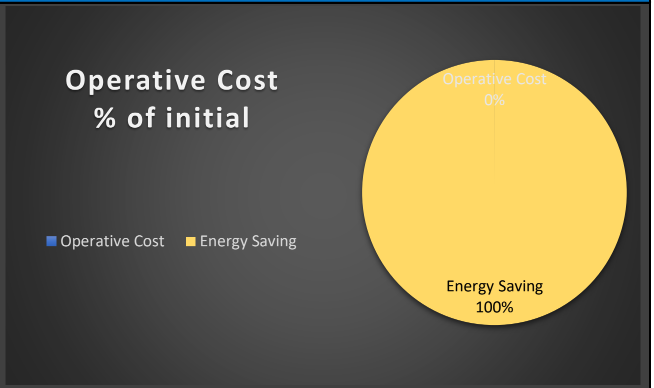


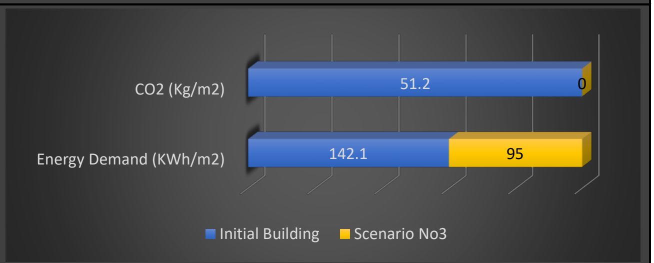


Energy Saving Interventions

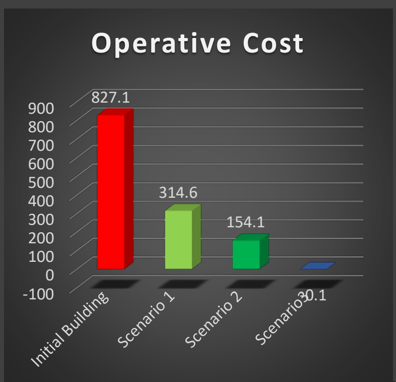
Scenario No3	P.E.S.	96.50%	Initial cost	€27,131.60	P.P. (Years)	32.8
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

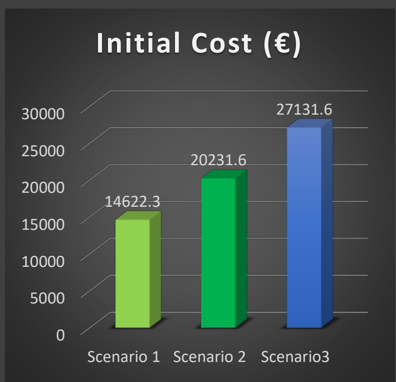


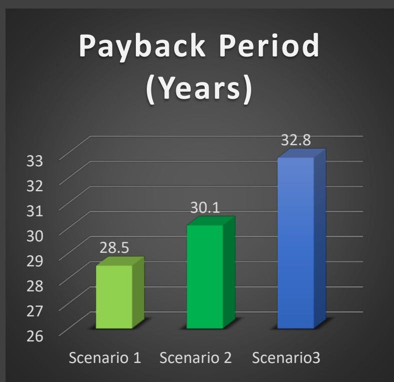


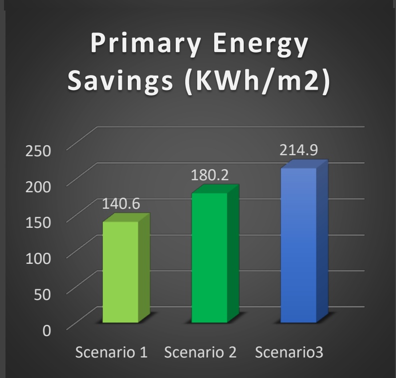


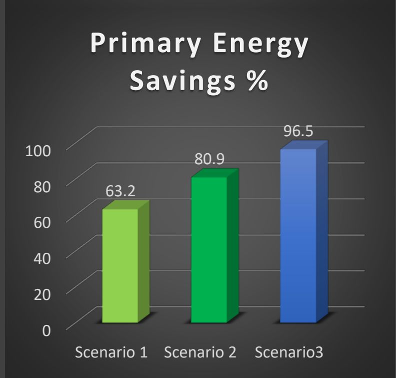
Scenario Comparison Diagrams

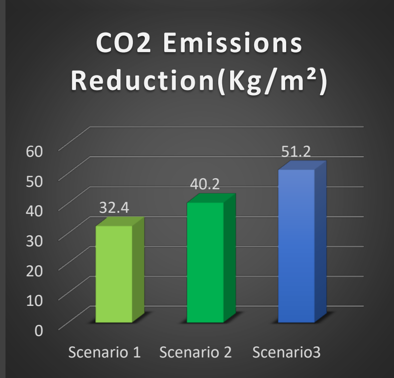












26	Multi-Family House			
	Apartment			
	Metron 24, Kalamaria			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	57.53			
Heater Volume	172.59			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Floor in contact with unheated space. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall, insufficient insulation (RTI 1979)
Concrete Structure	Insufficient insulation (RTI 1979)
Roof	Adiabatic surface
Openings	Sliding metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	With non-heated space

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	0.89
Roof	A/S
Floor	0.4
Openings	3.9
g-openings	0.58

HVAC systems performance

	Heating	DHW
Production	0.929	0.929
Distribution	0.86	0.86
Terminal Units / Storage	0.87	1

Systems

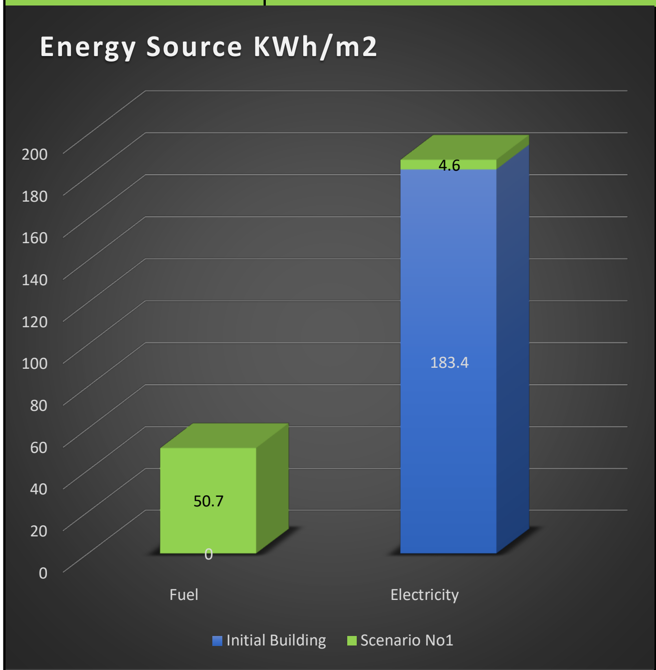
Production	Individual Gas Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Individual Gas Boiler

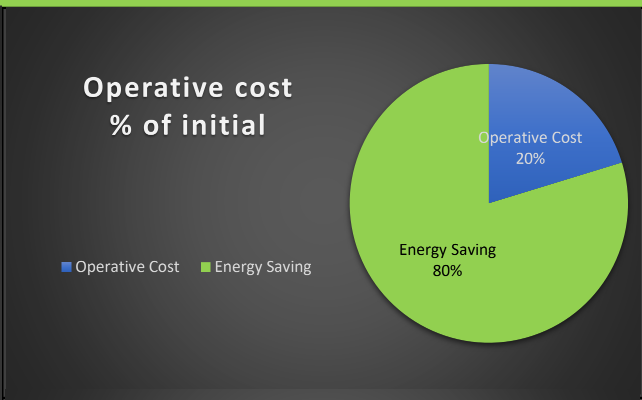
Annual Energy Characteristics

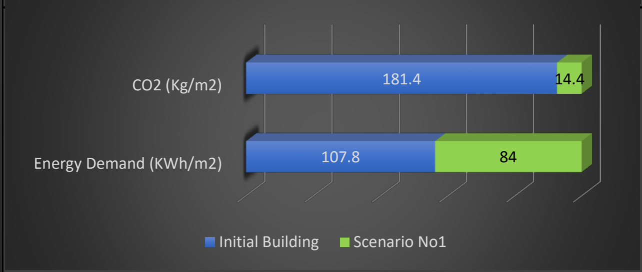
Energy Demand (KWh/m2/a)	107.8
Energy Consumption (KWh/m2/a)	183
Thermal Energy (KWh/m2/a)	0
Electricity (KWh/m2/a)	183.4
Primary Energy (KWh/m2/a)	530.7
CO2 Emissions (Kg/m2/a)	181.4
Total Final Thermal Energy	0
Total Electricity Consumption	10551.002
Operating cost	€1,192.50

Energy Saving Interventions

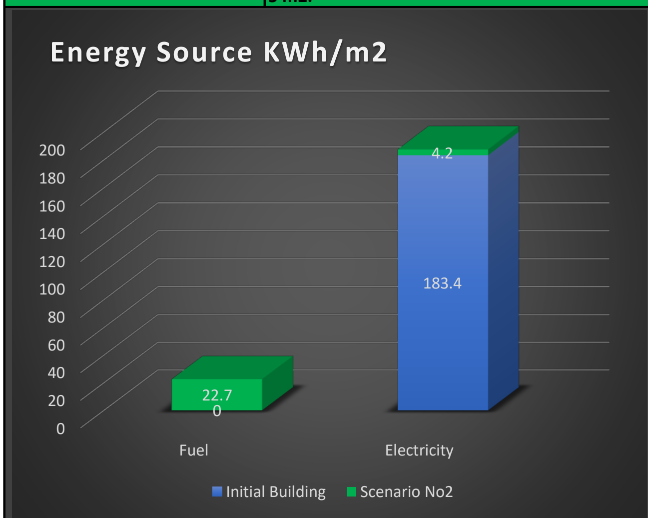
Scenario No1	P.E.S.	87.60%	Initial cost	€13,554.40	P.P. (Years)	14.3
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

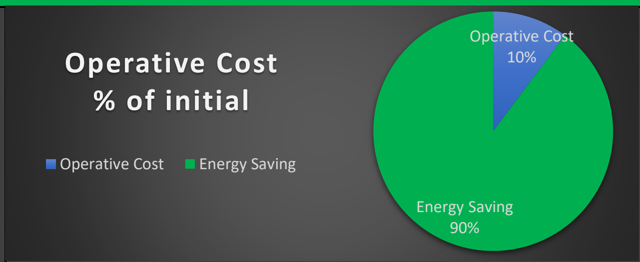


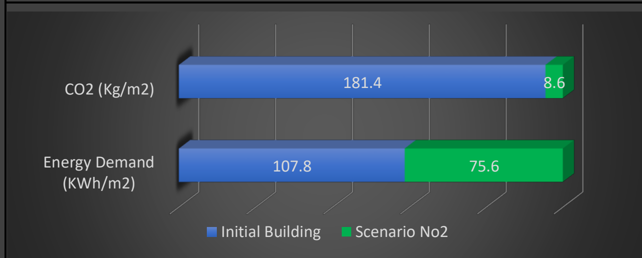




Scenario No2	P.E.S.	93.40%	Initial cost	€17,857.60	P.P. (Years)	16.7
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

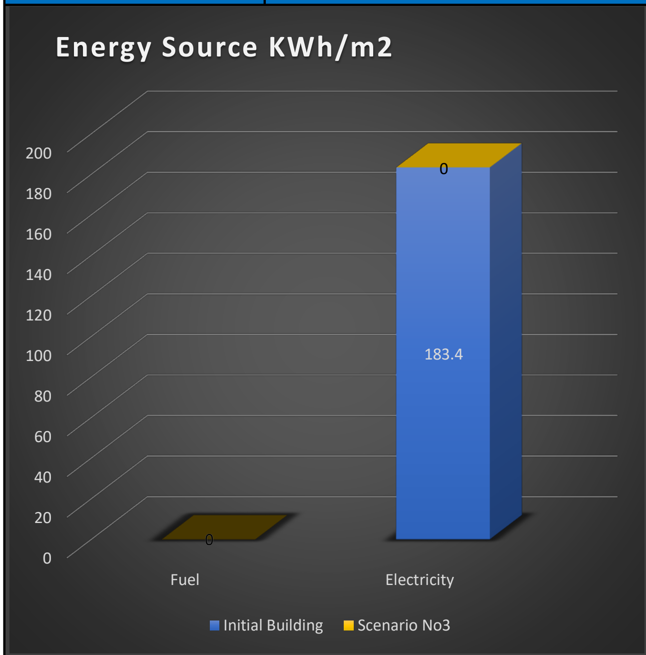


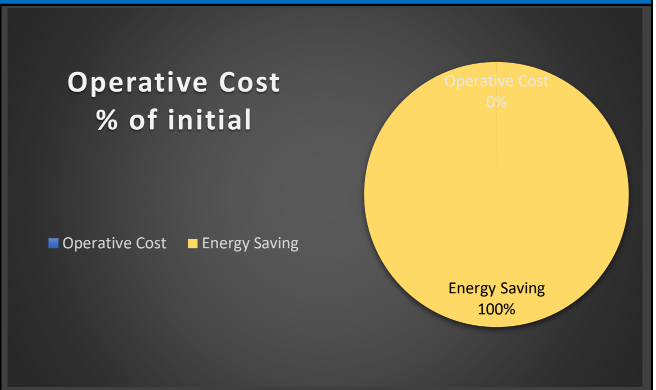


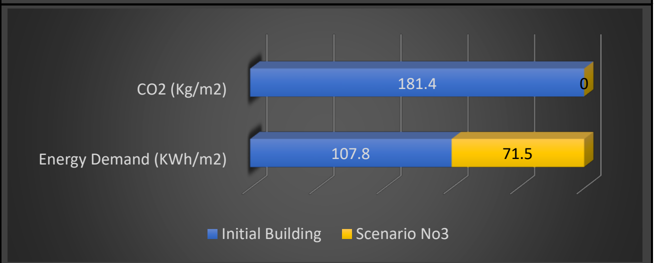


Energy Saving Interventions

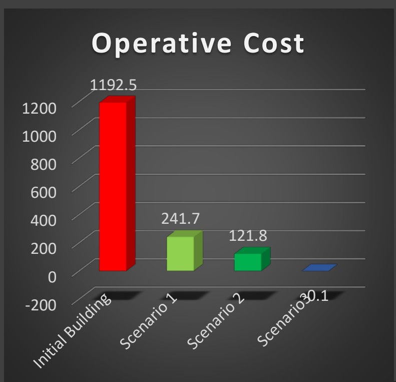
Scenario No3	P.E.S.	99.40%	Initial cost	€24,657.60	P.P. (Years)	20.7
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

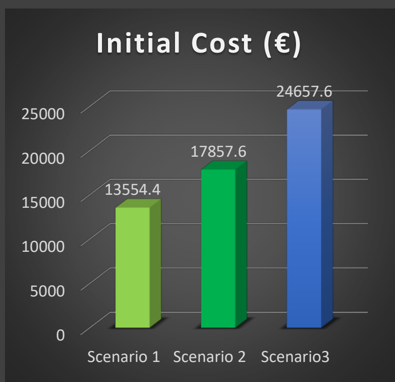


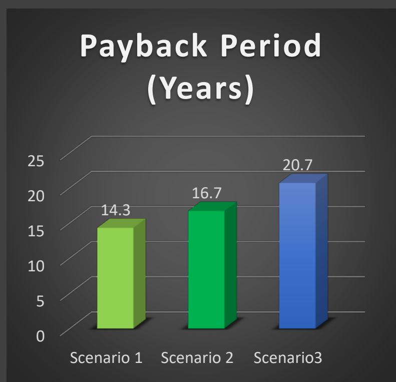


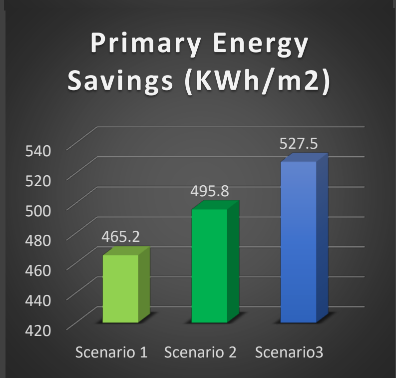


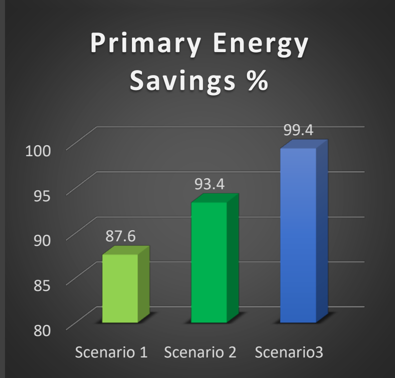
Scenario Comparison Diagrams

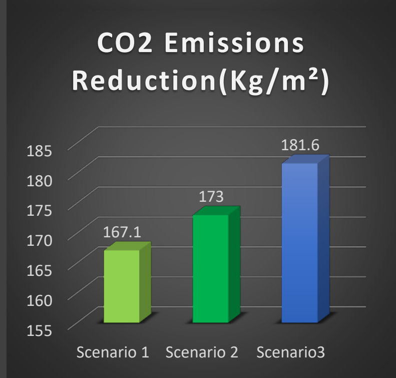












27	Multi-Family House			
	Apartment			
	Pontou 29, Kalamaria			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	55			
Heater Volume	165			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall with insulation (RTI1979)
Concrete Structure	With insulation (RTI 1979)
Roof	Adiabatic surface
Openings	Sliding metal Frame single glazing
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	0.7
Roof	A/S
Floor	A/S
Openings	5.95
g-openings	0.65

HVAC systems performance

	Heating	DHW
Production	0.85	0.85
Distribution	1	0.72
Terminal Units / Storage	1	0.98

Systems

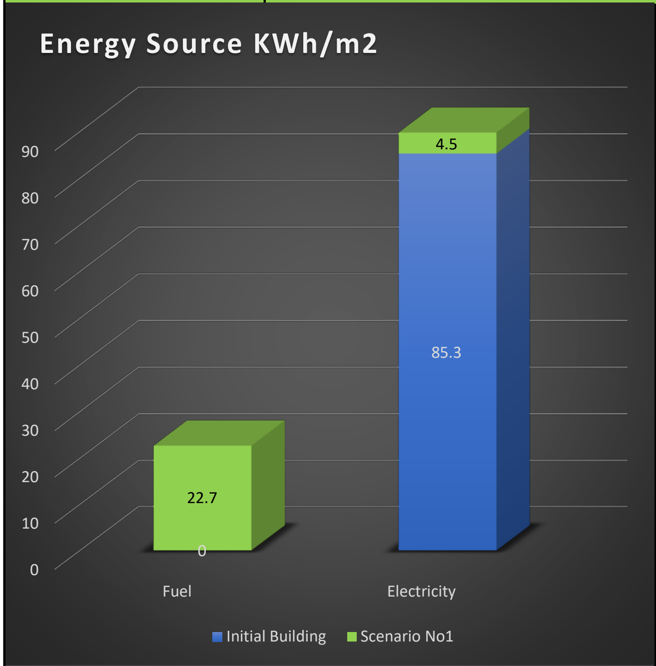
Production	Local electric radiators
Distribution	Non applicable
Solar thermal	Non applicable
DHW	Local electric boiler

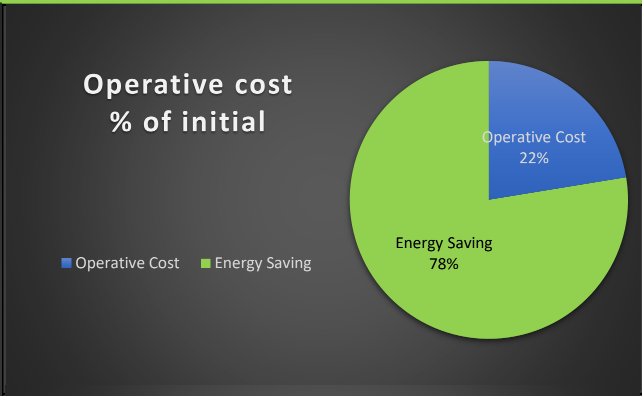
Annual Energy Characteristics

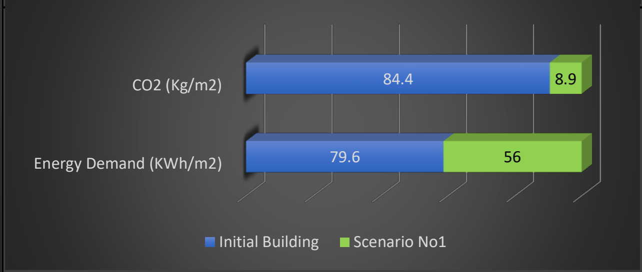
Energy Demand (KWh/m2/a)	79.6
Energy Consumption (KWh/m2/a)	84.9
Thermal Energy (KWh/m2/a)	0
Electricity (KWh/m2/a)	85.3
Primary Energy (KWh/m2/a)	246.1
CO2 Emissions (Kg/m2/a)	84.4
Total Final Thermal Energy	0
Total Electricity Consumption	4691.5
Operating cost	€530.10

Energy Saving Interventions

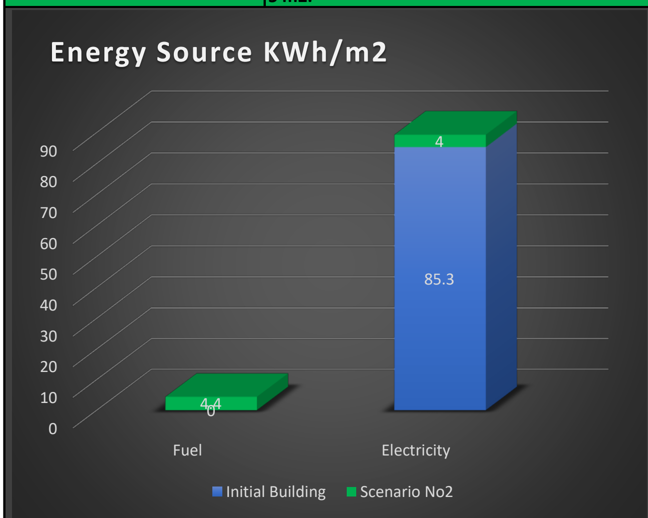
Scenario No1	P.E.S.	85.50%	Initial cost	€8,450.50	P.P. (Years)	20.5
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

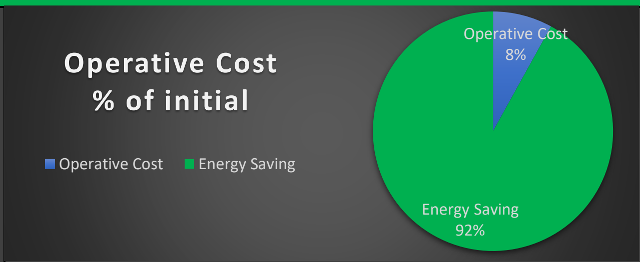


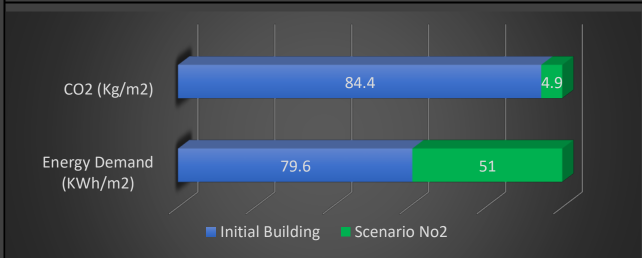




Scenario No2	P.E.S.	93.90%	Initial cost	€11,658.40	P.P. (Years)	23.9
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

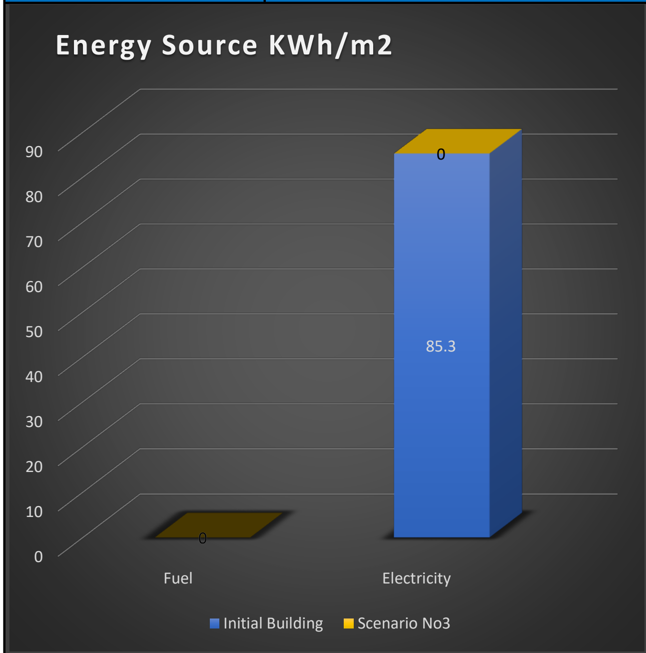


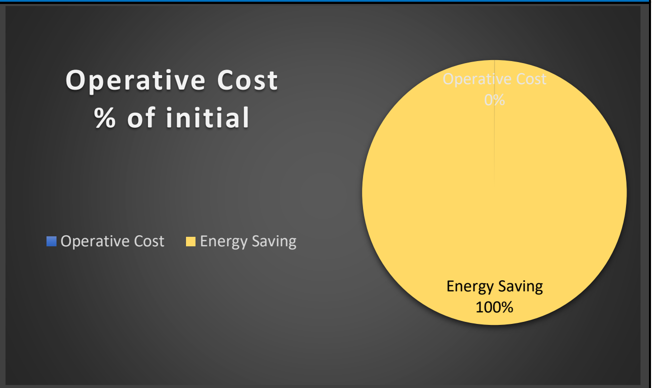


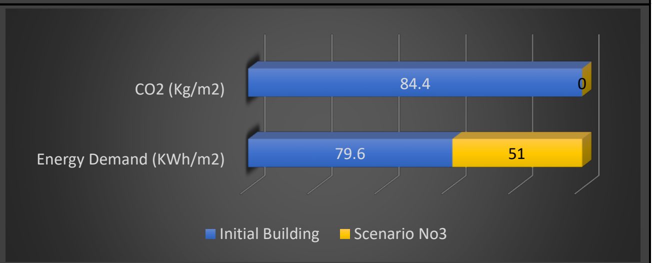


Energy Saving Interventions

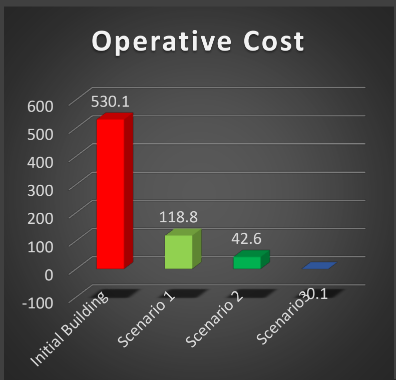
Scenario No3	P.E.S.	100.50%	Initial cost	€18,658.40	P.P. (Years)	35.2
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

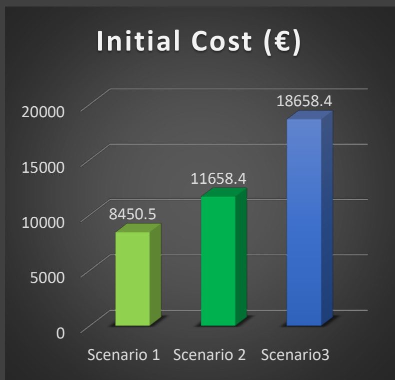


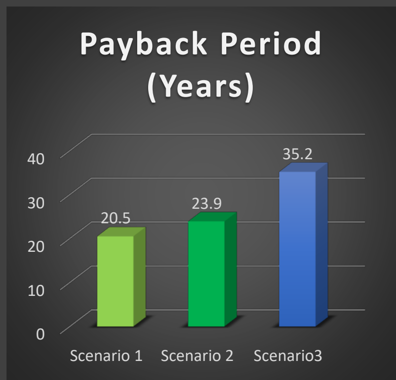


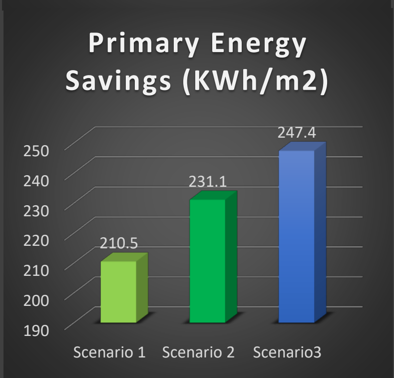


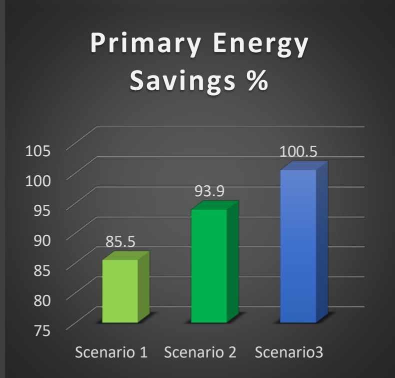
Scenario Comparison Diagrams

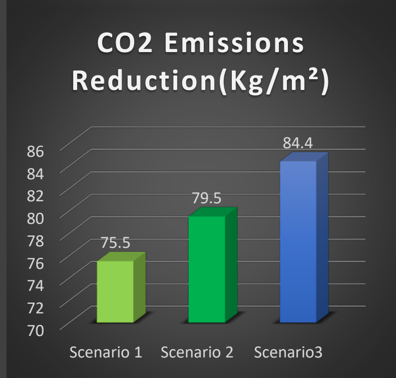












28	Multi-Family House			
	Apartment			
	Stratigou Sarafi 2, Neapoli			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	40.51			
Heater Volume	121.53			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall with insulation (RTI1979)
Concrete Structure	With insulation (RTI 1979)
Roof	Adiabatic surface
Openings	Sliding metal frame double glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	0.7
Roof	A/S
Floor	A/S
Openings	3.7
g-openings	0.54

HVAC systems performance

	Heating	DHW
Production	0.935	1
Distribution	0.95	0.84
Terminal Units / Storage	0.93	0.98

Systems

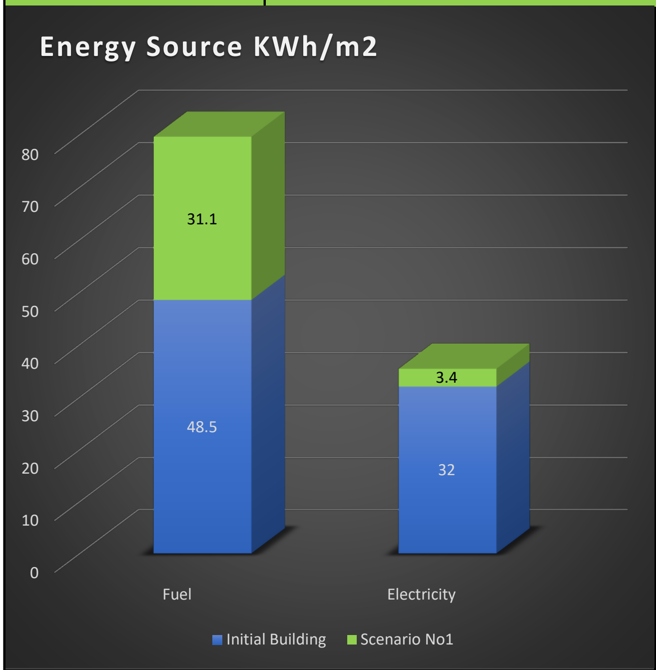
Production	Oil boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Local eletric boiler

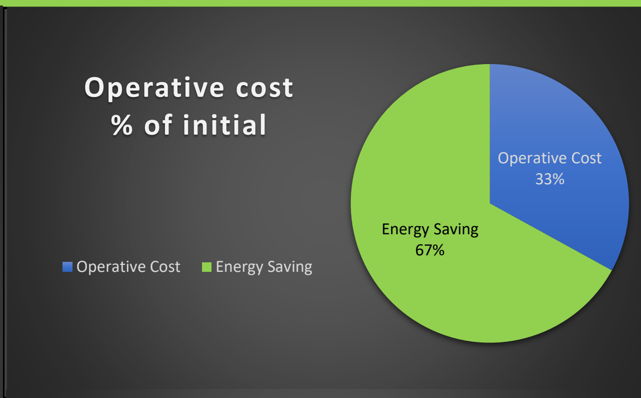
Annual Energy Characteristics

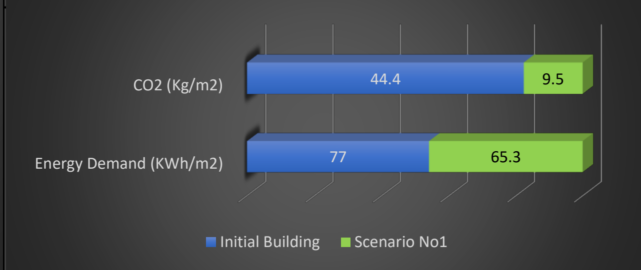
Energy Demand (KWh/m2/a)	77
Energy Consumption (KWh/m2/a)	80.3
Thermal Energy (KWh/m2/a)	48.5
Electricity (KWh/m2/a)	32
Primary Energy (KWh/m2/a)	145.6
CO2 Emissions (Kg/m2/a)	44.5
Total Final Thermal Energy	1964.735
Total Electricity Consumption	1296.32
Operating cost	€325.00

Energy Saving Interventions

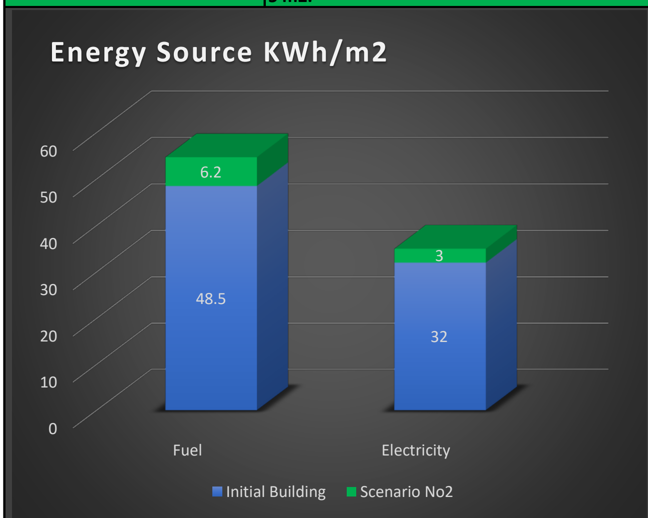
Scenario No1	P.E.S.	71.30%	Initial cost	€6,885.00	P.P. (Years)	31.6
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

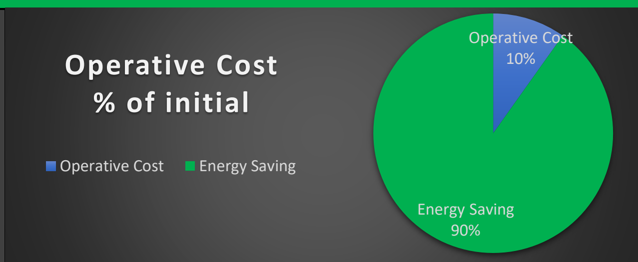


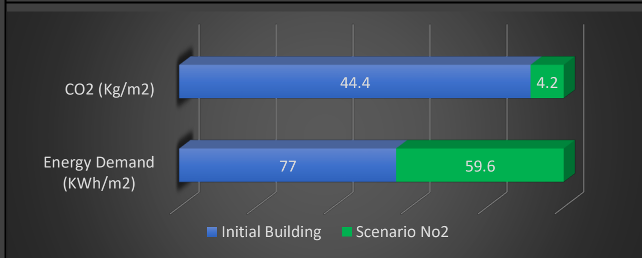




Scenario No2	P.E.S.	90.00%	Initial cost	€9,723.60	P.P. (Years)	33.2
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

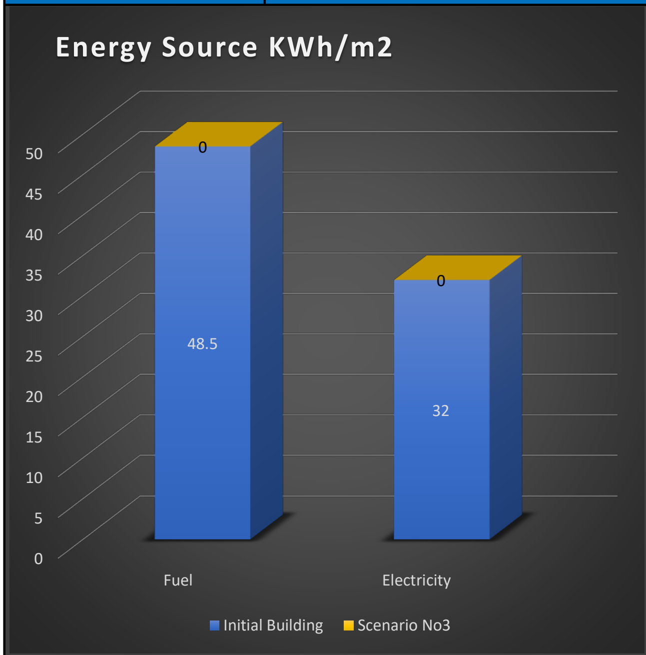


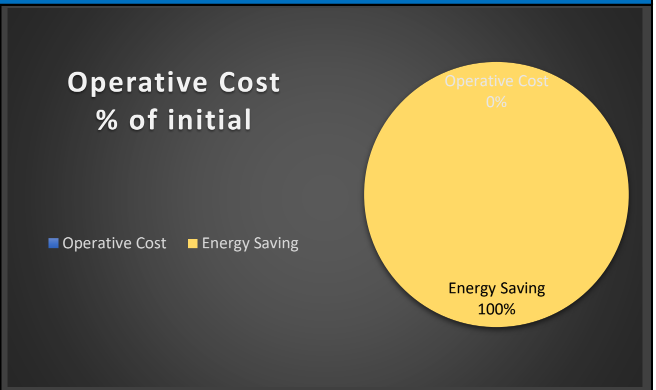


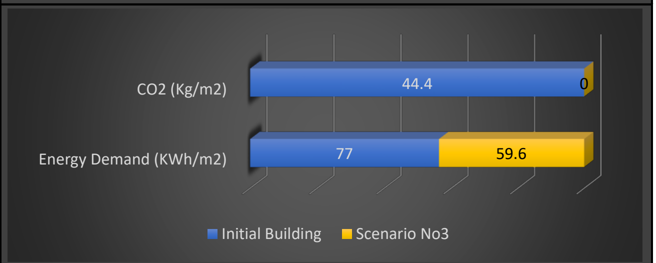


Energy Saving Interventions

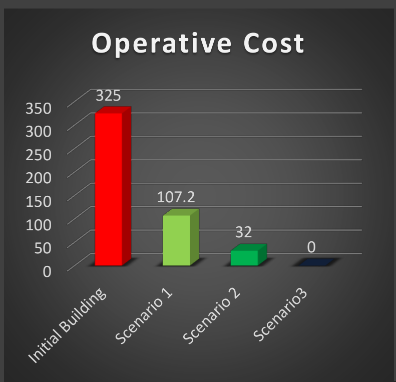
Scenario No3	P.E.S.	100.50%	Initial cost	€16,423.60	P.P. (Years)	50.5
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

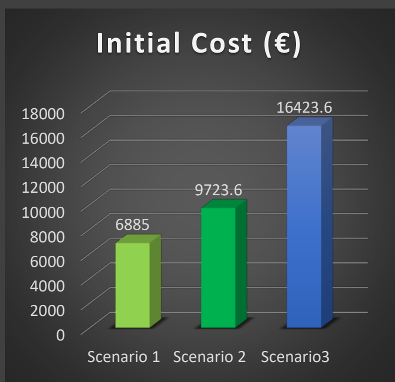


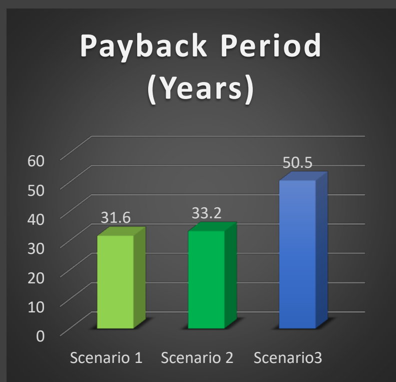


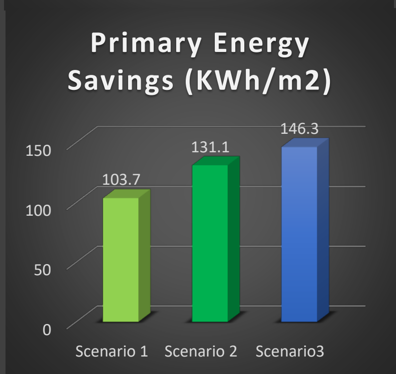


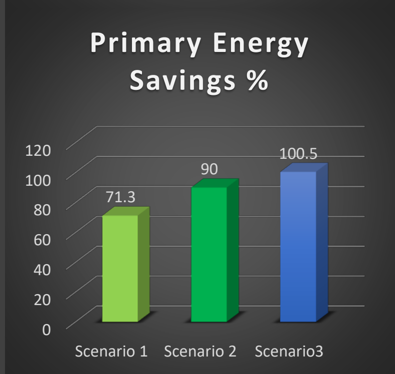
Scenario Comparison Diagrams

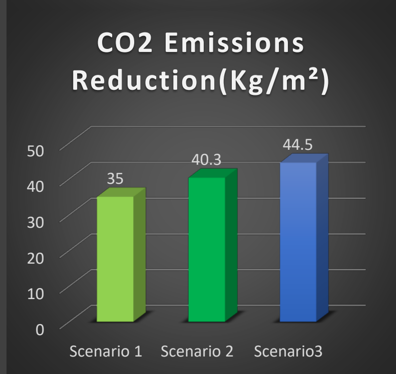












29	Multi-Family House			
	Apartment			
	Eratous 4a, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	26.91			
Heater Volume	76.69			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall with insulation (RTI1979)
Concrete Structure	With insulation (RTI 1979)
Roof	Adiabatic surface
Openings	Openable metal Frame Double Glazing 12mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Insulated pilotis (RTI 1979)

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	0.7
Roof	A/S
Floor	A/S
Openings	4.3
g-openings	0.58

HVAC systems performance

	Heating	DHW
Production	0.935	1
Distribution	0.95	0.72
Terminal Units / Storage	0.93	0.98

Systems

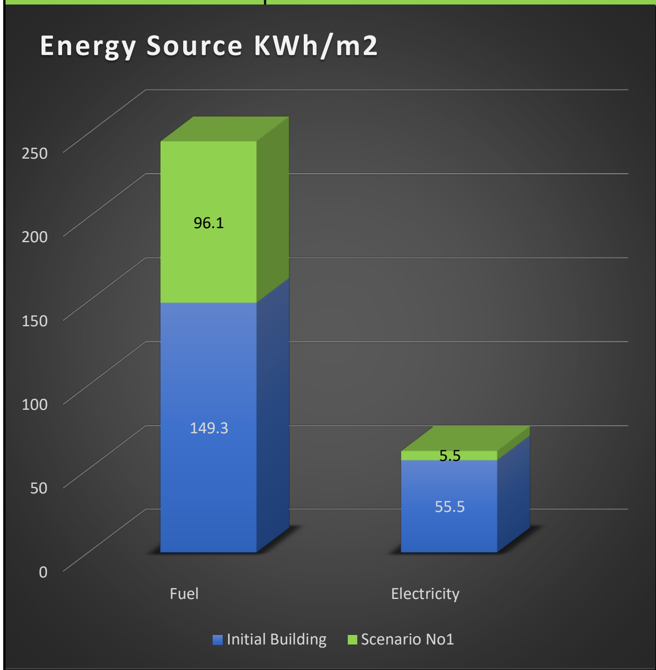
Production	Oil Boiler
Distribution	Pipes inside the residence at least 80% of their length
Solar thermal	Non applicable
DHW	Local electric boiler

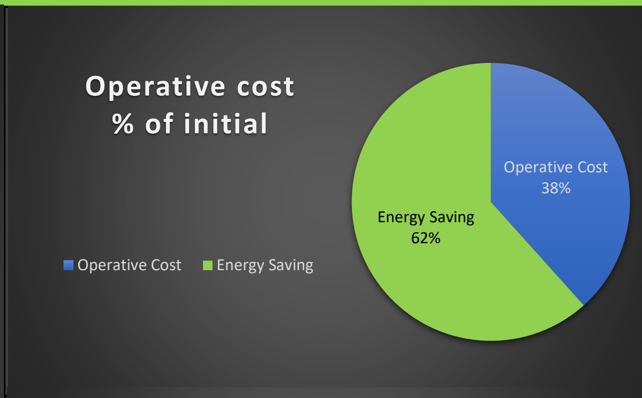
Annual Energy Characteristics

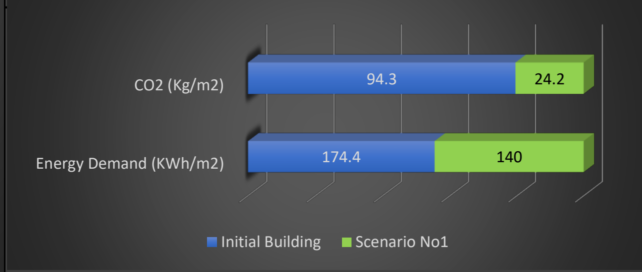
Energy Demand (KWh/m2/a)	174.4
Energy Consumption (KWh/m2/a)	204.4
Thermal Energy (KWh/m2/a)	149.3
Electricity (KWh/m2/a)	55.5
Primary Energy (KWh/m2/a)	323.9
CO2 Emissions (Kg/m2/a)	94.3
Total Final Thermal Energy	4017.663
Total Electricity Consumption	1493.505
Operating cost	€533.60

Energy Saving Interventions

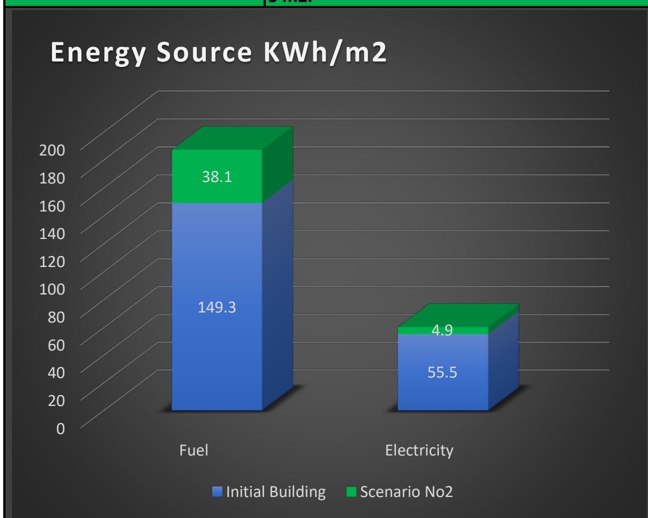
Scenario No1	P.E.S.	64.20%	Initial cost	€7,807.80	P.P. (Years)	23.7
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

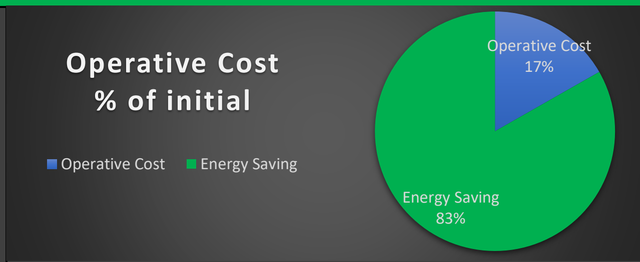


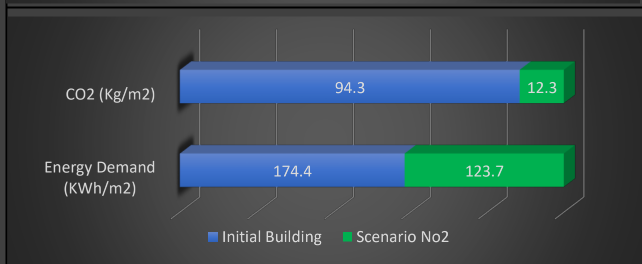




Scenario No2	P.E.S.	83.60%	Initial cost	€11,475.20	P.P. (Years)	25.8
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

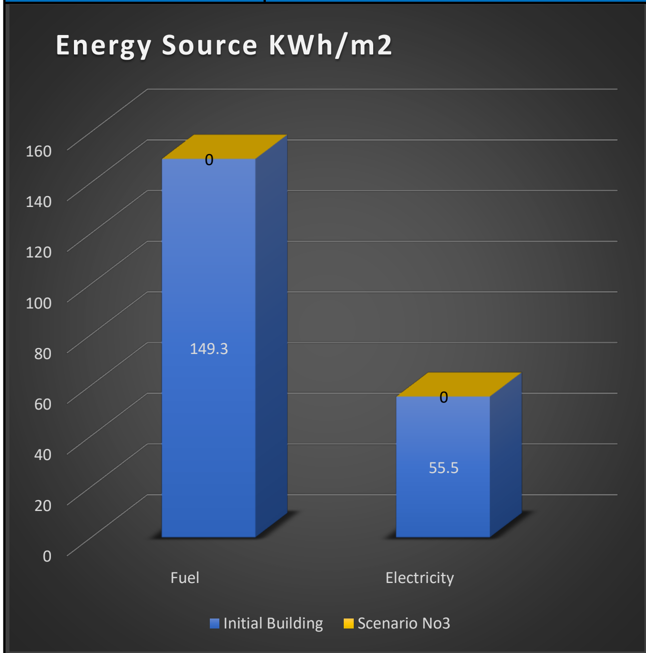


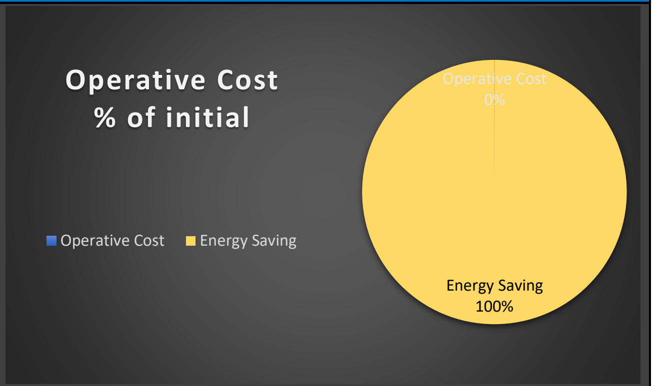


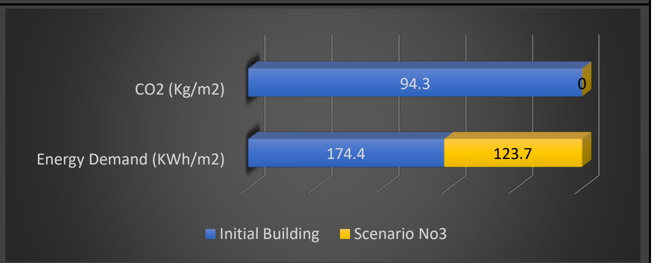


Energy Saving Interventions

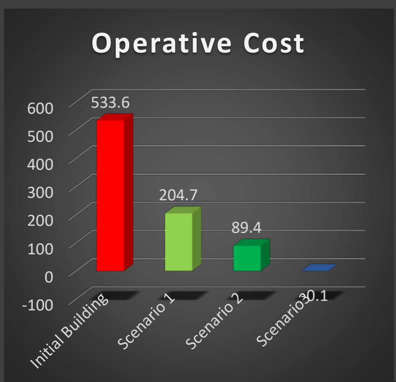
Scenario No3	P.E.S.	98.50%	Initial cost	€18,575.20	P.P. (Years)	34.8
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

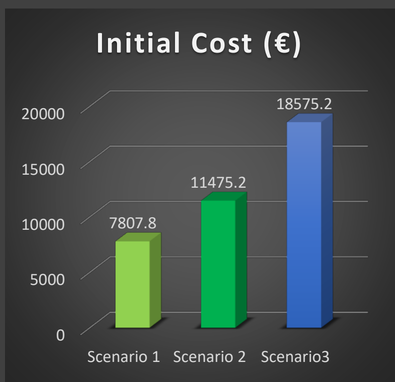


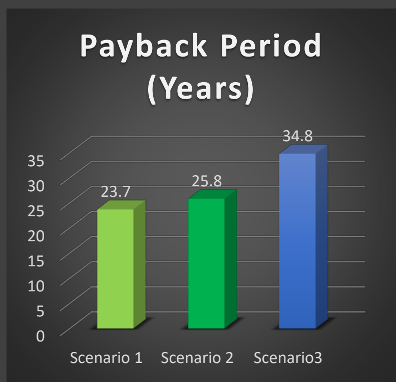


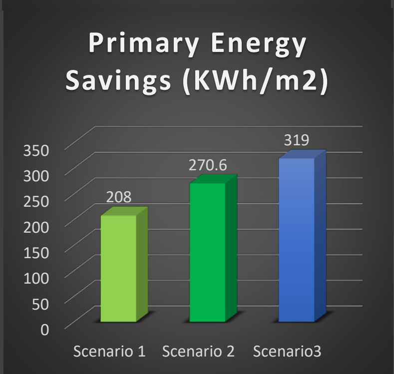


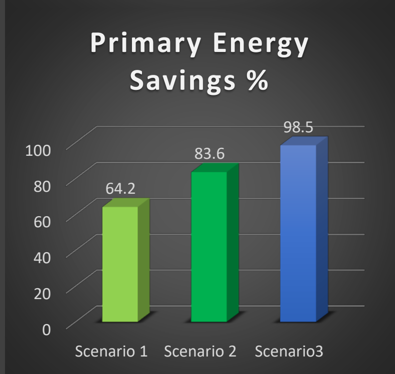
Scenario Comparison Diagrams

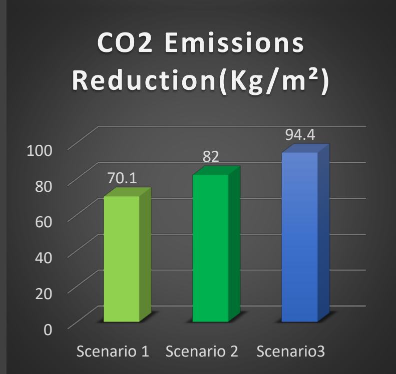












30	Multi-Family House			
	Apartment			
	Kalvou Andrea 7, Thessaloniki			
Age	-1980	1981-2000	2001-2010	2011+
Climatic Zone	A	B	C	D
Heated Area (m2)	21.44			
Heater Volume	60.03			

Building Description

Indermediate floor apartment in the center of Thessaloniki. Urban Zone. Dense structured area.

Construction

Walls	Double brick wall with insulation (RTI1979)
Concrete Structure	With insulation (RTI 1979)
Roof	Adiabatic surface
Openings	Sliding metal Frame Double Glazing 6mm
Blinds	Aluminum Blinds with polyurethan filling
Floor	Adiabatic surface

Thermal Conductivity Coefficients

Walls / Bearing / Basement walls	0.7
Roof	A/S
Floor	A/S
Openings	3.49
g-openings	0.56

HVAC systems performance

	Heating	DHW
Production	0.911	0.911
Distribution	0.92	0.84
Terminal Units / Storage	0.903	1

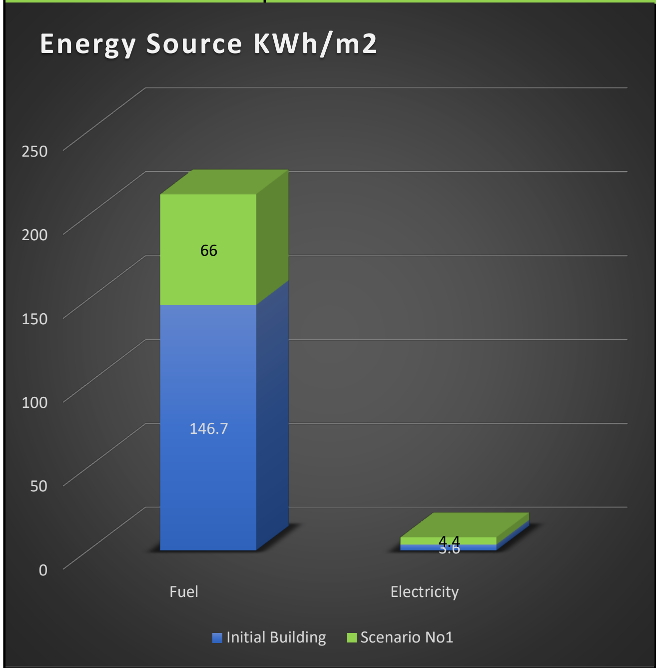
Systems

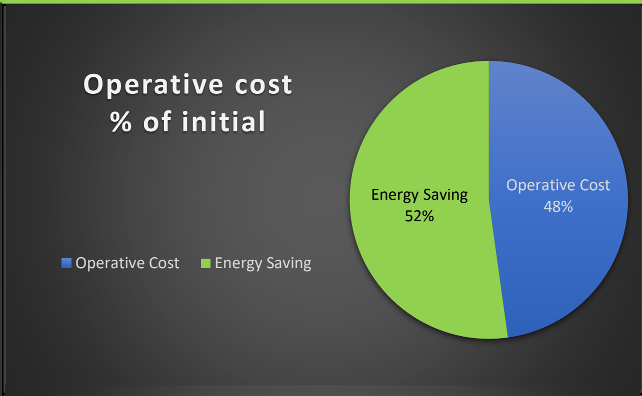
Production	Gas Boiler
Distribution	Pipes inside the building at least 80% of their length
Solar thermal	Non applicable
DHW	Gas Boiler

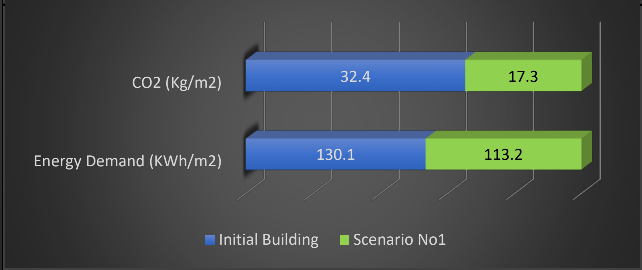
Annual Energy Characteristics

Energy Demand (KWh/m2/a)	130.1
Energy Consumption (KWh/m2/a)	150
Thermal Energy (KWh/m2/a)	146.7
Electricity (KWh/m2/a)	3.6
Primary Energy (KWh/m2/a)	163.7
CO2 Emissions (Kg/m2/a)	32.3
Total Final Thermal Energy	3145.248
Total Electricity Consumption	77.184
Operating cost	€237.20

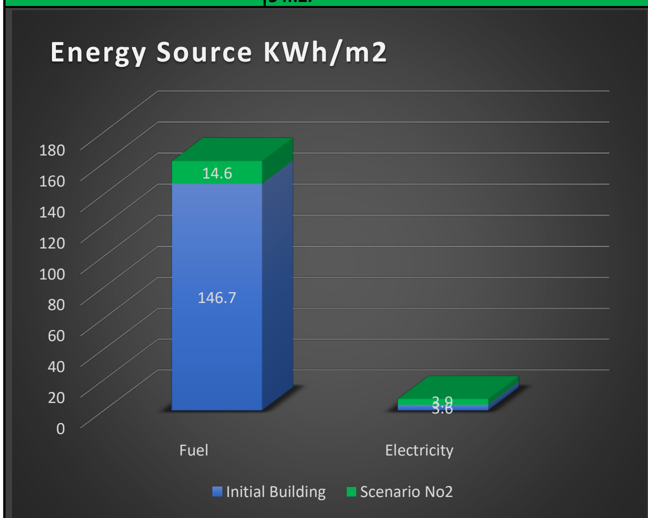
Energy Saving Interventions						
Scenario No1	P.E.S.	50.30%	Initial cost	€5,600.10	P.P. (Years)	45.3
Envelope	Application of insulation on the walls (Uvalue=0.4 W/m2K), roof (Uvalue=0.35 W/m2K) and pilotis if applicable (Uvalue=0.35 W/m2K). Use of 4-12-4 mm double glazing, low-e widows with thermal break and noble gas filling (Uvalue=2.4 W/m2K, g=0.45)					
Systems	Installation of new condensing gas boiler (η=0.95), low temperature heat-ing radiators, one thermostat per property. New heating and DHW distri-bution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation of 3 m2 solar thermal collector for DHW of a residence with two bedrooms. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a mini-mum of 3 m2.					

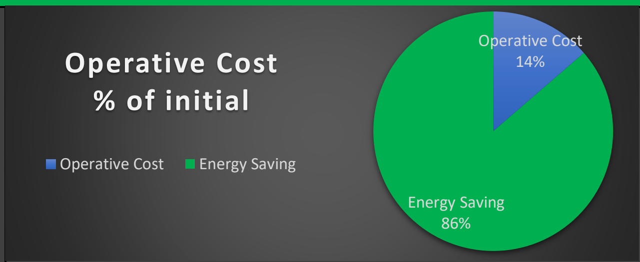


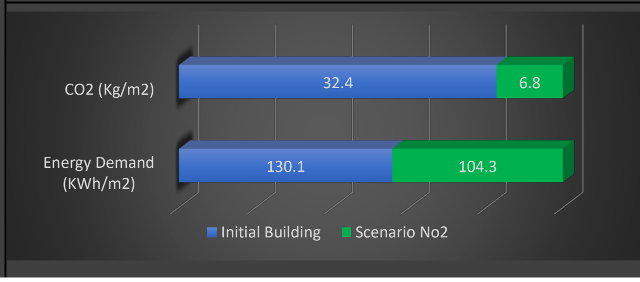




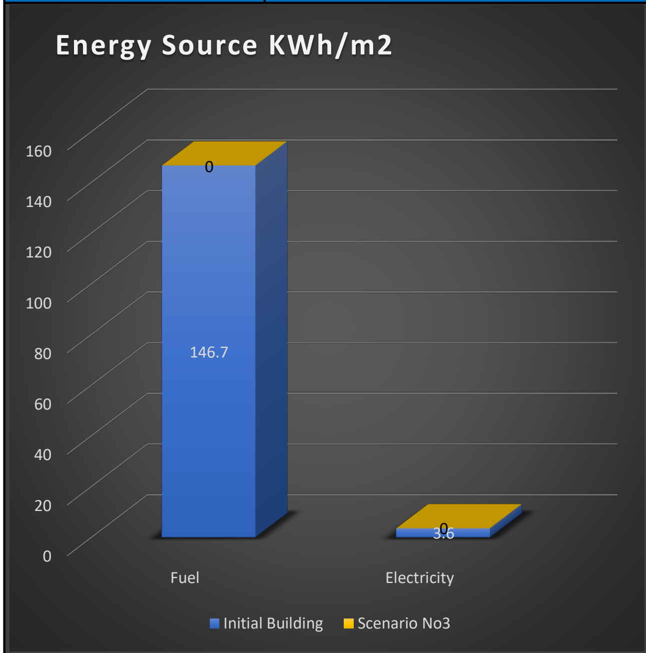
Scenario No2	P.E.S.	84.10%	Initial cost	€7,762.80	P.P. (Years)	37.9
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 double glazing, low-e widows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Installation of new condensing gas boiler (η=0.95) with weather compen-sation control, low temperature heating radiators, one thermostat and use of thermostatic valves in all terminal units. New heating and DHW dis-tribution systems if there aren't any installed or when the efficiency of the distribution system is low					
RES	Installation 5 m2 selective coating solar thermal collector for DHW and for partial heating, for a residence with two bedroom. If a residence has a different number of bedrooms, the surface of the solar collector will be respectively adjusted with a minimum of 5 m2.					

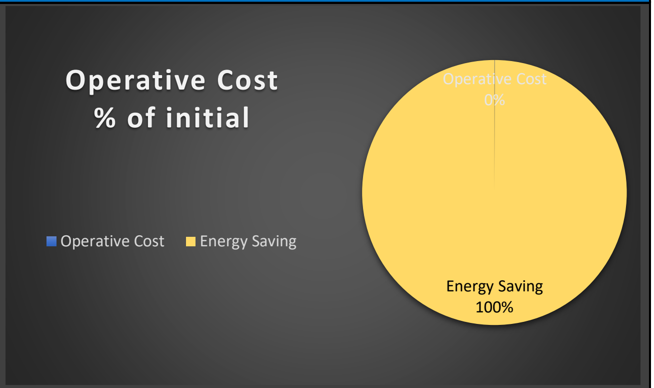


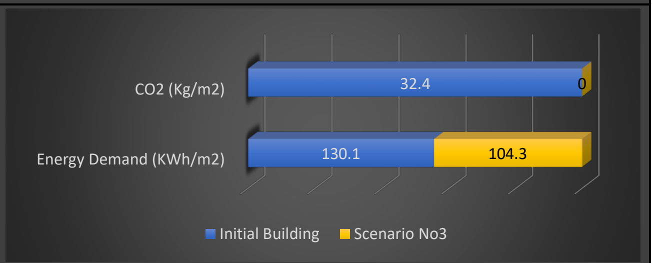




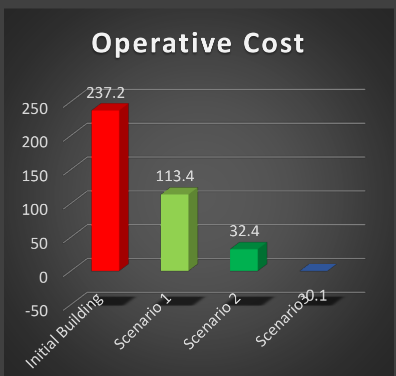
Energy Saving Interventions						
Scenario No3	P.E.S.	100.50%	Initial cost	€15,062.80	P.P. (Years)	63.5
Envelope	Application of thermal insulation on the walls (Uvalue=0.30 W/m2K), roof (Uvalue=0.25 W/m2K) and pilotis if applicable (Uvalue=0.25 W/m2K). Use of 4-12-4 mm gap double - glazing, low-e windows with thermal break and noble gas filling (Uvalue=1.7 W/m2K, g=0.45).					
Systems	Low temperatures heat pump (COP: 4.65, EER: 4.11) with weather compensation andunderfloor heating. Thermostat and user presence detection per operating space. New DHW distribution system when the efficiency of the existing is low.					
RES	Installation of 7 m2 selective solar thermal collector for DHW and for partial heating for a residence with 2 bedrooms. Installation of 2 m2 polycrystalline photovoltaic panels (n=16.9%, Nominal unit output= 0.26W).					

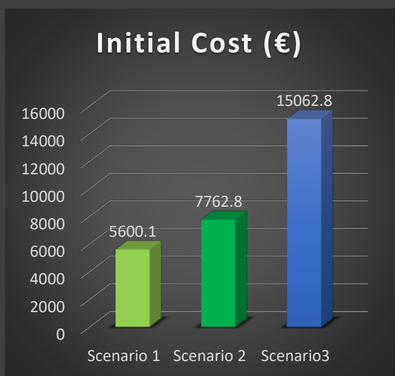


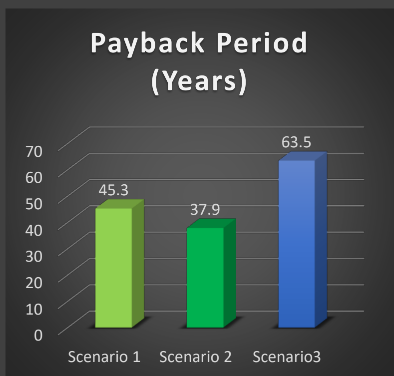


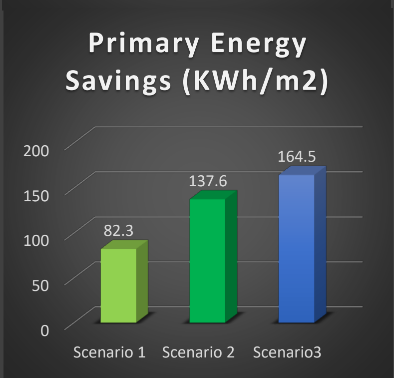


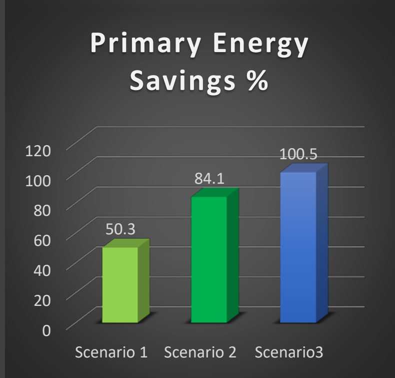
Scenario Comparison Diagrams

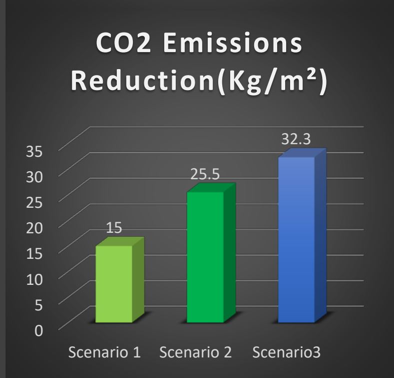












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