MASTER THESIS

"SMART BUILDINGS IN THE EU: ENERGY EFFICIENCY REGULATION & APPLICATIONS"

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LIST OF ABBREVIATIONS

EU	European Union
EC	European Commission
EPBD	Energy Performance of Buildings Directive
NEEAPs	National Energy Efficiency Action Plans
NECP	National Energy & Climate Plan
EED	Energy Efficiency Directive
UNFCCC	United Nations Framework Convention on Climate Change
RES	Renewable Energy Sources
CHP	Combined Heat and Power Plants
NZEB	Nearly zero-energy buildings
EPCs	Energy Performance Certificates
K.Ev.A.K.	Energy Efficiency Regulation of Buildings
T.E.E.-T.C.G.	Technical Chamberof Greece
TOTEE	Technical Directives TEE (T.C.G.)
EFSI	European Fund for Strategic Investments
SMEs	Small and medium-sized enterprises
IERSD	Institute for Environmental Research and Sustainable Development

CEP	Certificate of Energy Performance
ERDF	European Regional Development Fund
EER	Energy Efficiency Ratio
COP	Coefficient of Performance
EPS	Expanded Polystyrene System
Mtoe	Million tonnes of oil equivalent

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EXECUTIVE SUMMARY

Europe's building stock is entering a transition phase, becoming an active player in the energy system, controlling, producing, storing, and consuming energy. The explosion of smart technologies enabling a more efficient use of energy in buildings will inevitably redesign the built environment and the linked energy flows. This study attempts to offer a presentation of the legislative framework and targets of EU on energy efficiency and how this policy and long-term strategy affects the national plan of Greece for energy efficiency in building sector. Cases of energy upgrading of residential and office buildings in Greece will be presented and the amount of investment will be assessed in relation to the percentage of energy upgrade. The article concludes framing the five pillars of a smart built environment for EU.

1. INTRODUCTION

Building and construction sector are rapidly changing. According to the European Union's (EU's) 2050 long-term strategy new buildings will have to comply with the nearly zero energy standards and this is one of the main pillars of a deep transformation that goes far beyond the EU borders. EU commitment to mitigate climate change and the rapid technological development in the construction sector are turning buildings into major players in our energy systems.

In our analysis we will focus on energy and climate related challenges faced by the building and construction sector. The building sector is responsible for the largest share of total EU final energy consumption (40%) and produces about 35%-36% of all greenhouse emissions and this is a challenge that needs to be addressed.

BUILDINGS 2018-2019:

- **40% Of total energy consumption**
- **36% Of our CO_2 emissions**
- **9% EU GDP**
- **18**million **Direct jobs**
- **50% OF THE BUILDINGS BUILT <1975**
- **WILL STILL BE IN USE >2050**

Figure 1.1: Building sector in EU.[1]

The building sector is one of the big CO_2 emitters in Europe and globally. Our society has no more as an option to ignore the mandate to reduce greenhouse gas emissions associated with buildings. The Paris Climate Agreement in late 2015 marked a turning point for political and business decisions. It became clear to all in the industry and to those who regulate it that the building sector has to step up its efforts in reducing greenhouse gas emissions. The launch of the "Clean Energy Package for all Europeans" by the European Commission reflected the new policy paradigm to keep global temperature increase to well below 2°C. This package includes the November 2016 policy proposal for a revision of the "Energy Performance of Buildings Directive (EPBD)".[1]

The key question is whether innovation in the construction sector is a capable and necessary condition for reducing carbon dioxide emissions, where in the European Union the building sector is responsible for emitting about 30% of the total CO_2 emissions. European buildings are built for different uses, are based on different architectural and energy studies and are governed by complex constraints depending on the cultural, architectural and archaeological requirements of every area. A great amount of buildings will have to be renovated according to their potential so as to achieve a decarbonised building stock by 2050. Europe's renovation rate today is just around 1%: this needs to triple so as to renovate all buildings by the middle of the century.[1]

[1] (BPIE, 2018 June, Activities-Impact-Achievements, Biennial Report 2016-2017)

The adoption of an ' innovation wave ' and the use of technological applications in the construction sector will lead Europe's renovation rate to a level which results in almost a zero emission building stock by 2050. During this effort to create an energy-stable and deeply decarbonised urban environment, opportunities are created to strengthen Europe's industrial leadership in the construction value chain, together with economic and competitive advantages in and for Europe.

A decarbonised energy system needs a smarter and more efficient building stock and a new understanding of the role and function of buildings. The future of buildings in the EU is fully intertwined with their function as highly efficient micro-energy hubs, with integrating zero carbon energy production, with energy storage, with control and demand-response technologies, and power management for electric vehicles. The strategic step for building sector, in order to move to the center of the energy system, is its' transition to a zero carbon future.

Increased integration of distributed energy (re)sources, renewables and storage, coupled with growing peak demand for electricity, will drive the need for increased flexibility, demand-response capabilities, and consumer empowerment.[2]

On the other hand the lack of investment in upgrading and renovating buildings is one of the tallest barriers to a zero carbon building stock. Our analysis is trying to provide evidence that the investment risk is often lower than perceived, and that well-designed financial instruments can trigger private investments.

Energy efficiency policies need to set the right enabling framework soon enough to unlock private investments, in particular for building renovations. The conventional business case for achieving an energy-efficient building stock has been driven by energy cost reduction, while the indirect benefits cited have tended to focus on economic development and job creation in the local communities as a result of renovation projects, in addition to CO2 reduction. There is, however, increasing research showing that energy efficiency investments in buildings also result e.g. in decreased air pollution and broader health benefits for society. These multiple benefits of energy efficiency are rarely taken into account in investment decisions.[2]

At this fight for a decarbonised energy system each of the 28 European member states must transpose the EU Energy Performance of Buildings Directive into national law. In complying with the Directive, national policy makers have a high degree of freedom in designing national regulation, support programmes and other initiatives which all will contribute to the ultimate goal of the EU becoming climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions.

[2] (BPIE, 2018 June, Activities-Impact-Achievements, Biennial Report 2016-2017)

1.1 EU POLICY FOR A ZERO-CARBON BUILDING SECTOR

1.1.1 EU 2020 TARGET FOR ENERGY EFFICIENCY

By using energy more efficiently and thereby consuming less, Europeans can lower their energy bills, help protect the environment and reduce the EU's reliance on external suppliers of oil and gas. In order to achieve these benefits, energy efficiency needs to be improved throughout the full energy chain, from production to final consumption. At the same time, the benefits of energy savings must outweigh the costs, for instance those that result from carrying out renovations. EU measures therefore focus on sectors where the potential for savings is the greatest, such as buildings, or where a coordinated approach is required.

20% ENERGY SAVINGS BY 2020

In 2012, under the Energy Efficiency Directive 2012/27/EU, the EU set a **20% energy savings target by 2020** (when compared to the projected use of energy in 2020). In concrete terms, this means lowering the EU's final energy consumption to no more than 1,086 million tonnes of oil equivalent (Mtoe) and primary energy consumption to no more than 1,483 Mtoe. This is roughly equivalent to turning off 400 power stations.
In order to achieve this, EU countries were required to set their own indicative national energy efficiency targets, publish 3-year national energy efficiency action plans (NEEAPs) and annual progress reports. In December 2018, the revised Energy Efficiency Directive entered into force (Amending Directive EU2018/2002) updating some specific provisions and introducing new elements. Above all, it establishes **a headline EU energy efficiency target for 2030 of at least 32.5%** (compared to projections), with a clause for a possible upwards revision by 2023. The 32.5% target for 2030 translates into final energy consumption of 956 Mtoe and/or primary energy consumption of 1,273 Mtoe in the EU-28.
Under the new Governance rules, each Member States is required to set out a 10-year integrated **National energy & climate plan (NECP)** for 2021-2030, outlining how it intends to meet the 2030 targets for energy efficiency and for renewable energy. With the draft NECPs having been submitted by early 2019, the Commission published a detailed assessment of these draft plans in June 2019 with country-specific recommendations. Under the regulation, Member States had to finalize their respective NECPs by the end of 2019.[3]

NATIONAL ENERGY EFFICIENCY TARGETS FOR 2020

To reach the EU's 20% energy efficiency target by 2020, individual EU countries set their own indicative national energy efficiency targets.

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[3] (European Commission, 2019, Energy efficiency targets, https://ec.europa.eu/energy/topics/energy-efficiency/targets-directive-and-rules/eu-targets-energy-efficiency_en#2020-targets)

EU MEMBER STATE	ABSOLUTE LEVEL OF ENERGY CONSUMPTION IN 2020 [MTOE] AS NOTIFIED FROM MEMBER STATES IN 2013, IN THE NEEAP 2014, ANNUAL REPORTS OR IN SEPARATE NOTIFICATIONS TO THE EUROPEAN COMMISSION IN 2015 AND 2016.	
	Primary energy consumption	Final energy consumption
Austria	31.5	25.1
Belgium	43.7	32.5
Bulgaria	16.9	8.6
Croatia	11.15	7.0
Cyprus	2.2	1.8
Czechia	39.6	25.3
Denmark	17.4	14.4
Estonia	6.5	2.8
Finland	35.9	26.7
France	219.9	131.4
Germany	276.6	194.3
Greece	24.7	18.4
Hungary	24.1	14.4
Ireland	13.9	11.7
Italy	158.0	124.0
Latvia	5.4	4.5
Lithuania	6.5	4.3
Luxembourg	4.5	4.2
Malta	0.7	0.5
Netherlands	60.7	52.2
Poland	96.4	71.6
Portugal	22.5	17.4
Romania	43.0	30.3
Slovakia	16.4	9.0
Slovenia	7.3	5.1
Spain	119.8	80.1
Sweden	43.4	30.3
United Kingdom	177.6	129.2
Sum of indicative targets EU28	1526	1077
EU28 target 2020	1483	1086

Table 1.1: EU Member States˙energy efficiency targets for 2020 (Status: 04/01/2017).[4]

[4] (European Commission, 2017, Energy efficiency targets, https://ec.europa.eu/energy/topics/energy-efficiency/targets-directive-and-rules/eu-targets-energy-efficiency_en#2020-targets)

Depending on country preferences, these targets were based on primary or final energy consumption, primary or final energy savings, or energy intensity.

PROGRESS TOWARDS THE 2020 TARGET

Following a gradual decrease between 2007 and 2014, energy consumption increased between 2014 and 2017. The increase could partly be attributed to good economic performance since 2014 with low oil prices and colder winters. Data from Eurostat (April 2019) shows that the primary energy consumption was 5.3% above the 2020 targets in 2017, whereas the final energy consumption was 3.4% above those targets. If energy consumption continues to increase during 2020, the EU will not reach its 2020 target for both primary and final energy consumption.
Europe needs to further intensify its efforts to deliver energy savings in the short term and the Commission set up a **task force** in 2018 to look more closely at measures that might reverse this trend.[5]

TASK FORCE ON MOBILISING EFFORTS TO REACH THE 2020 TARGETS

The Commission established a task force with Member States to discuss with stakeholders the reasons for this new trend and potential measures to address the problem. The first two meetings (in September and November 2018) took a closer look at the figures and, in consultation with Member States and stakeholders, identified a number of actions that might address the situation. Further meetings in 2019 continued the close monitoring of figures and consumption trends in the context of the Member State annual progress reports and the latest Eurostat figures on energy efficiency. In addition, the Commission is closely following the implementation and transposition of energy efficiency legislation in EU Member States.[5]

OTHER MEASURES TOWARDS ENERGY EFFICIENCY

EU countries have implemented energy efficiency measures in all sectors, and these have produced substantial benefits for Europeans, for instance:[6]

- new buildings consume half the energy buildings did in the 1980s
- energy intensity in EU industry decreased by 16% between 2005 and 2014
- more efficient appliances are expected to save consumers €100 billion annually – about €465 per household – on their energy bills by 2020

[5] (European Commission, 2019, Energy efficiency targets, https://ec.europa.eu/energy/topics/energy-efficiency/targets-directive-and-rules/eu-targets-energy-efficiency_en#2020-targets)
[6] (European Commission, COM(2014) 520 final, Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy)

- EU countries have committed themselves to rolling out almost 200 million smart meters for electricity and 45 million for gas by 2020, leading to better information and savings for consumers

With the implementation of energy efficiency legislation and ambitious energy efficiency programmes in Europe, further benefits are expected in the future, such as:[7]

- lower demand for EU gas imports
- lower energy costs for people who live and work in energy efficient buildings, as well as additional benefits such as improved air quality and protection from external noise
- targeted energy efficiency measures in buildings can help households with lower incomes to improve their living conditions
- lower energy costs for companies, in particular energy-intensive industries
- less need for additional generation and grid capacities with higher energy efficiency levels
- boosting domestic energy efficiency investments will bring new business opportunities for European companies such as construction firms

1.1.2 EU 2030 TARGET FOR ENERGY EFFICIENCY

ENERGY EFFICIENCY FIRST: ACCELERATING TOWARDS A 2030 OBJECTIVE OF 32.5%

Figure 1.2: EU energy efficiency target by 2030.[8]

[7] (European Commission, 2014, Energy efficiency: helping to reduce greenhouse gas emissions and improve energy security, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM:180301_1)

[8] (European Commission, 2019 September, https://ec.europa.eu/info/news/energy-efficiency-first-accelerating-towards-2030-objective-2019-sep-25_en)

At September 2019 (25-09-2019) the European Commission adopted three recommendations to help Member States put the clean energy transition into practice.

Putting energy efficiency first is a key objective of the EU, as energy savings are the easiest way of saving money for consumers and to reduce greenhouse gas emissions. The EU has set binding targets of reducing our energy consumption through improvements in energy efficiency by 2030 by at least 32.5%, relative to a ‘business as usual’ scenario.

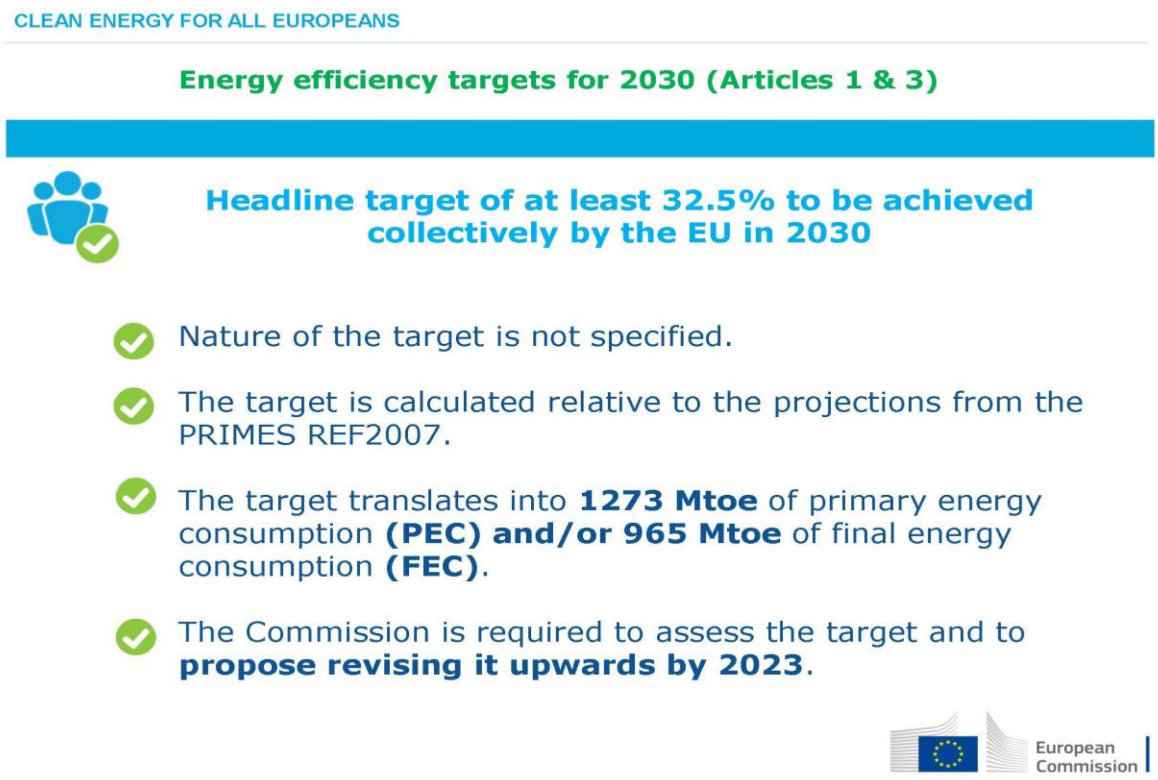

Figure 1.3: EU energy efficiency targets for 2030 (Articles 1 & 3).[9]

The recommendations contain detailed guidance for Member States on how to enact and best implement various aspects of the amending energy efficiency directive, which has been in place since December 2018. Specifically, the recommendations address:[10]

- the practical implementation of the energy savings obligation for the period 1 January 2021 to 31 December 2030
- the revised metering and billing provisions for thermal energy, and
- efficiency in heating and cooling

Member States were required to bring into force the laws, regulations and administrative provisions necessary to comply with the amended directive by 25 June 2020, and for the new

[9] (European Commission, Energy Community, 2nd Technical Working Group on Energy and Climate, 2018 October, How the EU built the 2030 energy efficiency target)

[10] (European Commission, 2019 September, https://ec.europa.eu/info/news/energy-efficiency-first-accelerating-towards-2030-objective-2019-sep-25_en)

provisions on individual metering and billing by 25 October 2020. The three recommendations adopted are:

- Commission recommendation on transposing the energy savings obligations under the energy efficiency directive - Annex:[11]

EU is committed to developing a sustainable, competitive, secure and decarbonised energy system (Treaty on the Functioning of the European Union, Article 292). The Energy Union Strategy established ambitious Union objectives. It notably aims to reduce greenhouse gas emissions by at least a further 40 % by 2030 compared with 1990, to increase the use of renewable energy to at least 32 %, and to make ambitious energy savings, improving energy security, competitiveness and sustainability. Directive 2012/27/EU1 (the 'Energy Efficiency Directive' (EED)), as amended by Directive (EU) 2018/20022, establishes a headline target of at least 32.5 % energy savings at EU level by 2030.
Moderation of energy demand is one of the five dimensions of the Energy Union Strategy, as established in the Commission Communication of 25 February 2015 on a framework strategy for a resilient energy union with a forward-looking climate change policy. The EU's achievement of its energy and climate goals depends on prioritising energy efficiency, applying the 'energy efficiency first' principle and considering the deployment of renewables. The amended 'Energy Efficiency Directive' (EED) clarifies that, when calculating energy savings, Member States can claim only savings that go beyond the minimum required under specific EU legislation. There is an exemption for energy savings from the renovation of buildings.
Given the importance of energy generated on or in buildings from renewable energy technologies, the guidance provided with this Recommendation explains how Member States may count end-use energy savings stemming from policy measures promoting the installation of small-scale renewable energy technologies against their energy savings obligation.

- Commission recommendation on the implementation of the new metering and billing provisions of the energy efficiency directive – Annex:[12]

Heating and cooling is the most significant source of end-use energy consumption, representing about **50% of the total energy demand in the European Union**. 80% of this is used in buildings. Therefore, the Union's achievement of its energy and climate goals is greatly influenced by its efforts to renovate building stocks and to promote a more optimal building operation and use. Clear and timely information and energy bills based on actual consumption empower consumers to play an active part in reducing energy needs for heating and cooling.

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[11] (COMMISSION RECOMMENDATION of 25 September 2019 on transposing the energy savings obligations under the Energy Efficiency Directive, C(2019) 6621 final)
[12] (COMMISSION RECOMMENDATION of 25 September 2019 on the implementation of the new metering and billing provisions of the Energy Efficiency Directive 2012/27/EU, C(2019) 6631 final)

More than 40% of dwellings in the Union are located in multi-family buildings or semi-detached houses, many of which have collective systems for the provision of space heating or for domestic hot water preparation. Accurate, reliable, clear and timely information about energy consumption is therefore important for occupants of such dwellings, regardless of whether or not they have a direct, individual contractual relationship with an energy supplier.

The 'Energy Efficiency Directive' (EED) is the Union level piece of legislation that addresses the metering and billing of thermal energy supplies. In 2018, the EED was amended. One of the aims of the amendment was to clarify and strengthen the applicable rules concerning **metering and billing.** The clarifications include the introduction of the notion of 'final users' alongside the notion of 'final customer' already used in the EED to clarify that the rights to billing and consumption information also apply to consumers without individual or direct contracts with the supplier of energy used for collective heating, cooling or domestic hot water production systems in multi-occupant buildings. The changes also make explicit the requirement for Member States to publish criteria, methodologies and procedures used to grant exemptions from the general requirement for sub-metering in multi-occupant buildings.

- Commission recommendation on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of the energy efficiency directive – Annex.[13]

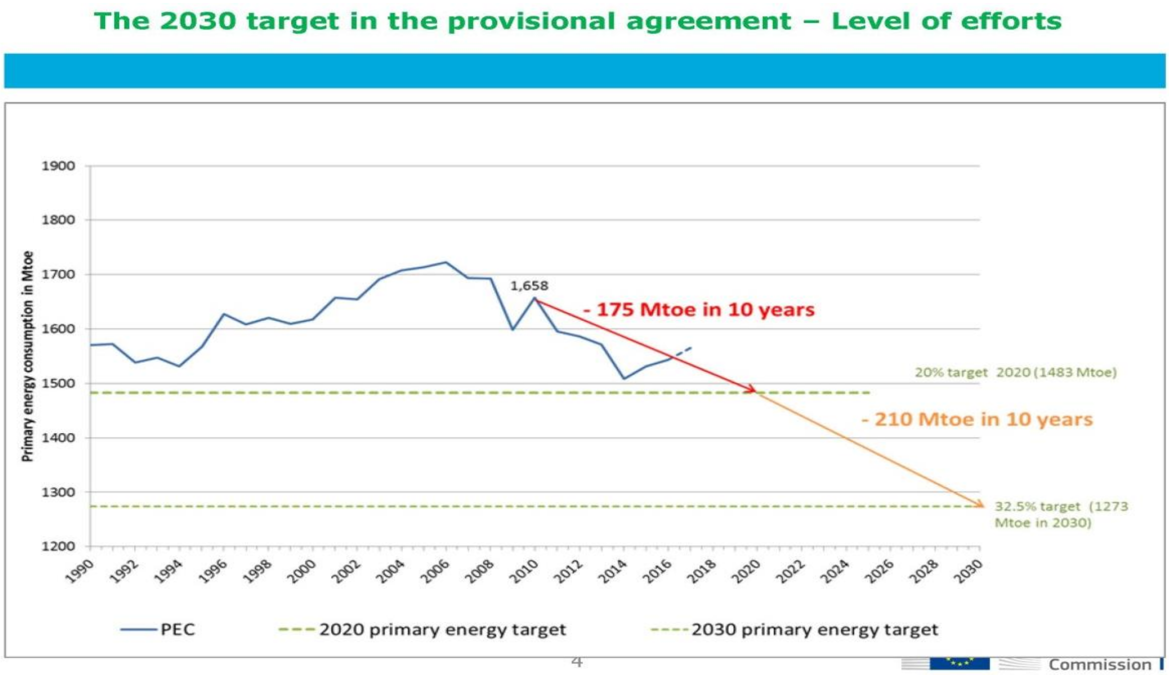

Figure 1.4: The 2030 target in the provisional agreement – Level of efforts.[14]

[13] (COMMISSION RECOMMENDATION of 25 September 2019 on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of Directive 2012/27/EU, C(2019) 6625 final)

[14] (European Commission, Energy Community, 2nd Technical Working Group on Energy and Climate, 2018 October, How the EU built the 2030 energy efficiency target)

1.1.3 EU 2050 LONG-TERM STRATEGY

The EU aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. This objective is at the heart of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement. The transition to a climate-neutral society is both an urgent challenge and an opportunity to build a better future for all.
All parts of society and economic sectors will play a role – from the power sector to industry, mobility, buildings, agriculture and forestry.
The EU can lead the way by investing into realistic technological solutions, empowering citizens and aligning action in key areas such as industrial policy, finance and research, while ensuring social fairness for a just transition.

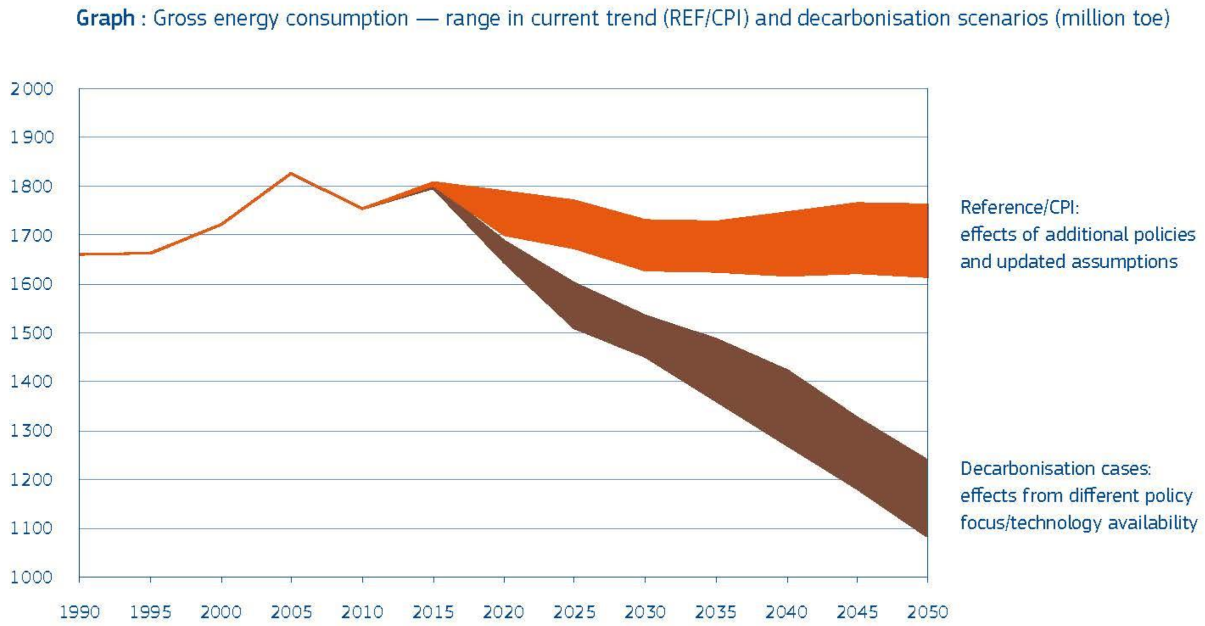

Figure 1.5: Gross energy consumption-range in current trend (REF/CPI) and decarbonisation scenarios (Mtoe).[15]

COMMISSION'S VISION

The Commission set out its vision for a climate-neutral EU in November 2018, looking at all the key sectors and exploring pathways for the transition. The Commission's vision covers nearly all EU policies and is in line with the Paris Agreement objective to keep the global temperature increase to well below 2°C and pursue efforts to keep it to 1.5°C. As part of the European Green Deal, the Commission proposed on 4 March 2020 the first European Climate Law to enshrine the 2050 climate-neutrality target into law.[16]

[15] (European Commission, 2012, Energy Roadmap 2050)
[16] (European Commission, 2018, https://ec.europa.eu/clima/policies/strategies/2050_en)

The Commission's vision launched an EU-wide reflection on the EU strategy, involving EU institutions, national parliaments, business sector, non-governmental organisations, cities, communities and citizens across Europe.

EU STRATEGY

All Parties to the Paris Agreement are invited to communicate, by 2020, their mid-century, long-term low greenhouse gas emission development strategies. The European Parliament endorsed the net-zero greenhouse gas emissions objective in its resolution on climate change in March 2019 and resolution on the European Green Deal in January 2020.
The European Council endorsed in December 2019 the objective of making the EU climate-neutral by 2050, in line with the Paris Agreement. The EU submitted its long-term strategy to the United Nations Framework Convention on Climate Change (UNFCCC) in March 2020.[17]

NATIONAL STRATEGIES

EU Member States are required to develop national long-term strategies on how they plan to achieve the greenhouse gas emissions reductions needed to meet their commitments under the Paris Agreement and EU objectives.[17]

MOVING FROM 2020 TO 2050 — CHALLENGES AND OPPORTUNITIES

Energy saving and managing demand: a responsibility for all[18]

The prime focus should remain on energy efficiency. Improving energy efficiency is a priority in all decarbonization scenarios. Current initiatives need to be implemented swiftly to achieve change. Implementing them in the wider context of overall resource efficiency will bring cost-efficient results even faster. **Higher energy efficiency in new and existing buildings is key**. Nearly zero-energy buildings should become the norm. Buildings, including homes, could produce more energy than they use. Products and appliances will have to fulfill highest energy efficiency standards. In transport, efficient vehicles and incentives for behavioral change are required.

Consumers will gain with more controllable and predictable energy bills. With **smart meters** and **smart technologies** such as home automation, consumers will have more influence on their own consumption patterns. Significant efficiency can be achieved with action on energy use-related resources such as recycling, lean manufacturing and prolonging product lifetime. Investments by households and companies will have to play a major role in the energy system transformation.

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[17] (European Commission, 2018, https://ec.europa.eu/clima/policies/strategies/2050_en)

[18] (European Commission, 2012, Energy Roadmap 2050)

Greater access to capital for consumers and innovative business models are crucial. This also requires incentives to change behavior, such as taxes, grants or on-site advice by experts, including the monetary incentives provided by energy prices reflecting the external costs.
In general, energy efficiency has to be included in a wide range of economic activities from, for example, IT systems development to standards for consumer appliances.
An analysis of more ambitious energy efficiency measures and cost-optimal policy is required. Energy efficiency has to follow its economic potential. This includes questions on to what extent urban and spatial planning can contribute to saving energy in the medium and long term and how to find the cost optimal policy choice between insulating buildings to use less heating and cooling and systematically using the waste heat of electricity generation in combined heat and power (CHP) plants.

Switching to renewable energy sources

The analysis of all scenarios shows that the biggest share of energy supply technologies in 2050 comes from renewables. Thus, the second major prerequisite for a more sustainable and secure energy system is a higher share of renewable energy beyond 2020. In 2030, all the decarbonization scenarios suggest growing shares of renewables of around 30% in gross final energy consumption. The challenge for Europe is to enable market actors to drive down the costs of renewable energy through improved research, industrialization of the supply chain and more efficient policies and support schemes.[19]

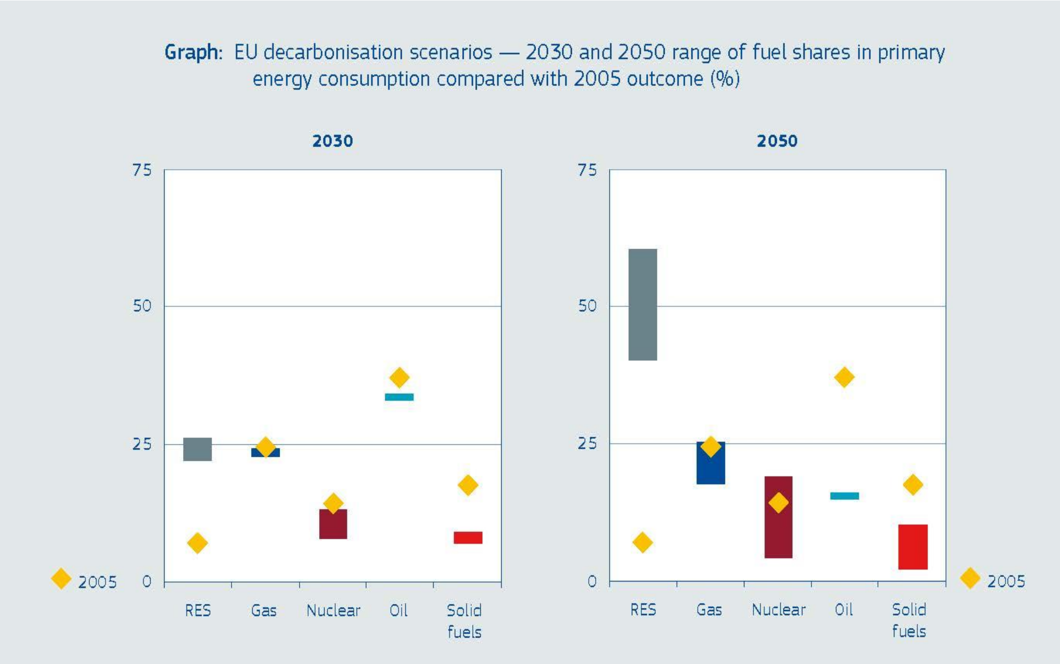

FIGURE 1.6: EU DECARBONISATION SCENARIOS - 2030 AND 2050 RANGE OF FUEL SHARES.[19]

[19] (European Commission, 2012, Energy Roadmap 2050)

Renewables will move to the center of the energy mix in Europe, from technology development to mass production and deployment, **from subsidised to competitive**. This changing nature of renewables requires changes in policy parallel to their further development. Renewable heating and cooling are vital to decarbonisation. A shift in energy consumption towards low carbon and locally produced energy sources (including heat pumps and storage heaters) and renewable energy (e.g. solar heating, geothermal, biogas, biomass), including through district heating systems, is needed.[20]

2. EU LEGISLATION FRAMEWORK FOR ENERGY EFFICIENCY OF BUILDING SECTOR

The building sector is crucial for achieving the EU's energy and environmental goals. At the same time, better and more energy efficient buildings improve the quality of citizens' life while bringing additional benefits to the economy and the society. To boost energy performance of buildings, the EU has established a legislative framework that includes the **Energy Performance of Buildings Directive 2010/31/EU (EPBD)** and the **Energy Efficiency Directive 2012/27/EU**. Together, the directives promoted policies that would help:[21]

- achieve a highly energy efficient and decarbonised building stock by 2050
- create a stable environment for investment decisions
- enable consumers and businesses to make more informed choices to save energy and money

Following the introduction of energy performance rules in national building codes, buildings today consume only half as much as typical buildings from the 1980s.

Both directives were amended, as part of the **Clean energy for all Europeans package, in 2018 and 2019**. In particular, the **Directive amending the Energy Performance of Buildings Directive (2018/844/EU)** introduces new elements and sends a strong political signal on the EU's commitment to modernise the buildings sector in light of technological improvements and increase building renovations. EU countries had to transpose the new and revised rules into national law by 10 March 2020. The Commission has introduced a renovation wave of public and private buildings, as part of the **European Green Deal**. It aims to take further action and create the necessary conditions to scale up renovations and reap the significant saving potential of the building sector.

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[20] (European Commission, 2012, Energy Roadmap 2050)

[21] (European Commission, 2019 May, Energy performance of buildings directive)

2.1 Energy Performance of Buildings Directive 2010/31/EU (EPBD)[22]

The Energy Performance of Buildings Directive 2010/31/EU (EPBD) replaced Directive 2002/91/EC setting a more ambitious framework to improve the energy efficiency of EU buildings.

Objectives EPBD

- to promote the improvement of the energy performance of buildings within the Union, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness

Actions for Member States

- Setting up minimum energy performance requirements for new buildings and existing buildings that undergo major renovation
- Applying energy performance certificates (EPCs) to buildings
- Ensuring that from the end of the decade only nearly zero-energy buildings (NZEB) are built.
- Setting up minimum requirements for technical buildings systems (heating, air conditioning, large ventilation systems and domestic hot water) and regular inspection of heating and air conditioning systems
- Ensuring compliance and control through independent control systems

Consequences

- Reduced energy use in buildings
- Relevant quality information for consumers on the energy performance of their homes
- Minimum energy performance requirements for new buildings and for renovating buildings and parts of buildings set at the right level (lowest cost during the estimated life cycle), and kept under regular review
- Only NZEB constructed from the end of 2020
- Enhanced level of ambition of national and regional building codes, diminishing differences across Member States
- Innovation in the building sector
- Relevant quality information available to regional and local authorities, MSs & EC

External Factors

- Characteristics of each national buildings stock (starting point)
- National and regional transposition and implementation measures
- Local climatic conditions and indoor climate requirements

[22] (DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on energy performance of buildings)

- National enforcement systems
- Cost-effectiveness
- Technological development and innovation
- Maturity of national energy services sectors
- Availability of national public and private financing
- Other legislation touching on buildings

Expected Results/Impacts

- Better energy performance and energy savings
- Reduced GHG emissions, air, noise, water and soil pollution
- More jobs (creation and retention) in the renovation, construction and energy services sectors
- Reduced gas imports, resource use for transformation, transportation and use
- Increased use of renewable energy sources in buildings
- Reduced resource use for energy extraction, transformation, transportation and use
- Co-benefits on human health and state of the ecosystems
- Consumers can compare the energy performance of apartments before renting or buying
- Reduced energy bills for EU citizens

2.2 Energy Efficiency Directive 2012/27/EU[23]

Directive 2012/27/EU establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. This means that overall EU energy consumption should be no more than 1483 million tonnes of oil equivalent (Mtoe) of primary energy or 1086 Mtoe of final energy. Under the directive, all EU countries are required to use energy more efficiently at all stages of the energy chain, including energy generation, transmission, distribution and end-use consumption.

In the context of the Energy Efficiency Directive, a number of important measures have been adopted throughout the EU to improve energy efficiency in Europe, including:[24]

- policy measures to achieve energy savings equivalent to annual reduction of 1.5% in national energy sales
- EU countries making energy efficient renovations to at least 3% per year of buildings owned and occupied by central governments
- national long-term renovation strategies for the building stock in each EU country
- mandatory energy efficiency certificates accompanying the sale and rental of buildings

[23] (DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC)
[24] (European Commission, 2019 August, the 2012 energy efficiency directive, https://ec.europa.eu/energy/topics/energy-efficiency/targets-directive-and-rules/energy-efficiency-directive_en)

- the preparation of national energy efficiency action plans (NEEAPs) every three years
- minimum energy efficiency standards and labeling for a variety of products
- the planned rollout of close to 200 million smart meters for electricity and 45 million for gas by 2020
- obligation schemes for energy companies to achieve yearly energy savings of 1.5% of annual sales to final consumers
- large companies conducting energy audits at least every four years
- protecting the rights of consumers to receive easy and free access to data on real-time and historical energy consumption

The Commission also published guidelines on good practice in energy efficiency.

2.3 Clean energy for all Europeans package[25]

a) Annex 1: Accelerating clean energy in buildings

By using energy more efficiently and thereby consuming less, Europeans can lower their energy bills, help protect the environment and reduce the EU's reliance on external suppliers of oil and gas. In order to achieve these benefits, energy efficiency needs to be improved throughout the full energy chain, from production to final consumption.
At the same time, the benefits of energy savings must outweigh the costs, for instance those that result from carrying out renovations. EU measures therefore focus on sectors where the potential for savings is the greatest, such as buildings, or where a coordinated approach is required.

Treating buildings as an essential part of Europe's clean energy transition and focusing on the places where we live and work, we develop a comprehensive, integrated approach that puts energy efficiency first, contributes to the EU's global leadership in renewables and delivers a fair deal to consumers in a way that helps Member States to deliver their energy and climate targets for 2020 and 2030.

The benefits of such an integrated approach are clear:[25]
- mobilizing investments, at national, regional and local level, and driving growth and jobs, while promoting innovation and skills
- energy savings, leading to lower running costs, a healthier living and working environment for citizens
- alleviating energy poverty, with a special focus on tackling energy-inefficient social housing and public buildings

[25] (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK of 30 November 2016 on Clean Energy For All Europeans, COM(2016) 860 final)

- gradual decentralisation of Europe's energy system through the use of sustainable energy in buildings
- plugging buildings into a connected energy, storage, digital and transport system
- empowering households, businesses and energy communities, and
- contributing to the circular economy

In order to set the right regulatory framework, in particular with the proposed revision of the Energy Efficiency Directive and the European Performance of Buildings Directive, there is a need for complementing actions to support rapid changes in the real economy and to address the question of financing now such as:[26]

- **Smart financing for smart buildings**

Sustainable energy renovation in buildings is an area where pooling of projects and public guarantees can make a huge difference. As part of the Investment Plan for Europe, the European Fund for Strategic Investments (EFSI) is key to unlock private financing for energy efficiency and renewables in buildings at a greater scale.
Already now, energy efficiency and renewables are prominent in EFSI projects. For instance, the vast majority of energy projects approved for financing so far (accounting for 22% of €154 billion worth of overall investment) concerns energy efficiency and the renewable energy sector. Building on the success of EFSI, the Commission extended its duration until the end of 2020 and required that at least 40% of projects in the EFSI infrastructure and innovation window should contribute to climate, energy and environment action in line with the COP21 (21st Conference of the Parties in Paris) objectives.

The support from the European Fund for Strategic Investments is combined with support, in the form of grants or financial products, from other EU funds, including the European Structural and Investment Funds. Over the period 2014-2020, the European Regional Development Fund and the Cohesion Fund invested €17 billion in energy efficiency in public and residential buildings and in enterprises, with a focus on SMEs (Small and medium-sized enterprises).

The European initiative to further boost investments by public sector entities, energy services companies, SMEs/midcaps and households in energy efficiency and smart buildings is based on three pillars:[26]

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[26] (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK of 30 November 2016 on Clean Energy For All Europeans, COM(2016) 860 final)

- Pillar I: More effective use of public funding

The aim is to maximize the use of available public funding via financial instruments addressing identified market failures and by better targeting grants towards vulnerable consumers.

- Pillar II: Aggregation and assistance for project development

The availability of a large-scale pipeline of bankable projects to feed investment platforms and financial instruments is essential for the success of this initiative. However, many project promoters – public authorities, individuals or businesses – lack the skills and capacity to set up, implement and finance ambitious clean energy building projects. The Commission has therefore to reinforce existing Project Development Assistance facilities at the EU level and to encourage Member States to develop dedicated local or regional one-stop-shops for project developers.

-Pillar III: De-risking

As called for by financial institutions, investors and financiers need to better understand the real risks and benefits of sustainable energy building investments based on market evidence and performance track record. Fundamentals such as the lower probability of default in the case of energy saving loans or an increased value of assets due to higher energy performance need to be progressively recognised by banks and reflected in the pricing of their financing products.

b) Energy Union[27]

The Energy Union is one of the most important priorities of EU. With the aim to modernise the EU's economy, it works hand in hand with other flagship initiatives such as the Digital Single Market, the Capital Markets Union and the Investment Plan for Europe in order to deliver on jobs, growth and investments for Europe. This package presents an opportunity to speed both the clean energy transition and growth. By mobilising up to an additional €177 billion of public and private investment per year from 2021, this package can generate up to 1% increase in GDP over the next decade and create 900.000 new jobs. It will also mean that on the average the carbon intensity of the EU's economy will be 43% lower in 2030 than now, with renewable electricity representing about half of the EU's electricity generation mix. The energy sector is important for the European economy: energy prices affect the competitiveness of the whole economy and represent on average 6% of annual household expenditure. It employs close to 2.2 million people, spread over 90,000 enterprises across Europe, representing 2% of total added value.

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[27] (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK of 30 November 2016 on Clean Energy For All Europeans, COM(2016) 860 final)

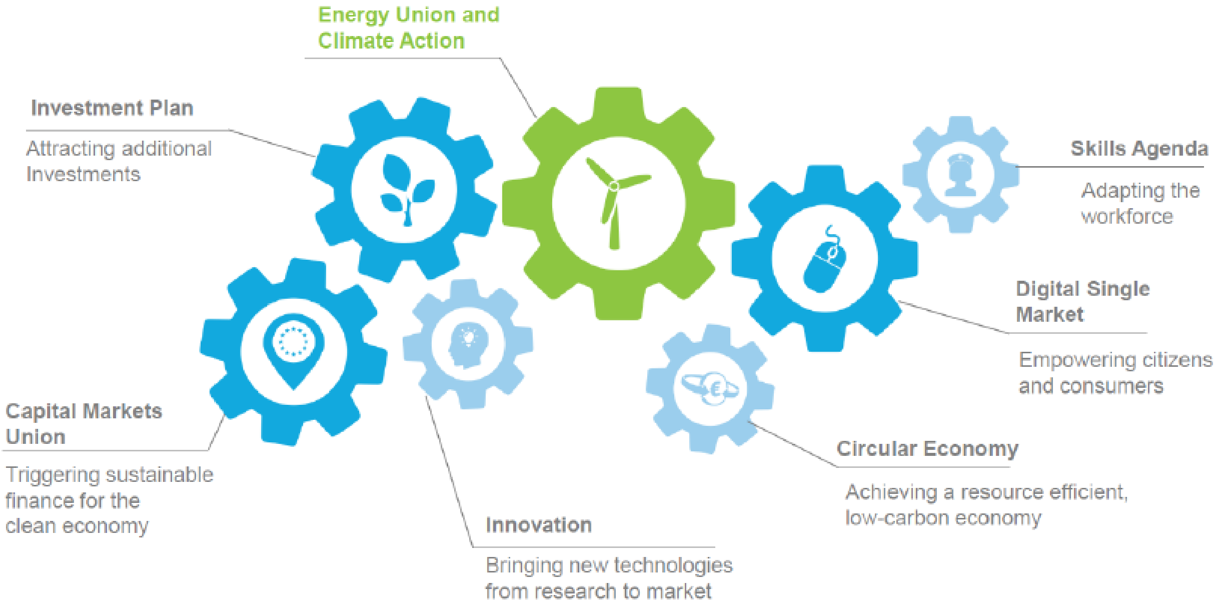

Figure 2.1: Modernisation of the economy – Role of the Energy Union and Climate Action.[28]

The development of renewable energy sources and energy efficiency products and services has led to the creation of new businesses throughout Europe providing new sources of jobs and growth for Europeans. The employment impacts of the Energy Union go well beyond the energy supply industry. For instance, more than one million workers are employed, directly or indirectly, in renewable energy related sectors **and around one million in the energy efficiency-related sector.**

It is equally important to ensure that the transition to a clean energy system will benefit all Europeans. All consumers, especially the vulnerable, should feel involved and reap the tangible benefits of access to clean, secure and competitive energy, which are the Energy Union's key objectives. The Commission has already presented the Energy Union Framework Strategy, proposals on security of gas supply, the EU emissions trading system and related rules on effort-sharing and land use and forestry as well as a strategy on low-emission mobility.

The regulatory proposals and facilitating measures presented in the package aim at accelerating, transforming and consolidating the EU economy's clean energy transition thereby creating jobs and growth in new economic sectors and business models. The legislative proposals cover energy efficiency, renewable energy, the design of the electricity market, security of supply and governance rules for the Energy Union. The tabled package pursues three main goals:[28]

- **Putting energy efficiency first**
- **Achieving global leadership in renewable energies**
- **Providing a fair deal for consumers**

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[28] (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK of 30 November 2016 on Clean Energy For All Europeans, COM(2016) 860 final)

The facilitating actions include initiatives to accelerate clean energy innovation and to renovate Europe's buildings as well as measures to: encourage public and private investment and make the most of the available EU budget; promote industry-led initiatives to foster competitiveness; mitigate the societal impact of the clean energy transition; involve multiple players including on the one hand Member States authorities, local and city authorities and on the other hand businesses, social partners and investors, and maximise Europe's leadership in clean energy technology and services to help third countries achieve their policy goals.

This package should be seen in the context of the EU leading the way towards **a smarter and cleaner energy for all**, to implement the Paris agreement, fuel economic growth, spur investment and technological leadership, create new employment opportunities and enhance citizen's welfare.[29]

PUTTING ENERGY EFFICIENCY FIRST[30]

Energy efficiency is the most universally available source of energy. Putting energy efficiency first reflects the fact that the cheapest and cleanest source of energy is the energy that does not need to be produced or used. This means making sure that energy efficiency is taken into account throughout the energy system, i.e. actively managing demand so as to optimise energy consumption, reduce costs for consumers and import dependency, while treating investment in energy efficiency infrastructure as a cost-effective pathway towards a low-carbon and circular economy. This will enable retiring generation over-capacity from the market, especially fossil fuel generation.

Buildings account for 40% of total energy consumption and around 75% of them are energy inefficient[31]. Energy efficiency in buildings suffers from underinvestment and numerous barriers. Whereas buildings are regularly maintained or improved, energy saving investments are often disregarded because they face a competition for scarce capital, a lack of trustworthy information, lack of skilled workers or doubts on the possible benefits. At today's rate of renovating around 1% of buildings each year, it would take a century to upgrade the building stock to modern, nearly-zero energy levels.[31] Clean energy buildings are about much more than saving energy: they increase living comfort and quality of life, have the potential to integrate renewables, storage, digital technologies and to link buildings with the transport system. Investment in a clean energy building stock can drive the transition to a low-carbon economy.

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[29] (European Commission, 2019 March, Clean energy for all Europeans, https://op.europa.eu/en/publication-detail/-/publication/b4e46873-7528-11e9-9f05-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=null&WT.ria_f=3608&WT.ria_ev=search)

[30] (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK of 30 November 2016 on Clean Energy For All Europeans, COM(2016) 860 final)

[31] (Impact Assessment for the amendment of the Energy Performance of Buildings Directive, SWD(2016) 414)

Upscaling investment in public buildings, such as hospitals, schools, and offices, also depends on availability of private finance and private energy service companies offering innovative mechanisms, such as **energy performance contracting**. Energy saving can also have a positive impact on public budgets, as about €1 billion is spent each year on energy in such public buildings. However, rules for public sector investments and for statistical treatment of assets renovation should be transparent and clear in order to facilitate energy efficiency investment in public assets.

The amendment of the Energy Performance of Buildings Directive[32] has accelerated building renovation rates by reinforcing provisions on long-term building renovation strategies, with a view to decarbonising the building stock by mid-century. European Commission has already proposed to extend beyond 2020 the **energy saving obligations** set in the Energy Efficiency Directive requiring energy suppliers and distributors **to save 1.5% of energy per year**. The proposal will also improve information for project promoters and investors by reinforcing energy performance certificates, making available information on operational energy consumption of public buildings and linking the intensity of public support to the level of energy savings achieved. The proposal calls on Member States to focus investments also on the energy poor, since **energy efficiency is one of the best ways to address the root causes of energy poverty.**

PROVIDING A FAIR DEAL FOR CONSUMERS[33]

Consumers are at the centre of the Energy Union. Energy is a critical good, absolutely essential for full participation in modern society. The clean energy transition also needs to be fair for those sectors, regions or vulnerable parts of society affected by the energy transition.

European Commission proposes to reform the energy market to **empower consumers** and enable them to be more in control of their choices when it comes to energy. For businesses, this translates into greater competitiveness. For citizens, it means better information, possibilities to become more active on the energy market and be more in control of their energy costs. The first step in the direction of putting consumers at the centre of the Energy Union is to provide them with better **information**[34] about their energy consumption and their costs. The proposals will entitle consumers to **smart meters**, clear bills and easier switching conditions. The proposals will also make it cheaper to switch through the elimination of termination fees. Certified comparison tools will provide consumers with reliable information about the offers available to them.

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[32] (DIRECTIVE (EU) 2018/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018, amending Directive 2012/27/EU on energy efficiency, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2002&from=EN, COM(2016) 765 final)

[33] (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK of 30 November 2016 on Clean Energy For All Europeans, COM(2016) 860 final)

[34] (European Commission, 2019 March, Clean energy for all Europeans, https://op.europa.eu/en/publication-detail/-/publication/b4e46873-7528-11e9-9f05-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=null&WT.ria_f=3608&WT.ria_ev=search)

The proposals will provide for more reliable energy performance certificates with a **'smartness' indicator.** The regulatory changes introduced by the current package and the shift from centralized conventional generation to decentralized, smart and interconnected markets will also make it easier for consumers to generate their own energy, store it, share it, consume it or sell it back to the market – directly or as energy cooperatives. **Consumers** will be able to offer **demand response directly** or through energy aggregators. New smart technologies will make it possible for consumers – if they chose to do so – to control and actively manage their energy consumption while improving their comfort. These changes will make it easier for households and businesses to become more involved in the energy system and respond to price signals.

2.4 Amending Energy Performance of Buildings Directive (2018/844/EU)

Directives 2010/31/EU and 2012/27/EU were amended accordingly to Directive 2018/844/EU.[35]

Amendments to Directive 2010/31/EU:

Article 2a (The following Article was inserted)[35]

Long-term renovation strategy

1. Each Member State shall establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings. Each long-term renovation strategy shall be submitted in accordance with the applicable planning and reporting obligations and shall encompass:

(a) an overview of the national building stock, based, as appropriate, on statistical sampling and expected share of renovated buildings in 2020

(b) the identification of cost-effective approaches to renovation relevant to the building type and climatic zone, considering potential relevant trigger points, where applicable, in the life-cycle of the building

(c) policies and actions to stimulate cost-effective deep renovation of buildings, including staged deep renovation, and to support targeted cost-effective measures and renovation for example by introducing an optional scheme for building renovation passports

(d) an overview of policies and actions to target the worst performing segments of the national building stock, split- incentive dilemmas and market failures, and an outline of relevant national actions that contribute to the alleviation of energy poverty

(e) policies and actions to target all public buildings

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[35] (DIRECTIVE (EU) 2018/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018, amending Directive 2012/27/EU on energy efficiency, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2002&from=EN)

(f) an overview of national initiatives to promote smart technologies and well-connected buildings and communities, as well as skills and education in the construction and energy efficiency sectors, and
(g) an evidence-based estimate of expected energy savings and wider benefits, such as those related to health, safety and air quality

2. In its long-term renovation strategy, each Member State shall set out a roadmap with measures and domestically established measurable progress indicators, with a view to the long-term 2050 goal of reducing greenhouse gas emissions in the Union by 80-95 % compared to 1990, in order to ensure a highly energy efficient and **decarbonised national building stock and in order to facilitate the cost-effective transformation of existing buildings into nearly zero-energy buildings.** The roadmap shall include indicative milestones for 2030, 2040 and 2050, and specify how they contribute to achieving the Union's energy efficiency targets in accordance with Directive 2012/27/EU.

3. To support the mobilisation of investments into the renovation needed to achieve the goals referred to in paragraph 1, Member States shall facilitate access to appropriate mechanisms for:

(a) the aggregation of projects, including by investment platforms or groups, and by consortia of small and medium-sized enterprises, to enable investor access as well as packaged solutions for potential clients
(b) the reduction of the perceived risk of energy efficiency operations for investors and the private sector
(c) the use of public funding to leverage additional private-sector investment or address specific market failures
(d) guiding investments into an energy efficient public building stock, in line with Eurostat guidance, and
(e) accessible and transparent advisory tools, such as one-stop-shops for consumers and energy advisory services, on relevant energy efficiency renovations and financing instruments

4. The Commission shall collect and disseminate, at least to public authorities, best practices on successful public and private financing schemes for energy efficiency renovation as well as information on schemes for the aggregation of small-scale energy efficiency renovation projects. The Commission shall identify and disseminate best practices on financial incentives to renovate from a consumer perspective taking into account cost-efficiency differences between Member States.

5. To support the development of its long-term renovation strategy, each Member State shall carry out a public consultation on its long-term renovation strategy prior to submitting it to the

Commission. Each Member State shall annex a summary of the results of its public consultation to its long-term renovation strategy.
Each Member State shall establish the modalities for consultation in an inclusive way during the implementation of its long-term renovation strategy.

6. Each Member State shall annex the details of the implementation of its most recent long-term renovation strategy to its long-term renovation strategy, including on the planned policies and actions.

7. Each Member State may use its long-term renovation strategy to address fire safety and risks related to intense seismic activity affecting energy efficiency renovations and the lifetime of buildings.

Article 6 (Article 6 was replaced by the following:)[36]

New buildings

1. Member States shall take the necessary measures to ensure that new buildings meet the minimum energy performance requirements laid down in accordance with Article 4.

2. Member States shall ensure that, before construction of new buildings starts, the technical, environmental and economic feasibility of high-efficiency alternative systems, if available, is taken into account.

Article 7 (In Article 7 the fifth paragraph was replaced by the following:)[36]

Member States shall encourage, in relation to buildings undergoing major renovation, **high-efficiency alternative systems**, in so far as this is technically, functionally and economically feasible, and shall address the issues of healthy indoor climate conditions, fire safety and risks related to intense seismic activity.

Article 8 (Article 8 was replaced by the following:)[36]

Technical building systems, electromobility and smart readiness indicator

1. Member States shall, for the purpose of optimising the energy use of technical building systems, set system requirements in respect of the overall energy performance, the proper

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[36] (DIRECTIVE (EU) 2018/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018, amending Directive 2012/27/EU on energy efficiency, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2002&from=EN)

installation, and the appropriate dimensioning, adjustment and control of the technical building systems which are installed in existing buildings. Member States may also apply these system requirements to new buildings. System requirements shall be set for new, replacement and upgrading of technical building systems and shall be applied in so far as they are technically, economically and functionally feasible.
Member States shall require new buildings, where technically and economically feasible, to be equipped with self- regulating devices for the separate regulation of the temperature in each room or, where justified, in a designated heated zone of the building unit. In existing buildings, the installation of such self-regulating devices shall be required when heat generators are replaced, where technically and economically feasible.

2. With regard to new non-residential buildings and non-residential buildings undergoing major renovation, with more than ten parking spaces, Member States shall ensure the installation of at least one recharging point within the meaning of Directive 2014/94/EU of the European Parliament and of the Council and ducting infrastructure, namely conduits for electric cables, for at least one in every five parking spaces to enable the installation at a later stage of recharging points for electric vehicles where:

(a) the car park is located inside the building, and, for major renovations, renovation measures include the car park or the electrical infrastructure of the building or
(b) the car park is physically adjacent to the building, and, for major renovations, renovation measures include the car park or the electrical infrastructure of the car park

The Commission shall report to the European Parliament and the Council by 1 January 2023 on the potential contribution of a Union building policy to the promotion of electromobility and shall, if appropriate, propose measures in that regard.

Amendment to Directive 2012/27/EU:[37]

Article 4 (Article 4 of Directive 2012/27/EU was replaced by the following:)

Building renovation
A first version of the Member States' long-term strategies for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private, shall be published by 30 April 2014 and updated every three years thereafter and submitted to the Commission as **part of the National Energy Efficiency Action Plans.**

[37] (DIRECTIVE (EU) 2018/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018, amending Directive 2012/27/EU on energy efficiency, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2002&from=EN)

2.5 European Green Deal

The biggest challenge and opportunity for EU is to become the first climate-neutral continent in the world by 2050. To this end, the European Commission presented at December 2019 the European Green Agreement or the well-known EU Green Deal. The EU Green Deal is the most ambitious package that could help Europe's citizens and businesses reap the benefits of a sustainable transition to green solutions. Essentially, it is the roadmap with actions aimed at energy transition through enhancing resource efficiency and reducing pollution with a view to moving to a clean, circular economy and defining profoundly transformative policies at regional and national level.

Figure 2.2: European Green Deal.[38]

The Green Deal has 3 parameters that must be manifested simultaneously. The first is to change the production process in the EU, in order to reduce greenhouse gas emissions but also to reuse materials, the second is to change the energy mix of all Member States in order to reach a Europe without coal. Finally, the third is the change of the consumer model. All these are divided into 7 policy areas, which are namely: Clean Energy, Sustainable Industry, Construction and Renovation, Sustainable Mobility, Biodiversity, the action "from farm to fork" and the elimination of pollution and aim to the well-being of citizens.

One of the main pillars of the Green Deal is the upgrading of the EU building stock. The building stock is responsible for 36% of CO_2 emissions in Europe, while the vast majority of buildings (at least 75%) are still energy inadequate. The majority (97%) of the existing building stock requires significant upgrades to achieve the 2050 targets. With the current rate of renovation of buildings at 1% per year, we realize that it would take about a century to convert today's buildings into buildings with almost zero energy consumption. Therefore, it is understood that **the renovation of existing buildings could reduce overall energy consumption in the EU by 5-6% and reduce CO_2 emissions by around 5%.**[38]

[38] (European Commission, 2019 December, What is the European Green Deal?)

Investments in energy efficiency stimulate the economy, especially the construction sector, which generates about 9% of Europe's GDP and directly represents 18 million jobs. In particular, SMEs benefit from an enhanced renovation market, as they contribute more than 70% of value added to the EU construction sector. To achieve this, we must ensure that energy demand is reduced.

The EU has adopted a number of measures, such as the Energy Performance of Buildings Directive (2012/27/EU), aimed at decarbonizing the structured environment. In addition, the recent initiative of the European Commission "**Renovation Wave**"[39] is an opportunity for energy and environmental upgrading of buildings with the main target of **achieving the goals of the Paris Agreement for 2050, and consequently tackling energy poverty. Moreover, the "Renovation Wave" can help in reducing the impact of the COVID-19 crisis, as it supports job creation in the construction and renewable energy sectors.**

Finally, the Amending Energy Performance of Buildings Directive (EPBD) aims to increase the ˈintelligenceˈ of the future building, including its ability to interact with other sectors and to create added value for European citizens.

From the above, it should be obvious that technology and design are at the heart of the efforts that allow the building sector to achieve sustainability. Energy efficiency actions for buildings can be considered important opportunities for the implementation of optimal cost solutions. The International Energy Agency supports that energy savings of 500 Mtoe per year worldwide could be achieved through multiple cost-effective technologies between 2020 and 2050. In addition, energy renovations and construction of high-efficiency buildings could reduce the energy use of the building sector by almost 30% by 2050. Also, a further reduction could be achieved through digitization and smart demand management of buildings.

Of course, achieving the EU 2050 target for energy efficiency is not an easy scenario. We need to mobilize public and private investment. The European Green Deal investment plan will provide around €500 billion from the EU budget, but we need at least €1 trillion to achieve the desired neutrality. The European Investment Bank Group, in particular, is expected to provide loans, guarantees and financial instruments, such as private financing for energy efficiency and the installation of a smart finance guarantee for **Smart Buildings**. In addition, in this context, **InvestEU[40]** is expected to fund small-scale, cost-effective social housing renovation initiatives and services. These sources of funding have different mechanisms and requirements, but it is hoped that, through EU investment, private organizations will be encouraged to invest as well.

The transformation of our buildings means that our cities will be upgraded and reborn. This urban transformation with sustainability benefits that includes social, capital and human investment combined with investment in transportation and telecommunications infrastructure for sustainable economic development is in fact sustainable territorial development.

[39] (European Commission, 2020 June, Renovation wave, https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en)

[40] (European Commission, 2020, InvestEU, Contribution to the Green Deal and the Just Transition Scheme, https://europa.eu/investeu/contribution-green-deal-and-just-transition-scheme_el)

3. IMPLEMENTATION OF THE REGULATION ON THE ENERGY PERFORMANCE OF BUILDINGS IN GREECE

In the context of Directive 2002/91/EC of the European Parliament and of the Council on the "Energy Performance of Buildings" Greece had the obligation to harmonize by adopting and implementing relevant legislation until January 2006.

3.1 Energy Efficiency Regulation of buildings (K.En.A.K.)

The first step for the alignment to this Community Directive was the issuance of **Law 3661/2008** (Government Gazette A'/89/2008) "Measures to reduce the Energy Consumption of Buildings and other provisions". By law there was an obligation to issue a relevant "Energy Efficiency Regulation of buildings" **(K.Ev.A.K.)** which, inter alia, should set the minimum technical specifications and energy efficiency requirements for new and radically renovated buildings, as well as the methodology for calculating the energy efficiency of buildings (semi-fixed monthly step status of the European standard ELOT EN ISO 13790 and other relevant standards).

Directive 91/2002/EC was amended by Directive 31/2010/EC and Greece's harmonization with the new directive took place with the adoption of the new **Law 4122/2013** (Government Gazette Series A'/42/2013) "Energy Efficiency of Buildings - Harmonization with Directive 2010/31/EU of the European Parliament and of the Council and other provisions ".

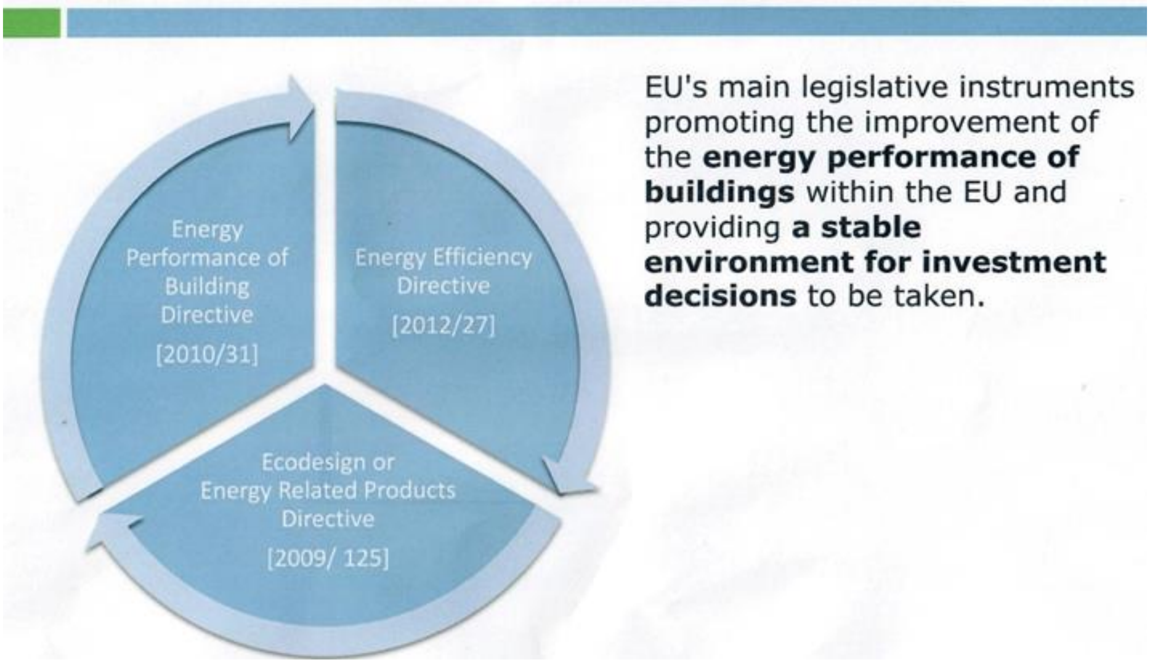


Figure 3.1: EU's main legislative instruments for the improvement of the energy performance of buildings.[41]

[41] (T.E.E.-T.C.G., Panhellenic Association of Certified Energy Inspectors, Konstantinos Laskos, n.d.)

The Energy Efficiency Regulation of Buildings **(K.Ev.A.K.)** is an obligation for Greece both to the requirements of the European Union (Community Directive), but more to its citizens.

The building wealth of the country must, according to modern living requirements, acquire better energy behavior through proper management and energy savings. In this way, in addition to the safety and aesthetics that until now were the main elements of a building, consideration is added, so that energy consumption is as low as possible, while ensuring excellent conditions for users. The Energy Efficiency Regulation of Buildings (K.Ev.A.K.) in accordance with the provisions of article 23, paragraph 2, of **Law 4122/2013**, continues to be valid until a new decision is issued for the revision of the Regulation.

3.1.1 LAW 4122/13 AND LAW 4342/15

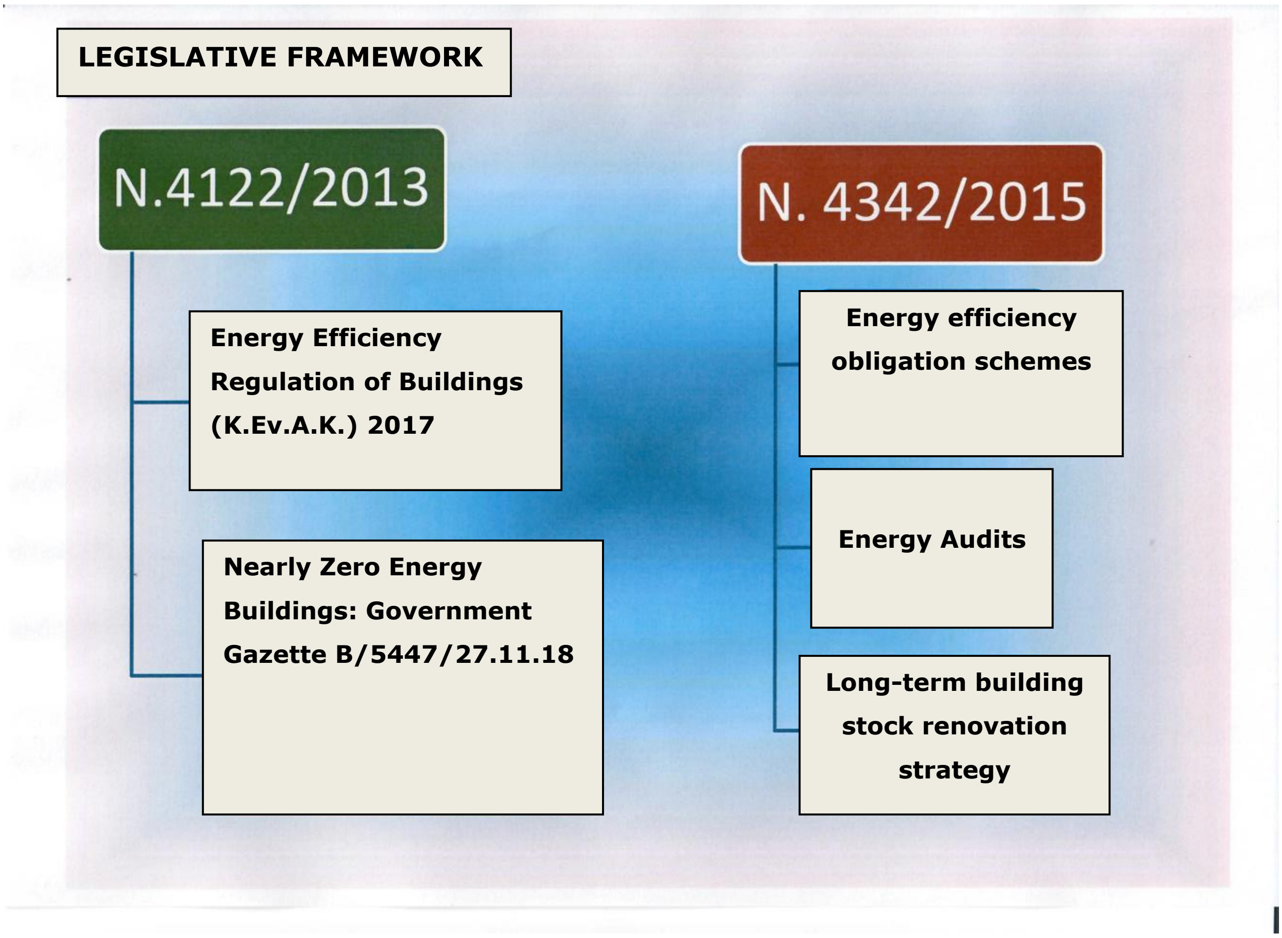


Figure 3.2: Greece's main legislative instruments for the improvement of the energy performance of buildings.[42]

[42] (Ministry of Environment, Energy and Climate Change of Greece, Vasiliki Sita, 2019)

Law 4122/2013 • Article 2, paragraph5: « building with nearly zero energy consumption "means" building with very high energy efficiency, determined in accordance with article 3 of the Law. Nearly zero or very low amount of energy required must be covered to a very large extent in energy from renewable sources, including energy produced on site or near the building. » •

Law 4122/2013 • Article 9, paragraph1: « From 1.1.2021, all new buildings must be buildings with nearly zero energy consumption, while for new buildings that house services of the public and wider public sector, this obligation enters into force from 1.1.2019. » •

Target for Energy Upgrading of Public Buildings:

Article 9 Law 4122/2013: From 1.1.2019 all new public buildings must be buildings of Nearly Zero Energy Consumption.

Article 7 Law 4342/2015: Every year, 3% of the total area of the central public administration buildings must be radically upgraded (buildings with area over 250sqm).

Government Gazette Series B' 5447/27.11.2018, Ministry of Environment, Energy and Climate Change Decision No. 85251/242 « Approval of a National Plan for increasing the number of nearly Zero Energy Buildings (nZEB) ».

To qualify a building as a Building with nearly Zero Energy Consumption (**nZEB**), it has to:[43]

- be energy **class "A",** if it is a **new building**,
- be energy **class "B+",** if it is an **existing building**.

The numerical index of primary energy consumption is the one that results from the current Energy Efficiency Regulation of Buildings **(K.Ev.A.K.).**

[43] (Ministry of Environment, Energy and Climate Change of Greece, 2019 January, National legislation on nZEB)

3.2 Technical Directives T.E.E.-T.C.G. (T.O.T.E.E.)

Effective energy management directly and indirectly protects the environment, saves energy resources and contributes to the economy not only of the building users, but also of the country itself. Utilizing the scientific potential of its Members, Technical Champer of Greece (T.E.E.-T.C.G.) prepared in collaboration with the State the necessary **Technical Directives**, which specify the standards of studies and inspections of the energy efficiency of buildings, in the Greek climatic and building data.

The Technical Directives T.E.E. (T.O.T.E.E.) were initially approved by the Ministry of Environment, Energy and Climate Change with **Decision No. 17178 / Government Gazette B 1387-2010** and are implemented as follows:[44]

- TOTEE 20701−1/2010 «Detailed national parameters for the calculation of the energy efficiency of buildings and the issuance of the energy efficiency certificate».
- TOTEE 20701−2/2010 «Thermophysical properties of building materials and audit of thermal insulation adequacy of buildings».
- TOTEE 20701−3/2010 «Climatic data of Greek regions».
- TOTEE 20701−4/2010 «Directives and forms of energy inspections of buildings, boilers and heating and air conditioning installations».

After the two-year implementation of K.Ev.A.K., several questions and comments arose and were recorded, both regarding the process of energy inspections of buildings, as well as the elaboration - submission of energy efficiency studies of buildings.

In order to facilitate, guide and uniformly address the issues that arose, as well as for what was mentioned in the explanatory circulars of the Ministry of Environment, Energy and Climate Change, Technical Champer of Greece (T.E.E.-T.C.G.) submitted relevant texts, per technical instruction, with the necessary clarifications, additions and modifications to the competent department of the Ministry (Special Service of Energy Inspectors).

[44] (T.E.E.-T.C.G., Ministry of Environment, Energy and Climate Change, n.d., The Technical Directives T.E.E. (T.O.T.E.E.))

The relevant texts "Clarifications & Additions of Technical Instructions" were approved by the Minister of the Ministry of Environment, Energy and Climate Change, with **Decision no. 1192 / Government Gazette B 1413-2012,** which were valid with the issuance of the relevant Government Gazette and were incorporated in the second edition of the respective Technical Instructions TEE (TOTEE): 20701-1/2010, 20701-3/2010 and 20701-4/2010.

By the same Decision the following technical directive was also approved:

- TOTEE 20701−5/2012 «Cogeneration of Electricity, Heat and Cooling: Facilities in Buildings».

After the issuance of law 4122/2013, the Ministry of Environment, Energy and Climate Change, notified a draft ministerial decision entitled "Approval and implementation of the Technical Directives TEE for the Energy Efficiency of Buildings" to the European Commission (2013/213/GR), in application of the provisions of Presidential Decree 39/2001 (Government Gazette A28/2001).

Subsequent comments were made by the European Commission with document No. C(2013) 4758 final / 19.7.2013, which were accepted and incorporated in the Technical Directives with document No. 724/2013 / 6.6.2014 of Ministry of Environment, Energy and Climate Change.

The final approval of the Technical Directives of the Technical Champer of Greece (T.E.E.-T.C.G.) by the European Commission, after the incorporation of its remarks, was made with its document No. 791 / 3.10.2014.

Following the approval of the Technical Directives of T.E.E.-T.C.G. by the European Commission, the Ministry of Environment, Energy and Climate Change re-issued a ministerial decision with No 2618 / 23.10.2014 (Government Gazette B2945) for the "Approval and implementation of the Technical Directives T.E.E. for the Energy Efficiency of Buildings" in which the new versions of the Technical Directives of the T.E.E.-T.C.G., amended with the incorporation of the above remarks, are notified in annexes. The same decision revokes the previous approvals.

The new versions of the Technical Directives that are valid after the last approval decision are listed in the following table:

TECHNICAL DIRECTIVES (T.O.T.E.E.)	Description	APPROVAL DECISIONS	REPUBLICATIONS
TOTEE 20701-1/2017	Detailed national parameters for the calculation of the energy efficiency of buildings and the issuance of the energy efficiency certificate.	Government Gazette B 4003/17-11-2017	First Edition
TOTEE 20701-2/2017	Thermophysical properties of building materials and audit of thermal insulation adequacy of buildings.	Government Gazette B 4003/17-11-2017	First Edition
TOTEE 20701-3/2010	Climatic data of Greek regions.	Government Gazette B 2945/23-10-2014	Third Edition
TOTEE 20701-4/2017	Directives and forms of energy inspections of buildings, boilers and heating and air conditioning installations.	Government Gazette B 4003/17-11-2017	First Edition
TOTEE 20701-5/2017	Cogeneration of Electricity, Heat and Cooling: Facilities in Buildings.	Government Gazette B 4003/17-11-2017	First Edition

Table 3.1: The new versions of the Technical Directives (T.O.T.E.E.).[45]

At the same time, Technical Champer of Greece (T.E.E.-T.C.G.) developed special software for the calculation of energy efficiency and classification of buildings, both during the process of energy inspections and during the preparation of an energy efficiency study.

The **software TEE-K.Ev.A.K.** will be constantly updated and enriched, in order to include each time the changes of the legislative framework and the technical directives that concern the application of The Energy Efficiency Regulation of Buildings **(K.Ev.A.K.).**

45 (T.E.E.-T.C.G., n.d., The Technical Directives T.E.E. (T.O.T.E.E.))

3.3 National Plan for Energy and Climate

The obligation to build all new buildings with energy class **A** and **A+** specifications was not implemented for 2020, as provided. As it appears from the Memorandum of Cooperation signed by the political leadership of the Greek Ministry of Environment and Energy, adopting a proposal of the Technical Chamber of Greece (T.E.E.-T.C.G.), the promotion of energy savings in the building sector faces new obstacles and challenges.

In particular, the Greek Ministry of Environment and Energy and the Technical Chamber of Greece (T.E.E.-T.C.G.), agreed that all buildings starting to be constructed with building permits issued in 2019 must meet the minimum energy class **B** requirements.

For those building permits that already issued from 01-January-2020 to 31-December-2020 and concern either new or additions to existing buildings, there is an obligation to submit an Energy Efficiency Study for energy category **B+**. The same regime applies to those that will be submitted until the first five months of 2021.

The aim is not to hurt, even further, the construction industry, which after the "blow" it received during the years of economic recession in Greece, has to face a new crisis brought to the building sector by the pandemic of the new coronavirus SARS-CoV-2.

From 1 June 2021, studies for new constructions will have to document their classification in energy category **A**, as provided by Community law and as committed by the Greek government to the National Energy and Climate Plan (NECP). The aim of the new regulations is to give the construction industry the opportunity to be properly prepared so that by 2022 the new buildings will have almost zero energy consumption.

As market participants point out, the obligation to construct buildings of category **A** and **A+** (from **B** that was in force in 2019) will increase the construction cost of an apartment by 5%-10% and a detached house by 15%.
For Greece one of the goals of NECP is for 15% of the existing houses to be renovated or to be replaced by new buildings with almost zero energy consumption. The total number of buildings to be renovated is estimated at around 600.000. Therefore, every year an average of 60.000 buildings or building units it is planned to upgrade their energy consumption or be replaced by new more energy efficient ones. In total, the improvement of the energy efficiency of the building stock is estimated to lead to an increase in domestic added value by €8 billion and the creation and maintenance of 22.000 new full-time jobs.
More generally, in the field of energy saving, Greece should have completed and sent to the Commission the long-term strategy which will outline all the measures and actions required for the renovation of Greece's building stock - including funding.

In fact, this is a criterion of conditionality for the release of funds from the next programming period (2021-2027) for energy saving projects. The deadline expired on 10 March 2020 and so far only five Member States (Belgium, Denmark, Finland, the Netherlands and Sweden) had submitted long-term building renewal strategies.

3.3.1 PROGRAM «SAVE-AUTONOMY»

The "Save-Autonomy" Program[46] is the new program for energy upgrading and housing autonomy, which is the successor scheme of the "Saving at Home" programs, with a total budget of approximately €900 million. The design of the Program takes into account the integrated approach of energy saving interventions in the residential building sector and aims at:

- reducing the energy needs of buildings and the emissions of pollutants that contribute to the deterioration of the greenhouse effect
- cost savings for citizens, the improvement of daily living and comfort conditions as well as the safety and health of citizens when using these buildings
- achieving a cleaner environment

The Program **is based on providing incentives for energy saving interventions** and enhancing energy autonomy in the residential building sector, with the aim of reducing energy needs and the consumption of conventional fuels, in the context of the transition to a **"Smart Home".** The Program concerns buildings that have a building permit or other legal document, are used as the **main residence** and whose owners meet specific income criteria. In particular, the Program includes five (5) categories of incentives, in which the Beneficiaries are included according to their income. Additional incentive is given to the lignite areas of the country, as a fair transition clause. There are also incentives for energy upgrading interventions in apartment buildings with individual applications for individual apartments that include shared and non-shared upgrading interventions, while a special category of incentives is provided for independent energy upgrading interventions only in the common areas of an apartment building, without including interventions in the apartments. The applications for detached houses and individual apartments started on 11/12/2020 and will be completed on 01.02.2021. The Program «Save-Autonomy» is funded by the European Regional Development Fund (ERDF) and national resources, and provides incentives in the form of a grant (direct aid) and a loan («Save II» Fund) with an interest rate subsidy. Beneficiary of the Program and Administrator of the "Save II" Fund is the Hellenic Development Bank S.A. and financing is provided through the Operational Program "Competitiveness, Entrepreneurship and Innovation".

[46] (Ministry of Environment, Energy and Climate Change of Greece, 2020, The "Save-Autonomy" Program, https://exoikonomo2020.gov.gr/to-programma

4. ENERGY AUDITS AND ENERGY UPGRADING OF BUILDINGS

4.1 TEE-KENAK SOFTWARE FOR ENERGY AUDITS OF BUILDINGS

TEE- KENAK software was produced by the Energy Saving Team of the Institute for Environmental Research and Sustainable Development (**IERSD**) of the National Observatory of Athens in coordination with the Technical Chamber of Greece (**T.E.E.-T.C.G.**).

It is applied for the energy inspection of buildings in order to export the Certificate of Energy Performance (CEP), the calculations for the buildings' energy performance and the submission of the Buildings Energy Performance Study.
The software was produced according to the European and National standards, the Regulations for the Buildings' Energy Performance (KENAK 2017) and the Technical Directives of the Technical Chamber of Greece (TOTEE).

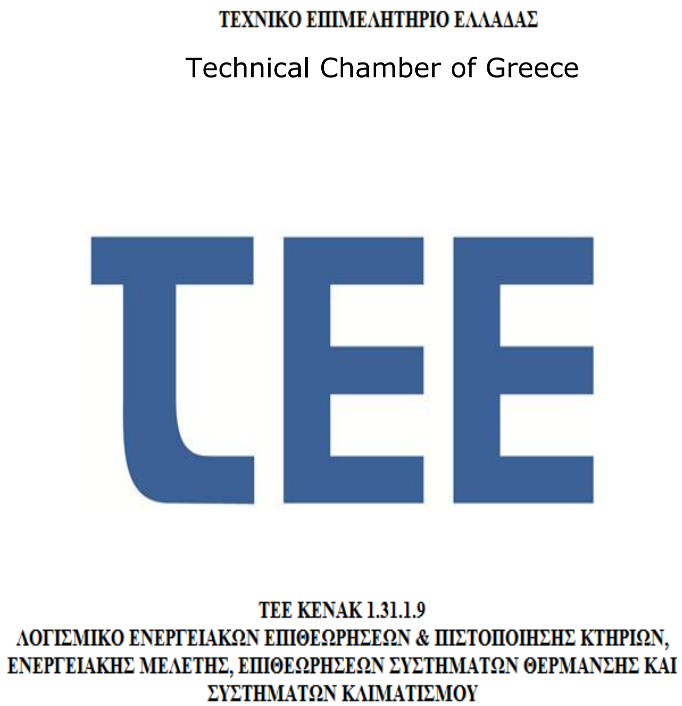


Figure 4.1: TEE-KENAK software.[47]

[47] (T.E.E.-T.C.G., n.d.)

4.2. STEP BY STEP METHODOLOGY OF TEE-KENAK SOFTWARE

4.2.1 GENERAL INFORMATION OF THE ENERGY INSPECTION

The **first step** of the software is to submit the **general information of the building** that is under energy inspection. The following figures introduce the fields that shall be completed with the following information:

- Name of the building
- Land registration number
- Owners name
- Communication representative
- Phone number
- Horizontal property's name
- Type of ownership
- Address
- Name/Surname
- E-mail
- Building construction history

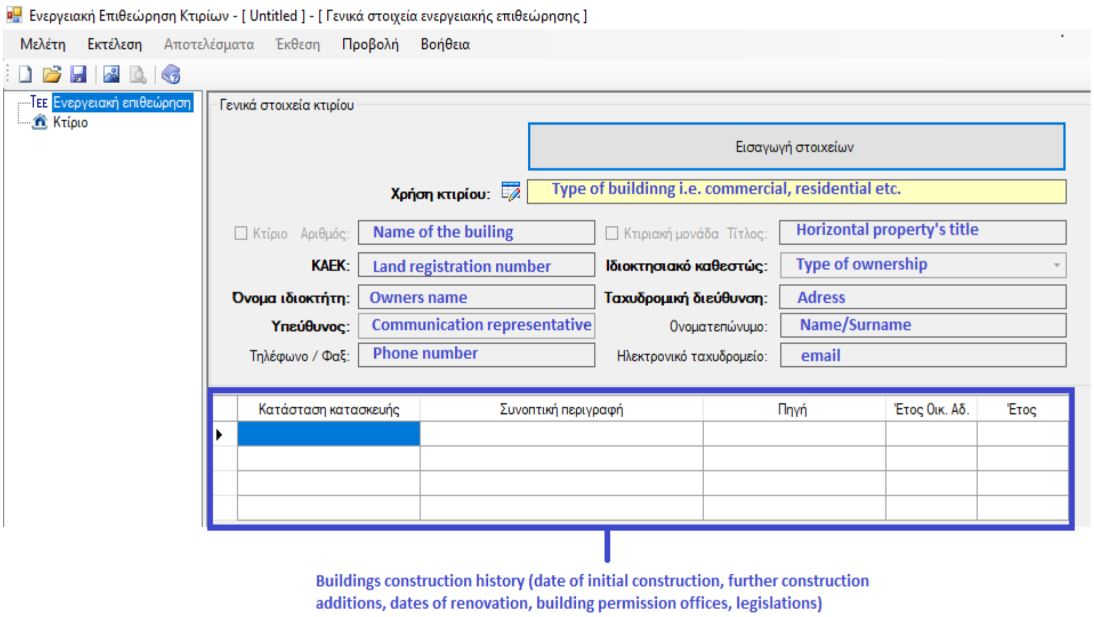


Figure 4.2: General information of the energy inspection (part 1).

- Climate data
- Property's Height
- Type of building

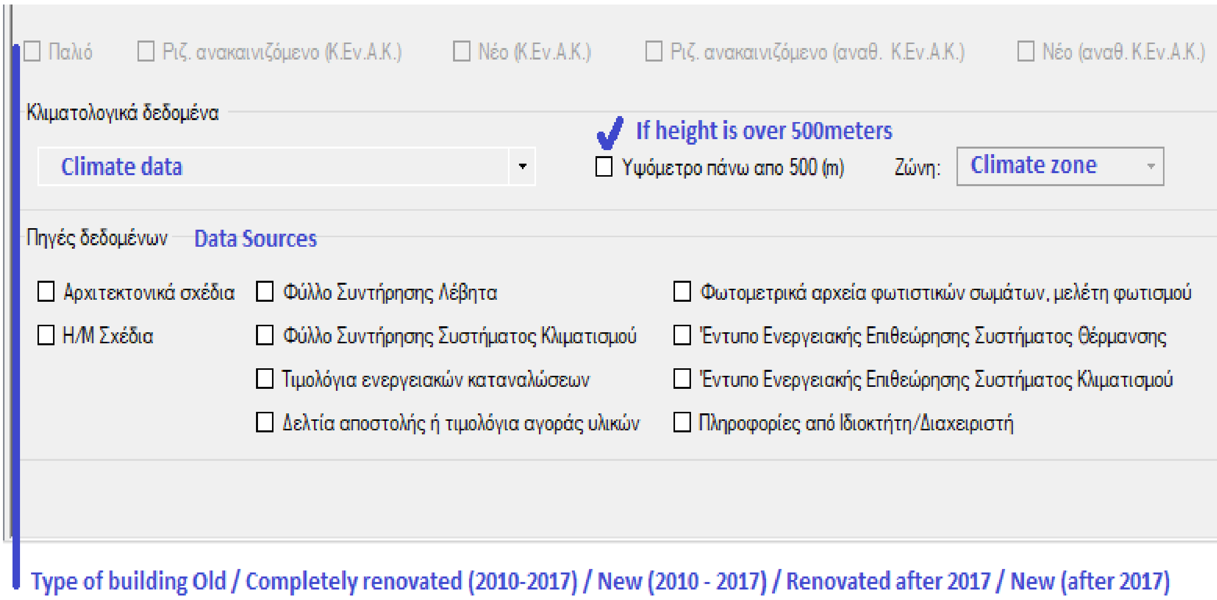


Figure 4.3: General information of the energy inspection (part 2).

- Climate zone

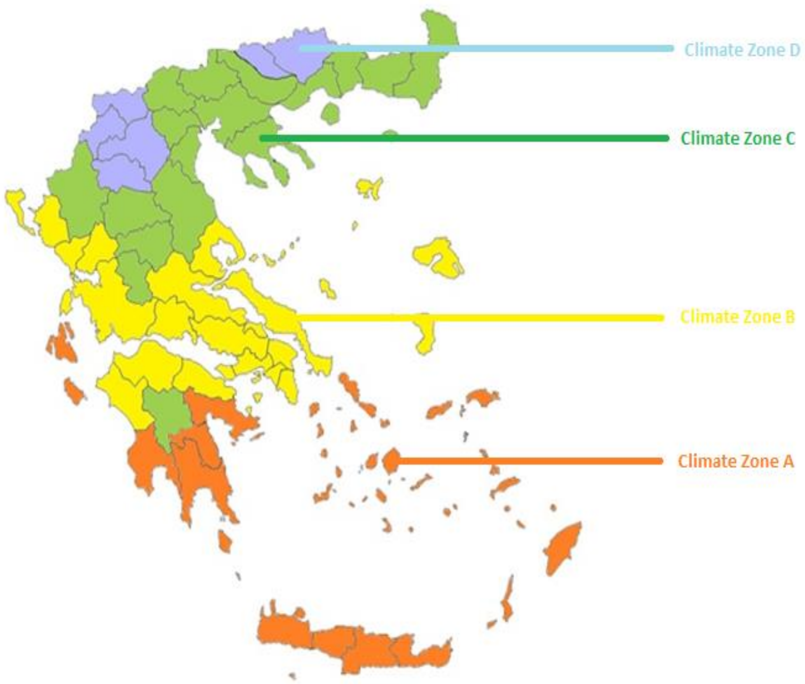


Figure 4.4: General information of the energy inspection (part 3-Climate zones).

The user can move through the aspects of the building by using the **software tree** on the left as shown in figure 4.5.

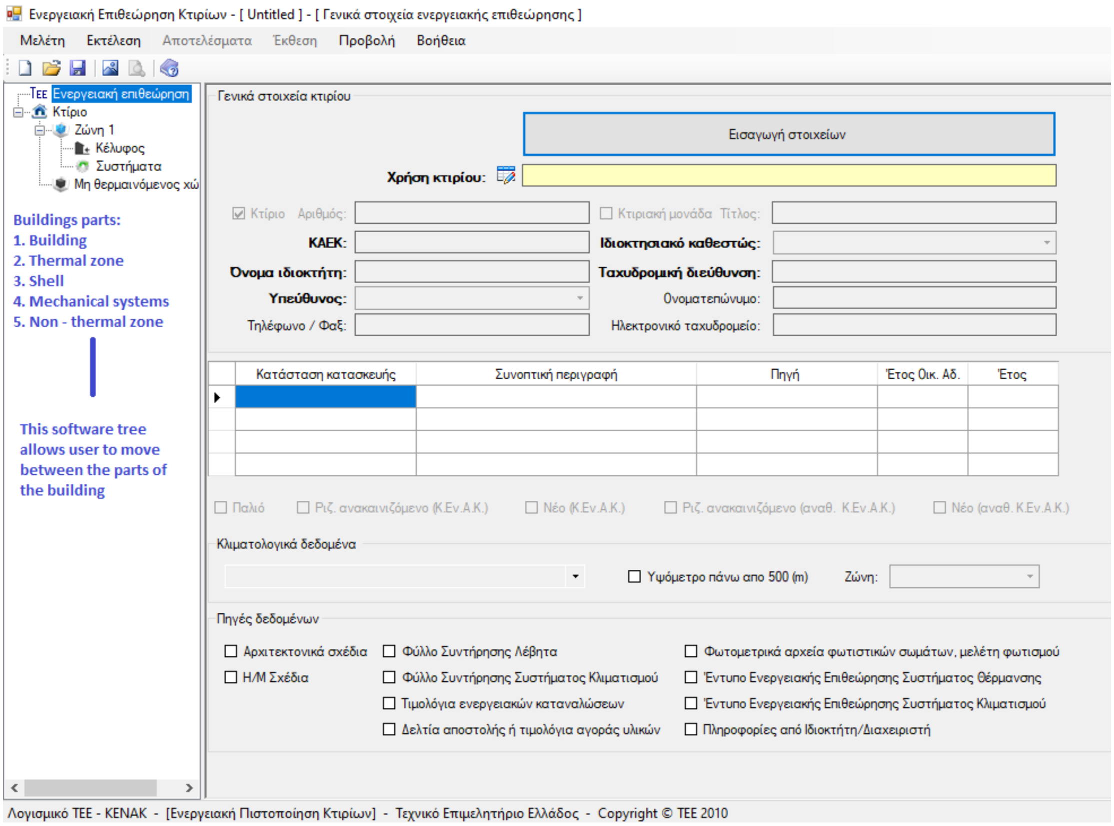


Figure 4.5: General information of the energy inspection (part 4).

4.2.2 BUILDING DETAILS

The **second step** of the software is to submit the **particular information of the building** that is under energy inspection. The following figure introduces the fields that shall be completed with the following information:

- Type of building
- Total Area
- Heating Area
- Cooling Area
- Total Volume
- Heating Volume
- Cooling Volume
- Number of storeys
- Typical floor height
- Height of ground floor
- Number of thermal zones

- Number of non thermal zones
- Number of sun affected areas
- Statistical energy consumption data

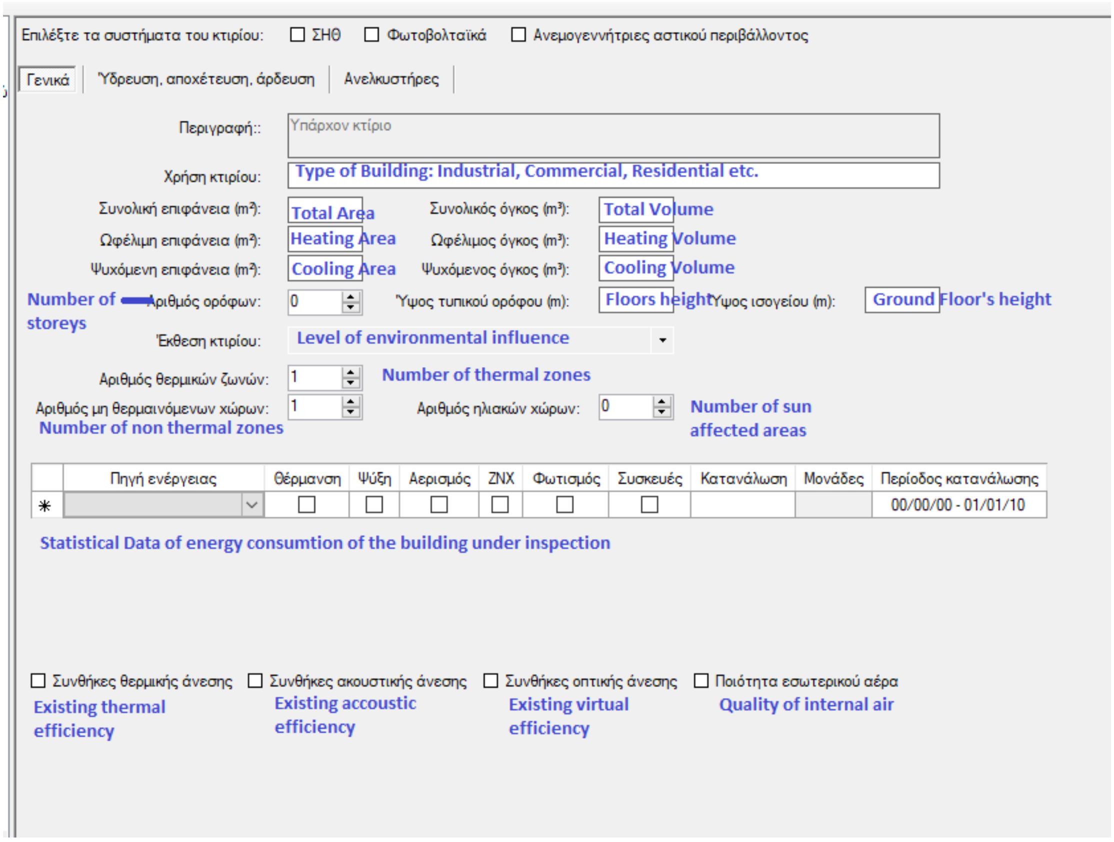


Figure 4.6: Building's particular information.

4.2.3 THERMAL ZONE'S GENERAL DETAILS

The **third step** of the software is to submit the **particular information** of the thermal zone that is under energy inspection. The following figure introduces the fields that shall be completed with the information listed below:

- Use of the thermal zone
- Area in sq. meters (m^2)
- Average use of hot water in cubic meters per year
- Type of control automations
- Air penetration through doors and windows in cubic meters per hour
- Number of chimneys
- Number of ventilators
- Number of external doors
- Number of ceiling fans

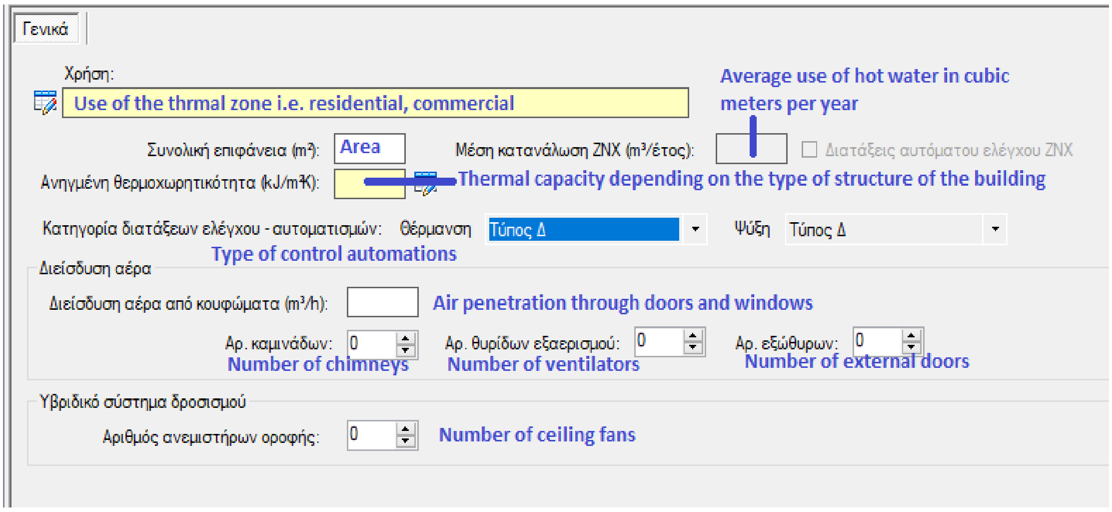


Figure 4.7: Thermal zone's particular information.

4.2.4 THERMAL ZONE'S SHELL CHARACTERISTICS

The **fourth step** of the software is to **list all the characteristics of the shell of the building** starting with the **non-transparent surfaces**, then the **surfaces that are in contact with the ground** and finally the **transparent surfaces**.

NON-TRANSPARENT SURFACES

For every single **surface of the thermal zone** of the building that is in **contact with the external air** or with **another thermal zone** with different standards than the zone that is under inspection the details must be listed in this sub step.The information required is:

- Type (Wall,Door,Open space ground level, Roof)
- Identification of the surface
- Orientation in degrees (γvalue)
- Slope in degrees (b value)
- Area in square meters
- Thermal transmittance (U value)
- Absorption(a value)
- Heat radiation emission factor (ε value)
- Shading factors

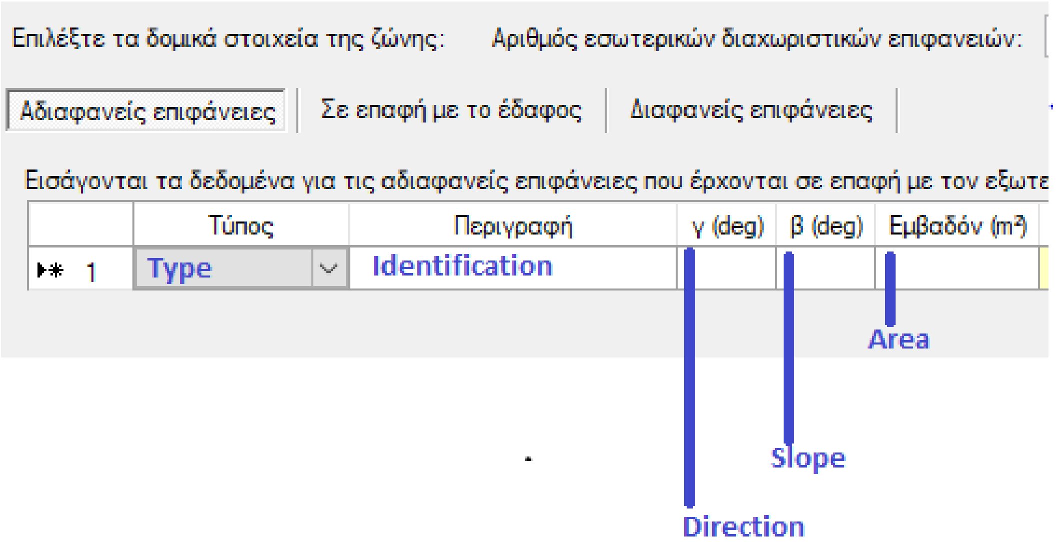


Figure 4.8: Non transparent surfaces information (part 1).

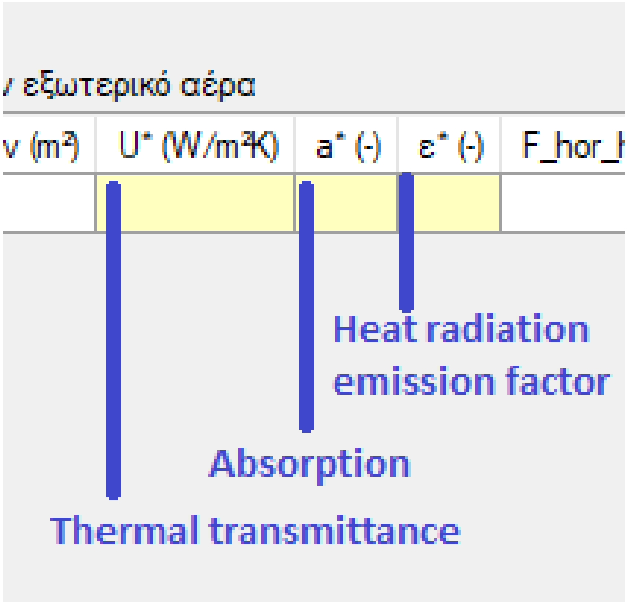


Figure 4.9: Non transparent surfaces information (part 2).

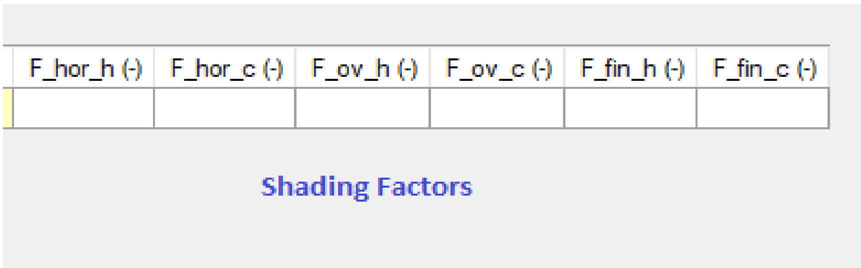


Figure 4.10: Non transparent surfaces information (part 3).

SURFACES IN CONTACT WITH THE GROUND

For every single **surface of the thermal zone** of the building that is in **contact with the ground**, the details must be listed in this sub step. The information required is:

- Type (Wall or Floor)
- Identification of the surface
- Area in square meters
- Thermal transmittance (U value)
- Depth
- Perimeter

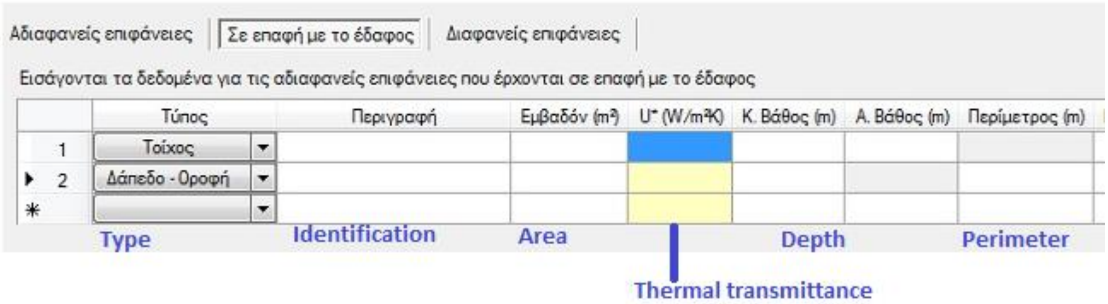


Figure 4.11: Surfaces in contact with the ground information.

TRANSPARENT SURFACES

For every single **transparent surfaces of the thermal zone** of the building the details must be listed in this sub step. The information required is:

- Type
- Identification of the surface
- Orientation in degrees (γvalue)
- Slope in degrees (b value)
- Area in square meters
- Construction details (wooden, metallic, etc)
- Thermal transmittance (U value)
- Transparency of sun radiation factor (g value)
- Shading factors

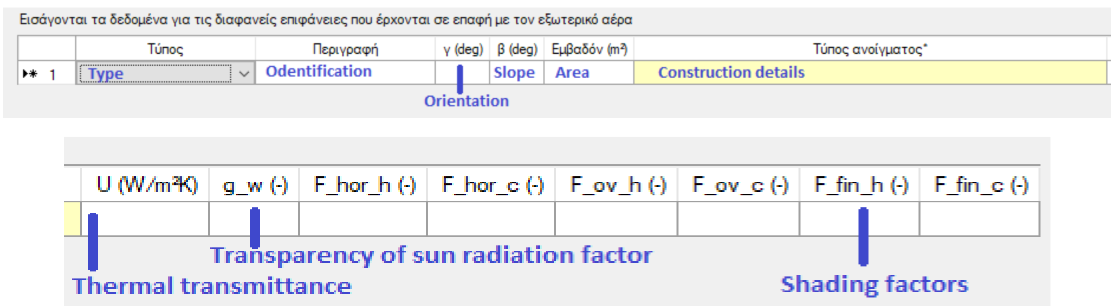


Figure 4.12: Transparent Surfaces information.

4.2.5 THERMAL ZONE'S SYSTEMS CHARACTERISTICS

The **fifth step** of the software is to list all the characteristics of the **systems of the building** that are applied for **heating and cooling** the thermal zone and additionally the method of covering the **hot water needs**. Moreover, if the zone belongs to a building in which the use is anything but residential then the characteristics of **lighting** and **ventilation systems** are also demanded.

Heating systems

In this sub step the energy inspector has to determine:

- One of the possible systems that is used for the thermal zone i.e. heating pumps, geothermal, boilers, furnaces etc.
- Type of energy that is consumed (electricity, biomass, oil etc)
- Power in Kw
- Energy Efficiency ratio
- Coefficient of performance (COP)
- The ratio of usage of the system for every month of the year
- The distribution network
- The losses due to the distribution network
- The terminal units
- The losses due to the terminal units
- The assisting units

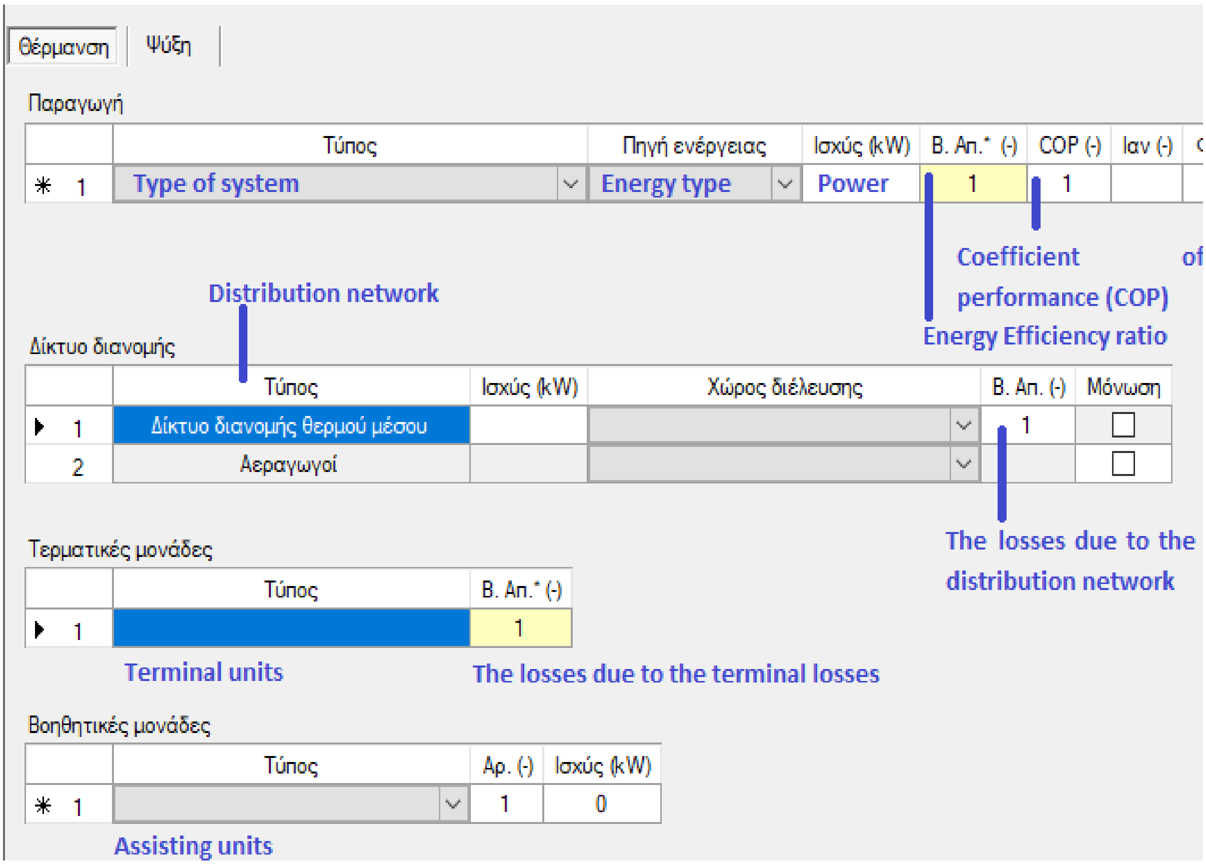


Figure 4.13: Details of the system used for covering the heating needs of the zone.

Cooling systems

In this sub step the energy inspector has todetermine:

- One of the possible systems that is used for covering the cooling needs of the thermal zone
- Type of energy that is consumed (electricity, biomass, oil etc)
- Power in Kw
- Energy Efficiency ratio
- The ratio of usage of the system for every month of the year
- The distribution network
- The losses due to the distribution network
- The terminal units
- The losses due to the terminal units
- The assisting units

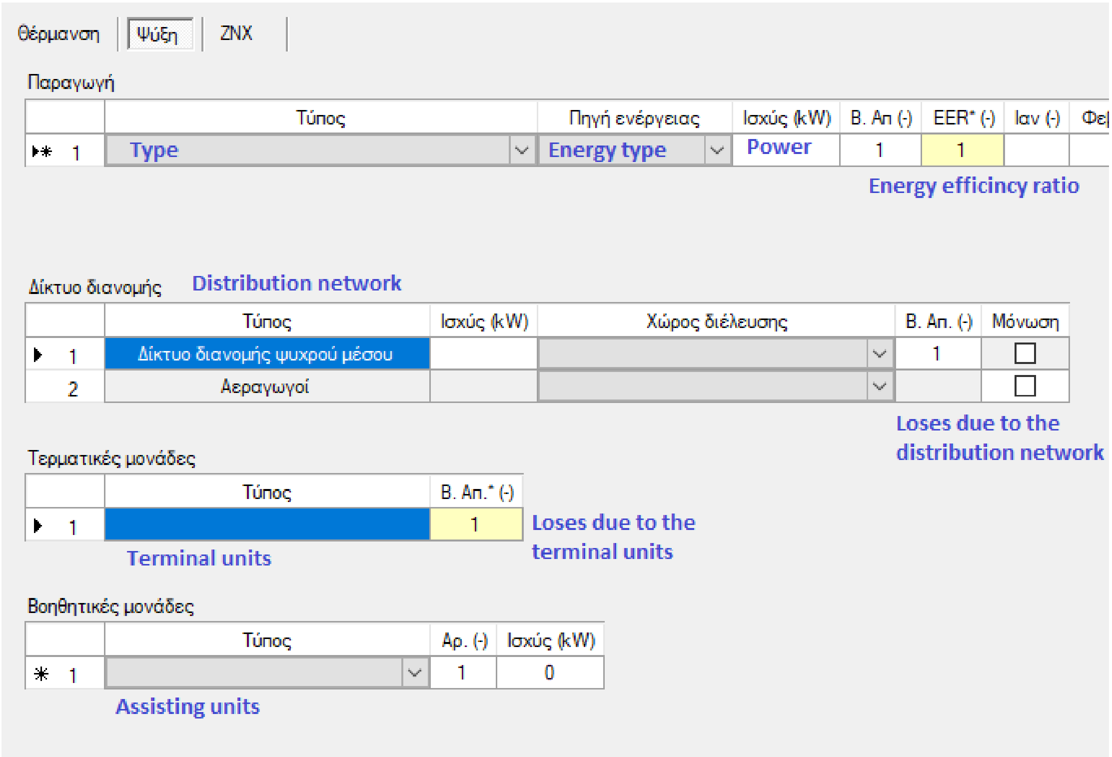


Figure 4.14: Details of the system used for covering the cooling needs of the zone.

System used for hot water consumption

In this sub step the energy inspector has todetermine:

- One of the possible systems that is used for covering the needs for hot water of the thermal zone
- Type of energy that is consumed (electricity, biomass, oil etc)
- Power in Kw
- Energy Efficiency ratio
- The ratio of usage of the system for every month of the year
- The distribution network
- The losses due to the distribution network

- The storage unit
- The losses due to the storage units
- The assisting units

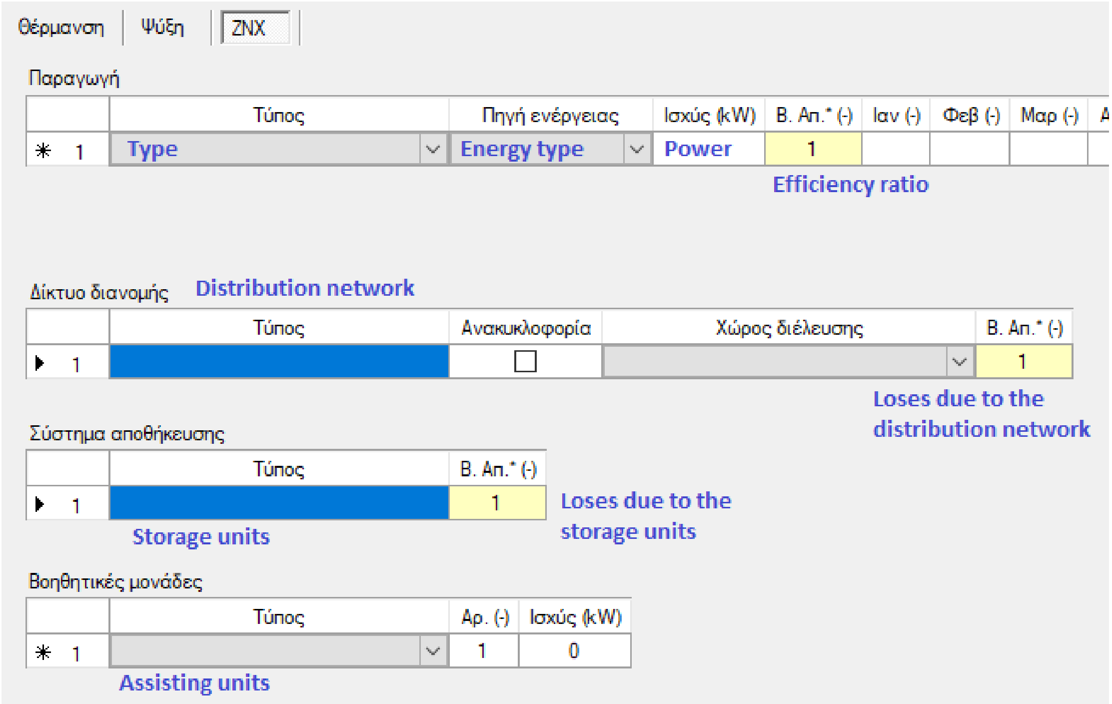


Figure 4.15: Details of the system used for covering the needs for hot water.

Solar system used for hot water

In this sub step the energy inspector has to determine:

- one of the possible solar systems that is used for covering the needs for hot water of the thermal zone
- Utilization rate of the solar radiation
- Area of the solar panels in square meters
- Orientation
- Slope
- Shading Factor

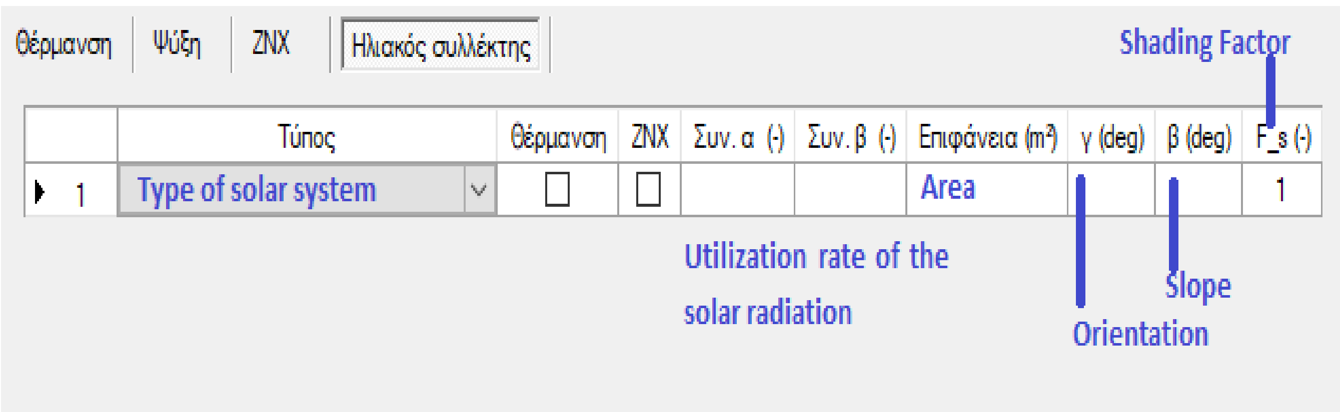


Figure 4.16: Details of Solar system used for hot water.

Ventilation system for non residential buildings

In this sub step the energy inspector has to determine:

- The type of the ventilation
- Volume of the air flow
- Recirculation factor
- Recovery factor
- Special electrical power

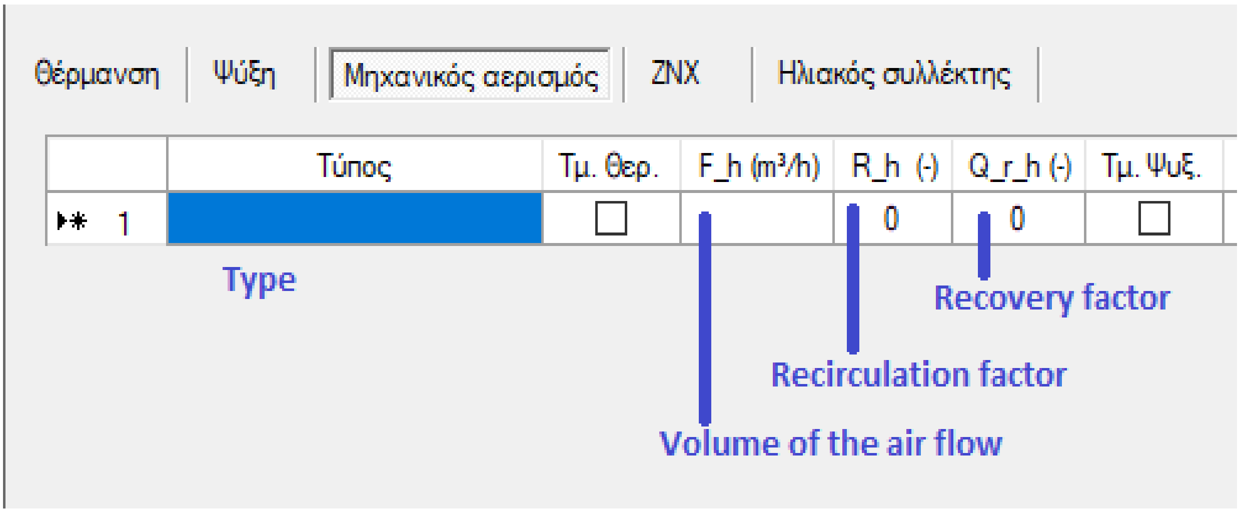


Figure 4.17: Details of the ventilation system.

Lighting system for non residential buildings

In this sub step the energy inspector has to determine:

- The power of the applied lighting and whether it is controlled by atmospheric lighting sensors or motion detectors
- Lighting zone according to the usage
- Type of automatic controllers
- Motion detectors
- System for thermal disposal
- Emergency lighting
- Ups assisted lighting

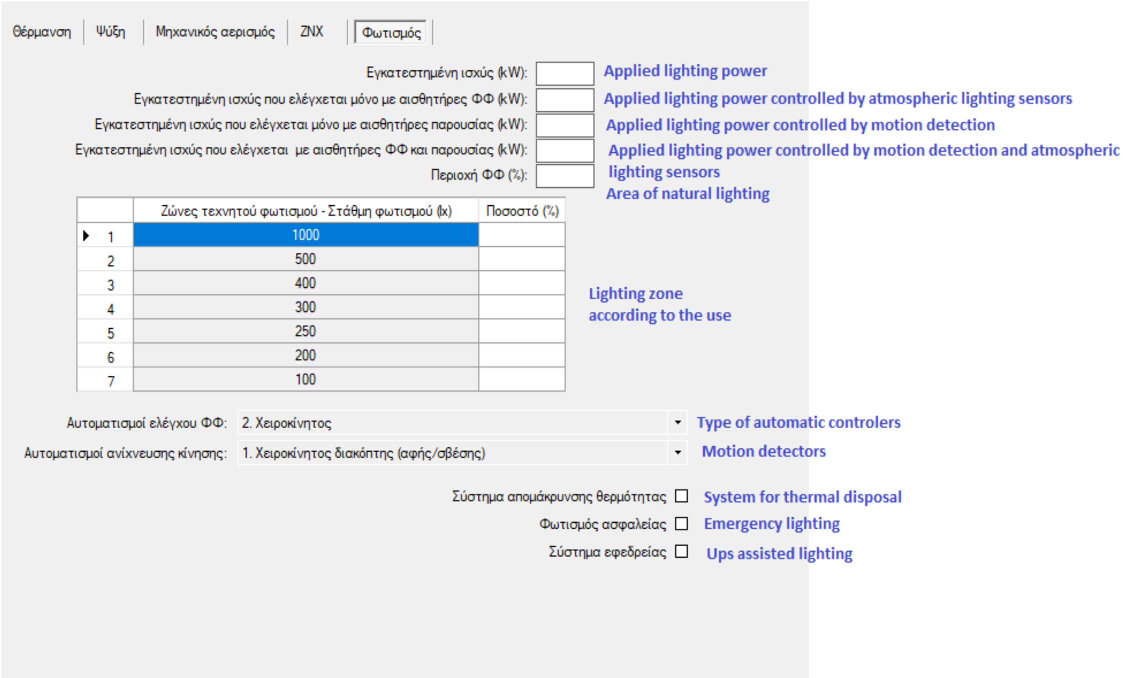


Figure 4.18: Details of the lighting system.

4.2.6 SOFTWARE RUNNING AND RESULTS EXPORTION

The **sixth step** of the software is to **run the data** in order to **produce the results**. Figures 4.19 and 4.20 present the buttons needed to complete the process.

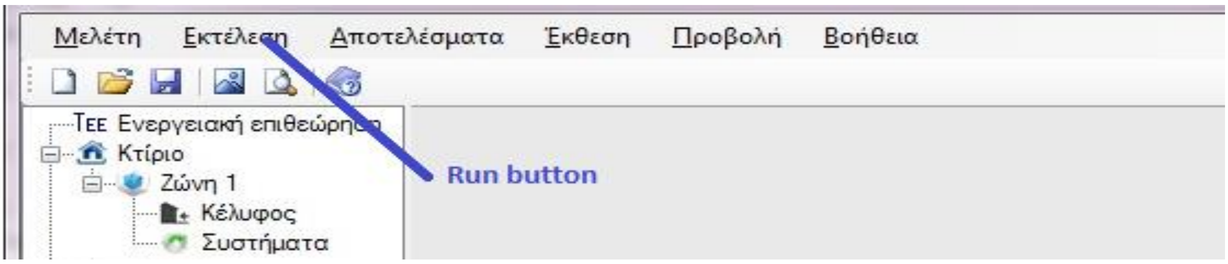


Figure 4.19: Run button.

When the running process is completed, the results button is activated and the user may select between three choices: the **energy class**, the **energy demands** and **consumption** and the **technical – economic analysis**.

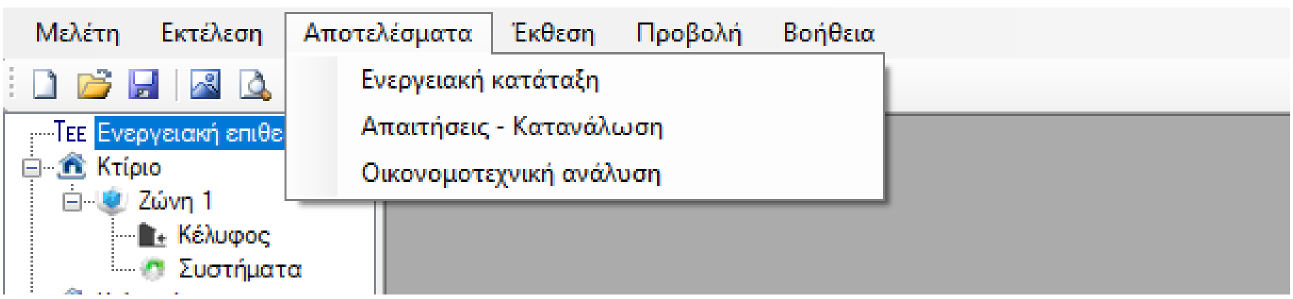


Figure 4.20: Results button.

The **first results** that are acquired are the consumptions for **heating, cooling, hot water, lighting in Kwh/m² for the theoretical building and the building under inspection**. **The results produced for theoretical building are the consumption values that the building should have in order to be classified as B.** Figure 4.21 illustrates the results presentation:

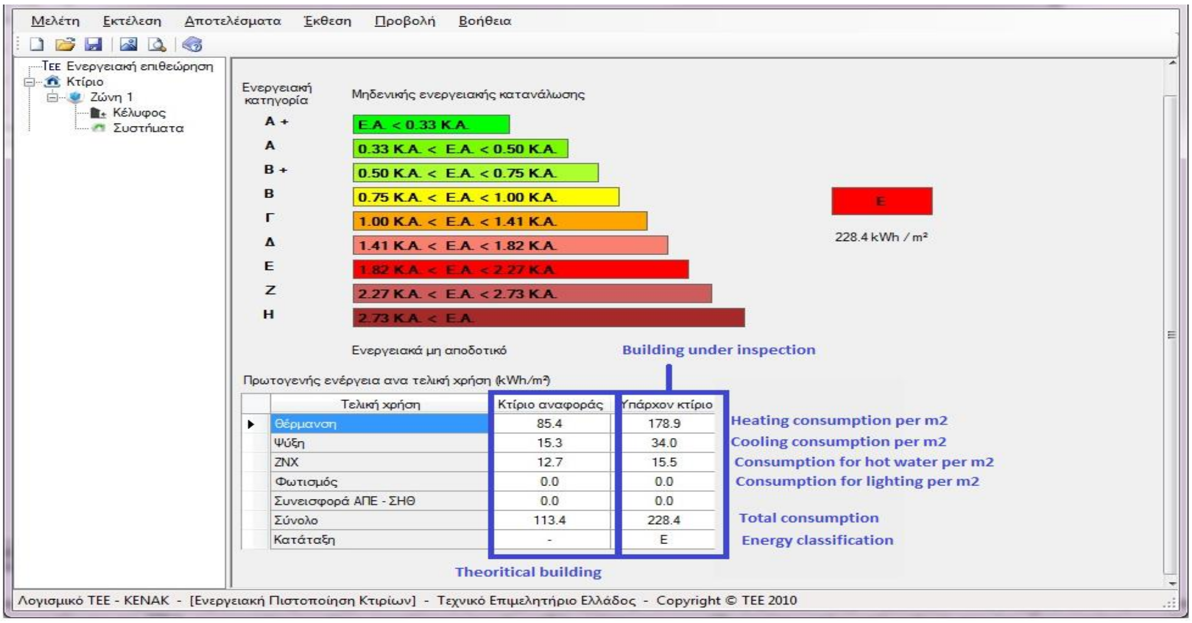


Figure 4.21: Results part 1.

The **second set of results** presents the **demands and consumptions of energy sources analyzed for all the different types of energy and also analyzed for every month** as shown in Figure 4.22.

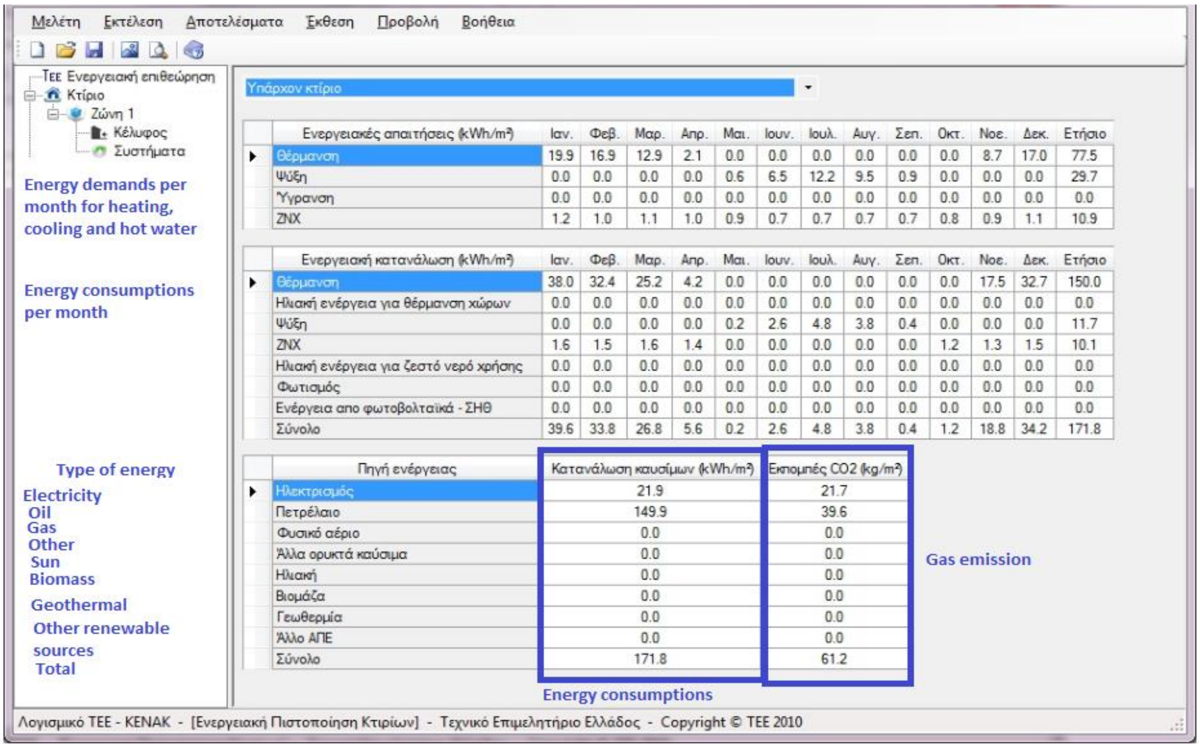


Figure 4.22: Results part 2.

Finally the user accesses the third part of the results that encloses the **cost in Euros for the theoretical building and the actual building under inspection.**

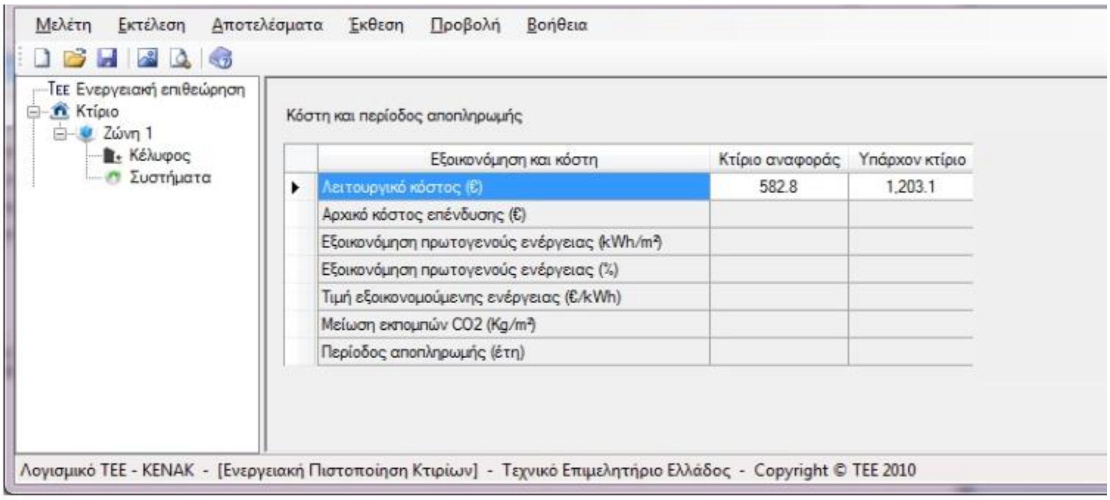


Figure 4.23: Results part 3.

4.2.7 ENERGY EFFICIENCY IMPROVEMENT SCENARIOS

The **results** of the previous step present the **actual demands of the building and the actual consumptions that take place in order to cover these demands.** In addition the results illustrate the parts that are mostly inefficient in the energy cycle of the building. By taking these results into consideration the user can decide the **scenarios** to suggest in order **to improve the energy efficiency of the building. The scenarios may suggest ways to reduce the demands, as well as the increase of the efficiency of the systems used to cover the demands.** In order to achieve this, the user simply duplicate the buildings information on the software's tree and they can make any possible change as presented in Figure 4.24.

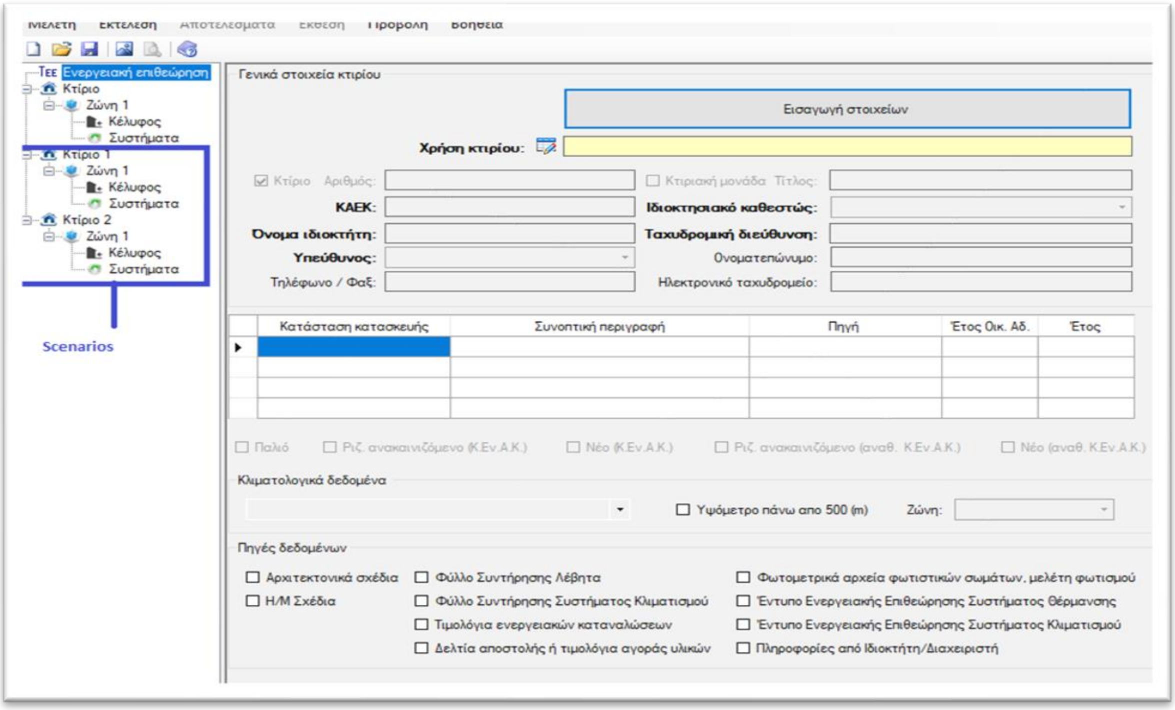
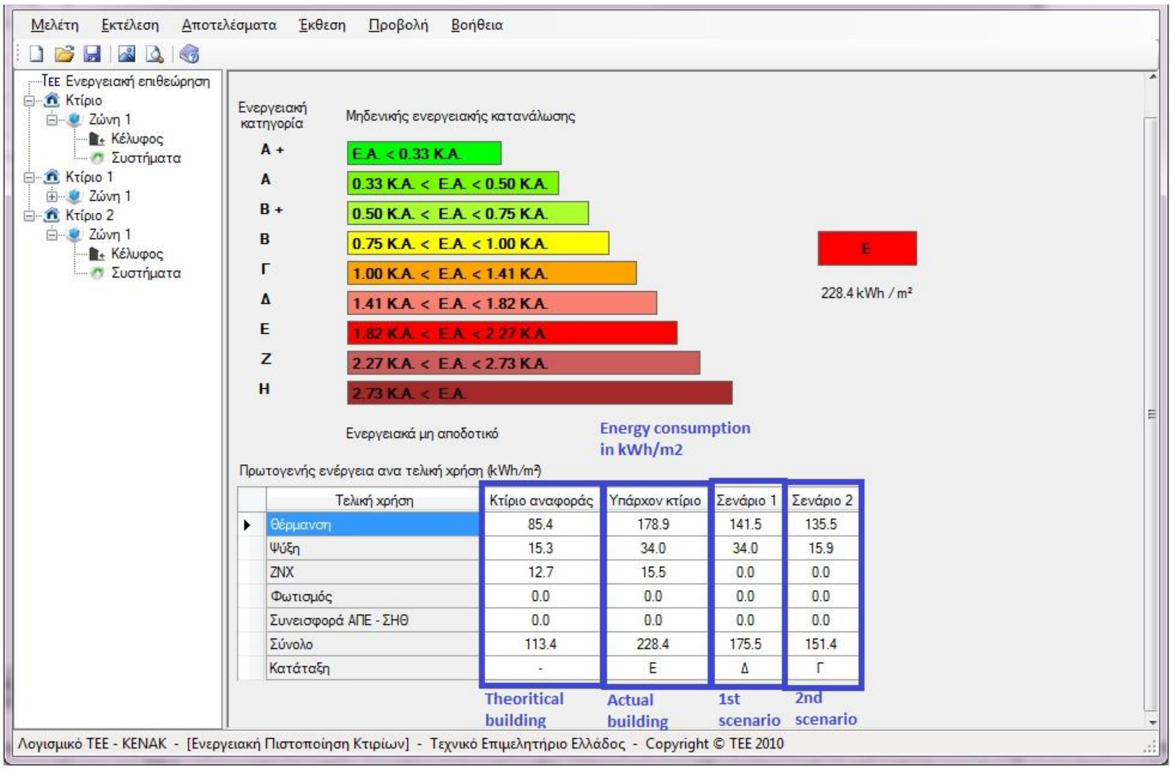


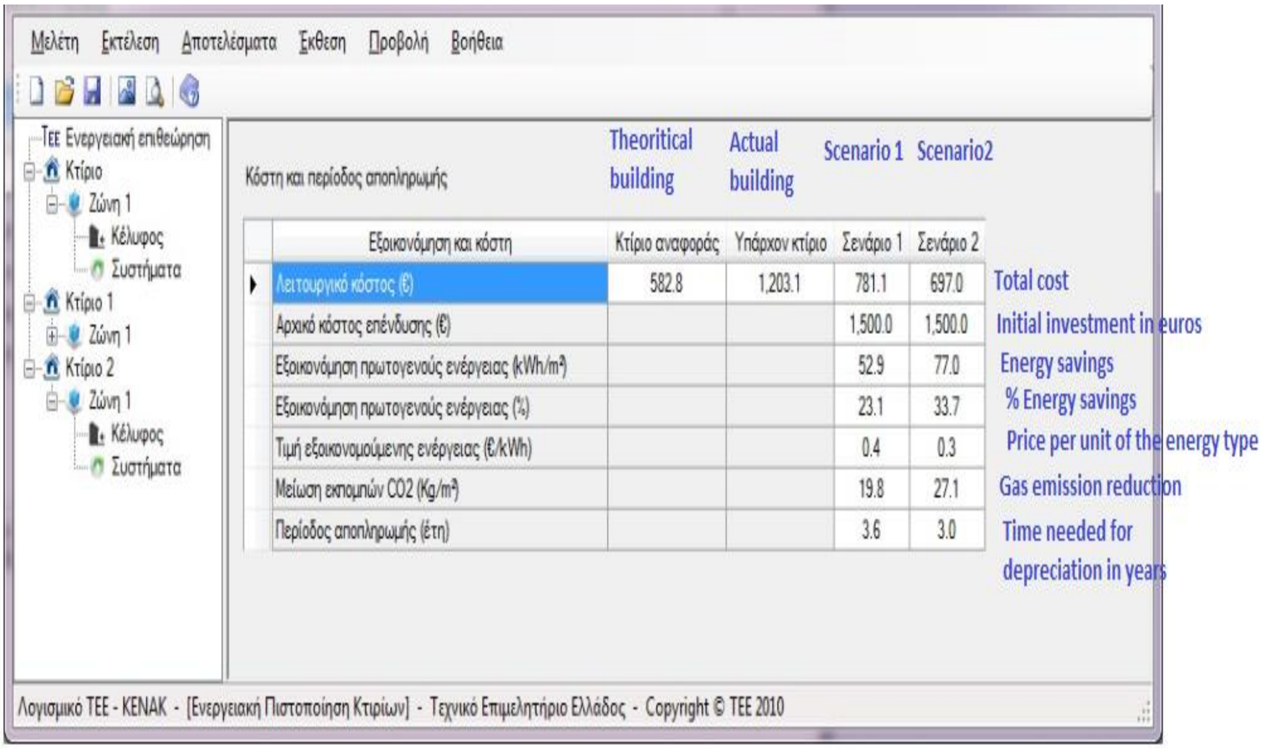
Figure 4.24: Creating scenarios.

Then the user can run again and compare the results of the **theoretical building**, the **actual building** and the potentially improved building that would be created if the suggestions were applied. **The comparison illustrates the results in terms of energy demands, energy consumption and costs in Euros.** Figures 4.25 and 4.26 present the results and the comparison provided by the software.



Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1	Σενάριο 2
Θέρμανση	85.4	178.9	141.5	135.5
Ψύξη	15.3	34.0	34.0	15.9
ΖΝΧ	12.7	15.5	0.0	0.0
Φωτισμός	0.0	0.0	0.0	0.0
Συνεισφορά ΑΠΕ - ΣΗΘ	0.0	0.0	0.0	0.0
Σύνολο	113.4	228.4	175.5	151.4
Κατάταξη	-	Ε	Δ	Γ

Figure 4.25: Energy consumptions before and after the scenarios.



Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1	Σενάριο 2
Λειτουργικό κόστος (€)	582.8	1,203.1	781.1	697.0
Αρχικό κόστος επένδυσης (€)			1,500.0	1,500.0
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			52.9	77.0
Εξοικονόμηση πρωτογενούς ενέργειας (%)			23.1	33.7
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0.4	0.3
Μείωση εκπομπών CO2 (Kg/m²)			19.8	27.1
Περίοδος αποπληρωμής (έτη)			3.6	3.0

Figure 4.26: Cost and savings analysis.

5. RESIDENTIAL EXAMPLE

This chapter aims to illustrate the demands and consumptions of a residential property and the energy savings gained by the improvements suggested.

As shown in previous chapter the variables that take part in the inspection are the property's shell whose losses provoke the demands for technical heating, cooling and hot water and the systems applied to cover the demands.

5.1 ENERGY INSPECTION AND CLASSIFICATION OF THE APARTMENT

This particular example presents a **one bedroom apartment** in Piraeus Attica whose total area is **51.06 square meters** on the first floor of a residential building. The mail facade of the apartment is on the main road and the second facade on the free space of the buildings field. It was constructed in 1965 and no renovation has been made since then.

The technical information gathered during the inspection were:

- The building was constructed before the 1989 (Thermal Insulation Regulation Act) and due to this fact the walls have no thermal insulation
- The doors and windows had metal frame and single glass
- The heating and cooling needs were covered with two split air condition units – one with 9000btu/h capacity and another with 12.000btu/h capacity
- Hot water needs were covered with a simple electrical heater with 4 kW power filling an 80 litters tank

In the next figure a picture of the main facade is shown:

Figure 5.1: Main facade of the apartment.

Next figure 5.2 presents the plan of the apartment:

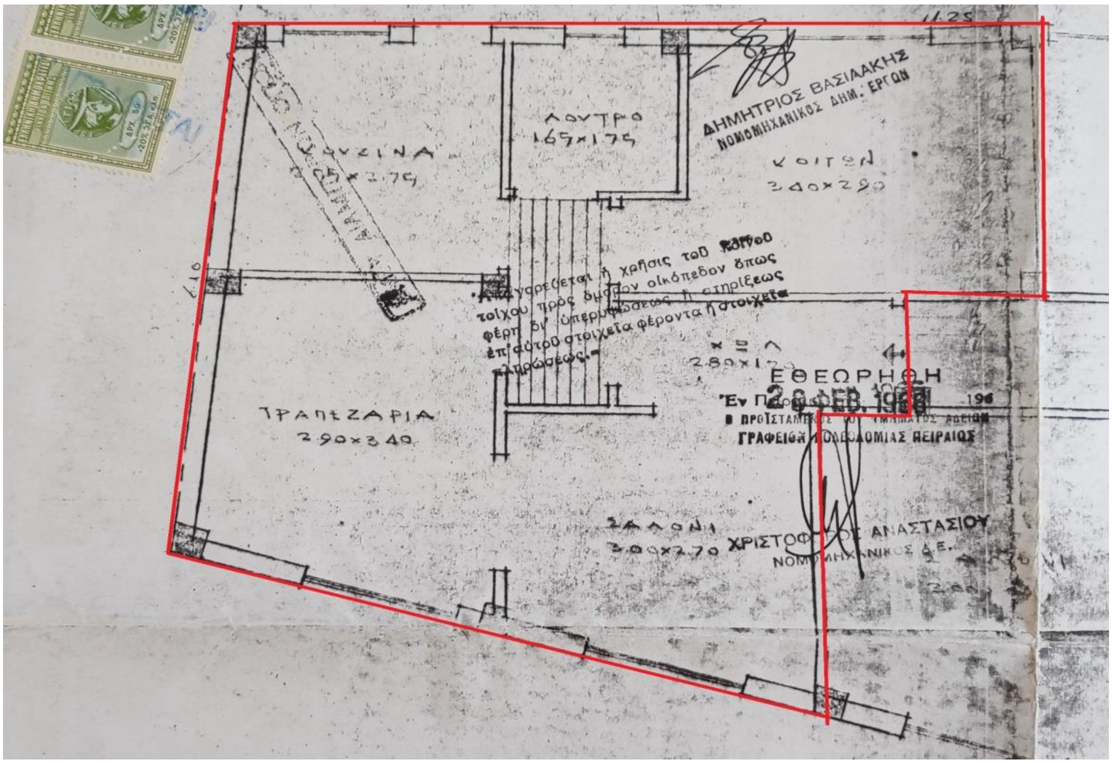
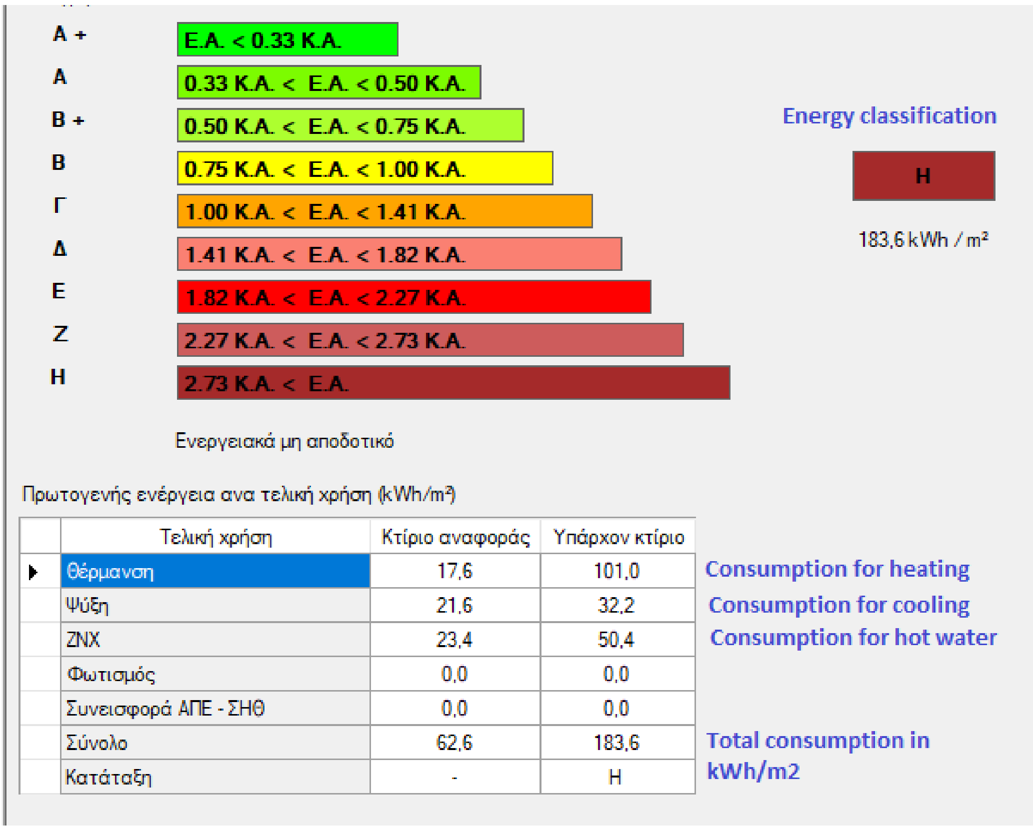


Figure 5.2: Floor Plan of the apartment.

Figure 5.3 shows the energy classification of the consumption of the apartment.



Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο
Θέρμανση	17,6	101,0
Ψύξη	21,6	32,2
ΖΝΧ	23,4	50,4
Φωτισμός	0,0	0,0
Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0
Σύνολο	62,6	183,6
Κατάταξη	-	H

Figure 5.3: Energy classification of the apartment.

In addition the calculations for the **annual energy cost** for this apartment is **549.30€.**

	Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο
▶	Λειτουργικό κόστος (€)	224,6	549,3
	Αρχικό κόστος επένδυσης (€)		
	Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)		
	Εξοικονόμηση πρωτογενούς ενέργειας (%)		Annual total cost in euros
	Τιμή εξοικονομούμενης ενέργειας (€/kWh)		
	Μείωση εκπομπών CO2 (Kg/m²)		
	Περίοδος αποπληρωμής (έτη)		

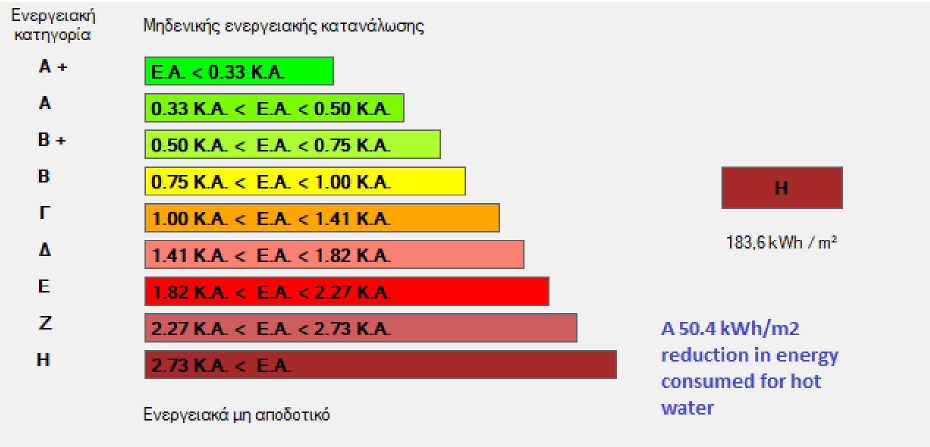
Figure 5.4: Annual energy cost of the apartment.

5.2 FIRST SCENARIO–SYSTEM IMPROVEMENT– SOLAR PANELS FOR HOT WATER

In this **scenario** the improvement applied is a **system of solar panels** to assist the production of hot water. The specifications of the solar panel are:

- the **area** of the panels which is **3 square meters**
- The **orientation** which is **180 degrees** (**directly to the north**)
- The **shading** which is **zero** (it is placed in the terrace)
- The **slope** which is **45 degrees**
- The **cost** which is **1200€**

The results are:



Πρωτογενής ενέργεια ανα τελική χρήση (kWh/m²)

	Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1
▶	Θέρμανση	17,6	101,0	101,0
	Ψύξη	21,6	32,2	32,2
	ZNX	23,4	50,4	0,0
	Φωτισμός	0,0	0,0	0,0
	Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0	0,0
	Σύνολο	62,6	183,6	133,3
	Κατάταξη	-	H	E

Figure 5.5: First scenario's results in kWh/m2.

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1
Λειτουργικό κόστος (€)	224,6	549,3	398,7
Αρχικό κόστος επένδυσης (€)			1.200,0
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			50,4
Εξοικονόμηση πρωτογενούς ενέργειας (%)			27,4
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0,5
Μείωση εκπομπών CO2 (Kg/m²)			17,2
Περίοδος αποπληρωμής (έτη)			8,0

Annual cost after the scenario
Initial investment in euros
Energy savings in kWh/m2
Years for depreciation

Figure 5.6: Savings due to the solar panels for hot water.

The conclusions drawn by Figures 5.5 and 5.6 are:

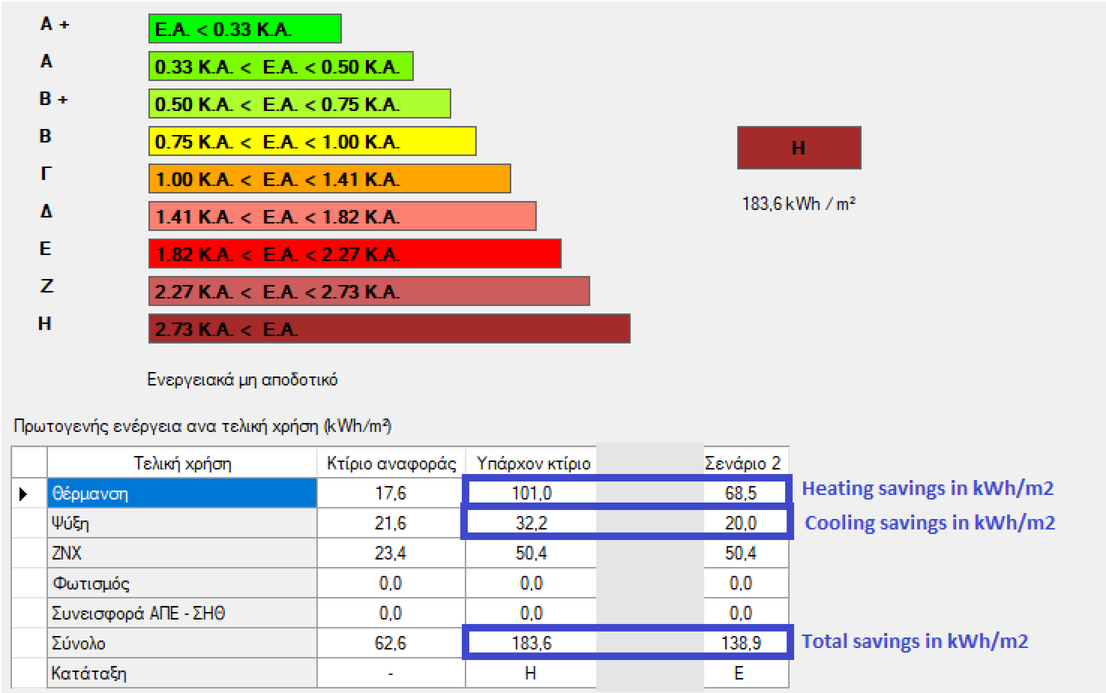
- The **installation of solar panels** has an **impact** on the energy consumptions **in hot water**
- The **annual total energy savings in kWh/m²** are: **50.4 kWh/m²**
- The **annual energy savings in kWh** are: 50.4 kWh/m² x 51.06 m² = **2.573,43 kWh**
- The **annual cost savings in €** are: 549.3€ – 398.7€ = **150.60€**
- The **time needed for depreciation** is: 1200€ (investment) / 150.60€ (savings/per year) = **8 years.**

5.3 SECOND SCENARIO – SYSTEM IMPROVEMENT – NEW SPLITS

The **second scenario** suggests the **installation of two new split units for heating and cooling** with the only specifications to be:

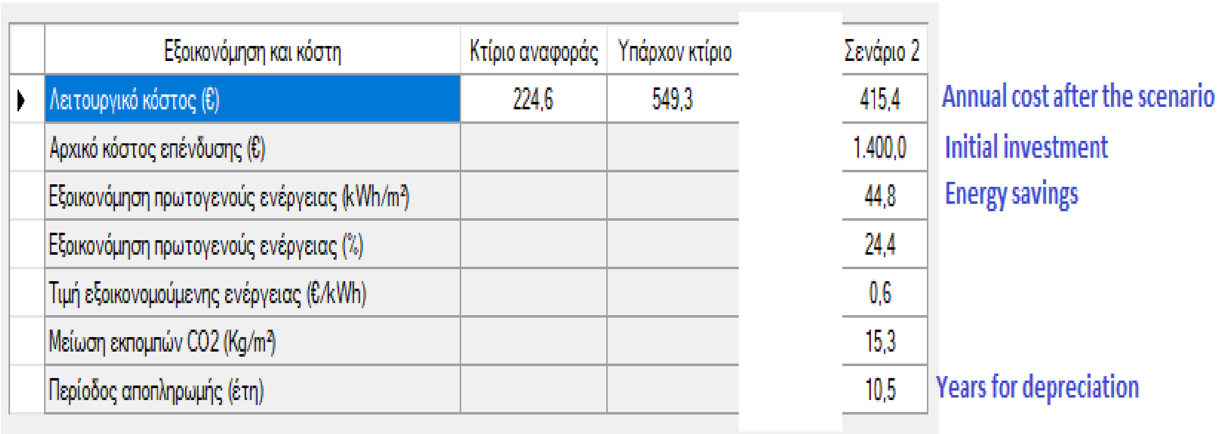
- Energy Efficiency Ratio (**EER**): 3.50
- Coefficient of Performance (**COP**): 3.20
- **Cost** for the **9000 btu/h: <u>600€</u>**
- **Cost** for the **12000 btu/h: <u>800€</u>**

The results are:



Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 2
Θέρμανση	17,6	101,0	68,5
Ψύξη	21,6	32,2	20,0
ZNX	23,4	50,4	50,4
Φωτισμός	0,0	0,0	0,0
Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0	0,0
Σύνολο	62,6	183,6	138,9
Κατάταξη	-	H	E

Figure 5.7: Second scenario's results in kWh/m2.



Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 2
Λειτουργικό κόστος (€)	224,6	549,3	415,4
Αρχικό κόστος επένδυσης (€)			1.400,0
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			44,8
Εξοικονόμηση πρωτογενούς ενέργειας (%)			24,4
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0,6
Μείωση εκπομπών CO2 (Kg/m²)			15,3
Περίοδος αποπληρωμής (έτη)			10,5

Figure 5.8: Savings due to the new splits.

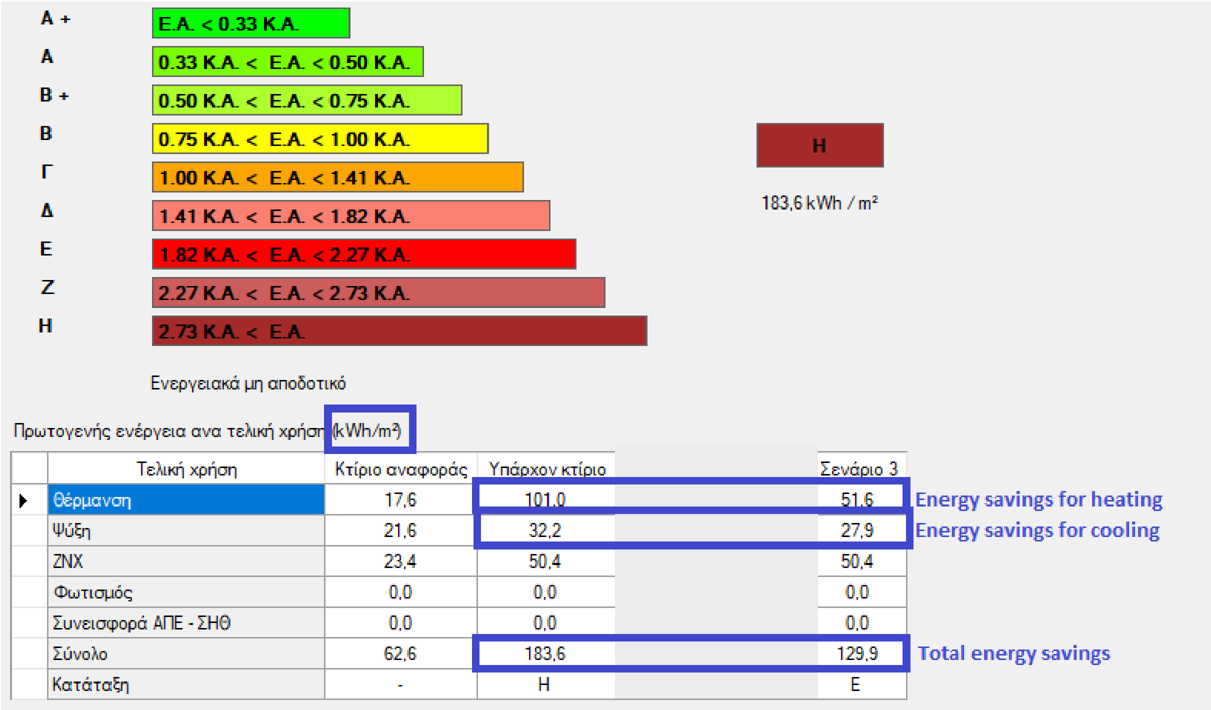
The conclusions drawn by Figures 5.7 and 5.8 are:

- The **installation** has an **impact** on the energy consumptions in **heating and cooling**
- The **annual total energy savings in kWh/m²** are: 32.5 (101.0 – 68.5) for heating and 12.2 (32.2 – 20) for cooling= **44.8 kWh/m²**
- The **annual energy savings in kWh** are: 44.8 kWh/m² x 51.06 m² = **2.287,49 kWh**
- The **annual cost savings in €** are: 549.3€ – 415.4€ = **133.90€**
- The **time needed for depreciation** is: 1400€ (investment) / 133.60€ savings/per year = **10.5 years**

5.4 THIRD SCENARIO–SHELL IMPROVEMENT–EXPANDED POLYSTYRENE SYSTEM

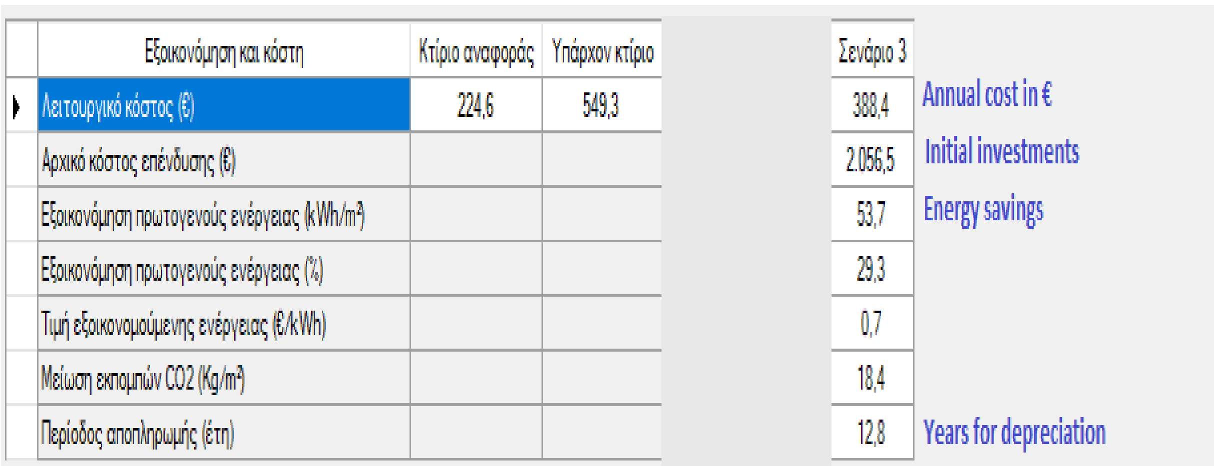
The **third scenario** suggests the **installation of expanded polystyrene panels** so that the thermal transmittance (U value) becomes **0.50 W/m²K**. The **cost** for such an improvement is estimated at **50€/m² of the area of the external walls.**

The results are:



Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 3
Θέρμανση	17,6	101,0	51,6
Ψύξη	21,6	32,2	27,9
ΖΝΧ	23,4	50,4	50,4
Φωτισμός	0,0	0,0	0,0
Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0	0,0
Σύνολο	62,6	183,6	129,9
Κατάταξη	-	H	E

Figure 5.9: Third scenario's results in kWh/m2.



Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 3
Λειτουργικό κόστος (€)	224,6	549,3	388,4
Αρχικό κόστος επένδυσης (€)			2.056,5
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			53,7
Εξοικονόμηση πρωτογενούς ενέργειας (%)			29,3
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0,7
Μείωση εκπομπών CO2 (Kg/m²)			18,4
Περίοδος αποπληρωμής (έτη)			12,8

Figure 5.10: Savings due to the EPS.

The conclusions drawn by Figures 5.9 and 5.10 are:

- The **installation** has an impact on the **energy consumptions in heating and cooling**
- The **annual total energy savings in kWh/m²** are: 49.4 (101.0 – 51.6) for heating and 4.3 (32.2 – 27.9) for cooling= **53.7 kWh/m²**
- The **annual energy savings in kWh** are: 53.7 kWh/m² x 51.06 m² = **2.741,92 kWh**
- The **annual cost savings in €** are: 549.3€ – 388.4€ = **160.90€**
- The **time needed for depreciation** is: 2056.50€ (investment) / 160.90€ savings/per year = **12.8 years**

5.5 FOURTH SCENARIO – SCENARIO 1 AND SCENARIO 2 COMBINED

The **fourth scenario** is the **combination of scenario 1 and 2** which means **installing a solar panel system for hot water and two splits for heating and cooling** with the initial investment **cost** raising at: (1200€ + 1400€) = **2600€.**

The results are:

Πρωτογενής ενέργεια ανα τελική χρήση (kWh/m²)

Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1	
Θέρμανση	17,6	101,0	68,5	Energy savings for heating
Ψύξη	21,6	32,2	20,0	Energy savings for cooling
ΖΝΧ	23,4	50,4	0,0	Energy savings for hot water
Φωτισμός	0,0	0,0	0,0	
Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0	0,0	
Σύνολο	62,6	183,6	88,5	Total energy savings
Κατάταξη	-	Η	Δ	

Figure 5.11: Fourth scenario's results in kWh/m².

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1	
Λειτουργικό κόστος (€)	224,6	549,3	264,8	Annual cost in €
Αρχικό κόστος επένδυσης (€)			2.600,0	Initial investment
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			95,1	Energy savings
Εξοικονόμηση πρωτογενούς ενέργειας (%)			51,8	
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0,5	
Μείωση εκπομπών CO2 (Kg/m²)			32,5	
Περίοδος αποπληρωμής (έτη)			9,1	Years for depreciation

Figure 5.12: Savings due to the new splits and the solar panels.

The conclusions drawn by Figures 5.11 and 5.12 are:

- The **installation** has an **impact** on the energy **consumptions in heating, cooling and hot water**
- The **annual total energy savings in kWh/m^2** are: **95.1 kWh/m^2**
- The **annual energy savings in kWh** are: 95.1 kWh/m^2 x 51.06 m^2 = **4855,806 kWh**
- The **annual cost savings in €** are: 549.3€ – 264.8€ = **284.50€**
- The **time needed for depreciation** is: 2600€ (investment) / 284.50€ savings/per year = **9.1 years**

5.6 FIFTH SCENARIO–SYSTEM AND SHELL IMPROVEMENTS COMBINED

The **fifth scenario** is the **combination of scenario 1, 2 and 3** which means **installing a solar panel system for hot water, two splits for heating and cooling and expanded polystyrene panels** with the initial investment **cost** raising at: (1200€ + 1400€ + 2056.50€)= **5656.50€.**

The results are:

Πρωτογενής ενέργεια ανα τελική χρήση (kWh/m²)

Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 2	
Θέρμανση	17,6	101,0	34,9	Energy savings for heating
Ψύξη	21,6	32,2	17,3	Energy savings for cooling
ΖΝΧ	23,4	50,4	0,0	Energy savings for hot water
Φωτισμός	0,0	0,0	0,0	
Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0	0,0	
Σύνολο	62,6	183,6	52,2	Total Energy savings
Κατάταξη	-	Η	Β	

Figure 5.13: Fifth scenario's results in kWh/m^2.

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 2	
Λειτουργικό κόστος (€)	224,6	549,3	156,5	Annual cost in €
Αρχικό κόστος επένδυσης (€)			4.656,5	Initial investment
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			131,4	Energy savings
Εξοικονόμηση πρωτογενούς ενέργειας (%)			71,6	
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0,7	
Μείωση εκπομπών CO2 (Kg/m²)			44,8	
Περίοδος αποπληρωμής (έτη)			11,9	Years for depreciation

Figure 5.14: Savings due to all the improvements.

The conclusions drawn by Figures 5.13 and 5.14 are:

- The **installation** has an **impact** on the **energy consumptions in heating, cooling and hot water**
- The **annual total energy savings in kWh/m^2** are: **131.4 kWh/m^2**
- The **annual energy savings in kWh** are: 131.4 kWh/m^2 x 51.06 m^2 = **6709.28 kWh**
- The **annual cost savings in €** are: 549.3€ – 156.5€ = **392.80€**
- The **time needed for depreciation** is: 4656.50€ (investment) / 392.50€ savings/per year = **11.9 years**

In order to summarize table 5.1 illustrates the results for all scenarios:

Nbr of scenario	Type of improvement	Impact on consumption	Initial Investment	Annual Energy savings in kWh/m2	% Energy savings	Energy class	Annual Cost savings in €	Years for depreciation
1	System	Hot water	1.200,00 €	50,4	27,40%	E	150,6	8
2	System	Heating Cooling	1.400,00 €	44,8	24,40%	E	133,9	10,5
3	Shell	Heating Cooling	2.600,00 €	53,7	29,30%	E	160,9	12,8
4	Both	Heating Cooling Hot water	2.056,50 €	95,1	51,80%	Δ	284,5	9,1
5	Both	Heating Cooling Hot water	4.656,50 €	131,4	71,60%	B	392,8	11,9

Table 5.1: Summary of the Scenarios' results.

6. OFFICE EXAMPLE

This chapter aims to illustrate the demands and consumptions of a commercial building˙s partition that is used as offices and the energy savings gained by the improvements suggested.
As shown in previous chapter the variables that take part in the inspection are the property's shell whose losses provoke the demands for technical heating, cooling and hot water and the systems applied to cover the demands.

6.1 ENERGY INSPECTION AND CLASSIFICATION OF THE OFFICE

This particular example presents an office in Koukaki Athens whose total area is: **78.22 square meters** on the first floor of a commercial building. The facades of the office are on the main road. It was constructed in 2004 and no renovation has been made since then.

The technical information gathered during the inspection were:

- The building was constructed after 1989 (Thermal Insulation Regulation Act) and due to this fact the walls have thermal insulation.
- The doors and windows had metal frame and double glasses
- The heating and cooling needs were covered with two split air condition units with 24.000btu/h capacity
- No units were installed for artificial air flows.
- The lighting units that were installed covered the area efficiently by consuming 1.25 kW in total

In the next figure a picture of the facade is shown:

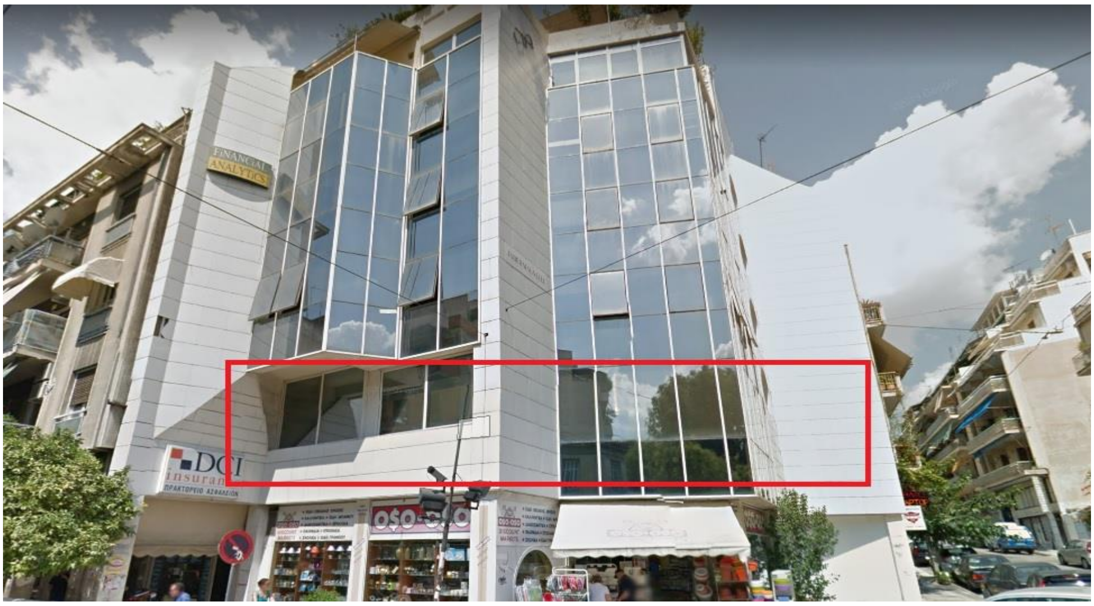


Figure 6.1 Main facade of the building.

Next figure 6.2 presents the plan of the office with an area: E= 78.22 m^2:

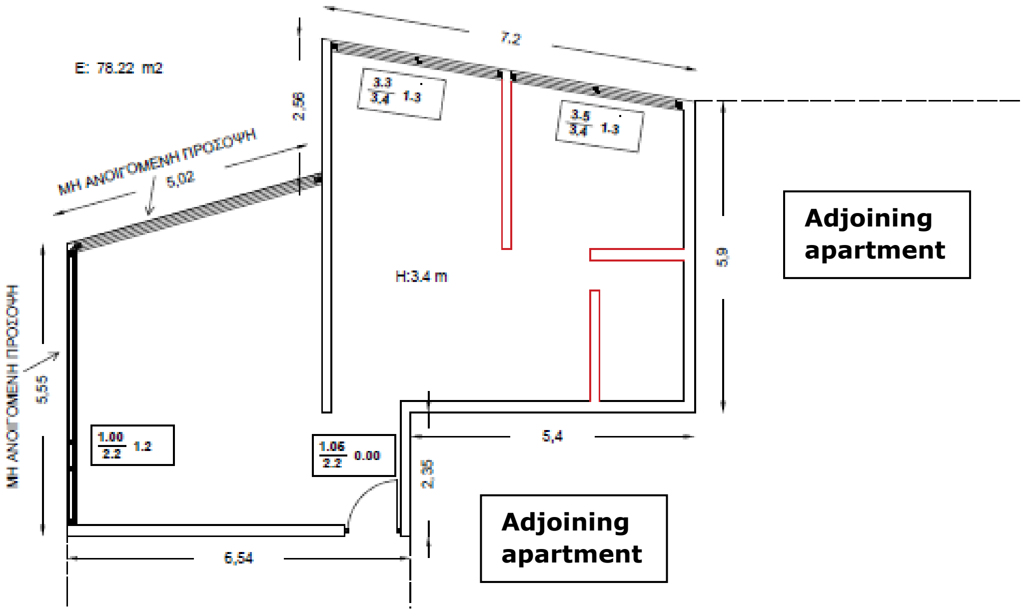
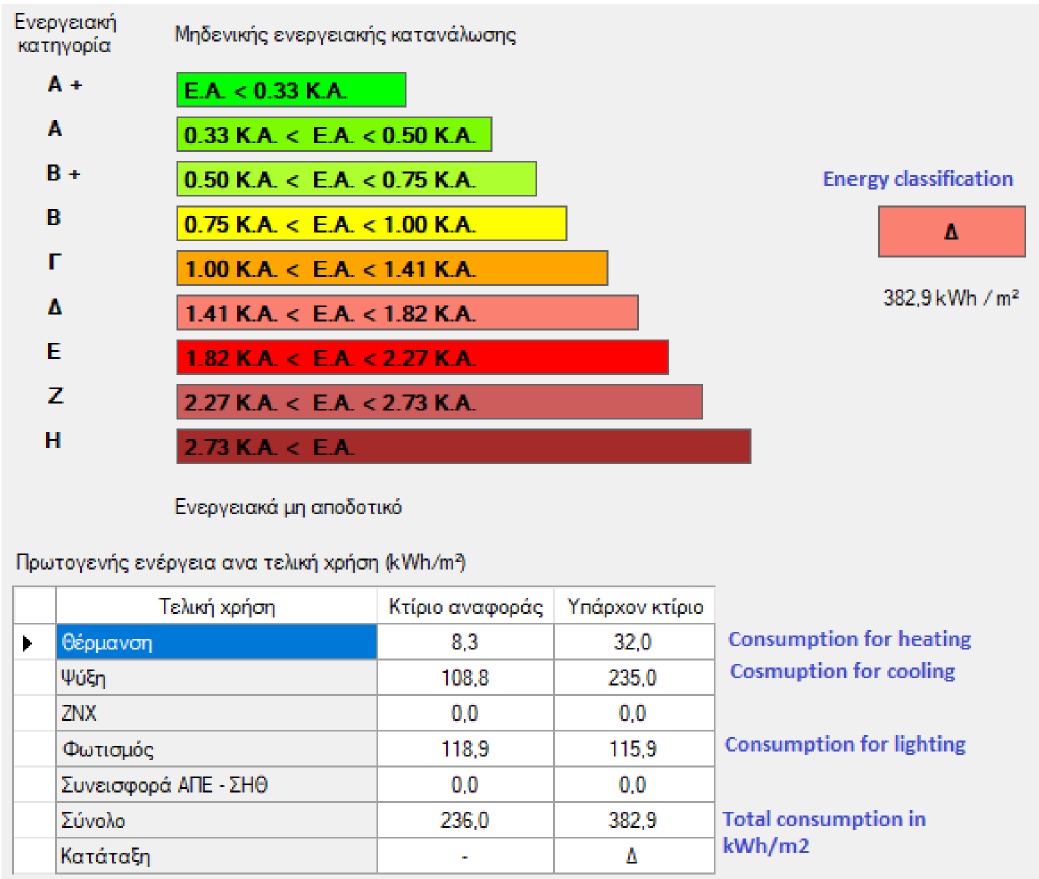


Figure 6.2: Floor Plan of the office.

Figure 6.3 shows the energy classification of the consumption of the office.



Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο
Θέρμανση	8,3	32,0
Ψύξη	108,8	235,0
ΖΝΧ	0,0	0,0
Φωτισμός	118,9	115,9
Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0
Σύνολο	236,0	382,9
Κατάταξη	-	Δ

Figure 6.3: Energy classification of the office.

In addition, the calculations for the **annual energy cost** for this property is **1754.70€.**

	Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο
▶	Λειτουργικό κόστος (€)	1.081,4	1.754,7
	Αρχικό κόστος επένδυσης (€)		
	Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)		
	Εξοικονόμηση πρωτογενούς ενέργειας (%)		
	Τιμή εξοικονομούμενης ενέργειας (€/kWh)		
	Μείωση εκπομπών CO2 (Kg/m²)		
	Περίοδος αποπληρωμής (έτη)		

Total annual cost in euros

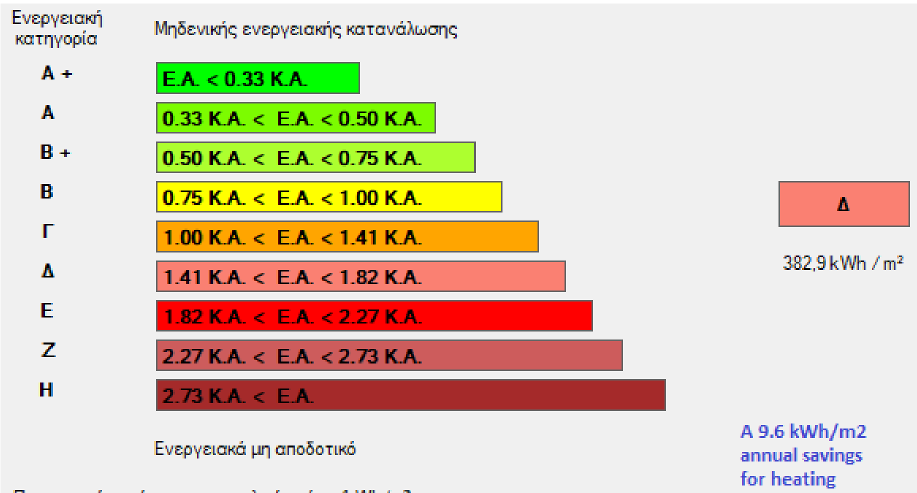
Figure 6.4: Annual energy cost of the office.

6.2 FIRST SCENARIO – SYSTEM IMPROVEMENT – AIR CONDITIONING WITH MORE EFFICIENT SPLIT UNITS

The **first scenario** suggests the **installation of two new split units for heating and cooling** with the only specifications to be:

- Energy Efficiency Ratio (EER): 3.50
- Coefficient of Performance (COP): 3.20
- Cost for each 24000 btu/h: **1200€**

The results are:



Πρωτογενής ενέργεια ανα τελική χρήση (kWh/m²)

	Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1
▶	Θέρμανση	8,3	32,0	22,4
	Ψύξη	108,8	235,0	148,8
	ZNX	0,0	0,0	0,0
	Φωτισμός	118,9	115,9	115,9
	Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0	0,0
	Σύνολο	236,0	382,9	287,1
	Κατάταξη	-	Δ	Γ

A 86.2 kWh/m2 annual savings for cooling

Figure 6.5: First scenario's results in kWh/m².

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1	
Λειτουργικό κόστος (€)	1.081,4	1.754,7	1.316,0	Annual cost after the scenario
Αρχικό κόστος επένδυσης (€)			2.400,0	Initial investment
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			95,8	Annual energy savings in kWh/m2
Εξοικονόμηση πρωτογενούς ενέργειας (%)			25,0	
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0,3	
Μείωση εκπομπών CO2 (Kg/m²)			32,7	
Περίοδος αποπληρωμής (έτη)			5,5	Years for depreciation

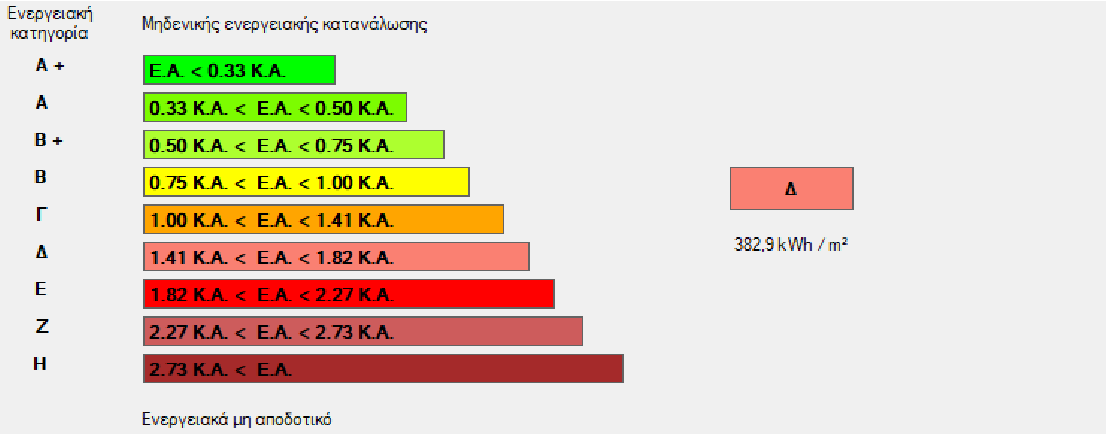
Figure 6.6: Savings due to the new split units.

The conclusions drawn by Figures 6.5 and 6.6 are:

1. The installation has an impact on the **energy consumptions in heating and cooling**
2. The annual total energy savings in **kWh/m²** are: 9.6 (32.0 – 22.4) for heating and 86.2 (235.0 – 148.8) for cooling**= 95.8 kWh/m²**
3. The annual energy savings in **kWh** are: 95.8 kWh/m² x 78.22 m² = **7.493,48 kWh**
4. The annual cost savings in **€** are: 1754.4€ – 1316.0€ = **438.70€**
5. The time needed for depreciation is: 2400€ (investment) / 438.70€ savings/per year = **5.5 years**

6.3 SECOND SCENARIO –SYSTEM IMPROVEMENT – NEW LIGHTING SYSTEM

The second scenario suggests the installation of 16 new lighting led panels of 40W each in order to cover the needs of the office. The results are:



Πρωτογενής ενέργεια ανα τελική χρήση (kWh/m²)

Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 2	
Θέρμανση	8,3	32,0	34,8	Annual increase for heating
Ψύξη	108,8	235,0	221,5	Annual savings for cooling
ΖΝΧ	0,0	0,0	0,0	
Φωτισμός	118,9	115,9	55,6	Annual savings in lighting
Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0	0,0	
Σύνολο	236,0	382,9	312,0	Total annual savings
Κατάταξη	-	Δ	Γ	

Figure 6.7: Second scenario's results in kWh/m².

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 2	
Λειτουργικό κόστος (€)	1.081,4	1.754,7	1.429,7	Annual cost in euros
Αρχικό κόστος επένδυσης (€)			1.000,0	Initial investment
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			70,9	Energy savings in kWh/m2
Εξοικονόμηση πρωτογενούς ενέργειας (%)			18,5	
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0,2	
Μείωση εκπομπών CO2 (Kg/m²)			24,2	
Περίοδος αποπληρωμής (έτη)			3,1	Years of depreciation

Figure 6.8: Savings due to the new lighting system.

The conclusions drawn by Figures 6.7 and 6.8 are:

1. The installation has an impact on the **energy consumptions in lighting**
2. The annual total energy savings in **kWh/m²** are: 13.5 (235.0 – 221.5) for cooling and 60.3 (115.9 – 55.6) for lighting **= 70.9 kWh/m²**
3. The annual energy savings in **kWh** are: 70.9 kWh/m² x 78.22 m² = **5.545,78 kWh**
4. The annual cost savings in **€** are: 1754.4€ – 1429.7€ = **324.70€**
5. The time needed for depreciation is: 1000€ (investment) / 324.70€ savings/per year = **3.1 years**

6.4 THIRD SCENARIO – SCENARIO 1 AND SCENARIO 2 COMBINED

The third scenario is the combination of scenario 1 and 2. The results are:

Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 3	
Θέρμανση	8,3	32,0	24,3	Energy savings for heating
Ψύξη	108,8	235,0	140,4	Energy savings for cooling
ΖΝΧ	0,0	0,0	0,0	
Φωτισμός	118,9	115,9	55,6	Energy savings for lighting
Συνεισφορά ΑΠΕ - ΣΗΘ	0,0	0,0	0,0	
Σύνολο	236,0	382,9	220,3	Total energy savings
Κατάταξη	-	Δ	Β	

Figure 6.9: Third scenario's results in kWh/m².

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 3	
Λειτουργικό κόστος (€)	1.081,4	1.754,7	1.009,6	Annual cost in euros
Αρχικό κόστος επένδυσης (€)			3.400,0	Initial investment
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			162,6	Energy savings
Εξοικονόμηση πρωτογενούς ενέργειας (%)			42,5	
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0,3	
Μείωση εκπομπών CO2 (Kg/m²)			55,5	
Περίοδος αποπληρωμής (έτη)			4,6	Years of depreciation

Figure 6.10: Savings due to the new splits and the new lighting system.

The conclusions drawn by Figures 6.9 and 6.10 are:

1. The installation of both systems has an impact on the **energy consumptions in heating, cooling and lighting**
2. The annual total energy savings in **kWh/m²** are: **162.6 kWh/m²**
3. The annual energy savings in **kWh** are: 162.6 kWh/m² x 78.22 m² = **12718,572 kWh**
4. The annual cost savings in **€** are: 1754.7€ – 1009.6€ = **745.10€**
5. The time needed for depreciation is: 3400€ (investment) / 745.10€ savings/per year = **4.6 years.**

In order to summarize table 6.1 illustrates the results for all scenarios:

Nbr of scenario	Type of improvement	Impact on consumption	Initial Investment	Annual Energy savings in kWh/m2	% Energy savings	Energy class	Annual Cost savings in €	Years for depreciation
1	System	Heating Cooling	2.400,00 €	95,8	25,00%	Γ	438,7	5,5
2	System	Heating Cooling Lighting	1.000,00 €	70,6	18,50%	Γ	324,7	3,1
3	System	Heating Cooling Lighting	3.400,00 €	162,6	42,50%	B	745,1	4,6

Table 6.1: Summary of the Scenarios' results.

7. HISTORIC PROTECTED BUILDING EXAMPLE (RESIDENTIAL BUILDING)

This chapter aims to illustrate the demands and consumptions of a historic protected residential building and the energy savings gained by the improvements suggested.
As shown in previous chapter the variables that take part in the inspection are the property's shell whose losses provoke the demands for technical heating, cooling and hot water and the systems applied to cover the demands.

7.1 ENERGY INSPECTION AND CLASSIFICATION OF THE BUILDING

This particular example presents a historic protected building with residential use in Athens Attica whose total area is 306.00 square meters. The main facade of the apartment is on the main road and the second facade on the free space of the building˛s field. It was constructed in 1935 and no renovation has been made since then.
The technical information gathered during the inspection was:

- The building was constructed before 1989 (Thermal Insulation Regulation Act) and due to this fact the walls have no thermal insulation
- The doors and windows had metal or wooden frame and single glass
- The heating and cooling needs were covered with split units – with 15kW capacity for heating and 12kW for cooling
- Hot water needs were covered with a simple electrical heater with 4 kW power filling an 80 litters tank.

In the next figure a picture of the main facade is shown:

Figure 7.1: Main facade of the Building.

Next figures present the floor plans of the building:

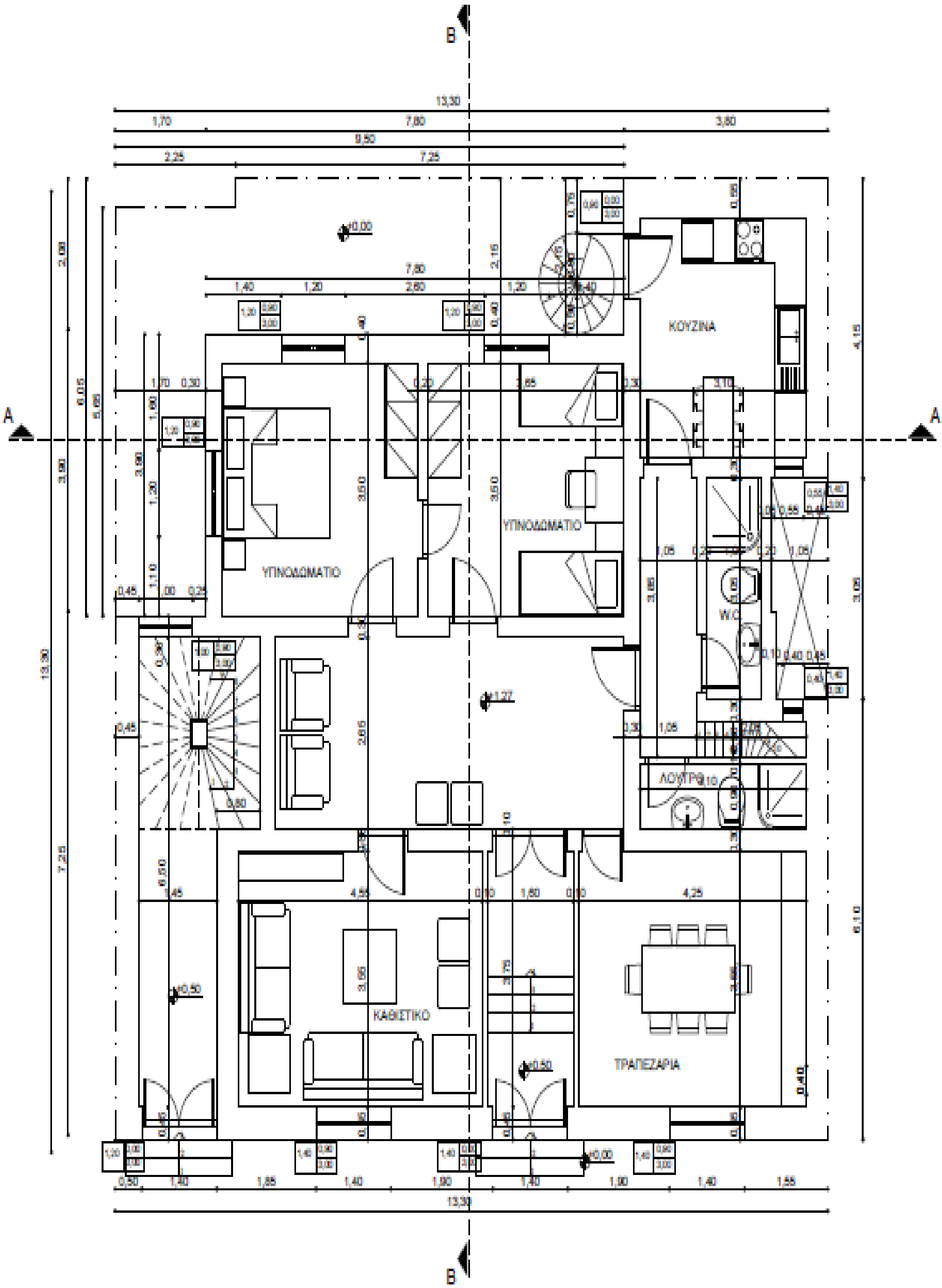


Figure 7.2: Floor Plan of the ground floor.

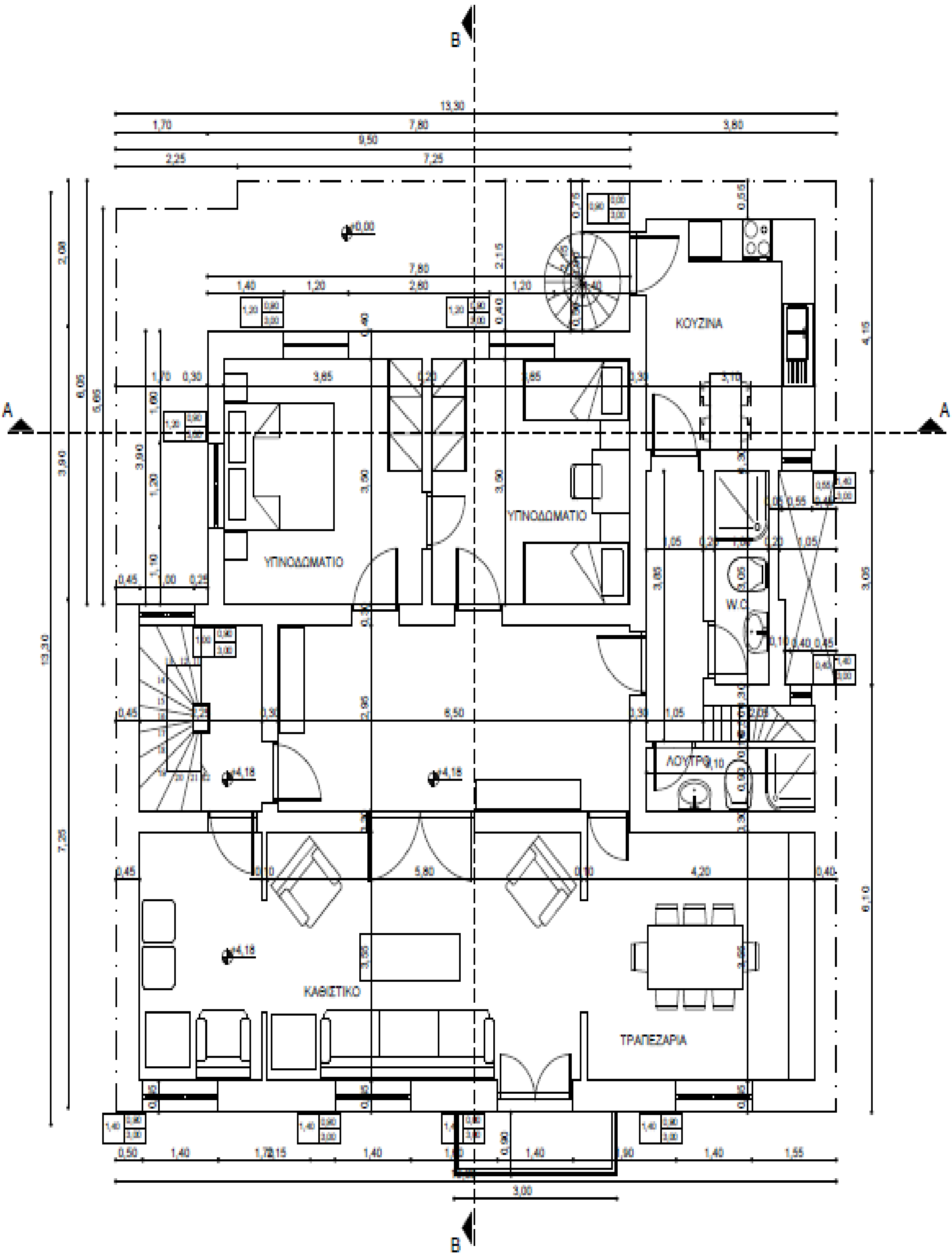


Figure 7.3: Floor Plan of the 1ST floor.

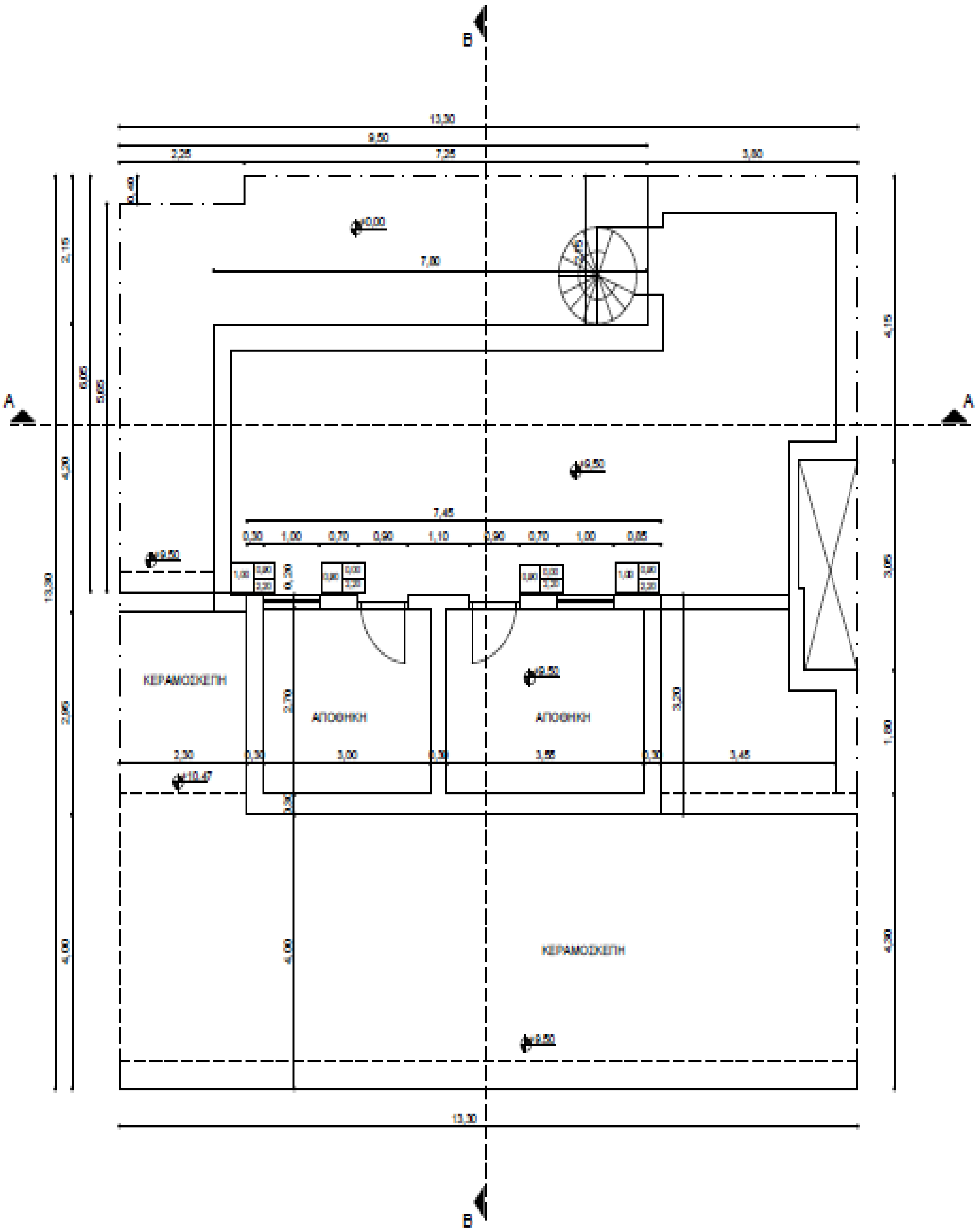


Figure 7.4: Floor Plan of the terrace.

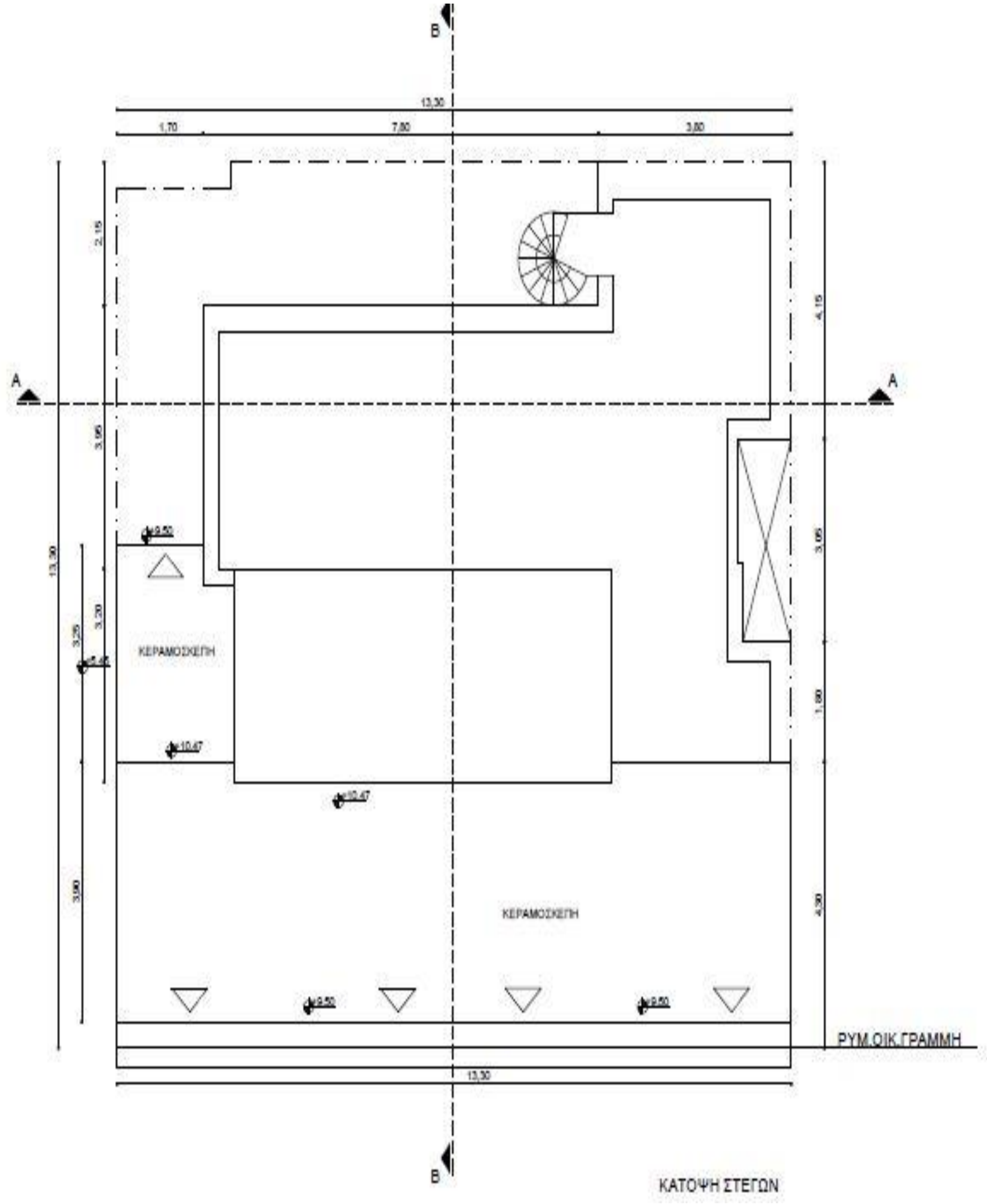


Figure 7.5: Floor Plan of the ceilings.

Figure 7.6 shows the energy classification of the consumption of the building.

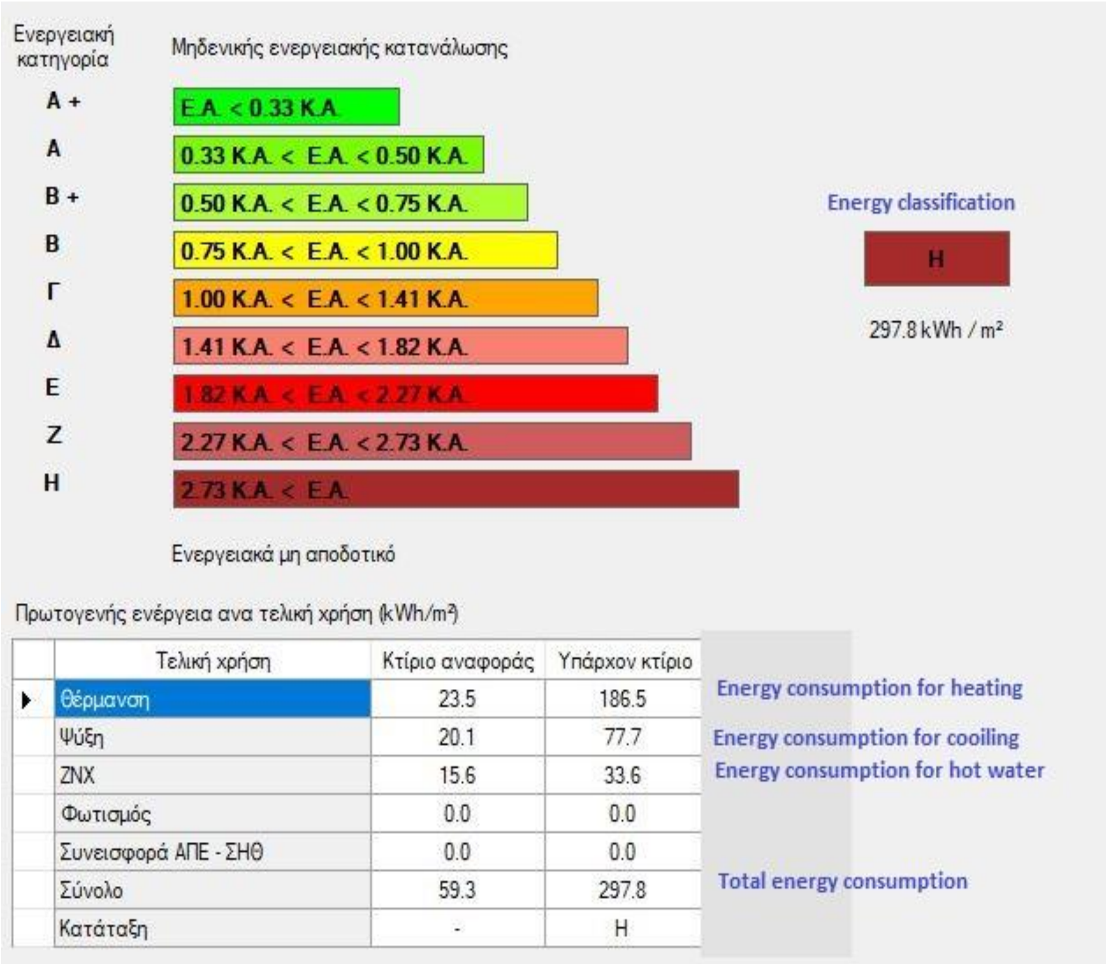


Figure 7.6: Energy classification of the building.

In addition, the calculations for the **annual energy cost** for this building is **5823.50€.**

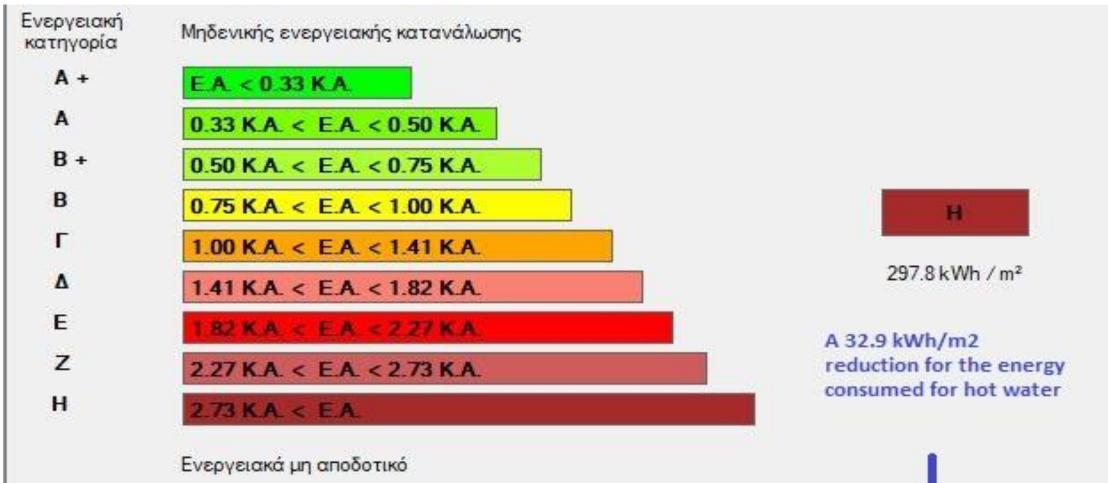
Figure 7.7: Annual energy cost of the building.

7.2 FIRST SCENARIO – SYSTEM IMPROVEMENT – SOLAR PANELS FOR HOT WATER

In this scenario the improvement applied is two systems of solar panels to assist the production of water. The specifications of the solar panels are:

- the area which is 4.5 square meters for each system
- The orientation which is 180 degrees (directly to the north)
- The shading which is zero (it is placed in the terrace)
- The slope which is 45 degrees
- The cost which is 1575€ for each of them

The results are:



Πρωτογενής ενέργεια ανα τελική χρήση (kWh/m²)

Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1
Θέρμανση	23.5	186.5	186.5
Ψύξη	20.1	77.7	77.7
ZNX	15.6	33.6	0.7
Φωτισμός	0.0	0.0	0.0
Συνεισφορά ΑΠΕ - ΣΗΘ	0.0	0.0	0.0
Σύνολο	59.3	297.8	264.9
Κατάταξη	-	H	H

Figure 7.8: First scenario's results in kWh/m².

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1
Λειτουργικό κόστος (€)	1,267.1	5,823.5	5,234.3
Αρχικό κόστος επένδυσης (€)			3,150.0
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			32.9
Εξοικονόμηση πρωτογενούς ενέργειας (%)			11.0
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0.3
Μείωση εκπομπών CO2 (Kg/m²)			11.2
Περίοδος αποπληρωμής (έτη)			5.3

Annual cost after the scenario
Initial cost in euros
Energy savings
Years for depreciation

Figure 7.9: Savings due to the solar panels for hot water.

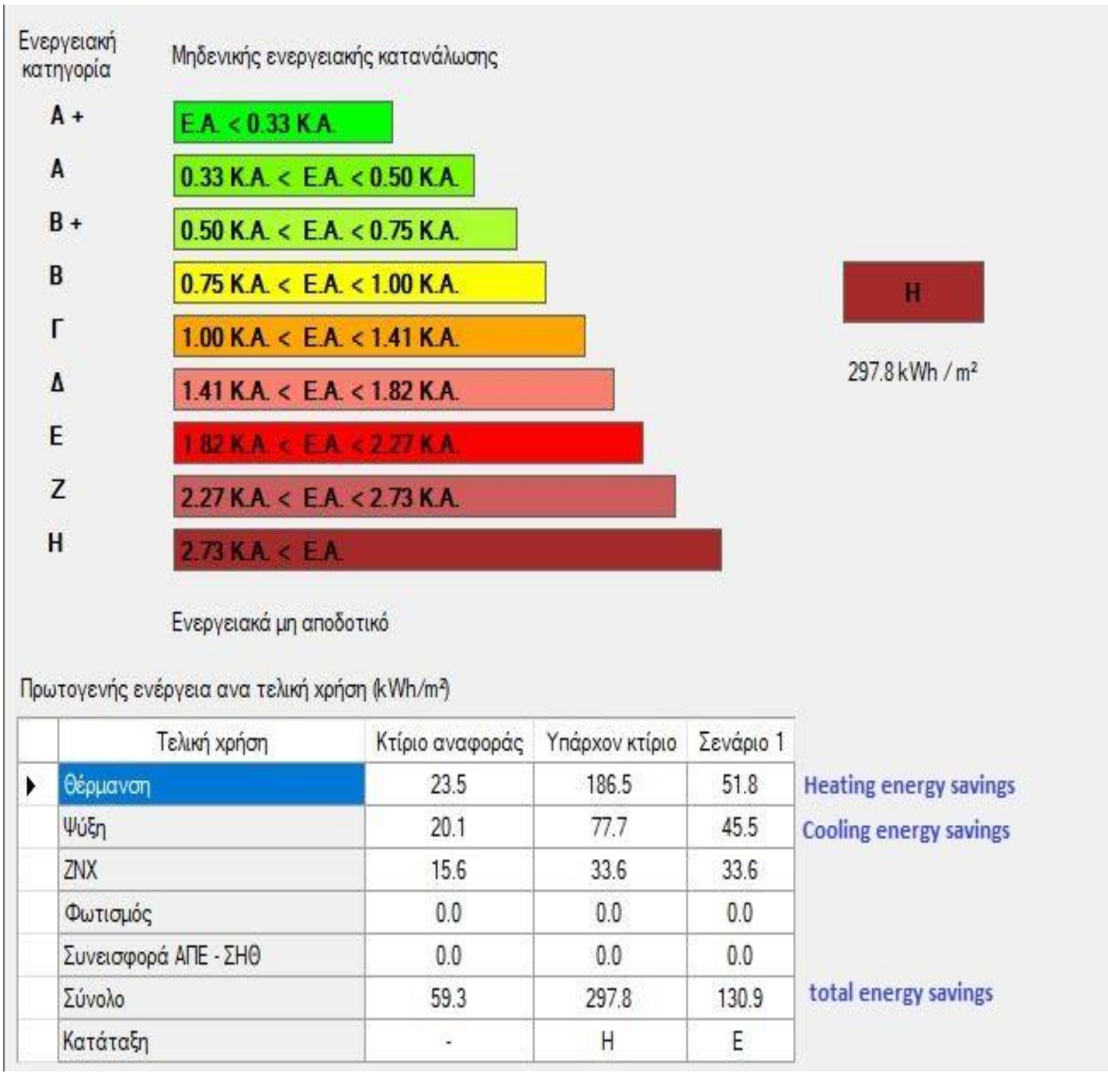
The conclusions drawn by Figures 7.8 and 7.9 are:

1. The installation of solar panels has an impact on the **energy consumptions in hot water**
2. The annual total energy savings in **kWh/m²** are: **32.9 kWh/m²**
3. The annual energy savings in **kWh** are: 32.9 kWh/m² x 306.0 m² = **10.067,4 kWh**
4. The annual cost savings in € are: 5823.50€ – 5234.30€ = **589.20€**
5. The time needed for depreciation is: 3150€ (investment) / 589.20€ savings/per year = **5.3 years**

7.3 SECOND SCENARIO-SHELL IMPROVEMENT-EXPANDED POLYSTYRENE SYSTEM

The second scenario suggests the installation of expanded polystyrene panels so that the thermal transmittance (U value) becomes **0.50 W/m²K**. The cost for such an improvement is estimated at 50€/m2 of the area of the external walls.

The results are:



Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1
Θέρμανση	23.5	186.5	51.8
Ψύξη	20.1	77.7	45.5
ΖΝΧ	15.6	33.6	33.6
Φωτισμός	0.0	0.0	0.0
Συνεισφορά ΑΠΕ - ΣΗΘ	0.0	0.0	0.0
Σύνολο	59.3	297.8	130.9
Κατάταξη	-	H	E

Figure 7.10: Second scenario's results in kWh/m².

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 1	
Λειτουργικό κόστος (€)	1,267.1	5,823.5	2,445.4	Annual cost after the scenario
Αρχικό κόστος επένδυσης (€)			21,364.5	Initial investment in €
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)			166.9	Energy savings
Εξοικονόμηση πρωτογενούς ενέργειας (%)			56.0	
Τιμή εξοικονομούμενης ενέργειας (€/kWh)			0.4	
Μείωση εκπομπών CO2 (Kg/m²)			52.8	
Περίοδος αποπληρωμής (έτη)			6.3	Years of depreciation

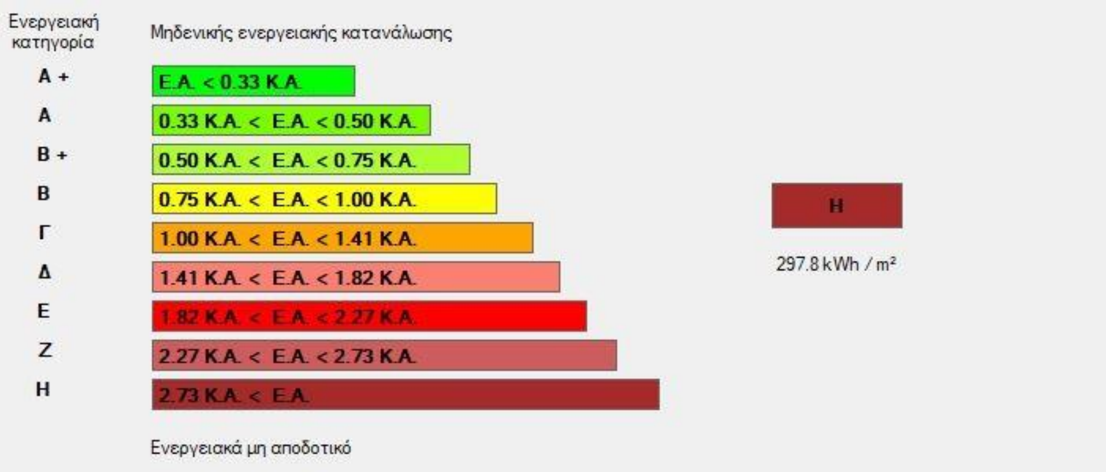
Figure 7.11: Savings due to the EPS.

The conclusions drawn by Figures 7.10 and 7.11 are:

6. The installation has an impact on the **energy consumptions in heating and cooling**
7. The annual total energy savings in **kWh/m²** are: **166.90 kWh/m²**
8. The annual energy savings in **kWh** are: 166.90 kWh/m² x 306.0 m² = **51.071,4 kWh**
9. The annual cost savings in **€** are: 5823.5€ – 2445.4€= **3378.10 €**
10. The time needed for depreciation is: 21.364,50€ (investment) / 3.378,10€ savings/per year = **6,3 years**

7.4 THIRD SCENARIO – SCENARIO 1 AND SCENARIO 2 COMBINED

The third scenario is the combination of scenario 1 and 2 which means installing a solar panel system for hot water and the installation of extended polystyrene panels with the initial investment cost raising at (3150€ + 21364.50€) = 24514.50€. The results are:



Πρωτογενής ενέργεια ανα τελική χρήση (kWh/m²)

Τελική χρήση	Κτίριο αναφοράς	Υπάρχον κτίριο	Σενάριο 2	
Θέρμανση	23.5	186.5	51.8	Energy savings for heating
Ψύξη	20.1	77.7	45.5	Energy savings for cooling
ZNX	15.6	33.6	0.7	
Φωτισμός	0.0	0.0	0.0	
Συνεισφορά ΑΠΕ - ΣΗΘ	0.0	0.0	0.0	
Σύνολο	59.3	297.8	98.0	Total annual savings
Κατάταξη	-	H	Δ	

Figure 7.12: Third scenario's results in kWh/m².

Εξοικονόμηση και κόστη	Κτίριο αναφοράς	Υπάρχον κτίριο		Σενάριο 2	
Λειτουργικό κόστος (€)	1,267.1	5,823.5		1,856.2	Annual cost after the scenario
Αρχικό κόστος επένδυσης (€)				24,514.5	Initial investment in €
Εξοικονόμηση πρωτογενούς ενέργειας (kWh/m²)				199.7	Energy savings
Εξοικονόμηση πρωτογενούς ενέργειας (%)				67.1	
Τιμή εξοικονομούμενης ενέργειας (€/kWh)				0.4	
Μείωση εκπομπών CO2 (Kg/m²)				64.1	
Περίοδος αποπληρωμής (έτη)				6.2	Years of depreciation

Figure 7.13: Savings due to the new splits and the solar panels.

The conclusions drawn by Figures 7.12 and 7.13 are:

6. The installation has an impact on the **energy consumptions in heating, cooling and hot water**
7. The annual total energy savings in **kWh/m²** are: 199.70 (297.80 – 98.0) **kWh/m²**
8. The annual energy savings in **kWh** are: 199.70 kWh/m² x 306.0 m2 = **61.108,2 kWh**
9. The annual cost savings in **€** are: 5823.5€ – 1856.20€ = **3967.30 €**
10. The time needed for depreciation is: 24.514,50€ (investment) / 3.967,30€ savings/per year = **6,2 years**

In order to summarize table 7.1 illustrates the results for all scenarios:

Nbr of scenario	Type of improvement	Impact on consumption	Initial Investment	Annual Energy savings in kWh/m2	% Energy savings	Energy class	Annual Cost savings in €	Years for depreciation
1	System	Hot water	3,150.00 €	32.9	11.00%	H	589.2	5.3
2	Shell	Heating Cooling	21,364.50 €	166.9	56.00%	E	3378.1	6.3
3	System and Shell	Hot water Heating Cooling	24,514.50 €	199.7	67.10%	Δ	3967.3	6.2

Table 7.1: Summary of the Scenarios˙ results.

8. CONCLUSIONS

The European building stock and energy system are at the initial stages of a journey towards becoming smart: moving from a centralised, fossil fuel-based and highly energy-consuming system towards one that is more efficient, decentralised, consumer focused and powered by renewable energy. The international law to limit global warming to below 2°C following the Paris Agreement puts a renewed emphasis on the need for Europe to accelerate the smart energy transition.

For the European building stock to effectively contribute to the global climate target, the built environment must undergo a deep transformation and become both **smart and efficient**. Increasing Europe's renovation rate to a level which results in a zero emission building stock by 2050 will require a wave of innovation in the construction sector.[48]

The current approach of European legislation encourages smart buildings, promoting the implementation of smart meters and intelligent metering systems under the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED). Many European countries, such as Greece, have already put in place legislation to take steps towards a smart built environment, such as encouraging the optimisation of the heating system, supporting building energy storage or deploying smart meters. A smart building revolution is not just about upgrading our building stock, mitigating emissions or balancing energy flows, it is about delivering direct benefits for EU citizens in terms of lower energy bills and warmer homes, and wider benefits for Europe as a whole with jobs created and boosts to economic growth.

In this study we made a presentation of the legislative framework and targets of EU and Greece on energy efficiency and we focused in building sector. As we analyzed **EU and Greece**, as a Member State, **have shaped and institutionalized the appropriate legislative framework and financial instruments so as to facilitate actions including initiatives to accelerate clean energy innovation and to renovate buildings as part of 2050 long-term strategy of EU.**

In the cases of energy upgrading of residential and office buildings in Greece which we presented, we conclude that with a small amount of investment (as a percentage of the building's commercial value) and with targeted interventions **we can achieve a large percentage of energy savings with a short period of depreciation.**

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[48] (BPIE, 2017 February, IS EUROPE READY FOR THE SMART BUILDINGS REVOLUTION?, http://bpie.eu/wp-content/uploads/2017/02/STATUS-REPORT-Is-Europe-ready_FINAL_LR.pdf)

However EU and European citizens have to invest to five pillars for the creation of a smart built environment:[49]

- First of all, a smart-ready built environment requires **efficient and healthy buildings**. The basic need of most occupants is to have a healthy and affordable home. The building performance, indoor air quality and the ability to keep the indoor temperature at a comfortable level are vital characteristics of a smart built environment.

- A smart-ready built environment needs **dynamic operability** providing a better indoor environmental quality for the occupants. They should be able to configure the building's technical management system (including options of various levels of automation) based on individual preferences and the system should be able to adapt according to energy needs and price fluctuations.

- A smart built environment requires **energy-system-responsive** buildings, ready to answer the needs of the electricity, district heating and cooling grids and the broader energy system, for instance in case of peakloads.

- A smart-ready built environment enables **renewable energy uptake**. The EU's vision to decarbonise the building stock by 2050 requires a much greater share of renewable energy in the establishment of the building stock's energy requirements.

- Finally, a smart built environment needs proper **dynamic and self-learning control systems**, in order to optimise the various interactions and energy uses. This feature enables buildings to become truly smart and ensures synergies between different operations within the building and the energy system.

EU Member States' energy efficiency targets are very difficult to achieve but as we have seen we have all the legislative, financial and scientific instruments to succeed.

[49] (BPIE, 2017 February, IS EUROPE READY FOR THE SMART BUILDINGS REVOLUTION?, http://bpie.eu/wp-content/uploads/2017/02/STATUS-REPORT-Is-Europe-ready_FINAL_LR.pdf)

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