Retrofitting of representative multifamily buildings. Can intervention scenarios influence the strategies of funding?

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SCHOOL OF SCIENCE & TECHNOLOGY

A thesis submitted for the degree of

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Abstract

This dissertation was written as a part of the MSc in Energy Building Design at the International Hellenic University.

The residential building stock is constantly growing on a global level. The majority of the European building stock has no or minimal energy related codes. Buildings are responsible for 40% of final energy consumption. Most of the European buildings will remain in use by 2050, so the need for energy refurbishment is necessary.

In the first part of this study, a general perspective of the European and Greek building stock is presented. Greek building typology is different than the one in Europe, architecturally and at its building's characteristics. The programs which fund the retrofitting measures both at Europe and Greece are also presented at this part. In the second part, a case study of retrofitting a typical polykatoikia in climatic zone C in Greece is presented. The state of the art and its findings on retrofitting measures, as well as an economic analysis, are presented.

I would like to thank my Professors in International Hellenic University Ms. Ifigeneia Theodoridou and Mr. Agis Papadopoulos, for their constant help and guidance throughout the dissertation period.

Dakouki Anastasia - Paraskevi

01/12/2019

“As each country looks to meet their emissions reduction, energy efficiency, or renewable energy goals, they will look to cities as places where transformational change can make the most difference.”

Patricia Espinosa

Contents

1 Introduction

The existing building stock is responsible for over 40% of Europe's energy requirements, and over 36% of CO_2 emissions. [1][2] European citizens spend most of their time at their homes, so it is very important to refurbish the existing residential building stock and conserve the quality of the indoor climate conditions.

New buildings are constructed according to energy related regulations. European Union energy legislation aims all new buildings, and as many existing buildings as possible, to have nearly zero energy requirements in the years to come. The existing building stock was constructed before energy related regulations, so it is necessary to be refurbished to meet the targets of the energy regulation.

Energy Efficiency Regulations in Europe and Greece

The residential building stock of Europe is aged with poor energy-performing standards. The retrofitting of the building stock is direct connected to the climate change and energy poverty. The need for retrofitting led to the implementation of energy related regulations. The first one was implemented by Energy Performance of Buildings Directive in 2002. EPBD set the requirements for energy audits, certifications and renovation measures. [1] The majority of the European countries had no energy related regulations. In Greece, the energy related regulation, KENAK, was implemented in 2010.

The Article 4 of the Energy Efficiency Directive (EED) requires all Member States to establish long-term strategies for the renovation of their building stock. The first deadline for the implementation of the strategies was on the 30th April 2014, but six Member States weren't able to submit their strategies on time. [2]

The Article 4 of the Energy Efficiency Directive concerns the requirements needed for the energy refurbishment of the building stock. The Member States should establish their energy strategies so as to renovate their building stock, and transform the buildings into nearly zero-energy buildings (nZEB). [1]

EPBD strongly suggests the deep renovation of the building stock. The residential building stock is responsible for 40% of the overall energy consumption and 36% of the CO_2 emissions. By retrofitting, buildings assist to eliminate the climate change and energy poverty. European

Union implemented energy packages to motive the energy refurbishment of the building stock. The packages are presented at the next chapter. [1]

The residential building stock in Europe

The residential building stock of Europe is aged, and it has low energy performance. The majority of the buildings was constructed before the energy saving regulations. It is a mix of various construction types designed with different considerations, technologies and materials. The building stock is different at each European country, as each country has different climate, construction methods and materials, energy production, financial context and users' behavior. [EU Facts]

The existing building stock consists of inadequate envelope and old-technology HVAC systems. This leads to high energy demand, poor indoor air quality and deficit thermal comfort conditions. [EU Facts]

According to BPIE, 97% of buildings in the EU need to be upgraded. By studying the European EPCs, nowadays less than 3% of the existing building stock qualifies the A-label. According to BPIE, 75% of the European building stock can be upgraded and be 'energy efficient'. [2]

Funding Schemes - Economic Background

There are numerous funding programs in Europe for renovation projects. The retrofitting measures are financed by international organizations or institutions and also by raising investment through the private sector (REITs, ESCOs, Supranational banks etc.).

More specifically for the residential building sector, the national funding is not enough to cover the need. So, it is necessary the building renovations to be co-financed by the private sector. In order to do so, the private sector needs to be persuaded and assured that the return risk of the investment is low.

In Greece, Eksikonomisi kat' Oikon Program funds the energy refurbishment of the residential building stock. It is co-financed by EU funds (European Regional Development Fund) and from National Financial Resources through Regional Operational Programs and the Operational Program "Competitiveness, Entrepreneurship, Innovation" of ESPA 2007-2013, and ESPA 2014-2020. It provides motive and interest subsidy at loans, capital subsidy and also covers the costs of the energy inspections of residences. [3]

2 LITERATURE REVIEW – STATE OF THE ART

The first Energy Performance of Buildings Directive (EPBD) was implemented in 2002, and it was recast in 2010. EPBD set the requirements for the Energy Certificate, the energy audit, and the retrofitting measures and meanings. [1]

The European Union implemented "energy packages" and set high standards. The energy packages are presented at the next paragraphs.

2020 climate & energy package

The European Union adopted the 2020 climate and energy package to ensure that the countries will meet the climate and energy targets, through three goals: [1]

- 20% cut in greenhouse gas emissions (from 1990 levels)
- 20% of EU energy from renewables
- 20% improvement in energy efficiency

They were set in 2007 and enacted in legislation in 2009. [1]

2030 climate & energy framework

The 2030 climate and energy framework was adopted by the European Council in October 2014 and it includes the revised targets for the period 2021 to 2030: [1]

- At least 40% cuts in greenhouse gas emissions (from 1990 levels)
- At least 32% share for renewable energy (original target 27%)
- At least 32.5% improvement in energy efficiency (original target 27%)

The targets for renewables and energy efficiency were revised upwards in 2018. [1]

2050 long-term strategy

The 2050 long term strategy aims to climate neutrality. It is in line with the Paris Agreement to keep the temperature of the globe before 2°C and pursue efforts to keep it to 1.5°C. Those targets will be achieved by investing to realistic technological solutions and empowering citizens to act. [1][2]

The EU legislative framework
The EU adopted the 2002/91/EC Energy Performance of Buildings Directive (EPBD) to define and restrict the energy use at buildings. The member states have specific requirements: [1]

- Energy certificate for new and existing buildings, necessary for constructing, selling or renting;
- Inspection to assess the air condition unit and the heating system;
- A general framework for a methodology for calculating the integrated energy performance of buildings;
- A framework that defines the minimum standards of the energy performance of new and existing buildings that undergo a major renovation.

The recast
The scope of the recast was to extend the initial framework to all existing and new buildings. Also, it aimed to abolish $1000m^2$ threshold for major renovations. Finally, it requires from all member states to take measures and define the nZEB, so the new and the refurbished buildings to become, or at least approach the nZEB. [1]

EPBD also defines the meaning of renovation. More specifically, the term “major or deep renovation” means the renovation of a building where (a) the total cost of the renovation related to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated, or (b) more than 25 % of the surface of the building envelope undergoes renovation. This report supports ongoing discussions on whether the 25% in the value-related definition of major retrofit represents a balanced and practical value. [1][2]

2.1 European residential building stock

Austria
The majority of buildings (90%) in Austria are used for residential purposes. There are 1,973,979 [STATISTICS AUSTRIA, Register-based Census 2011] residential buildings in Austria, of which 87 % has one or two conventional dwellings, whereas only 13% has three or more conventional dwellings. During the period 1971 to 1990, about 28.8% of the residential building stock was built, and only 25% of the residential buildings have been constructed post-1990. (Appendix, Table 1)

According to “Statistik Austria 2014”, until 2013 there were 1,724,286 residential buildings in total in Austria, including Single Family Houses, Multi-Family Houses and Apartment Blocks. (Appendix, Table 2) During the period 2000-2010, only 1.8% - 2.4% of the residential building stock has refurbished the buildings’ envelope. (Appendix, Table 3)

Bosnia and Herzegovina

In Bosnia Herzegovina there are 1,619,300 residential buildings in total. The majority of them was constructed during the period 1992 to 2014. The number of Single Family Houses (63.49%) is significantly higher than the one of Multi-Family Houses (16.71%). (Appendix, Table 4) Also, during the period 1992-2014 the number of Single Family Houses which were constructed is higher, but the number of the Multi-Family Houses which were constructed is higher during the period 1971-1980. (Appendix, Table 4)

The total percentage of dwellings that have exterior thermal insulation is only 28.07%. (Appendix, Table 5) From these dwellings, 59.32% have external thermal insulation with a thickness smaller than 5cm, and only 6.22% of them have external thermal insulation with thickness 6-10cm. During the period 1992- 2014, the percentage of buildings that have applied thermal insulation on the exterior walls is almost doubled than the previous periods, and the percentage of thickness of thermal insulation smaller than 5cm is reduced, and the percentage of thickness of 5cm and 6-10cm is increased. (Appendix, Table 6)

Belgium

In Belgium there are 4,552,784 residential buildings in total. (Appendix, Table 7) The highest number of buildings is of “buildings with built-up land area larger than 104 m²”, especially of houses in open buildings, hooves and castles. (Appendix, Table 8) Table 9 in Appendix is in accordance with these observations and specifies that the highest number of buildings is of housing units, and the category of houses in open buildings, hooves and castles has also the highest number of houses in compare to the other categories. (Appendix, Table 9)

Bulgaria

In Bulgaria there are 14,435,886 residential buildings in total. (Appendix, Table 10) From these buildings only 428,473 (16.1%) have external thermal insulation, and only 917,574 (35.2%) of them have energy saving windows. (Appendix, Table 11)

Cyprus

In Cyprus there are 175,827 Single Family Houses, 17,824 Terraced Houses and 70,126 Multi Family Houses in total. The majority of dwellings were built at the period from 1981 to 2006, so the majority of the residential stock at Cyprus has no thermal insulation. (Appendix, Table 12)

Czech Republic

In Czech Republic the majority of dwellings was constructed during the period 1961-1980. (Appendix, Table 13 and Table 14) There are 1,554,800 Single Family Houses and 211,300 Multi-Family Houses in total. Taking into consideration the period of construction, the majority of dwellings has no thermal insulation, and it also has high u-values.

Germany

In Germany there is a total of 18,368,000 residential buildings, most of them being Multi-Family Houses (42%). The majority of the residential buildings was constructed until 1978, and later at the period 1989-1994 it was constructed the highest percentage of residential buildings for the whole period 1979-2009. (Appendix, Table 15 and Table 16) For the residential building stock the highest percentage of thermally refurbished walls, roofs, basements and change of windows is observed at buildings constructed until 1978. (Appendix, Table 17)

Denmark

In Denmark there is a total of 1,526,284 residential buildings. The majority of them was constructed before 1978, so the most of the buildings have no thermal insulation. Also, the u-values of the envelope are very high. (Appendix, Table 18)

Spain

In Spain there is a total of 9,804,090 residential buildings, of which 49% were constructed at the period 1971- 2001, and 32% of them at the period 1981- 2001. So, compare to other European countries, a relatively high percentage of the dwellings is thermally insulated. (Appendix, Table 19)

France

For France, there are available data until 2000. The majority of residential buildings was constructed until 1975. The percentages of refurbishment in France are very high in compare to other countries. (Appendix, Table 20 and Table 21) For Single Family Houses, during the period 1975-2000, there were thermally refurbished the 88% of the walls, the 90% of the roofs and also there were replaced the 75% of the windows. For Multi Family Houses, during the period

1975-2000 there were thermally refurbished the 52% of the walls, the 65% of the roofs and also there were replaced the 57% of the windows. (Appendix, Table 22)

Great Britain

At Great Britain, many dwellings were constructed before 1965, with a peak for Single Family Houses at the period 1965-1980. In general, the most of the residential buildings were constructed until 1980, according to data available. (Appendix, Table 23) There are significant percentages of thermally insulated buildings after 1965, with thermal insulation applied on walls and roofs, and the replacement of the glazing at windows. (Appendix, Table 24) But still there are a lot of data missing to have a clear overview.

Hungary

In Hungary there is a total of 2,640,543 residential buildings. There are no available data for thermal insulation at the building stock. (Appendix, Table 25)

Ireland

In Ireland there is a total of 1,649,408 residential buildings. (Appendix, Table 26) Only 9.00% of the building stock was refurbished until 2012. (Appendix, Table 27)

Italy

For Italy there are available data about the refurbished apartments, but not for thermally refurbished envelope areas. Until 2001, the 52.5% of the apartments of Italy at middle climatic regions were refurbished, with the highest percentage for the refurbished apartments been constructed at the period 1962-1971. (Appendix, Table 28 and Table 29)

The Netherlands

The number of the residential buildings in the Netherlands is 7,266,000. (Appendix, Table 30) The Table 31 in Appendix shows the percentage of thermally refurbished dwellings in 2012. The highest percentage (86%) is noticed at the replacement of glazing. The appliance of thermal insulation on walls and roofs was 70% and 79% respectively. There are now available data for the period before 2012. (Appendix, Table 31)

Norway

There are no data available for thermal refurbished buildings in Norway. The Single Family Houses constitute the majority of the residential buildings in Norway. (Appendix, Table 32)

Poland

In Poland there is a total of 5,215,328 residential buildings. (Appendix, Table 33) After 2002 the energy efficient standards were obligatory, so all new buildings fulfilled them. The highest percentage of thermally refurbished envelope areas is noticed at buildings constructed at the period 1967-1985. (Appendix, Table 34)

Serbia

In Serbia there is a total of 3,188,000 residential buildings. (Appendix, Table 35) Insulation in exterior walls exists in 16% of buildings. At the period 1991-2011, 48% of the dwellings were refurbished, with 48% of them having insulation thickness of 5cm. (Appendix, Table 36 and Table 37)

Sweden

In Sweden the majority of dwellings, which applied external thermal insulation, was constructed during the period 1941-1970. (Appendix, Table 38, Table 39 and Table 40)

Slovenia

The apartment buildings in Slovenia are in total 852,693. (Appendix, Table 41) In Slovenia, Single Unit Houses applied thermal insulation mainly on roofs, and replaced the windows. (Appendix, Table 42) The percentages are lower for the appliance of thermal insulation on walls and upper floor ceilings. Multi-Family Houses have also higher percentages at the appliance of thermal insulation on roofs, and at the replacement of windows, and lower percentages at the appliance of thermal insulation on walls and upper floor ceilings.

Greece

In Greece, the national regulation for the Energy Performance of the Building Sector (KENAK) has distributed the country at four climatic zones, considering as basis the Heating Degree Days. The climatic zones of Greece are:

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

Table 2.1.1: Frequency of Building Types of the National Building Stock

Climatic Zone A	SFH		MFH	
	buildings	Floor area in 1000 m^2	buildings	Floor area in 1000 m^2
		National		National
pre 1980	256,126	24,010.738	14,815	2,987.390
1980-2000	101,543	16,535.476	10,851	6,309.271
2001-2010	82,250	13,022.744	16,007	8,932.135
***2011-**	129	18.902	33	18.444
Total	440,048	53,587.860	41,706	18,247.240

Source: EPC database (status: 13/11/2013, analysis NOA). Data refer to whole buildings with building permit issued after 2010 (reporting period: 2011-2013) and an EPC issued for reasons of rent, sale or major renovation.

Last updated: 19.10.2015

Climatic Zone B	SFH		MFH	
	buildings	Floor area in 1000 m^2	buildings	Floor area in 1000 m^2
		National		National
pre 1980	589,178	59,222.241	134,423	52,591.634
1980-2000	187,005	30,665.932	51,239	38,614.093
2001-2010	108,160	18,443.480	67,400	51,126.938
***2011-**	179	33.400	168	113.017
Total	884,522	108,365.053	253,230	142,445.682

Source: EPC database (status: 13/11/2013, analysis NOA). Data refer to whole buildings with building permit issued after 2010 (reporting period: 2011-2013) and an EPC issued for reasons of rent, sale or major renovation.

Last updated: 22.03.2016

Climatic Zone C	SFH		MFH	
	buildings	Floor area in 1000 m^2	buildings	Floor area in 1000 m^2
		National		National
pre 1980	471,650	45,250.489	42,918	18,500.091
1980-2000	141,938	23,051.218	27,375	19,554.006
2001-2010	95,506	16,012.634	37,610	26,973.806
***2011-**	142	19.592	59	32.458
Total	709,236	84,333.933	107,962	65,060.361

Source: EPC database (status: 13/11/2013, analysis NOA). Data refer to whole buildings with building permit issued after 2010 (reporting period: 2011-2013) and an EPC issued for reasons of rent, sale or major renovation.

Last updated: 22.03.2016

Climatic Zone D	SFH		MFH	
	buildings	Floor area in 1000 m²	buildings	Floor area in 1000 m²
		National		National
pre 1980	54,688	5,193.004	2,511	527.809
1980-2000	20,237	3,184.299	1,978	1,248.487
2001-2010	15,365	2,435.837	2,686	1,667.568
***2011-**	4	0.395	3	1.381
Total	90,294	10,813.535	7,178	3,445.245

Source: EPC database (status: 13/11/2013, analysis NOA). Data refer to whole buildings with building permit issued after 2010 (reporting period: 2011-2013) and an EPC issued for reasons of rent, sale or major renovation.

Last updated: 22.03.2016

Source: Hellenic Statistical Authority (HSA), Census 2001 (http://www.statistics.gr/portal/page/portal/ESYE/PAGE-themes?p_param=A1602&r_param=SAM05&y_param=2011_00&mytabs=0)

Source: Hellenic Statistical Authority (HSA), Building Construction Activity (2001-2010) (http://www.statistics.gr/portal/page/portal/ESYE/PAGE-themes?p_param=A1302)

Table 2.1.2: Number and percentage of buildings with non-insulated walls

Building classes	Climatic Zone A		Climatic Zone B		Climatic Zone C		Climatic Zone D		Total	
	Number of buildings	Percentage	Number of buildings	Percentage	Number of buildings	Percentage	Number of buildings	Percentage	Number of buildings	Percentage
SFH										
pre 1980	256,126	100 %	589,178	100 %	471,650	100%	54,688	100%	1,371,642	100%
1980-2000	10,595	10.4 %	25,262	13.5 %	17,659	12.4%	2,353	11.6%	55,869	12.4%
2000-	0	0	0	0	0	0	0	0	0	0
MFH										
pre 1980	14,815	100 %	134,423	100 %	42,918	100%	2,511	100%	194,667	100%
1980-2000	1,097	10.1 %	5,236	10.2 %	2,707	9.9%	196	9.9%	9,236	10.1%
2000-	0	0	0	0	0	0	0	0	0	0

Source: D. Lalas, C.A. Balaras, A. Gaglia, E. Georgakopoulou, S. Mirasgentis, I. Serafidis, S. Psomas, Evaluation of supporting policies for the advancement of the Ministry's policies in relation to the abatement of CO_2 emissions in the residential and tertiary sectors, 650 p. in Hellenic, IERSD, National Observatory of Athens, Ministry for the Environment, Physical Planning and Public Works, Directorate Urban Planning & Housing, November (2002).

In Greece, at all climatic zones, there are more Single Family Houses than Multi Family Houses. Climatic zone B is the biggest zone as it contains the majority of residential buildings. Also, there is a very large building stock. The majority of buildings constructed before 1980, so according to Table 2.1.2 these buildings are uninsulated as they were constructed before the national regulation for the Energy Performance of the Building Sector. After 1980, the new buildings were insulated, but according to Table 2.1.2 the percentage of insulated buildings at the period 1980-2000 is very small (~ 10%). Unfortunately there are no data available after 2000.

So, the European building stock is at its majority uninsulated and energy inefficient, as it was built before EU energy regulations. The buildings that were built after the EU energy regulation are more energy efficient than those which were built before EU energy regulation, but they are also aged. To achieve EU 2050 energy targets, 97% of the residential building stock in Europe needs to be refurbished. [2] The energy performance of the building stock is constantly improving, but only the residential buildings constructed after 2010 can be considered efficient. Those buildings consist only the 3% of the total existing building stock. [2]

By studying the Tables 1-42 in Appendix, it is shown that the uninsulated European building stock is around to 72-85%. North and West Countries have the most aged building stock, as its majority was constructed before 1990, followed by Central and East Europe. Therefore, many countries fund the refurbishment of their building stock. For instance, Germany, France, The Netherlands and Slovenia have high percentages on windows' replacement and on installation of thermal insulation on roofs and ceilings. Serbia and Sweden refurbished at most the external walls and windows, and Great Britain refurbished the external walls, roofs and ceilings, and windows. Also, it worth to mention that Italy accomplished to refurbish 52.50% of its residential building stock by 2001, and Poland has the higher percentage of refurbished buildings at buildings constructed at the period 1967-1985. Finally, ten Member States (Austria, Belgium, Czech Republic, Denmark, France, Germany, Netherlands, Romania, Spain and UK) were selected by BPIE as they stood out for their effort to submit their energy strategy on time, on April's 2014 deadline. The report of BPIE about the ten Member States concludes that there are more to be done, not only on energy sector, but also on economic, social and environmental sector. The energy packages should be developed and countries should invest on deep renovation measures. [2]

2.2 Building Typology

Nowadays the global population at the urban environment is 54% of the world's population and is expected to increase in the years to come. By 2050 it will be 66%.

A huge proportion of the European building stock has no or minimal energy related codes. Buildings are responsible for 40% of final energy consumption. Most of the European buildings will remain in use by 2050, so the need for energy refurbishment is necessary. The challenge and the target for the years to come is the energy efficient renovation in the existing building stock. [EU Facts]

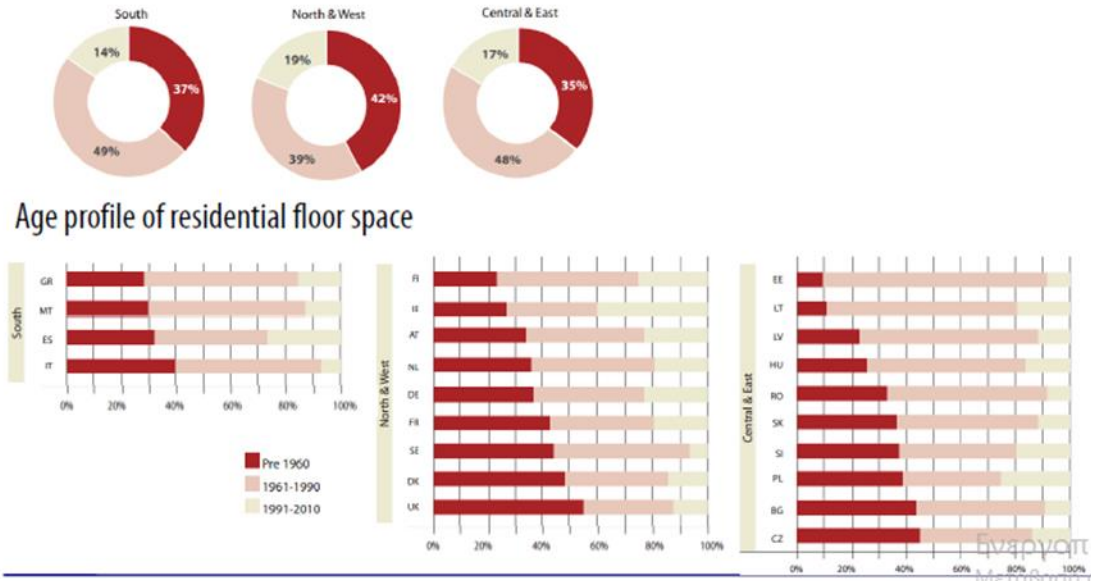
In Europe, in 2014, it was calculated 151.8 billion m^2 of building surface, of which 75% was in residential buildings. It is also important that it is expected a compound annual growth rate of 1.2% at residential buildings by 2030. Also, 64% of the residential buildings are single family houses, and the remaining 36% are apartments. [EU Facts]

It is also important to mention that Europe has the highest building density, followed by China and then US. In Europe the largest sector of final energy is consumed by transport (34%), followed by households (27%) and industry (24%). [THEODORIDOY, 2019]

The majority of the residential buildings is located at urban areas. The countries of Central and East Europe have similar typology of single family houses and apartments, and also have the lowest residential space in compare to the rest of Europe. North and West countries have the highest residential floor areas per capita. Finally, the countries in the South Europe have the highest single family house floor space per capita. [2]

In order to study and understand better the building stock, it has been divided to three main age categories: [2]

- Old: typically representing buildings up to 1960
- Modern: typically representing buildings from 1961 to 1990
- Recent: typically representing buildings from 1991 to 2010



Picture 2.2.1 Age profile of residential floor space

Source: BPIE

The European building stock is huge and is ageing. It is more important to renovate and energy refurbish than constructing new buildings. 97% of buildings in the EU need to be upgraded. By 2050 the majority of the European building stock has to be highly energy efficient and have, at least, an Energy Performance Certificate (EPC) of A-label At this point, less than 3% of the buildings qualify an EPC of A-label. According to BPIE, 75% of the European building stock can be upgraded and be 'energy efficient'. [2]

The TABULA project is a significant project that studies the European building stock. It defined the construction period of the building stock (of each country in Europe), the buildings' size, the location and climatic conditions, the type and age of the supply system. It can provide with significant information to refurbish the existing building stock of Europe. [TABULA Project]

2.3 Description of Europe and of Greece's residential building typology

2.3.1 Multifamily buildings

Multifamily buildings, or multi-dwelling units (MDU), are composed of multiple separate residences, which are contained in one building or apartment. [4] The residences may be owned by individuals or by one apartment/ building owner. [5] To form a MF building, the units can be next to each other or on top of each other, and there must be at least two adjacent housing units, either horizontally or vertically. [4][5]

2.3.1.1 Types of European residential buildings

The multifamily houses can have multiple forms. The most common one is apartment building. An apartment building contains multiple units that usually are arranged at multiple floors. [4] An apartment building is owned by one individual owner. [4] This is the main difference with a condo building. A condo building has the same building characteristics as an apartment building, but the ownership is different. At a condo building the ownership is divided among all condo owners. [4]

Another type of multifamily housing is the townhouse. It is an individual owned building, attached to similar buildings. It has multiple floors, and each townhouse has its own individual entrance. [4]

A duplex building is a building divided to two separated houses, usually attached side by side. Each house is autonomous with its own entrance.

The triplex and quadruplex buildings are similar to duplex, but they have three and four house units respectively. [4]

Finally, a mixed-used building can be used for multiple purposes, like residential, commercial, industrial or other uses. Usually, the residential areas are located at the upper floors and the other uses at the bottom floors, or the residential uses are at the back of the building and the other uses in the front of the building.

2.3.1.2 Multi-Family vs Single Family Houses

A single family house has more privacy than a multifamily house. There are no shared areas, walls or doors. [6] It is detached from other buildings, and usually the owners occupy the unit.

On the other hand, a multifamily building contains many houses. It can contain an apartment building, duplexes and triplexes. [6] The people that live at a multifamily building are usually tenants who rent the units from the building owner. [6]

2.3.1.3 Classification

The classification has four categories. The purpose of the classification is for investors to understand the property’s characteristics and assess the value. [7] The classifications are:

Class A: the luxury apartments belong at this category, which are less than 10 years old and they have a high rent. Usually these apartments are located at good and desirable areas. [7]

Class B: the buildings at this category are usually 10 to 25 years old, and they are well maintained. Usually these buildings are middle class residences. [7]

Class C: the buildings at this category are usually 30 to 40 years old, and they are occupied by low income residents. [7]

Class D: the units at this category are generally positioned in lower socioeconomic areas. [7]

2.3.2 The Greek Polykatoikia

The Greek multifunctional dwelling is also known as polykatoikia [8]. It is a composite word, from poly- (meaning multi), and katoikia (meaning house, or at this case better translated as multi-storey apartment building). [8] The term polykatoikia describes all housing buildings in Greece that are occupied by multiple residents. [8][9] In 1918-1919, the first apartment building was built in Athens at Philellinon and Othonos Streets, but the Greek apartment building known as the polykatoikia was born in the 1930s. [10] The architect was Alexandros Metaxas. He designed the building in eclectic style. [9] At the time, it was the first building in Greece constructed by reinforced concrete, and it was not fit with the existing buildings. For this reason, the framework about the polykatoikia in Greece set the height for buildings according to the width of the street they lay on, with a maximum height of 26 meters for wide streets. [9]

After the Greco-Turkish war of 1919-1922 there was population exchange between the two countries. [9] Athens’s population almost doubled at 1928 when the refugees came from Asia Minor. The increase in the population create the need for more residences. [10] The housing need had a huge impact on the Greek economy and influenced the framework of polykatoikia [9] Polykatoikia became very soon the dominant building typology in Greece to meet the needs of the social and economic elite. [10]

The polykatoikia was supported by the State in the form of a general building regulation and a property law, which formed also the architecture of polykatoikia. [8] More specifically, the law of horizontal property that was adopted in 1929, enabled the antiparochi system (antiparochì, literally "a supply in exchange"). [9][10] The law of horizontal property made it possible for many different owners to own o whole building (polykatoikia), each one owning his own apartment unit, but the management of shared spaces is done collectively. [9][11] According to antiparochi system, the owner of the plot, who cannot afford to build a polykatoikia by his own, can exchange it tax-free to a contractor to build indoor space, and he will keep the ownership of as many apartments as the contract states. [8][9][10] Each apartment corresponds to a percentage of the original plot. [9] It is defined at the polykatoikia statue, declaring the ratio of the plot that every owner has the right to build, multiplied by the permitted floor area ratio. [11] It also defines the common space, the entrance, the akalyptos (the back yard), and everything concerning the co-living of owners and/or residents at polykatoikia, which means the whole building and the shared spaces. [11] Soon antiparochi became the principal method of financing the construction of polykatoikies from 1950s. [9][10]

2.3.2.1 The Domino model

At 1914, Le Corbusier designed the Dom-ino model (from the Latin dooms, "house", and an abbreviation of "innovation"). [8] Domino model became the basis model of construction at all countries. It is composed by an open framework of columns and slabs made of reinforced concrete. Le Corbusier designed this model to bring closer architecture and everyday building construction, adopting the new technological methods and materials. [8] It is a flexible design that is “the best embodiment of Le Corbusier's motto "Architecture or Revolution"”. [8]

Like domino model, polykatoikia is a flexible designed building, using simple materials and techniques for its construction. [8] It is an evolution of Le Corbusier’s domino model. [10] It is composed by a framework of slabs and columns of reinforced concrete, a staircase and an elevator. [10] It is a cheap, adaptable construction that can accommodate multiple uses and services, like shops, offices, storages, house units etc. [11]

2.3.2.2 Greek residential buildings before 1930

At the beginning of the 20th century, Greek architects did not succeed either to follow the European movements of architecture, like Art Nouveau and Art Deco, or evolve Neoclassicism. [9] Buildings following classical styles were constructing, giving Athens an electrical style. [9]

2.3.2.3 Greek residential buildings during the period 1930-1940

At the period 1930-1940, modern architecture grew in Athens. Greek architects were influenced by European modern architects, like Le Corbusier, Walter Gropius, and Erich Mendelsohn, but still architecture was also influenced by conservatism and classicism. [9]

After the adoption of the law of horizontal property at 1929, the first General Building Regulation was also adopted. [9] It established the framework for the height of polykatoikies, as mentioned at previous paragraphs, but also introduced new architectural elements embedded at the design of polykatoikia, like “erker” (bay windows) as known at Greek terminology, which can protrude up to 1.4 meters, and spacious entry halls. Other architectural characteristics are the flat roof and the position of pergola on it, as well as flat facades with long horizontal windows. [9][11] The facades lack of decoration. There are only the openings, the doors and the windows, and finally the balconies. [11] Usually, the polykatoikies had 4 to 7 storeys. [11] An example is the “Ble Polykatoikia”, designed by Kyriakos Panagiotakos at 1932, at Exarcheia Square, an apartment building with a lot of “erkers” at its façade but no other decorative elements. [9]

2.3.2.4 Greek residential buildings during the period 1950-1990

At 1950s, the conservatism and classicism that were dominant at 1930s were also implemented at the new buildings. At this period apartment buildings were decorated the same way as public buildings. The entrance and the stairway were elaborate decorated with classical ornaments by iron. Also, it was used white marble at the inside shared spaces and colorful facades at the exterior of the polykatoikies. [9]

The need of housing was huge after the World War II, and after the Civil War that followed. The State was unable to accommodate the population that moved from rural areas to the cities. [10] The need for new apartment buildings and the easy and fast construction of new concrete building contributed to the growth of the construction industry. [10]

At 1955, the framework changed the width of penthouses at 2.5m narrower as the floor changing, so polykatoikies had the shape of a pyramid. [11] As antiparochi system was adopted, civil engineers instead of architects designed the polykatoikies. [11][12] The repetition of the same floor and the repetition of balconies, the lack of architectural design and the need to create as much of useful space as possible, formed the type of polykatoikia that was built repetitively at Greece. [11] At the period 1950-1980 more than 35,000 polykatoikies were built, with most apartments having 3 rooms and an average of 75 sq.m. [11] Polykatoikia made real the “osmosis of private and public spheres” [13] in the urban environment of Greece and helped its development. [13] The repetition of polykatoikia produced a “form-less, border-less and placeless urban landscape” [15] that has covered the whole Attica basin. [10]

The evolvement of Greek cities accomplished by the antiparochi system been supported by the government. The cities recovered without great economic support from the government and with minimum state intervention. [8] This system helped Greek cities to obtain more housing units, owned by citizens, at less time period. [8] Soon, it became the key pillar of the Greek economy. [10] Polykatoikia was the apartment building that could house people from all different classes, and form the new cities. [8] It created new cities and new social structure. [14] Polykatoikia introduced a new way of life. [10] It is a unique form of apartment building that can be transformed from small/medium scale to large scale building maintaining its individualism. [8] It is a manifesto with its own architectural language that changed the form, density and the urban environment of Greek cities. [8] Using polykatoikia as a unit the fragmentation of cities could be changed, and cities could be reconstructed with a collective urban environment. [8]

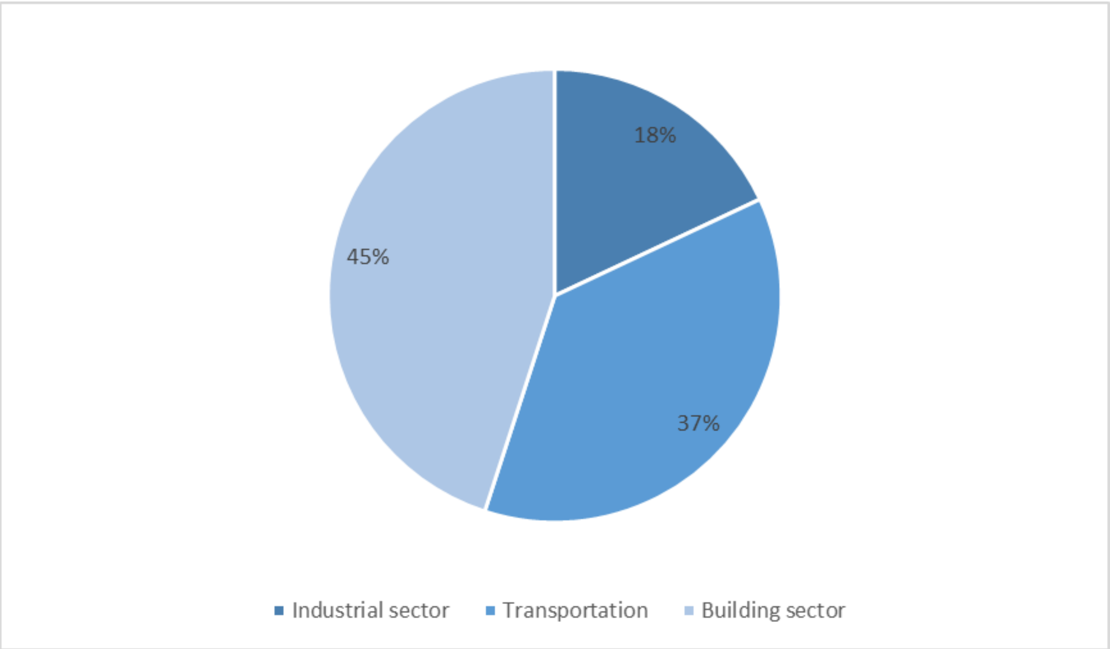
2.3.2.5 Greek residential buildings after 2000

By the change of the century and the change of lifestyle, the form of polykatoikia had to adapt to the new way of living so to cover the needs. [10] The existing form of the floor plans had to be transformed to satisfy the new type of users. [16] The need for a new type of polykatoikia needed the intervention of architects to be developed. [10]

3 Funding Schemes

3.1 Eksikonomisi Kat' Oikon Program

The building sector is responsible for 45% of the total energy consumption of Greece. [18]



Graph 3.1.1: Distribution of final energy consumption per use, 2012

Source: [3][18]

The directive 2012/27/EU of the national law of Greece refers to buildings' energy efficiency. The target is the reduction of the total final energy consumption to 18.4 million TOE (Tonnes of Oil Equivalent) by 2020. [17]

The majority of the existing building stock was built before 1980, so the refurbishment of the building sector can attribute to a very large extend to energy saving. [17] The residential sector constitutes the 83.68% of the building stock of Greece. [19] It consumes huge amounts of energy. A significant factor is the buildings' age. The 55% of the residential buildings was built before 1980, which means that these buildings have no thermal insulation. [3] Because of the economic crisis, only 1.5% of the building stock is constructed after 2010 when the framework for energy efficiency was launched. [3] It is important to mention that 83.82% of the residential buildings constructed before 1980 have an energy label of H, according to EPCs on 2014. [20] The buildings that were constructed the next three decades had an energy label of C or D. [3]

To facilitate the owners to refurbish their residential buildings, a funding program was developed, and it was implemented in two stages:

- "Eksikonomisi kat' Oikon I", which was co-financed by the European Regional Development Fund, from the National Financial Resources and Environment and Sustainability of ESPA 2007-2013; and
- "Eksikonomisi kat' Oikon II", which was also co-financed by the European Regional Development Fund, from the National Financial Resources and Environment and Sustainability of ESPA 2014-2020.

"Eksikonomisi kat' Oikon" is a funding program that provides motive and interest subsidy at loans, capital subsidy and also covers the costs of the energy inspections of residences with resources from the repository of "Eksikonomisi kat' Oikon II Funds" and the "Direct Aid Program" of households for energy saving interventions at residential building stock for the period 2014-2020. [3] This program is co-financed by EU funds (European Regional Development Fund) and from National Financial Resources through Regional Operational Programs and the Operational Program "Competitiveness, Entrepreneurship, Innovation" of ESPA 2014-2020. The total public expenditure of the Program amounts to 778.01 million€. [3] [17] Eksikonomisi kat' Oikon I had a total budget of 396 million€. Energy investments make a significant contribution to the universal and international (for Greece) decrease of climate change. [17]

Eksikonomisi kat' Oikon financed the energy refurbishment of 60,000 residences. [17] This funding program aims to reduce the energy needs of the residences, the CO_2 emissions, and achieve cleaner environment. [17] The program meets the thematic target 4 that is set by the strategy of Europe for 2020 concerning "the support of the transition to a low carbon economy in all sectors". [3] More specifically, Eksikonomisi kat' Oikon is in accordance with the target for energy efficiency support, the smart management of energy and the use of renewable energy sources. [3]

The specific program funds the energy refurbishment of residential buildings that are used as the main residence. A building permit or other legal document has to be adduced at the application. The residence should also has been excluded from demolition. [3] The owners must meet specific income criteria. [17] The program grants a grant to the owners and also subsidizes the interest of the loan. [17]

The implementation of the Program is based on the adjustment of the national framework that has been formulated by the Energy Efficiency Regulation of Buildings of Greece, KENAK. [17]

The benefits of the energy refurbishment would be: [17]

- Energy saving;
- Reduction of CO_2 emissions;
- Upgrade of the urban environment;
- Improvement of the living conditions in buildings and cities, and improvement of the everyday life;
- Additional benefits in both economic and social aspects, such as energy security, reduction of energy poverty, employment and health;
- The owners improve the energy efficiency of their residence, and at the same time they increase its value. [17]

Detached houses, polykatoikies and single apartments can be included at the program. The criteria that should follow the residences to be funded by this program are: [17]

- Be located in areas with a zone price lower than or equal to 2,100 € / sqm.
- Have been classified under the Energy Performance Certificate (EPC) in a category of less than or equal to D (of Greek energy framework).

There are seven categories of beneficiaries as presented at the table below:

Table 3.1.1: Categories of beneficiaries

Category	Individual income	Family income	Subsidy	Increase of subsidy per child	Maximum subsidy
1	<=10,000€	<=20,000€	60%	5%	70%
2	10,000€ - 15,000€	20,000€ - 25,000€	50%	5%	70%
3	15,000€ - 20,000€	25,000€ - 30,000€	40%	5%	70%
4	20,000€ - 25,000€	30,000€ - 35,000€	35%	5%	70%
5	25,000€ - 30,000€	35,000€ - 40,000€	30%	5%	50%
6	30,000€ - 35,000€	40,000€ - 45,000€	25%	5%	50%
7	>35,000€	>45,000€	0%	0%	0%

Source: Eksikonomisi kat' Oikon II Program, YPEKA.

At the seventh category, there is not a subsidy but an interest free loan.

The interest free loan can be taken for 4-6 years. A 40% deposit of the application budget is provided when the beneficiary is selected. [17]

An energy inspection before and after the complete of the program should be accomplished for all residences. [17] The cost of the inspection is completely covered by the program, after the successful implementation of the energy refurbishment. [17] Also, the program covers the fee of the consultant up to 250€ without taxes. [17] The interventions are made after the release of the EPC of the first energy inspection. [3]

The selection of the applications for the funding of interventions is expired at 16/06/2023. [3] The selection of the expenditure of the program is expired at 31/12/2023. [3]

The energy savings after the refurbishment should upgrade the residence by at least one energy category according to Greek framework, or reduce by 30% the final energy consumption of the residence compared to the reference building. [17]

The interventions that can be implemented are: [17]

- Retrofitting of thermal insulation at the building's envelope: at the external walls, on the roof and on the Pilotis.
- Replacement of the windows and installation of shading systems.
- Upgrade of the heating system and of the system of the hot water supply.

The maximum budget for interventions at each residence, including taxes, is 15,000€. [17]

The distribution of the resources per region of Eksikonomisi kat' Oikon II Fund and of the Direct Aim Program is presented at the table below:

Table 3.1.2: Distribution of total resources

Region	Eksikonomisi kat' Oikon II Fund (€)	Direct Aid Program (€)	Total budget (€)
East Macedonia - Thrace	18,025,022.49	5,983,553.36	50,614,936.68
Central Macedonia		17,110,535.57	130,440,216.73
Epirus		5,670,840.35	47,731,004.73
Thessaly		10,958,957.32	89,544,361.40
West Greece		6,949,696.53	53,980,218.96
Attica	7,469,361.08	15,012,307.15	129,182,451.62
South Aegean	890,034.19	1,343,753.62	14,438,330.50
Central Greece	1,785,395.28	4,196,404.40	35,090,810.42
West Macedonia	5,830,186.97	3,221,642.68	29,059,825.62
Peloponnesus		4,035,460.56	32,263,873.42
Ionian Islands		1,172,973.87	11,879,532.54
North Aegean		1,361,295.36	17,877,679.97
Crete		3,660,162.73	33,902,033.19
Total	34,000,000.00	80,677,583.52	676,006,075.78

Source: [3]

The distribution of the funding was allocated at the regions according to population criteria and not by energy saving needs or climatic conditions. As a result, the distribution at some population groups was unfair. For example, North Greece has huge needs for heating at winter but South Greece has higher population density.

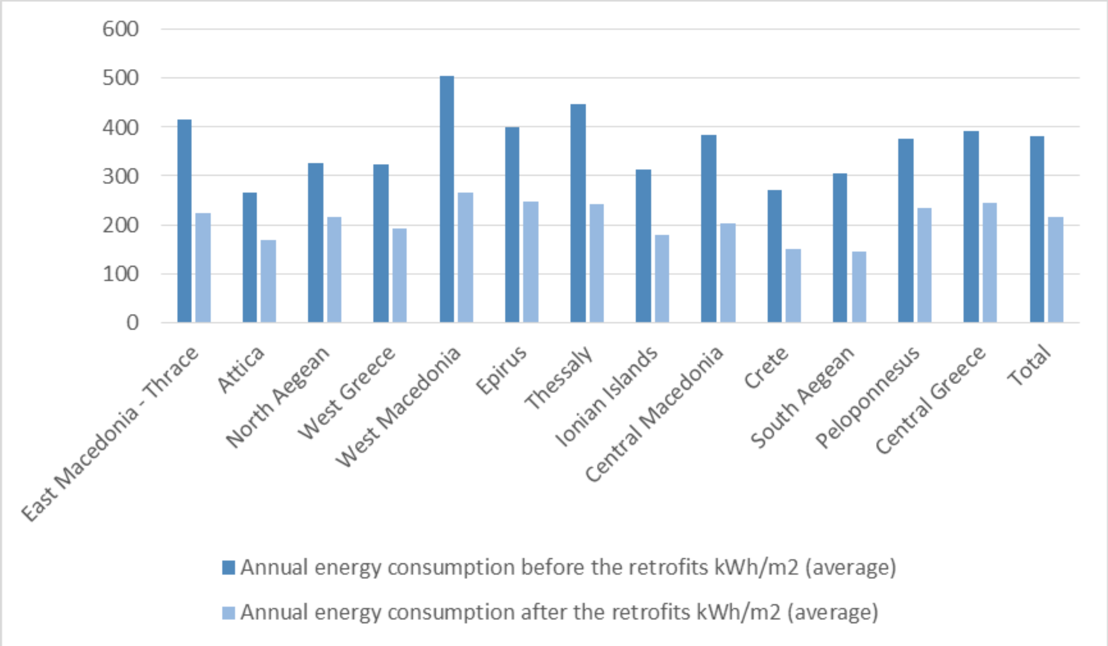
The table below shows the total energy consumption before and after Eksikonomisi kat' Oikon program at regions of Greece, and the number of households that participated at the program.

Table 3.1.3: Total energy consumption before and after Eksikonomisi kat' Oikon interventions program per Region

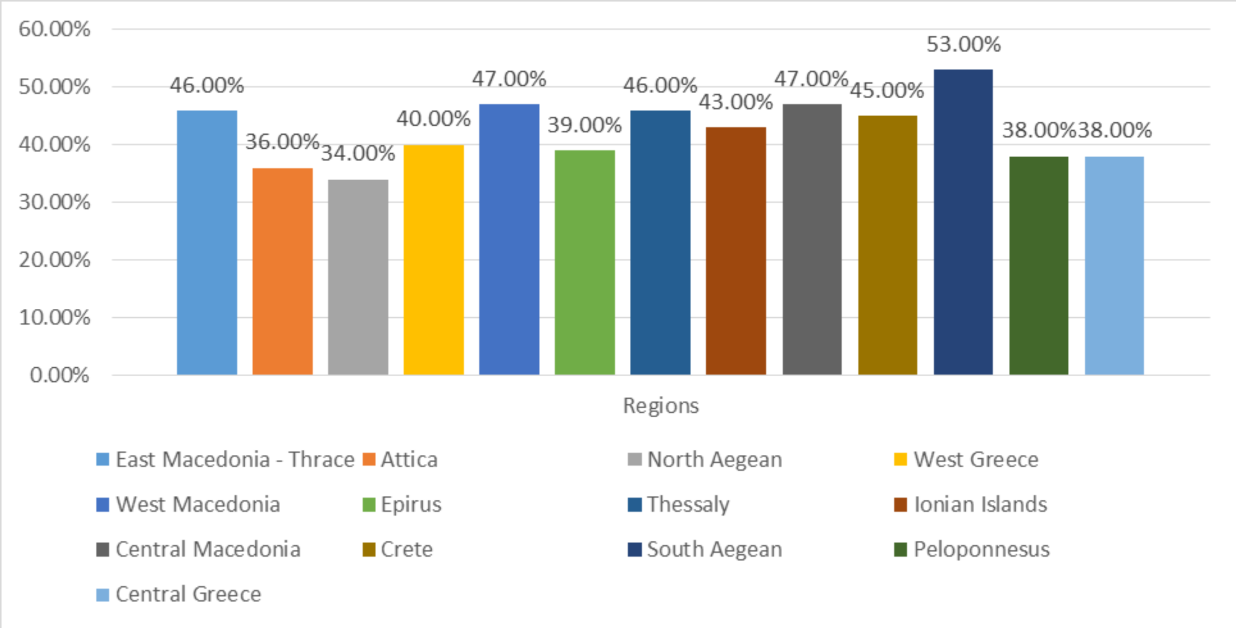
Region	Annual energy consumption before the retrofits kWh/m² (average)	Annual energy consumption after the retrofits kWh/m² (average)	Number of participants (households)	Average rate of change (%)
East Macedonia - Thrace	416	223	3,850	46
Attica	265	169	6,309	36
North Aegean	325	215	1,474	34
West Greece	323	192	2,584	40
West Macedonia	506	267	3,207	47
Epirus	401	247	3,181	39
Thessaly	448	243	7,906	46
Ionian Islands	312	178	439	43
Central Macedonia	384	202	10,207	47
Crete	270	149	1,468	45
South Aegean	306	144	487	53
Peloponnesus	376	234	1,673	38
Central Greece	392	245	2,618	38
Total	381	215	45,403	43

Source: [21]

According to Table 3.1.3, South Aegean has the highest percentage of energy saving, and North Aegean the lowest. West and Central Macedonia have also high percentages, followed by Crete.



Graph 3.1.2: Total energy consumption before and after interventions of Eksikonomisi kat' Oikon program, per Region



Graph 3.1.3: Total energy consumption after Eksikonomisi kat' Oikon program, per Region

The highest budgets of Eksikonomisi kat' Oikon Program were allocated at Central Macedonia and Attica and, as mention at a previous paragraph, the distribution of the funding was allocated by financial population criteria and not the energy requirements of the buildings, or the climatic conditions. The average energy savings in Greece after the completion of the program were 43%. The higher percentages of energy savings are allocated at the north regions, at climatic zones C and D, and the lowest percentages at climatic zones A and B. These results are an indicator that should be considered carefully for the evolution of the program, as the energy requirements and the climatic conditions affect the effectiveness of the retrofitting measures, and not the financial conditions of the owner.

3.2 Funding programs in Europe

European cities are responsible for about 70% of the overall primary energy consumption. [European Institute for Energy Research] C40 Cities have already implemented over 1,500 actions at the building sector. [Climate Action in Megacities report] The Covenant of Mayors created and implemented Sustainable Energy Action Plans (SEAPs) and Sustainable Energy and Climate Action Plan (SECAP), since 2016. [THEODORIDOU, 2019]

European Union policy initiatives for smart buildings aims to fund public and private energy efficient projects, and also contribute to the reduction of energy poverty. [22] However, the amount of EU funds available is not enough for all these expectations, so the contribution of the private sector is needed. [23] It is a fact that the private sector finances the majority of energy efficiency projects in buildings.

To persuade investors to fund energy projects, the risk on investment has to be low and the return on investment has to be satisfying. The risk associated with energy efficiency investments is low in compare to other types of investments, but still it is difficult to estimate it. [23] So the Commission introduced two Tools:

- "The De-risking Energy Efficiency Platform (DEEP) is a pan-EU open-source database containing detailed information and analysis of over 10,000 industrial and buildings-related energy efficiency projects." [23]
- "The Energy Efficiency Financial Institutions Group (EEFIG) Underwriting Toolkit, a guide to value and risk appraisal for energy efficiency financing, was launched in June 2017." [23]

National governments also fund energy efficiency projects in buildings. The National Energy Efficiency Action Plans (NEEAPs) and the EPBD have a major contribution on this field. The reports present very high energy savings at the building sector.

Eksikonomisi kat' Oikon Program in Greece is co-financed by the European Regional Development Fund, from the National Financial Resources and Environment and Sustainability of ESPA 2007-2013, and of the second stage of ESPA 2014-2020. [3] The total public expenditure of Eksikonomisi kat' Oikon II Program amount of 778.01 million€, and financed the refurbishment of over 60,000 residences. [17] Because of the limits of financial resources, the program was not able to cover the demand of all applications. A number of applications remained "frozen" and were never able to be completed, as there was not available fund to cover the demand. [24] Unlike other European Programs, Eksikonomiki kat' Oikon was not co-financed by private sector, and maybe this is a reason for its limited budget and the eligibility of the beneficiaries mainly by financial criteria.

Other funding schemes are analyzed at the next subchapters.

3.2.1 Energy Service Companies (ESCOs)

ESCOs are companies that deliver energy services or efficiency upgrades through mechanisms such as EPCs, accepting a financial risk during the process. The payment for their services is based on the results of the energy refurbishment.

According to European Commission, ESCOs have three main characteristics: [25]

- They assure the final customer for the energy savings of its building at a low cost.
- Their payment is directly connected on the energy efficiency of the building.
- They provide assurance on the operation of the energy system by immediately financing it, or they assist in finance.

ESCOs also provide EPCs (Energy Performance Contracting). This document is a legal agreement between the two participants, the customer and the ESCO, and it allows funding energy upgrades from cost reductions. Under an EPC, the ESCO has the responsibility, and the risk, to provide the final customer with a study and an extensive retrofit of the building, or a renewable energy project, and also cover all the stages of the process. If the results are not the same as agreed, ESCO pays the difference to the building owner. [26]

3.2.2 Real Estate Investment (REIT)

A REIT is a company that owns or finances income-producing real estate. [THEODORIDOU, 2019] More specifically, REITs invest in real estate and own specific tax advantages. Investors are able to buy shares in commercial real estate portfolios at a variety of properties. Anyone can invest on large-scale properties through the purchase of stock. Stockholders of a REIT benefit by the income produced through real estate investment, without buy or finance property. All investors are able to invest in property assets without large amounts of money.

Typically, REITs pay all of their taxable income as dividends to shareholders, and shareholders pay the income taxes on those dividends. [THEODORIDOU, 2019] REITs provide a great research on energy and environmental performance of the building stock.

3.2.3 Third-Party Financing (TPF)

TPF refers to debt financing. The retrofit is financed by a third party, an ESCO or a financial institution, which is not the user or customer. [THEODORIDOU, 2019]

3.2.4 Project Development Assistance (PDA) - PDA H2020

PDA H2020 is an initiative of the European Commission which aims to assist individuals and public sectors to develop sustainable projects with a small or medium size investment of at least 7.5 million€ and up to 50 million€, covering up to 100% of eligible project development costs. [25]

3.2.5 IEE Projects - IEA-EBC Programme

The Intelligent Energy Europe Programme (IEE) (2006)

The Intelligent Energy Europe Programme (IEE) was established to fund organizations that improve energy efficiency and sustainability. It is a part of the Competitiveness and Innovation Framework Programme, and it was supported by the European Union to meet the EU 2020 targets. [27]

IEE PROJECT - DATAMINE (2006-2008)

The DATAMINE Project was established to enrich the knowledge of the energy performance of the existing building stock. To succeed this, it used the data of the energy certificates. So, it was also established the Energy Performance Certificate (EPC) databases in European countries. Many projects were implemented and their results were analyzed, creating a common database for EU countries, where representative building types were defined with their perspective characteristics according to their age and size. [28]

IEE PROJECT – TABULA (2009-2012)

The TABULA Project was launched in 2009 using the DATAMINE Project data structure. It was created to relate the energy characteristics of the existing building stock as a classification to building typology's definition. At the TABULA Project, 13 European countries were studied. Each country has its own classification of its building stock by age, size and other parameters. The results can be found at "Building Typology brochures", and at "TABULA Web tool". The platform "TABULA Web tool" also provides the users with the possible energy savings by the implementation of retrofitting measures. It calculates the energy needs of the building, its CO_2 emissions and the cost. The results for all countries can be compared and the energy consumption of the buildings can be measured. Finally, there have been created residential building stock models for seven countries, according to each country's typology. The models estimate the actual energy consumption and the potentials for the residential building sector. [29]

IEE PROJECT – EPISCOPE (2013-2016)

The EPISCOPE Project was based on the TABULA Project. By using TABULA Project's building typology database, it calculates the energy performance of the buildings on the energy saving and climate change mitigation targets. Experts on energy efficiency can be informed about retrofitting procedures and ameliorating interventions. EPISCOPE Project aims to assure the climate protection actions. The TABULA Project database for each country will be updated and will also include NZEB buildings, as well as the retrofitting measures needed to succeed those targets. The procedure will be monitored, and the simulation results will be compared to true measured results to find out the true energy savings. According to the results, the TABULA Project platform and database will be enriched with more classifications and retrofitting proposals and results. The results will be used to compare different scenarios at different countries. Finally, the Energy Performance Certificates will be enriched with energy performance indicators. [30]

International Energy Agency (IEA) - Energy in Buildings and Communities Programme (EBC)

The International Energy Agency (IEA) is an organization which was established in 1974 after the oil crisis of 1973. [31] Its role is to supervise the demand and supply of primary energy, Renewable Energy Sources (RES), energy efficiency aspects etc. [32] IEA focusses on four main areas: [32]

- Energy Security by promoting diversity, efficiency, flexibility and reliability for the primary energy sources;
- Economic Development by supporting the development of free markets and eliminating energy poverty;
- Environmental Awareness by offering environmental friendly solutions regarding the use of energy sources and their impact on environment and on climate change; and
- Worldwide Engagement by working with countries, especially those which have major impact on international economy, to propose solutions regarding energy saving and environmental concerns.

The Energy in Buildings and Communities Programme (EBC) was established in 1977 by IEA, in order to reduce the energy consumption of the building sector. Its primary target is to inform the countries about the energy consumption of the building stock, after thorough research. To fulfill its purpose, a series of “Annexes”, were implemented. EBC Programme offers the possibility to individuals to take advantage of the knowledge of experts, who were funded by national program to study in depth the energy field. So, a network of expertise was created and established the communication of the member countries. All 26 member countries can participate at current projects and propose new ones. Most of the projects are on “task shared” basis, at which the experts of the organization of the projects take part. [33]

Other IEE Projects

Other IEE Projects are presented at the Table 3.2.5.1 below.

Table 3.2.5.1: IEE Projects

Acronym	Title	Teaser	Start date	End date
LABEL 2020	New Label driving supply and demand of energy efficient products	The EU energy label for products has been a key driver supporting innovation and market development for energy efficient products for more than 20 years. The label stimulated innovation by manufacturers and demand for energy efficient products by consumers and professional...	1/6/2019	30/11/2022
HACKS	Heating And Cooling Know-how and Solutions	The objective of Heating And Cooling Knowhow and Solutions (HACKS) is to achieve market transformation for heating and cooling (HAC) appliances by motivating consumers to replace old and inefficient equipment with new energy efficient equipment; and to encourage solutions that...	1/9/2019	31/8/2022
Digi-Label	Delivering digital Energy Labelling solutions to enable consumer action on purchasing energy efficient appliances	Digi-Label will design and deliver digital tools and solutions to compliment the EU energy label. Through these we aim to positively influence consumer buying choices and ultimately deliver greater energy savings and increased market share of the highest performing appliances...	1/4/2016	31/3/2019
SCOoPE	Saving COOPerative Energy	SCOoPE project will work directly with energy-intense	1/4/2016	31/3/2019

		agro-food industries to implement cross-cutting and collaborative energy management systems addressed to reduce their energy consumption, and will further spread this knowledge within technicians, businesses managers, and...		
ODYSSEE-MURE	ODYSSEE-MURE, a decision support tool for energy efficiency policy evaluation.	The 2012 Energy Efficiency Directive (EED) establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. Countries have also set their own indicative national energy efficiency targets. To reach these targets, EU countries have to...	1/2/2016	31/7/2018
EEPLIANT	Energy Efficiency Complaint Products 2014	The objective of EEPLIANT 2014 (Energy Efficiency Compliant Products 2014) is to help deliver the intended economic and environmental benefits of the Eco-design Directive 2009/125/EC and the Energy Labelling Directive 2010/30/EU by strengthening market surveillance and...	1/3/2015	30/6/2017
FinEERGo-Dom	Financing scheme for Energy Efficiency and Renewable energy Guaranteed in Deep renovations of building stock	The National Fund "NFOSiGW" supported by KAPE and partners seek to replicate the financing scheme, systems and procedures developed for private and public sectors under the Latvian Baltic Energy Efficiency Facility' "LABEEF". The Fund will structure	1/6/2019	31/5/2023

		demand and...		
ODYSSEE-MURE	Monitoring EU energy efficiency first principle and policy implementation	The ODYSSEE-MURE project aims to support policy makers in EU Member States to fulfill their obligations in the framework of the EU Energy Efficiency Directive (EED). In particular, it provides user-friendly databases and web-tools for monitoring and evaluating the impact of...	1/6/2019	30/11/2021
DiBiCoo	Digital Global Biogas Cooperation	The overall objective of the project is to support the European biogas/bio methane industry by preparing markets for the export of sustainable biogas/bio methane technologies from Europe to developing and emerging countries. This will be achieved by the development and...	1/10/2019	30/6/2022
ENSMOV	Enhancing the Implementation and Monitoring and Verification practices of Energy Saving Policies under Article 7 of the EED	ENSMOV will support public authorities and key stakeholders in 14 Member States represented by its consortium (NL, BE, IT, FR, GR, AT, DE, PL, RO, UK, HR, BG, HU, LT) in implementing the Article 7 EED requirements. More specifically it will assist them to monitor, improve and...	1/6/2019	31/5/2022
CoME EASY	SYncronising EEA to CoM and other EU initiatives (SCIS-EIP, CEN-ISO,S3...) about energy and climate policies to accompany more and more tuned municipalities in their 2030 per-	CoME EASY - Synchronizing European Energy Award (EEA) to CoM and other EU initiatives about energy and climate policies to accompany more and more tuned municipalities in their 2030 perfor-	1/5/2018	30/4/2021

	formance	mance. To facilitate municipalities in adopting energy and climate EU targets, CoME EASY...		
REPLACE	Making heating and cooling for European consumers efficient, economically resilient, clean and climate-friendly	With over 80 million inefficient heating & cooling (HC) systems still installed across Europe motivating consumers to replace those units with more efficient, greener alternatives will be key for a decarbonized Energy Union fueled by renewable energy. REPLACE therefore aims...	1/11/2019	31/10/2022
ANTICSS	ANTICSS - ANTI-Circumvention of Standards for better market Surveillance	"ANTICSS objectives are (I) to assess and define ""circumvention"" in order to achieve a better product positioning in relation to EU Eco-design and Energy labelling legislation and relevant harmonized standards; this includes clear delimitation from other effects to facilitate...	1/4/2018	31/3/2021
PremiumLight_Pro	Next-level energy efficient lighting systems in the service sector	Innovative LED lighting technology for the private and public service sector provides many opportunities for more efficient high quality lighting systems. Modern LED solutions are based on optimized luminaires and advanced flexible lighting control and allow a more effective...	1/4/2016	31/7/2019
EEPLIANT2	Energy Efficiency Compliant Products 2	The objective of EEPLIANT2 (Energy Efficiency Compliant Products 2016) is to help deliver the intended economic and environmental benefits	1/9/2017	29/2/2020

		of the Eco-design Directive 2009/125/EC and the Energy Label-ling Directive 2010/30/EU by strengthening mar-ket surveillance and increasing...		
EPATEE	Evaluation into Practice to Achieve Targets for Energy Effi-ciency	Directives on ener-gy efficiency such as the EED or the EPBD trigger a great variety of poli-cies throughout EU Member States. The effort put into devel-oping and imple-menting these poli-cies is well docu-mented in existing NEEAPs. Soon, emphasis will be put on finding out how...	1/5/2017	31/10/2019
NEWCOM	New competence for building pro-fessionals and blue collar work-ers – certified qualification schemes to up-grade the qualifi-cation for building nZEBs	In order to imple-ment the EPBD sys-tematically and thereby reach the EU's energy and climate targets, building owners, constructors and municipalities should be aware of how energy saving measures have to be planned, applied and monitored. The buildings being built or renovated...	1/9/2017	31/8/2020
NESOI	New Energy Solu-tions Optimized for Islands	Funds are available to finance energy efficiency and re-newable energy projects. Many is-lands are engaged in energy transition; however most of them haven't the expertise to con-cretely launch in-vestments, access finance and kick start the projects. NESOI aims at fill-ing this...	1/10/2019	30/9/2023
PROSPECT	Peer Powered Cities and Re-gions	The overall aim of PROSPECT is to enable peer to peer	1/6/2017	31/5/2020

		learning in regional and local authorities in order to finance and implement sustainable energy plans. The learning will empower them to make use of best practices in developing financing for these plans. PROSPECT will...		
CoNZEBs	Solution sets for the Cost reduction of new Nearly Zero-Energy Buildings - CoNZEBs	CoNZEBs will identify and assess technology solution sets that lead to significant cost reductions of new Nearly Zero-Energy Buildings. The focus of the project is on multi-family houses. Close cooperation with housing associations allows for an intensive interaction with...	1/6/2017	30/11/2019
EUCF	European City Facility	Our vision of the European City Facility (EUCF) is one where European cities have their say on how the EUCF financial support will be used to meet their needs and help them overcome barriers they face in financing and implementing their ambitious energy and climate strategies...	1/8/2019	31/7/2023

Source: CORDIS, EU research results.

3.2.6 The Smart Finance for Smart Buildings Initiative (SFSB)

The Smart Finance for Smart Buildings Initiative (SFSB) is a part of the “Clean Energy for All Europeans” package. [22] It will improve the funding on the building sector and will bring higher return on EU money invested, by de-risking investments at this sector and provide investors with a clear overview on the investment’s potential risk and return. [23] It is also important that this initiative will assist individuals who wish to refurbish their residence, by providing expertise’s knowledge on the development of the project. [22]

The Smart Finance for Smart Buildings Initiative focusses on the effectively use of the public funds on ambitious energy efficiency projects, and also promotes the renewable energy sources. [23]

3.2.7 Supranational banks

Supranational Banks fund projects related to energy saving. At Supranational Banks belong European Investment Bank, European Bank for Reconstruction and development (EBRD) and International Bank for Reconstruction and Development (IBRD). European Investment Bank focusses on cities' energy saving and on their efforts to be more energy efficient. European Bank for Reconstruction funds energy projects at the building sector. International Bank for Reconstruction and Development (IBRD) funds also energy projects and also promotes actions related to sustainability. Supranational Banks have major contribution at the implementation of energy refurbishment projects, as they develop and deploy attractive financial products for energy refurbishment of the residential building stock. [THEODORIDOU, 2019]

3.2.8 Policy makers

At this field belong many institutions and organizations, such as European Environment Agency, C40Cities, and Energy Cities etc. Policy Makers develop initiatives and projects to promote sustainability and energy efficient measures at the building sector. [THEODORIDOU, 2019]

3.2.9 Public Private Partnerships (PPPs)

Public Private Partnerships (PPPs) is a collaboration of public and private sectors in order to share the risk of the investment/ funding. It is very effective at funding energy efficient projects of the building sector. A return on the investment has to be guaranteed in order both parts of the contract to be satisfied. [THEODORIDOU, 2019]

3.3 Comparison of Eksikonomisi kat' Oikon Program with other European Funding Programs

Eksikonomisi kat' Oikon II has no significant differences to Eksikonomisi kat' Oikon I. The differences noticed concern the budget of the program and the economic criteria of the beneficiaries, not the energy saving of the building stock and the improvement of its energy performance. Social aspects should be considered, as well as the elimination of fuel poverty.

Eksikonomisi kat' Oikon Program could evolve next years, implement more interventions and change the eligibility of the beneficiaries from the owner's financial statement to the building's needs. Eksikonomisi kat' Oikon is a funding program that aims to retrofit the residential building stock of Greece, reduce the energy needs and increase the energy performance of the buildings for all residences, in spite of their financial situation. Eligibility criteria could be based on four main categories: "cost effectiveness, level of energy performance of the building, level of energy performance of technical systems and other requirements such as conducting an energy audit". [3]

The interventions at the building stock aim to minimize the heating loads, increase in the capacity of electric equipment used in buildings and increase thermal comfort. The EPBD also encourages to "develop policies and take measures such as the setting of targets in order to stimulate the transformation of buildings that are refurbished into nearly zero-energy buildings". [30] The various measures are concern building's envelope and thermal insulation, space heating and cooling, domestic hot water, ventilation systems and lighting. The target is the retrofitted buildings to be in compliance with the refurbishment demand, install RES (if possible), reduce CO_2 emissions and increase their energy efficiency. [30]

The interventions proposed at Eksikonomisi kat' Oikon are: external thermal insulation; replacement of the window frames and installation of shading systems; and upgrade of the heating system and of the system of the hot water supply. The implementation of external thermal insulation upgrades to a large extent the building's envelope, but it cannot reduce the energy needs of the building to a high degree. As measured by the energy certificates, the upgrade of the heating system contributes to a very large extent to this target. [30]

An example of a funding program for energy refurbishment is KfW in Germany. KfW funds every residential building owner who wants to energy-refurbish its building. To succeed this, six levels of support are created for a "KfW Efficiency House": [35]

- KfW Efficiency House 55
- KfW Efficiency House 70
- KfW Efficiency House 85
- KfW Efficiency House 100
- KfW Efficiency House 115
- KfW Efficiency House Monument

Those levels indicate the maximum primary energy requirement in percentages, as specified by the Energie-spar-verordnung/EnEV. So, KfW Efficiency House 55 is the best category, and so it is supported at most. [35]

The interventions that are financed by the program are: [35]

- Thermal insulation at walls, on roof and on floor;
- Replacement of windows and exterior doors;
- Installation or replacement of a ventilation system;
- Upgrade of the heating system; and
- Upgrade of heat distribution system, for existing heating systems.

The beneficiaries could also have a loan or a grant, as an additional support. The Grant they can have per housing unit is: [35]

- 30.0 % for a KfW Efficiency House 55, not more than EUR 30,000
- 25.0 % for a KfW Efficiency House 70, not more than EUR 25,000
- 20.0 % for a KfW Efficiency House 85, not more than EUR 20,000
- 17.5 % for a KfW Efficiency House 100, not more than EUR 17,500
- 15.0 % for a KfW Efficiency House 115, not more than EUR 15,000
- 15.0 % for a KfW Efficiency House Monument, not more than EUR 15,000
- 15.0 % for a heating or ventilation package, not more than EUR 7,500
- 10.0 % for the implementation of individual measures, not more than EUR 5,000

The beneficiaries can have this financial support at their accounts after the completion of the interventions. [35]

As far as concerns the loan, the beneficiaries can take a loan up to 100,000€ per housing unit, plus a repayment bonus up to 27,500€ calculated on the amount of the loan. If they choose a package of interventions, the loan can be up to 50,000€ per housing unit. [35]

During the period 1996-2004, KfW granted loans of a total budget of 6,000,000,000€. The budget for the period 2006-2009 was calculated at 4,000,000,000€, and after that, 2,000,000,000€ every year for the period 2010-2011. Also, at the period 1996-2007, more than 2,500,000 residences were energy refurbished, and the energy savings was 1.5 TWh/yr for 2006 and 703 kt CO_2 emission reduction annually. It is calculated that the CO_2 emission reduction will be almost 1Mt/yr. [36]

Another example is the program of “Subsidies to households to improve energy efficiency” in Belgium, which was launched in 2000. This program funds the energy refurbishment of the residential building stock in Wallonia and the metropolitan area of Brussels. The interventions that are funded are: [36]

- Installation of thermal insulation at walls, on roofs and on floors;

- Replacement of windows;
- Upgrade of the heating system; and
- Replacement of the electrical appliances.

The budget is 6,000,000€/yr. At Wallonia, it was also decided to start a three-year program (2005-2007), that will be provide grant to low-budget families, so as to renovate their residence. The budget is 6,000,000€. [36]

Another example is the "Renovation loans in apartment buildings" Program in Estonia, which was launched in 2001. This program funds the energy refurbishment of residential buildings that were constructed before 1993. The target is to succeed energy savings of more than 20% of the energy consumption. The program grants loan on favorable terms. [36]

The total budget is 49 million € and consists of: 17 million € of the European Regional Development Fund and Public sector involvement (co-financing), and 32 million € Loan from CEB and KredEx own funds. By 2009, 65 loans were granted each one on the amount of 71,000€ on average (the highest amount was 255,000€ and the lowest amount was 6,300€). The energy saving on average will be 32% of the energy consumption. [36]

3.3.1 Intervention Proposals for Eksikonomisi kat' Oikon Program

Other interventions that could also be implemented through Eksikonomisi kat' Oikon are presented at the next paragraphs:

HVAC

There are a lot of interventions that could be implemented by Eksikonomisi kat' Oikon Funding. For the HVAC of the building, a suggestion could be to implement Building Automation and Control (BAC) Systems for the HVAC. BAC Systems are widely used at commercial buildings, but not at residential buildings in Greece. They can control the indoor temperature, the humidity levels, the lighting, and if there is a mechanical ventilation system, they can control also the ventilation. BAC can ensure the energy savings and the efficiently use of the HVAC of the building, and also the optimal use of any possible RES used. For instance, they can control the lighting system depending on the building orientation, the month, the day and time of the year, the natural lighting inside the room and the presence of people inside each room, by using sensors. BAC can also preheat or precool the building, and control the use of the electrical equipment. [34]

Another intervention regarding on HVAC could be the replacement of the distribution system. Most buildings in Greece use old technology radiators for space heating. These radiators are oversized for the heating systems that are used nowadays, and as a result, the system operates at a lower efficiency. So, there is no much energy saving for the residence, even if the old heating system is changed with a heat pump or a condensing boiler. Eksikonomisi kat' Oikon could fund the replacement of old radiators with low temperature heating radiators or underfloor heating system. Both distribution systems operate at low temperatures and are compatible with high efficiency HVAC. This intervention would be very important to reduce fuel poverty.

Eksikonomisi kat' Oikon Program funds the replacement of the heating system with a condensing boiler or a heat pump. Biomass heating systems (including district heating) and solar thermal systems could also be implemented, and they can also be combined with low temperature underfloor heating systems and high efficiency radiators. Biomass uses a stove or a boiler to heat the fluid of the distribution system. Solar thermal systems use a solar collector that heats the fluid of the system. [34]

Eksikonomisi kat' Oikon funds the implementation of Thermosiphons for the Domestic Hot Water. Domestic Hot Water could be provided by the condensing boilers, especially in winter when the solar radiation is not enough to cover the needs.

Lighting is also energy consuming for a residence. In compare to HVAC system, it is quite a cheap intervention at the residence, and it has a small payback period. But it has a great contribution at energy savings. It is measured that at residential buildings at least 10% of electricity is consumed by lighting. [34] Traditional light bulbs could be replaced by new technology energy efficient light bulbs, such as Light Emitting Diode (LED) lamps or Compact Fluorescent Lamps (CFLs). [33] This specific intervention could be integrated with bioclimatic design.

Electrical equipment needs also to be replaced with new high efficient and energy saving. A part of the funding could be spent to the upgrade of the electrical equipment.

Ventilation systems are not used at residences in Greece. Eksikonomisi kat' Oikon Program could be the trigger to implement mechanical ventilation systems with heat recovery at residential buildings. A ventilation system ensures the indoor environmental quality. It also can assist at eliminating the mould and retain humidity at desired levels inside the residence. It is very important to implement a ventilation system, especially at very well insulated and airtight buildings. It improves the energy performance of the heating system and ensures the thermal comfort of the residences.

Building's envelope

For the upgrade of the building's envelope, Eksikonomisi kat' Oikon Program proposes thermal insulation, replacement of the window frames and implementation of shading elements. The implementation of external thermal insulation also eliminates the thermal bridges of the building. Thermal insulation is very important for the building's energy performance. At summer months, it reduces the cooling load and respectively at winter months the heating load. It also increases the thermal comfort in the interior. [34]

The replacement of the window frames with new airtight ones, and of the glazing with double or triple glazed windows with low emissivity coating, improves the thermal efficiency of the windows. Low emissivity coating allows visible light to pass inside the room, but reflects back most of the radiant heat. The radiant heat that passes inside is reflected back inside the room, so it maintains the warmth of the room. The airtight construction of the frames reduces the heat losses of the envelope.

Shading elements is a technique to reduce the thermal gains at summer months, and optimize the use of the cooling system and of the ventilation system. The shading elements could be external or internal, moveable or fixed, coating between the glazings of the windows, and sometimes seasonal. Shading elements can reduce the cooling load needed in summer, when external temperature is very high at Greece. The shadings implemented at the building should allow enough natural light inside the building, but not block the view. According to the orientation, the season and the hours that the room is occupied, the appropriate shading element can be selected. For instance, at south orientation is preferred horizontal shadings. For the west oriented openings is preferred vertical shadings, if used most at evenings, when the elevation of the sun is less than 50^o (respectively for east oriented openings at morning hours). In general, for east and west orientation the implementation of a combination of vertical and horizontal shadings is recommended.

A new intervention that could be implemented is an air chimney. It is a cheap intervention that enforces the natural ventilation of the building. It could be constructed at the stairway. The air chimney has glazing at its south or south/west side to let the solar radiation pass it through, and heat up the thermal mass of the chimney. This will cause the raise of the temperature of the air inside the chimney, so the effect of natural ventilation will be enforced, and the air will flow inside the building.

Another intervention could be a double glass shell. It could improve the thermal comfort inside the building, and also shade it throughout the year. The shell can assist the building to avoid overheating and succeed acceptable temperature at its envelope. It also improves acoustic comfort, manages the natural lighting and reduces the dazzle, as well as it protects the envelope from extreme weather conditions.

Green roofs could also be implemented at polykatoikies. All residences would have access, and the residences of the upper floor would reduce significantly the heating load in summer and the cooling load in winter. The green roof has beneficial effect on the microclimate of the urban environment, as it reduces the heat island effect and improves the thermal behavior of the building. It can reduce the rainwater runoff up to 40% and enrich the ecosystem of the area. Finally, it reduces the air pollution and the noise levels, and enriches the atmosphere with oxygen during the day.

Water management is also feasible and very important for energy saving. Eksikonomisi kat' Oikon could fund the rainwater collection and the use of grey water, as water management of the whole polykatoikia. The rainwater could be collected at a tank in the basement. Grey water could be used for watering the plants, toilets or even washing machines.

Finally for the building's envelope, another intervention could be the design of passive systems. For instance, thermal storage (direct solar gain), a Trombe wall (indirect solar gain), an attached greenhouse (isolated solar gains) could be implemented when possible, mainly at detached residences. Solar gains can be collected through the envelope, store heat in the mass and distribute it later in the interior.

Renewable Energy Sources (RES)

As far as is concern the Renewable Energy Sources, at existing buildings in the urban environment it is feasible to implement Photovoltaic Systems (PVs), Building Integrated or Applied, and at some cases small scale micro-wind turbines. At detached houses can also be implemented geothermal systems. PVs cannot cover the demand of electricity of a whole polykatoikia, but they could reduce it specifically. PVs are usually grid-connected systems, and they use the grid as their "battery". Building Integrated Photovoltaic Systems (BIPV) are integrated at the building's design. For instance, at a retrofitting the glazing could be replaced by BIPV and produce electricity and shading at the same time. Building-applied PV (BAPV) are usually mounted on a racking system. Micro-wind turbines are low efficient and the complex of the built environment makes their use difficult. Geothermal Heat Pumps use the earth or a well water to provide heating, cooling and hot water, and an earth loop is needed to be implemented, horizontally or vertically. This is the reason why it is not always possible to design such a system at an existing building in the urban environment, but it may be an option at a detached house.

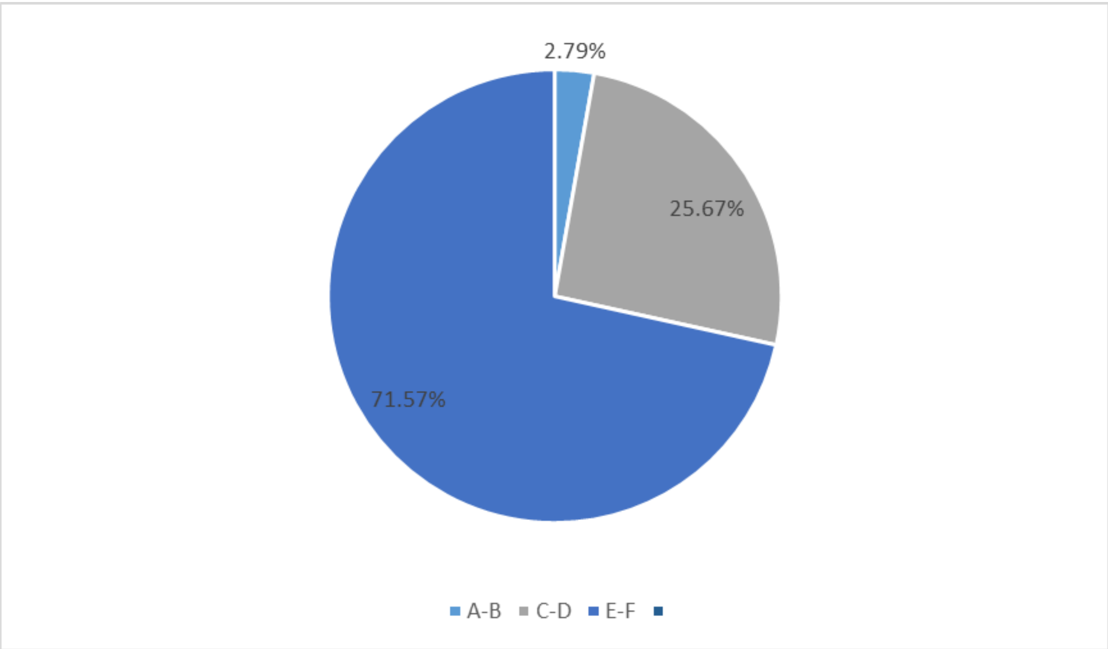
User's behavior

All those systems cannot be efficient if the users are not aware of all those new technologies and their use. Users' behavior is very important for energy saving. For instance, users should be advised to avoid overheating at winter and use properly the BAC systems, as well as to avoid overuse the air-condition systems at summer. This way, the energy cost would be reduced and the energy savings would be increased, and slowly smart meters and smart grid could also be implemented at residential buildings of Greece. At this point, Eksikonomisi kat' Oikon, as it can fund all those interventions, could also fund seminars for the users that choose these interventions. The education of the users is very important for the energy efficiency of the buildings.

3.4 Statistical analysis of Eksikonomisi kat' Oikon Program

According to the statistical results of YPEKA, on the energy audits in Greece for the year 2018, the Energy Performance Certificates (EPCs) of residential buildings was 83.33% of the total EPCs. More specifically, the total number of EPCs was 254,372 of which 153,793 EPCS concern residential buildings at South Greece and the rest 100,579 concern residential buildings at North Greece. For residential buildings, 18.20% of EPCs relates to detached houses, 80.33% of EPCs relates to apartments and 1.46% of EPCs relates to polykatoikies. [20]

The energy Label of the residential buildings of Greece is at most (71.57%) energy category E and F. Only 2.79% of the residential buildings enlist at energy categories A, A+, B and B+, and the rest 25.64% enlist at energy categories C and D. [20]



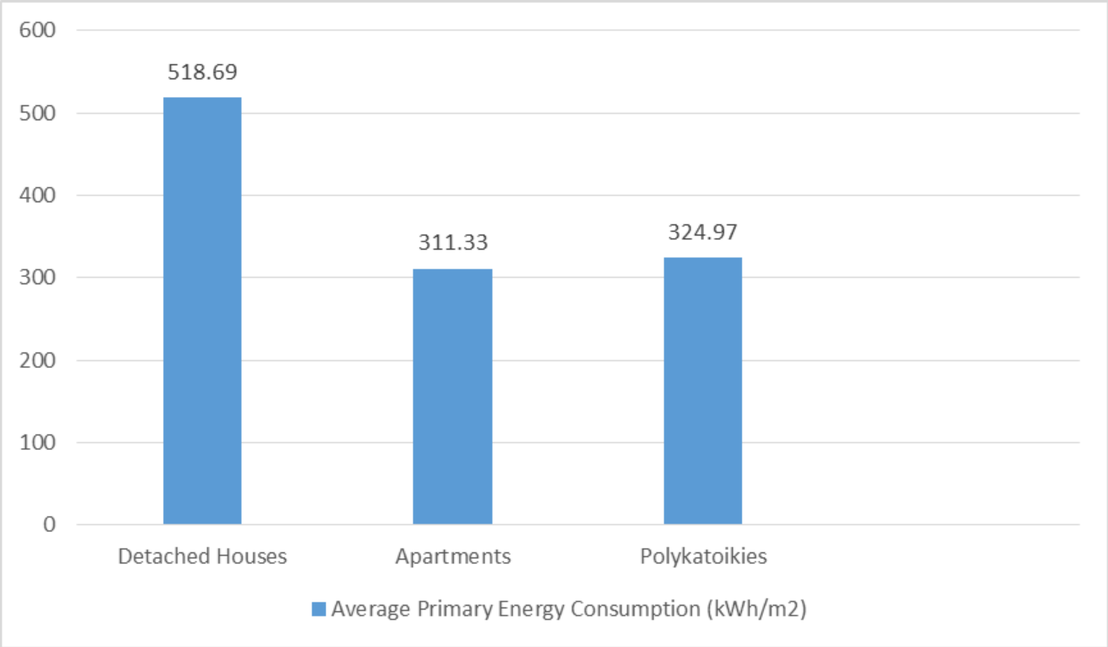
Graph 3.4.1: Energy Label Percentages of EPCs for 2018

The average primary energy consumption is: [20]

- for detached houses: 518.69kWh/m^2;
- for apartments: 311.33kWh/m^2; and

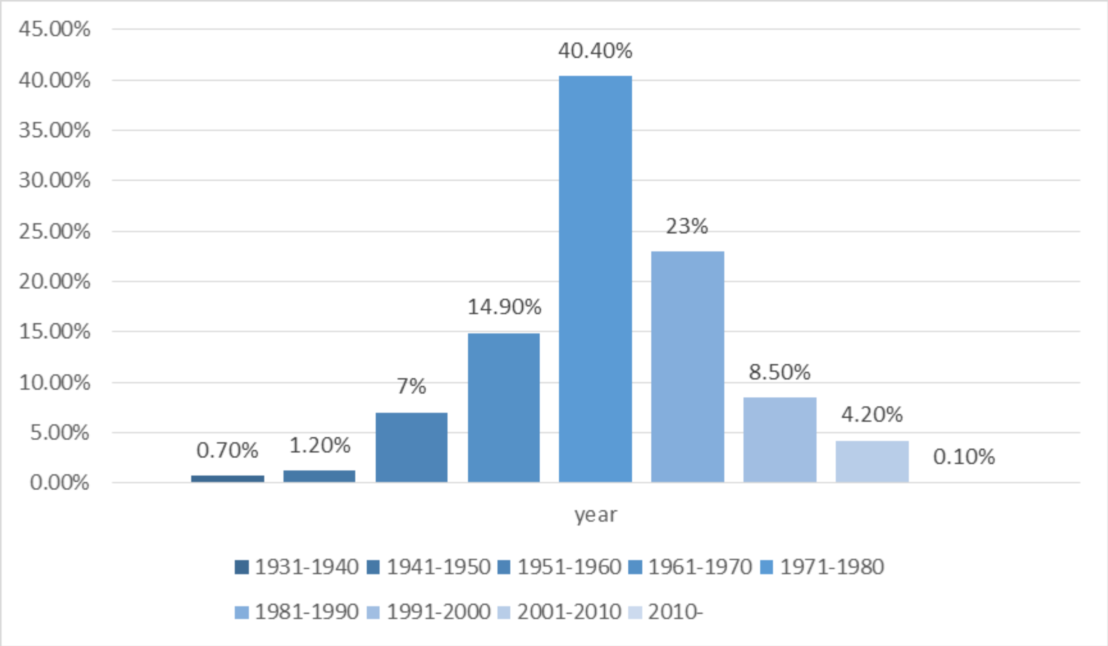
• for polykatoikies: 324.97kWh/m^2.

The average annual primary energy consumption for heating is equal to 250.39kWh/m^2. [20]



Graph 3.4.2: Average Primary Energy Consumption (kWh/m^2)

For the buildings which was refurbished by the program, their classification per construction date shows that the majority of residences were constructed during the period 1971-1980 (40.40%). The average year was 1978 for the period 1931-2014. The 50% of the building permits were published during the period 1971-1984. [37]



Graph 3.4.3: Year of construction of the first building permit of the households, which were funded by the program [37]

3.4.1 Statistical analysis of the residential building stock of Greece for the period 2011-2018

The total number of EPCs for the period 2011-2018 is 1,500,613 of which 17.50% concerns residential buildings. The statistical results of Eksikonomisi kat' Oikon I Program mention that after the refurbishment the majority of residential buildings enlist at energy categories C (26.55%) and D (25.01%).

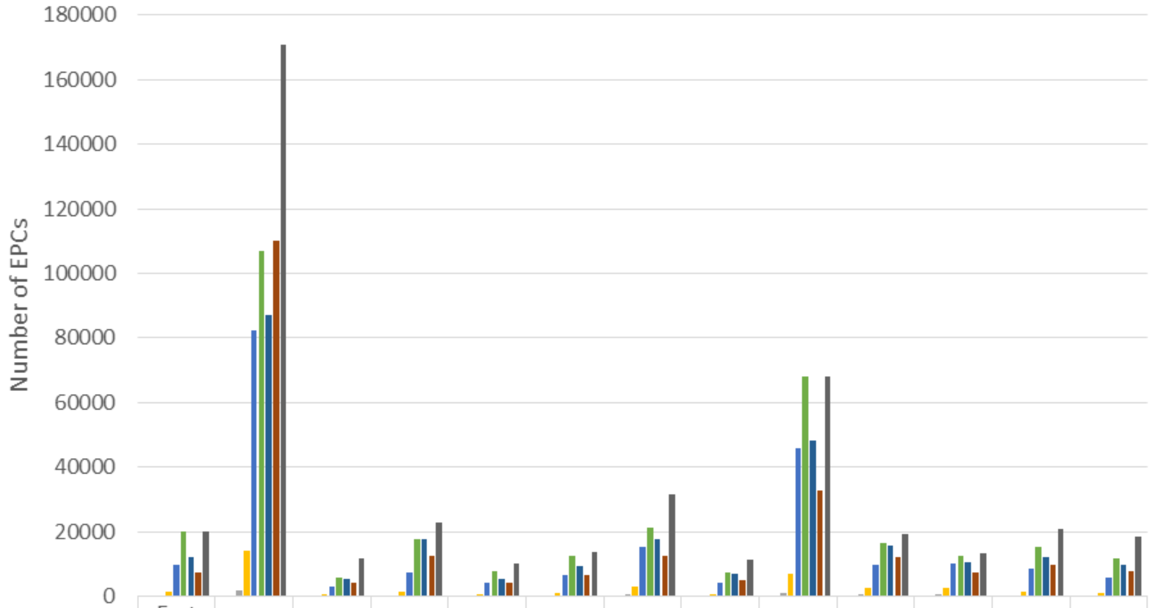
The EPCs concern at most old buildings (99.47%), constructed until 2009. The majority of them (61.36%) enlist at energy categories E and F, the 35.71% of them enlist at energy categories C and D, and the rest 2.94% enlist at energy categories A, A+, B and B+. A very high percentage (94.90%) of the new buildings undergoing deep renovation, enlist at energy categories A, A+, B and B+. Finally, the majority (83.80%) of residential buildings undergoing an EPC are about to be sold or rented.

Table 3.4.1.1: Energy data of residential buildings for the period 2011-2018

Year	**Number of EPCs**	**Total Area (m²)**
2018	304,095	31,064,778
2017	255,041	23,744,256
2016	281,474	26,671,203
2015	56,486	7,827,597
2014	121,491	15,036,106
2013	221,668	25,534,583
2012	209,692	23,804,512
2011	53,666	7,002,025
TOTAL	1,500,613	160,685,058

Source: YPEKA

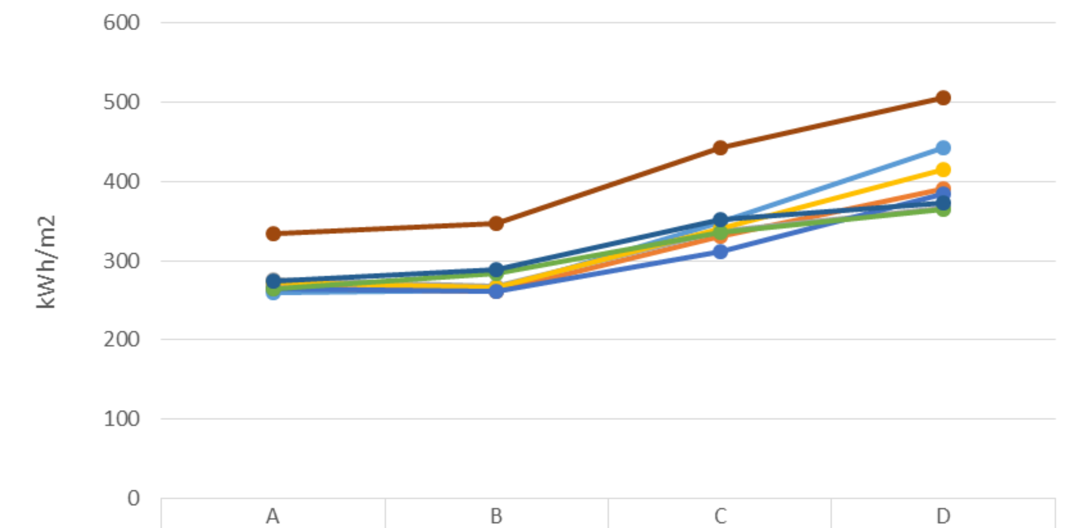
The Graph below presents the energy category of the residential building stock of Greece per region, for the period 2011-2018.



	East Macedonia and Thrace	Attica	North Aegean	West Greece	West Macedonia	Epirus	Thessaly	Ionian Islands	Central Macedonia	Crete	South Aegean	Peloponnesus	Central Greece
A+	16	38	2	8	4	9	18	1	18	59	21	3	8
A	11	216	4	25	5	30	41	37	69	53	60	21	8
B+	257	1831	101	264	75	233	417	175	1129	452	495	278	149
B	1294	14104	541	1345	508	1125	2902	767	7007	2579	2639	1590	1004
C	9908	82360	3018	7524	4224	6744	15143	4245	45976	9830	10105	8341	5593
D	20062	106757	5668	17504	7777	12461	21249	7373	68019	16410	12653	15183	11722
E	12117	87211	5355	17492	5464	9151	17502	6807	48411	15594	10691	11999	9585
F	7535	109984	4184	12640	4026	6383	12669	4803	32590	12300	7480	9557	7661
G	20107	170660	11588	22900	9989	13706	31533	11335	67922	19313	13129	20722	18623

Graph 3.4.1.1: Number of EPCs per region, Source: YPEKA

The comparison of the average primary energy consumption of the residential building stock shows that the buildings located on the climatic zones C and D have the highest energy consumption (360.84 kWh/m^2 and 408.76 kWh/m^2 respectively). [20]

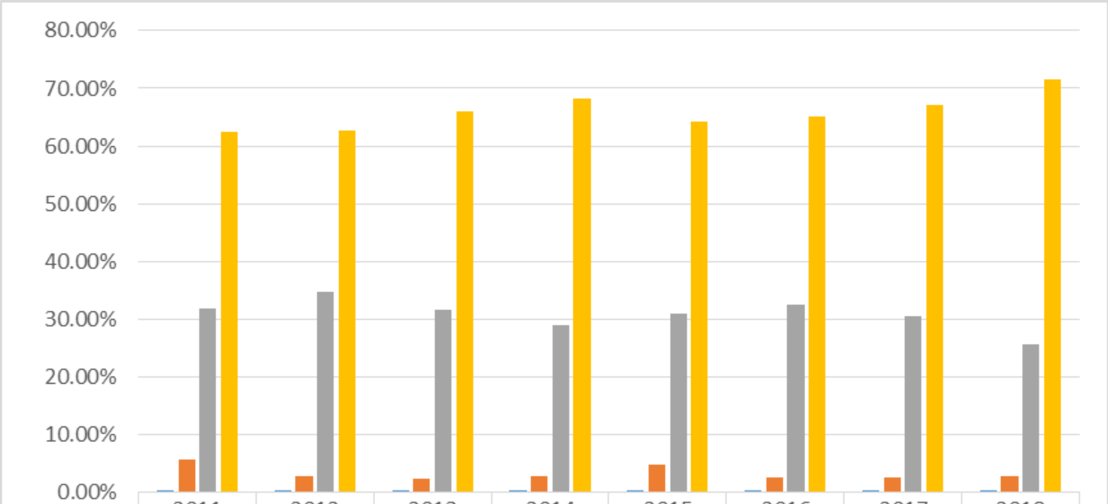


	A	B	C	D
2011	259.5	262.12	349.27	442.52
2012	266.85	261.36	330.35	391.4
2013	275.99	267.73	336.97	366.38
2014	272.02	266.87	341.38	414.42
2015	264.78	261.33	312.31	384.58
2016	264.88	284.08	335.69	364.25
2017	274.9	289.56	351.95	372.34
2018	333.85	347.82	443.06	506.7

Graph 3.4.1.2: Average primary energy consumption per climatic zone for the period 2011-2018

Source: YPEKA

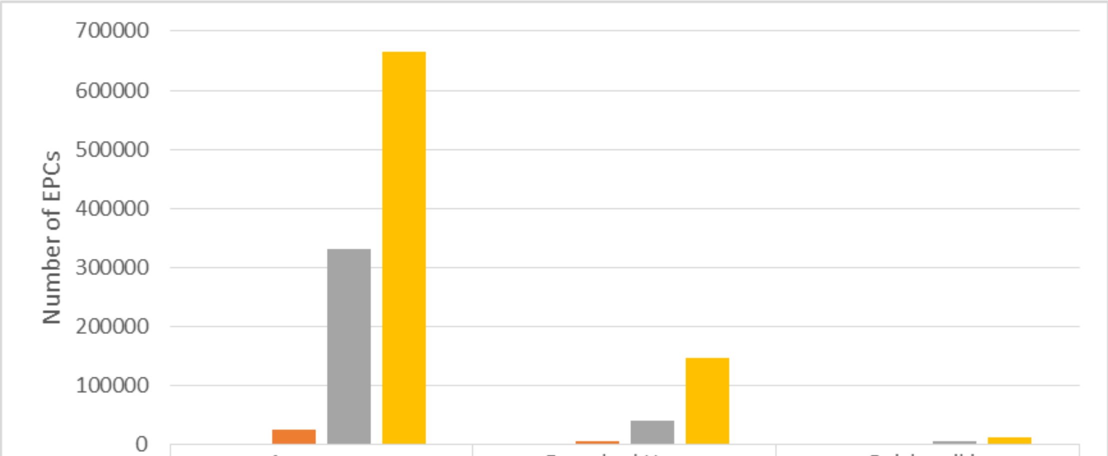
The Graphs below present the energy category of the residential building stock of Greece per year, for the period 2011-2018.



	2011	2012	2013	2014	2015	2016	2017	2018
A+ - A	0.06%	0.02%	0.02%	0.03%	0.07%	0.03%	0.05%	0.08%
B+ - B	5.65%	2.67%	2.37%	2.73%	4.69%	2.40%	2.50%	2.71%
C-D	31.89%	34.59%	31.68%	28.98%	31.02%	32.53%	30.45%	25.64%
E-F	62.39%	62.72%	65.93%	68.26%	64.22%	65.04%	67%	71.57%

Graph 3.4.1.3: Residential buildings per energy category for the period 2011-2018

Source: YPEKA

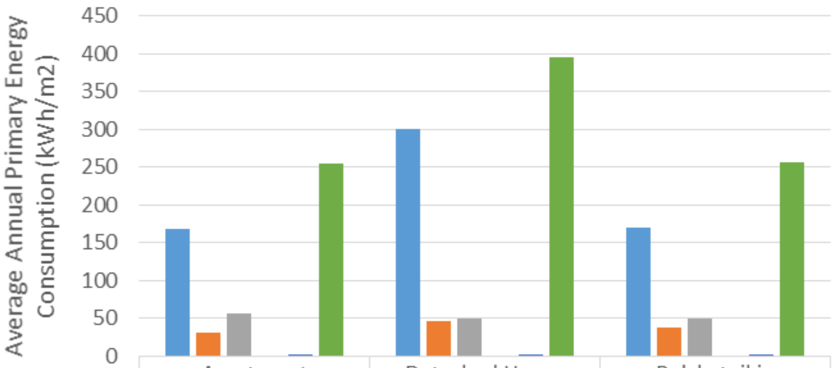


	Apartment	Detached House	Polykatoikia
A+ - A	280	199	56
B+ - B	25694	6957	1489
C - D	331969	41121	5330
E - F	664881	147431	12618

Graph 3.4.1.4: Number of EPCs for the period 2011-2018

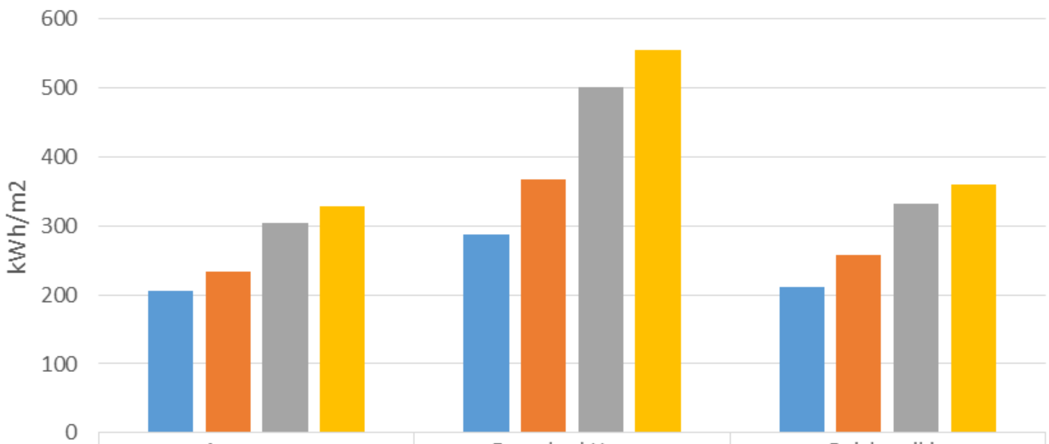
Source: YPEKA

For the period 2011-2018, the majority (66.63%) of buildings enlist to energy category E and F, and the highest percentage of primary energy for heating is 188.97 kWh/m^2. [20]



	Apartment	Detached House	Polykatoikia
Average Annual Primary Energy Consumption for Heating	168.01	300.37	170.09
Average Annual Primary Energy Consumption for Cooling	31.31	46.86	38.03
Average Annual Primary Energy Consumption for Domestic Hot Water	55.64	48.89	49.09
Average Annual Primary Energy Consumption for Lighting	0	0	0
Average Annual Primary Energy Consumption for RES	0.01	0.17	0.34
Average Annual Primary Energy Consumption	254.95	396.02	257.08

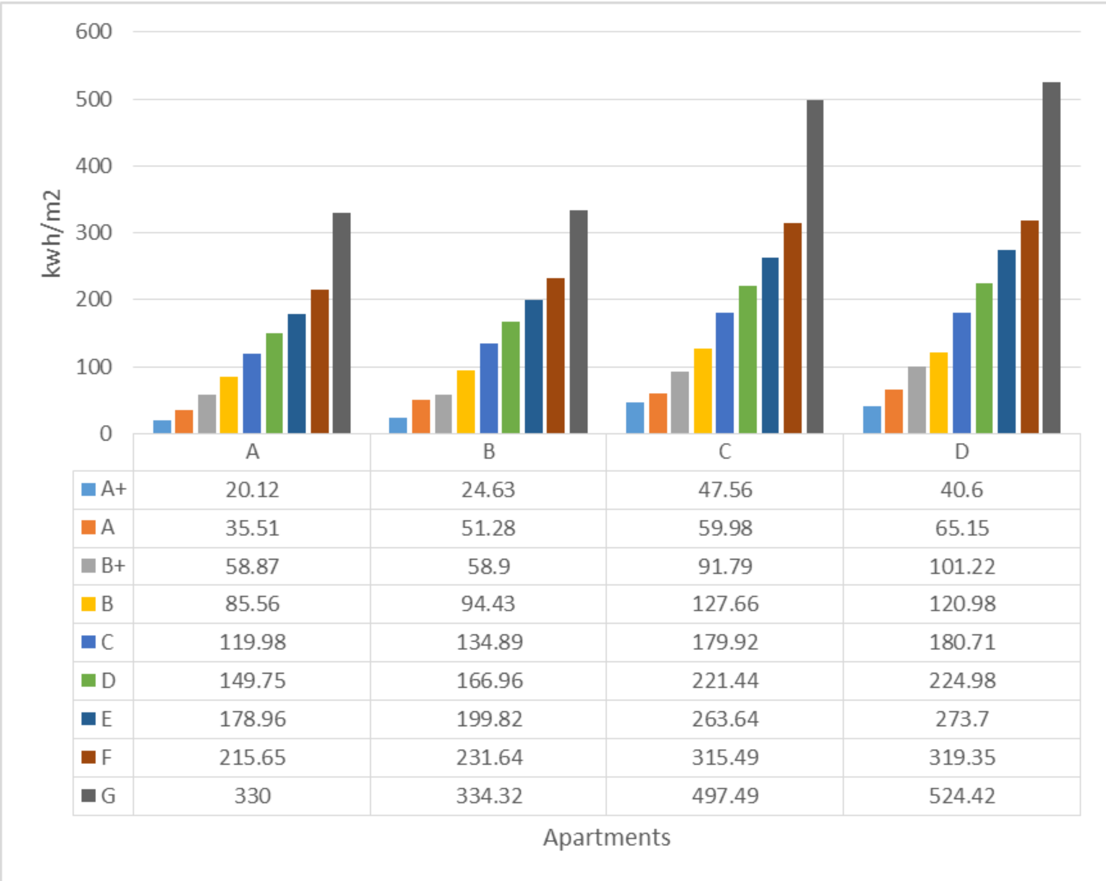
Graph 3.4.1.5: Average Annual Primary Energy Consumption (kWh/m^2) [20]



	Apartment	Detached House	Polykatoikia
A	205.78	287.17	212.04
B	234.65	367.85	257.87
C	303.44	500.68	332.36
D	328.64	555.67	359.93

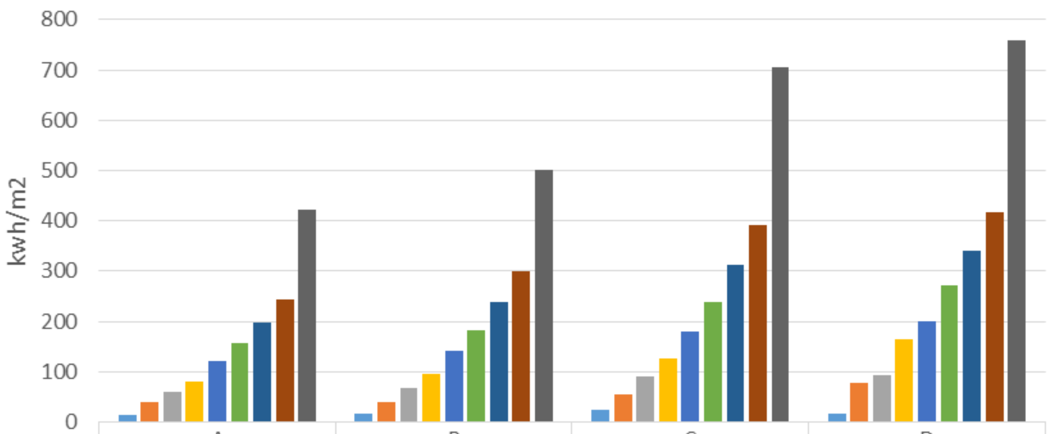
Graph 3.4.1.6: Average Annual Primary Energy Consumption per climatic zone for the period 2011-2018 [20]

The average primary energy consumption of detached houses (396.02 kWh/m^2) is higher than the one of the apartments (257.08kWh/m^2). Also, the detached houses that are located on the climatic zones C and D have the highest average primary energy consumption (500.68 kWh/m^2 and 555.67 kWh/m^2 respectively). The graphs below show the distribution of the average primary energy consumption per climatic zone. [20]



	A	B	C	D
A+	20.12	24.63	47.56	40.6
A	35.51	51.28	59.98	65.15
B+	58.87	58.9	91.79	101.22
B	85.56	94.43	127.66	120.98
C	119.98	134.89	179.92	180.71
D	149.75	166.96	221.44	224.98
E	178.96	199.82	263.64	273.7
F	215.65	231.64	315.49	319.35
G	330	334.32	497.49	524.42

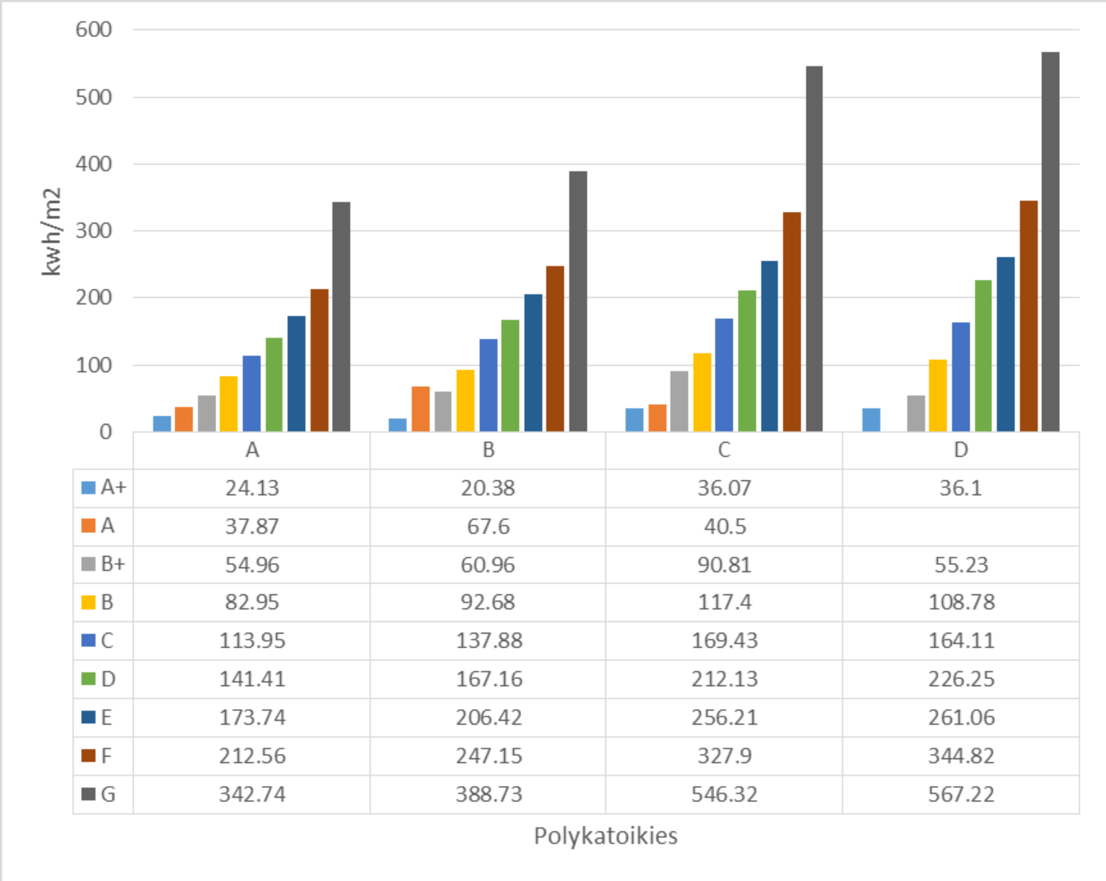
Graph 3.4.1.7: Average Annual Primary Energy Consumption of apartments per climatic zone [20]



	A	B	C	D
A+	13.83	16.63	24.31	17.1
A	38.66	40.37	53.76	76.53
B+	58.79	67.21	91.04	92.81
B	80.5	95.66	126.46	164.67
C	120.42	141.28	180.71	200.03
D	157.76	181.95	238.65	270.51
E	196.79	237.42	312.23	341.53
F	244.01	298.51	391.87	416.9
G	421.64	500.53	704.35	759.71

Detached houses

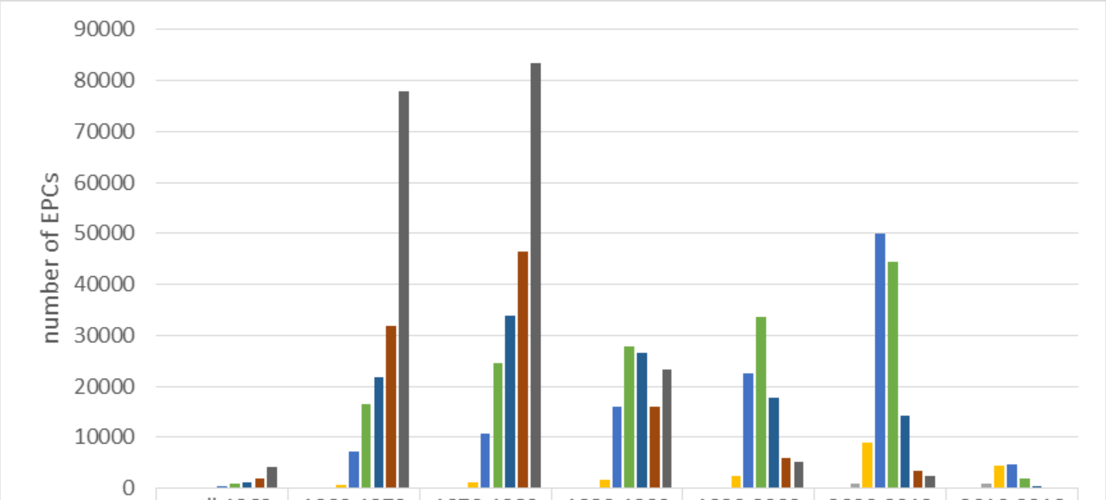
Graph 3.4.1.8: Average Annual Primary Energy Consumption of detached houses per climatic zone [20]



	A	B	C	D
A+	24.13	20.38	36.07	36.1
A	37.87	67.6	40.5	
B+	54.96	60.96	90.81	55.23
B	82.95	92.68	117.4	108.78
C	113.95	137.88	169.43	164.11
D	141.41	167.16	212.13	226.25
E	173.74	206.42	256.21	261.06
F	212.56	247.15	327.9	344.82
G	342.74	388.73	546.32	567.22

Graph 3.4.1.9: Average Annual Primary Energy Consumption of polykatoikies per climatic zone [20]

The residential buildings that were refurbished with Eksikonomisi kat’ Oikon I Program and Eksikonomisi kat’ Oikon II Program, after the refurbishment had lower primary energy consumption, and their energy category was changed at most between categories C, D and E. The graph below shows the number of EPCs per decade of construction, and per energy category. [20]

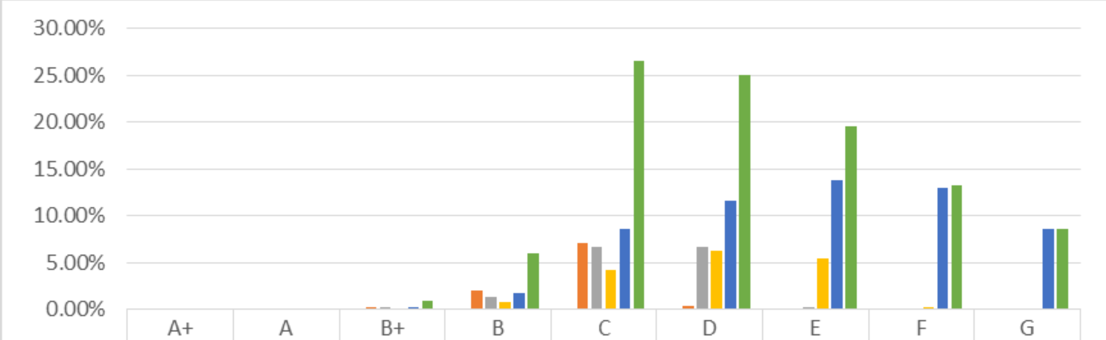


	until 1960	1960-1970	1970-1980	1980-1990	1990-2000	2000-2010	2010-2016
A+		1	2	1	2	14	15
A		11	10	24	25	121	86
B+	2	102	159	194	219	814	944
B	40	722	1133	1612	2432	8939	4367
C	348	7305	10704	15950	22606	50019	4760
D	862	16487	24591	27825	33716	44470	1843
E	1166	21875	33895	26440	17707	14153	432
F	1783	31743	46377	15934	5946	3370	117
G	4186	77809	83438	23280	5203	2419	97

Graph 3.4.1.10: Number of EPCs per energy label and per buildings’ construction decade [20]

3.4.1.1 Statistical results for Eksikonomisi kat’ Oikon I Program

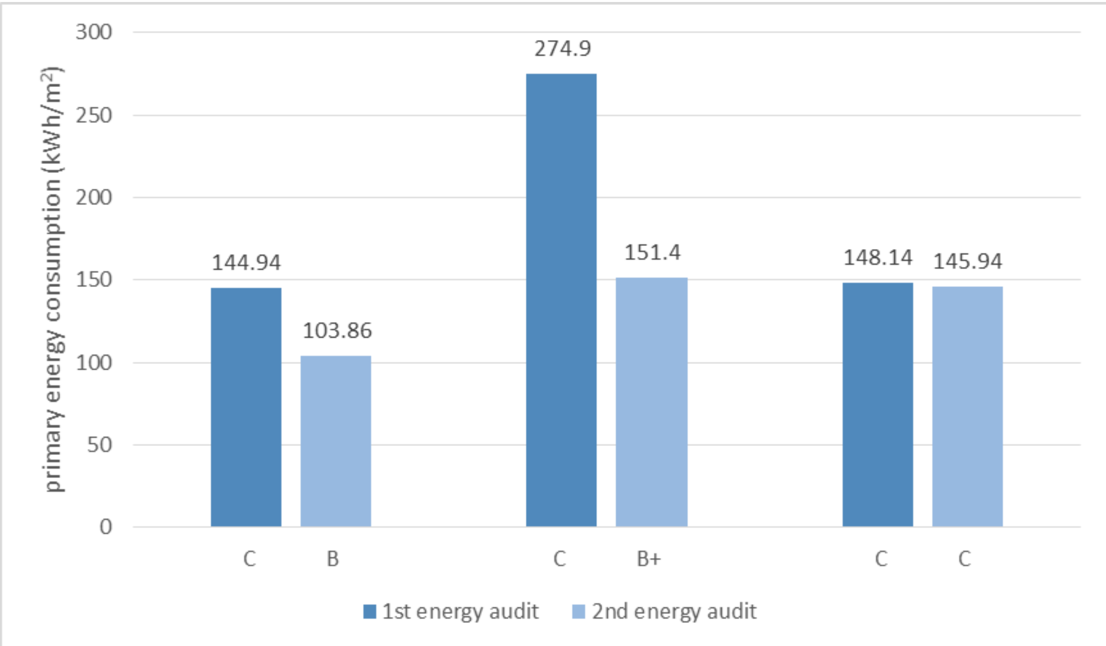
The residential buildings that were refurbished with Eksikonomisi kat’ Oikon I Program, after the refurbishment enlist at their majority at energy categories C and D (26.55% and 25.01% respectively). The graphs below present the rate of change of energy categories of the refurbished residential buildings, and the average primary energy consumption of the 1st and 2nd energy audits at residences, at different energy category improvements. [20]



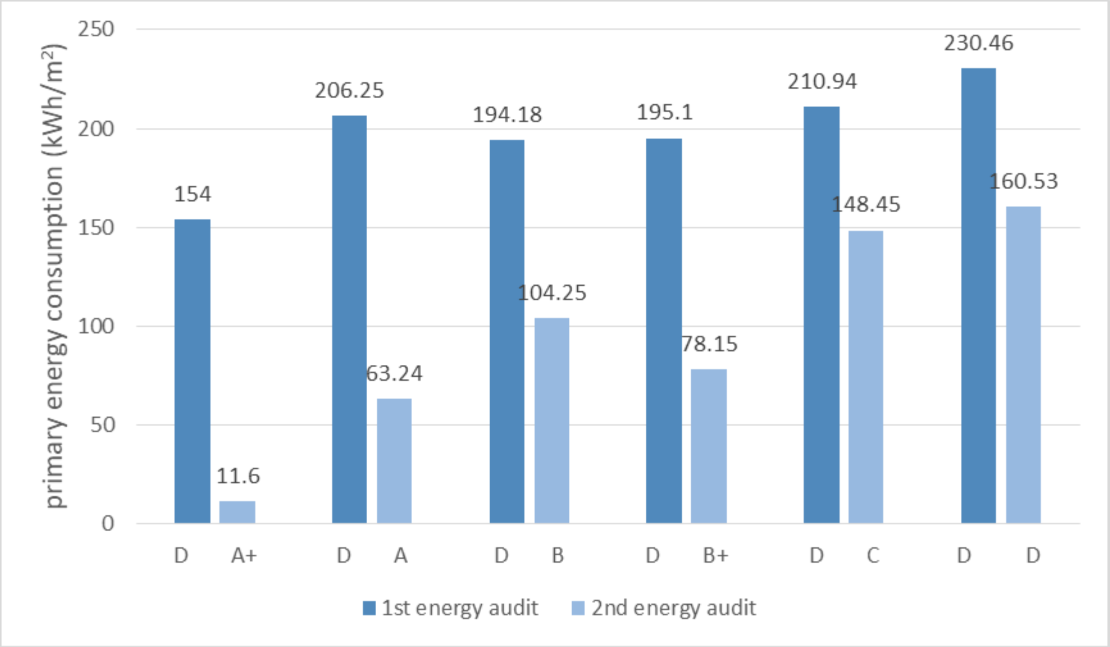
	A+	A	B+	B	C	D	E	F	G
C	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%
D	0.00%	0.02%	0.29%	2.08%	7.07%	0.39%	0.00%	0.00%	0.00%
E	0.00%	0.01%	0.23%	1.38%	6.67%	6.73%	0.29%	0.00%	0.00%
F	0.00%	0.00%	0.11%	0.85%	4.25%	6.26%	5.51%	0.24%	0.00%
G	0.01%	0.01%	0.23%	1.72%	8.55%	11.64%	13.83%	13.04%	8.57%
SUM	0.01%	0.04%	0.87%	6.04%	26.55%	25.01%	19.62%	13.28%	8.57%

2nd energy audit

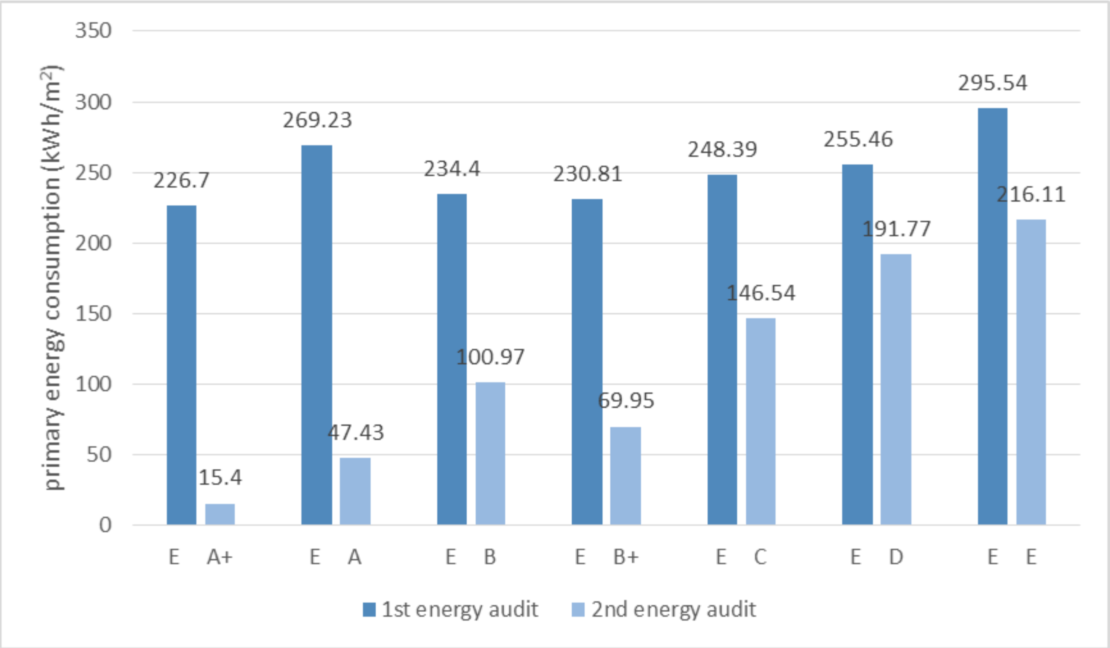
Graph 3.4.1.1.1: Rate of change of the energy category of residential buildings (between the 1st and 2nd energy audits) [20]



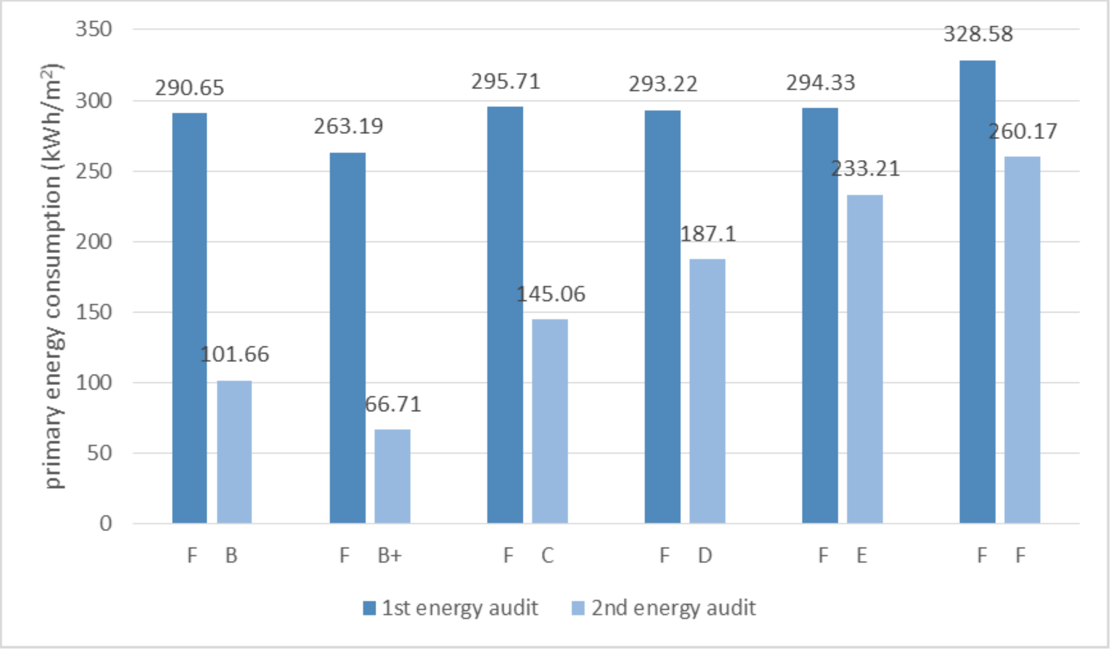
Graph 3.4.1.1.2: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category C [20]



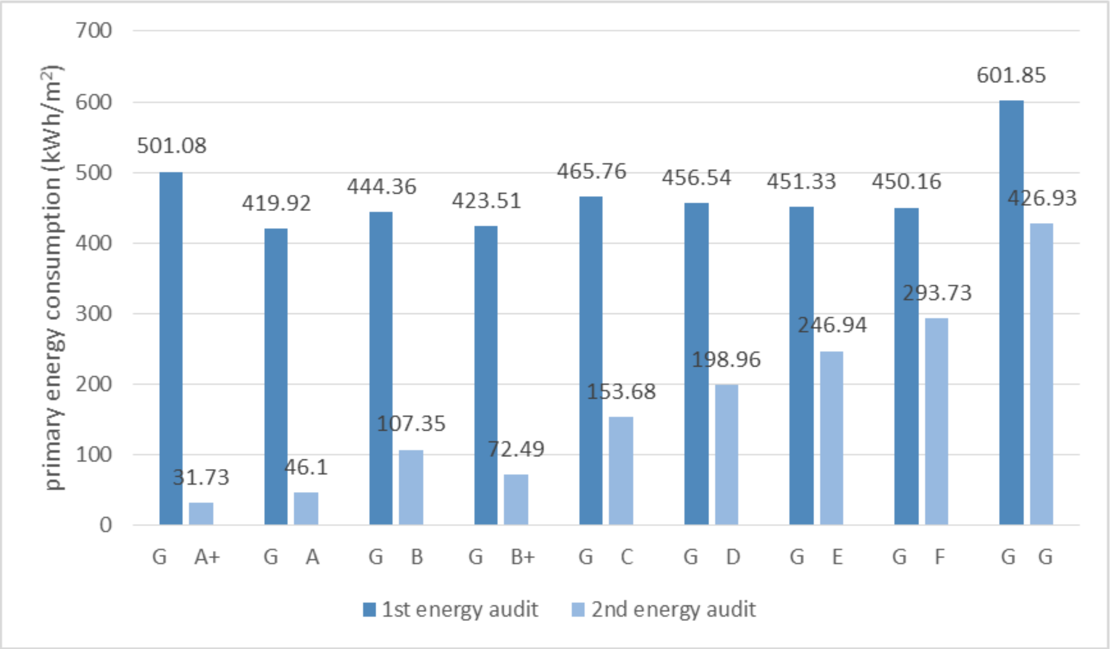
Graph 3.4.1.1.3: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category D [20]



Graph 3.4.1.1.4: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category E [20]



Graph 3.4.1.1.5: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category F [20]

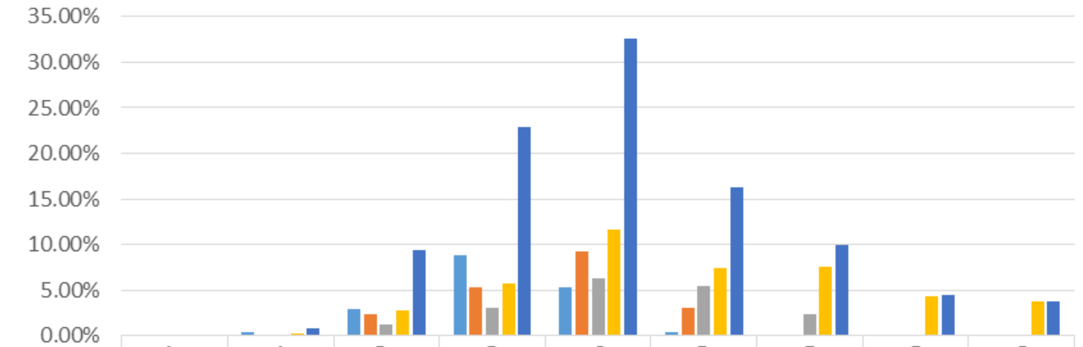


Graph 3.4.1.1.6: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category G [20]

It is noticed that the majority of refurbished buildings have an energy label of C and D, followed by energy labels of E, F and G. There are only a few buildings that belong to energy categories A, A+, B, B+ and C. Therefore, after the refurbishment the buildings have significant reduction on their energy consumption, especially the buildings of the lowest energy categories.

3.4.1.2 Statistical results for Eksikonomisi kat’ Oikon II Program

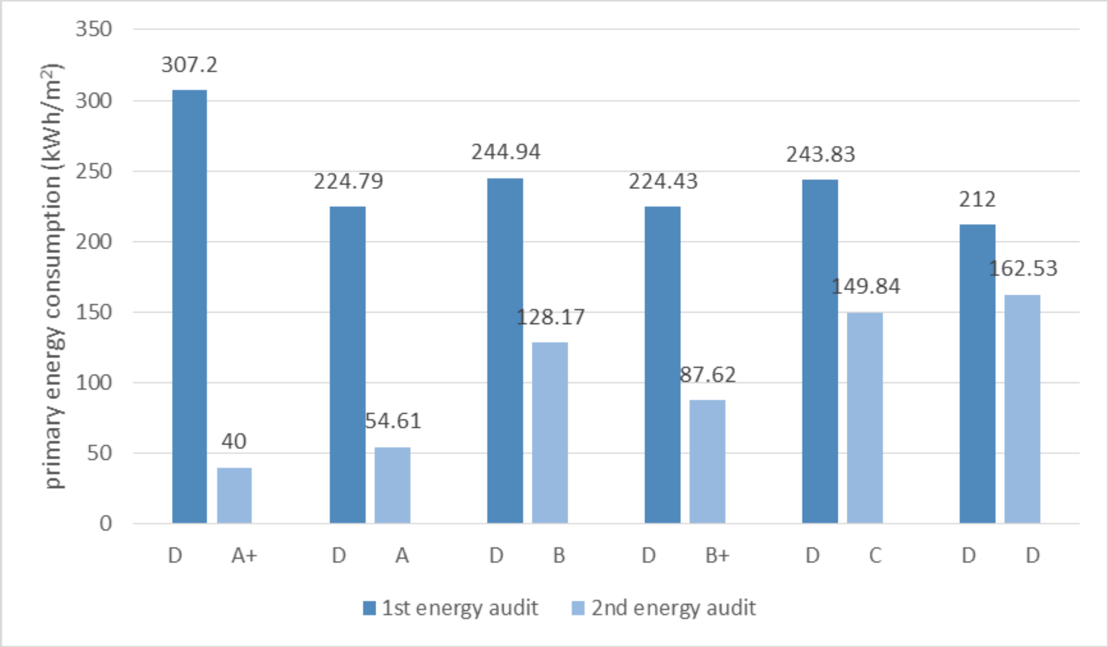
The residential buildings that were refurbished with Eksikonomisi kat’ Oikon II Program, after the refurbishment enlist at their majority at energy categories B and C (22.91% and 32.55% respectively). The graphs below present the rate of change of the energy categories of the refurbished residential buildings, and the average primary energy consumption of the 1st and 2nd energy audits at residences, at different energy category improvements.



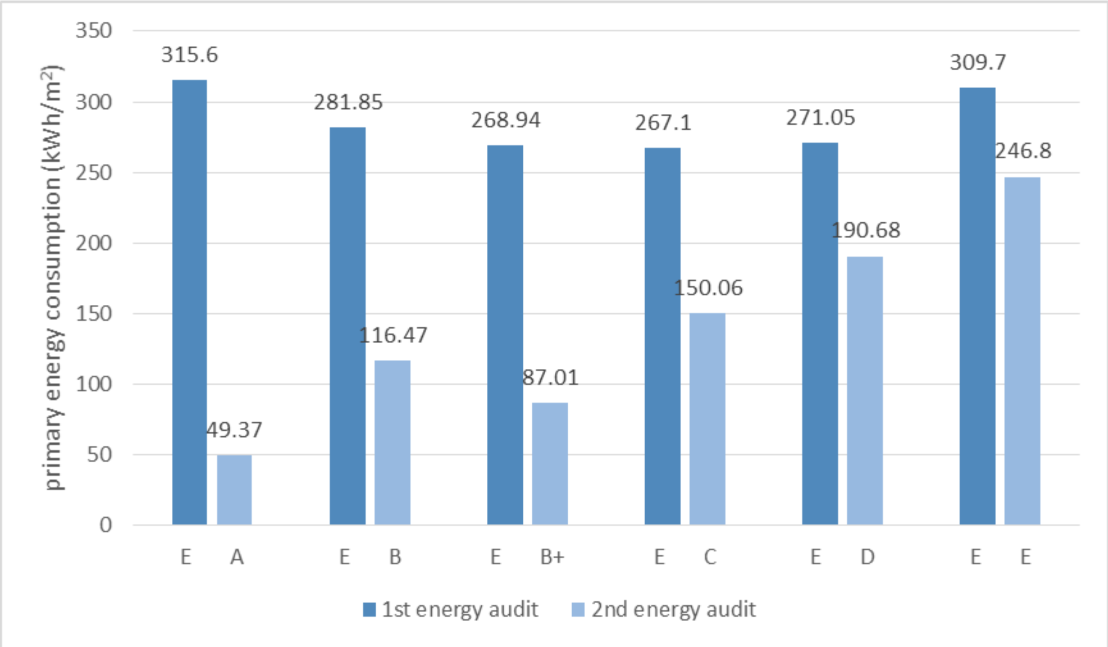
	A+	A	B+	B	C	D	E	F	G
D	0.04%	0.34%	2.90%	8.87%	5.25%	0.34%	0.00%	0.00%	0.00%
E	0.00%	0.13%	2.39%	5.29%	9.30%	3.03%	0.04%	0.00%	0.00%
F	0.00%	0.09%	1.28%	3.07%	6.31%	5.50%	2.39%	0.04%	0.00%
G	0.04%	0.17%	2.82%	5.67%	11.69%	7.42%	7.51%	4.35%	3.71%
SUM	0.09%	0.73%	9.39%	22.91%	32.55%	16.30%	9.94%	4.39%	3.71%

2nd energy audit

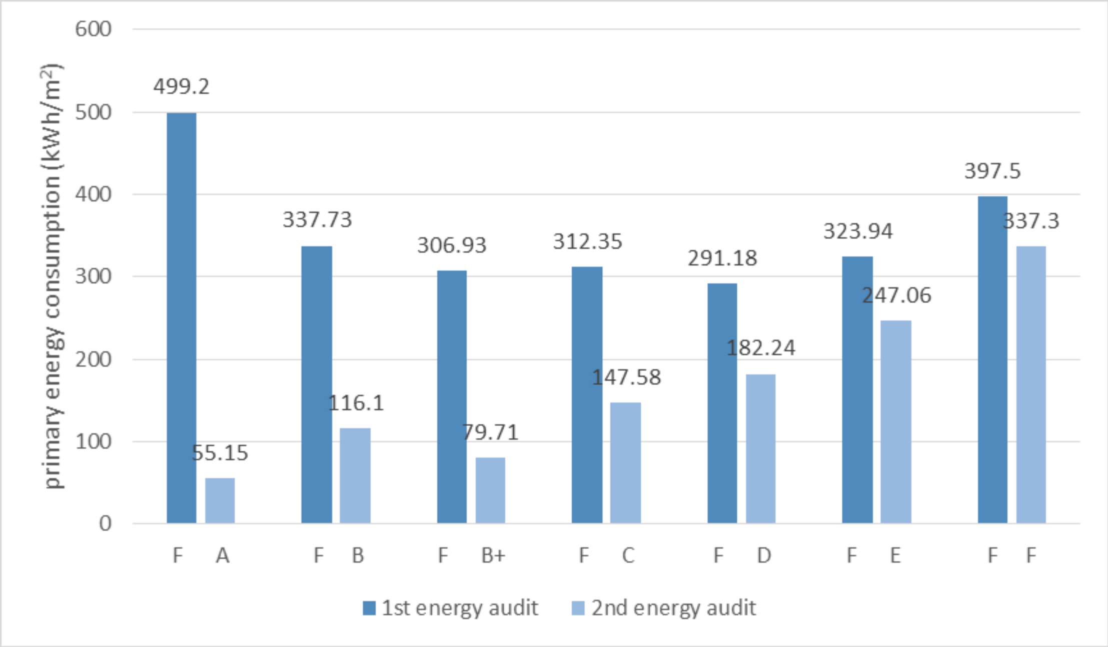
Graph 3.4.1.2.1: Rate of change of the energy category of residential buildings (between the 1st and 2nd energy audits) [20]



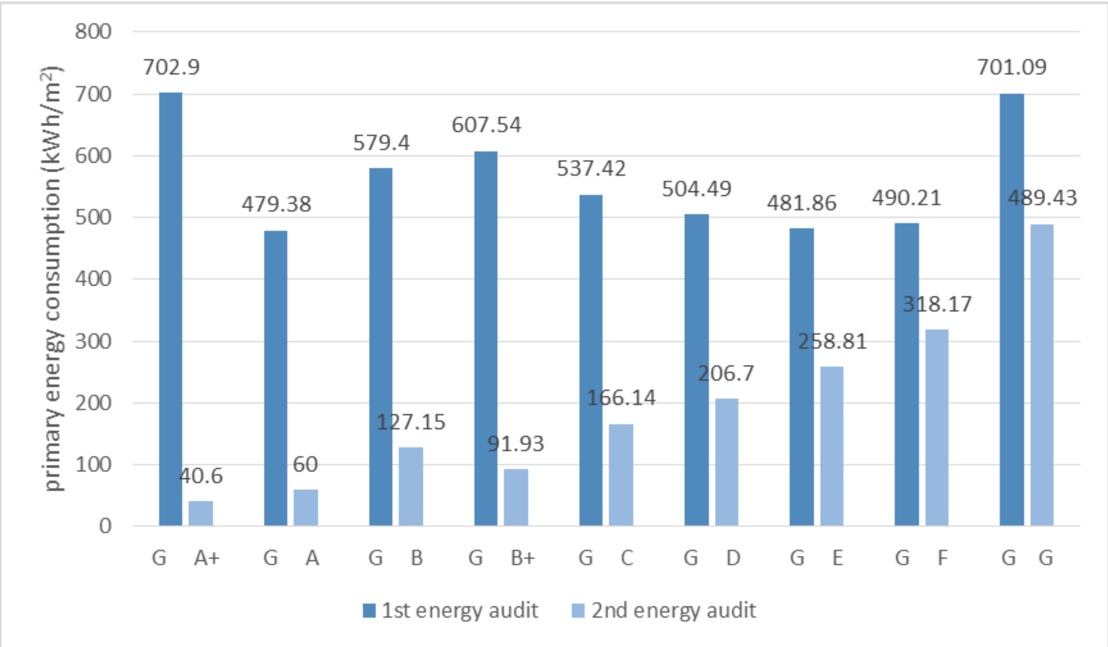
Graph 3.4.1.2.2: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category D [20]



Graph 3.4.1.2.3: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category E [20]



Graph 3.4.1.2.4: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category F [20]



Graph 3.4.1.2.5: Average primary energy consumption of the 1st and 2nd energy audits, for residences of energy category G [20]

Before the refurbishment, the majority of the residences belonged to the lower energy categories. After the refurbishment the majority of the buildings belong to energy category C (32.55%), followed by the energy category B (22.91%). The energy categories that follow are D

(16.30%), E (9.94%) and B+ (9.39%). It worth to mention that even after the refurbishment, a small percentage of residences remained at the lowest categories. It is also noticed that the energy consumption is quite lower after the refurbishment, at all energy categories. With the refurbishment, the buildings of the lower energy categories had more energy savings in compare to buildings of the higher energy categories. The lower the energy label, the highest the energy savings.

The energy category C has primary energy consumption on average of 150kWh/m^2, as presented at the graphs above, and the energy category B has primary energy consumption on average of 120kWh/m^2. The difference at the primary energy consumption before and after the refurbishment is at least 100kWh/m^2, which is almost the double of the primary energy consumption after the refurbishment. The difference is even higher at the refurbishment of low energy category buildings, that achieve to reach high energy category. For instance, a building of energy category F has primary energy consumption on average of 310kWh/m^2, and if it was refurbished and reached the energy category B, would have on average 115kWh/m^2.

3.4.2 Financial valuation of Eksikonomisi kat’ Oikon Program

As mentioned at previous paragraphs, Eksikonomisi kat’ Oikon is a national program that offers financial support to the owners who want to refurbish their residence. Eksikonomiki kat’ Oikon I, launched in 2011 and the subsidies that provided ranged from 15% to 70 %. The beneficiaries can also be provided with a zero-interest loan. The maximum eligible amount of fund was 15,000 €. [39]

The program aims to contribute to reach the energy and environmental targets, and also achieve energy savings up to 1 billion kWh/year. Also, it contributes to enrich public awareness related to environmental issues, improve the living conditions of the residential building stock. [39] Finally, it contributed to the creation of more than 2,500 jobs (engineers, energy inspectors, bank accountants etc.). [24] The refurbishment of the residential building stock will reduce energy poverty, improve thermal comfort and the quality of life of the beneficiaries, and aims to decrease the average primary energy consumption by 43% (164 kwh/m^2). The energy savings will be approximately to 1,200 €/year per household. [41]

Eksikonomisi kat’ Oikon I Program (2007-2013)

The initial budget of Eksikonomisi kat’ Oikon was 396million €, of which 241 million € came from national funds. The program is co-financed by national funds (YPEKA ministry) and major banks. By the end of 2015, the budget was 385 million €, pus 130 million € which was provided by the major banks, so the total budget was about 520 million €. The total number of applications was over 200,000, and 50% of them was granted with a loan. An ongoing barrier was that due to economic criteria, many applications were "frozen" and never were able to be completed. [24] So, 45,403 applications were received the final approval and proceed to the implementation phase. The annual primary energy savings of these refurbished residences were on average 753.91 GWh per year, based on the EPCs performed before and after the implementation of the interventions. [39]

At the middle of 2016: The total budget was 96.1million €, with a contribution of national funds of 59.1million €. The total number of applications was 8,518. [38]

At the 3^{rd} semester of 2017: the total budget was 81.5million €, with a contribution of national funds of (68.6million € + 12.9million €). The total number of applications was 7,000. [38]

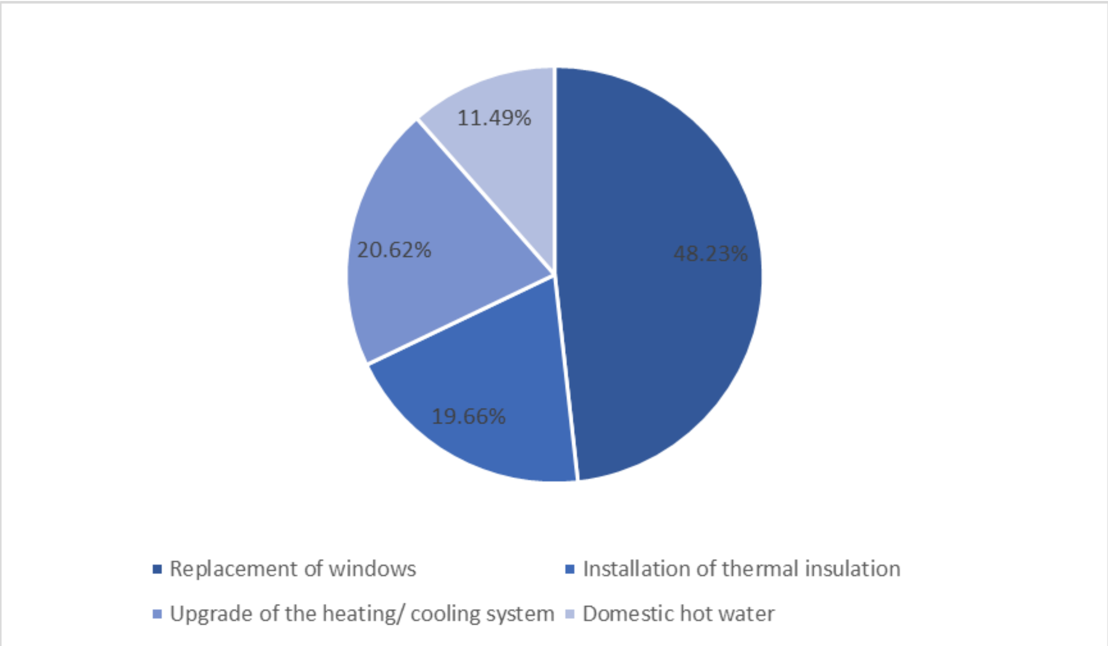
Eksikonomisi kat' Oikon II Program

The maximum eligible intervention budget per application is 250€/m^2 of residence. The maximum budget per residence is 25,000€ (taxes included). [38]

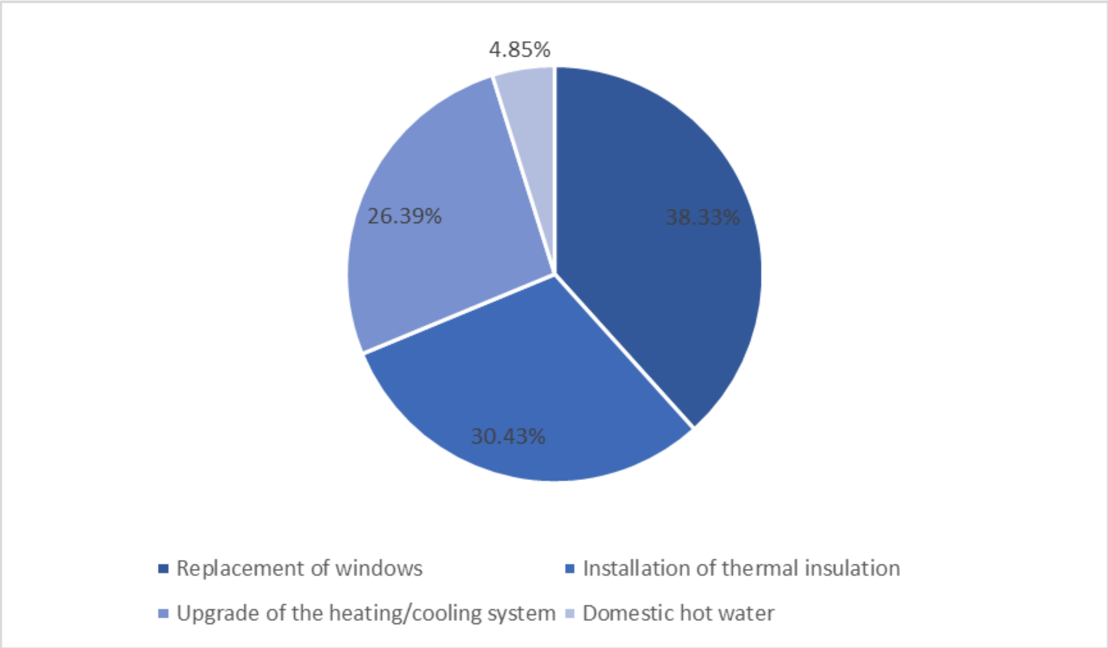
The total budget is 224.4million € of Direct Aid, of which 180.1million € are funded of EPANEK and the rest 44.3million € are funded of PEP. Also, Eksikonomisi kat' Oikon Fund, funded the program with 68million €. [38]

The total number of applications was 45,600.

The graphs below show the rate of interventions and the rate of budget per type of intervention.



Graph 3.4.2.1: Rate of interventions per type of intervention [34]



Graph 3.4.2.2: Rate of budget per type of intervention [38]

Table 3.4.2.1: Data of Eksikonomisi kat’ Oikon I Program

Classification of regions	Regions	Number of households	National fund	Number of loans	cash absorption (national fund)	“frozen” applications	Requirement of “frozen” applications
		Data from the 1st specialization of EP-ANEK		Data from the implementation of “Eksikonomisi kat’ Oikon I” (2007-2013)			
Less developed regions	East Macedonia and Thrace, Central Macedonia, Epirus, Thessaly, West Greece	13,545	156,843,693.75€	30,182	62,931,116€	21,389	37,290,231€
More developed regions	South Aegean	441	8,155,952.00€	558	1,364,182€	461	846,909€
	Attica	3,990	45,877,233.75€	7,267	14,695,500€	5,517	8,500,205€
Regions in transition	Central Greece	357	6,658,868.00€	2,878	6,254,128€	2,455	4,252,435€
	West Macedonia, Ionian Islands, North Aegean, Peloponnesus, Crete	1,667	30,519,808.75€	9,195	20,489,762€	6,121	10,778,335€
Total		21,000	248,055,556.00€	50,080	105,734,688€	35,943	61,668,115€

Source: [37]

Table 3.4.2.2: Annual limit of primary energy consumption of energy category A+ for typical detached houses and polykatoikies, per climatic zone and period

Period	**Climatic zone**	**Annual limit of primary energy consumption of energy category A+ (kWh/m²)**	
		Detached houses	**Polykatoikies**
1955-1980	A	35	25
	B	40	28
	C	58	42
	D	56	46
1980-2000	A	50	26
	B	63	29
	C	86	44
	D	94	48
2000-2010	A	50	27
	B	46	30
	C	72	46
	D	87	50
2010-2016	A	34	28
	B	36	31
	C	54	47
	D	58	51
2016-today	A	34	28
	B	36	31
	C	54	47
	D	58	51

Source: [40]

So, by studying the table it is noticed that the annual limit for primary energy consumption for the buildings constructed at the period 1955-2016 is 34-94 kWh/m^2 for the detached houses, and 25-51kWh/m^2 for polykatoikies. For the period 2016-today, it is 34-58kWh/m^2 and 28-51kWh/m^2 respectively.

Barriers [39]

- The beneficiaries were obliged to be granted with a loan, but due to creditworthiness reasons, many beneficiaries couldn’t proceed with the program.
- The eligible interventions were the same for all climatic zones.
- Due to the complexity of the residential building sock, and specifically of polykatoikies, the number of residences of polykatoikies that were accepted at the program was limited.

3.4.2.1 Financial assessment of energy efficiency interventions

The initial cost of interventions was estimated to 12,885€ for the detached houses, 10,486€ for apartments and 26,789€ for polykatoikies. The Table 3.4.2.1.1 shows the initial estimate of the cost of interventions per type of residence. [37]

Table 3.4.2.1.1: Initial estimate of the cost of interventions per type of residence

	Detached houses	Apartments	Polykatoikies
Average value	12,885€	10,486€	26,789€
Standard deviation	3,508€	4,116€	14,560€
Lower value	1,300€	1,014€	5,817€
Maximum value	28,390€	30,983€	89,761€

Source: [37]

The Table 3.4.2.1.2 presents the average amount of loan per type of residence.

Table 3.4.2.1.2: Average amount of loan per type of residence.

	Detached houses	Apartments	Polykatoikies
Average value	5,389€	4,407€	-
Standard deviation	2,331€	2,181€	-
Lower value	624€	390€	-
Maximum value	12,750€	12,750€	-

Source: [37]

The average cost of intervention per residence is 10,798€. The Table 3.4.2.1.3 presents the average cost of intervention per type of residence. For polykatoikies, the average cost of intervention is 25,078€. [37]

Table 3.4.2.1.3: Average cost of intervention per type of residence

	Detached houses	Apartments	Polykatoikies
Average value	12,281€	9,981€	25,078€
Standard deviation	3,321€	3,927€	13,346€
Lower value	1,200€	1,014€	5,454€
Maximum value	23,443€	24,765€	89,762€

Source: [37]

The average cost of intervention per square meter of residence is 110.45€/m^2. The Table 3.4.2.1.4 presents the average cost of intervention per square meter of residence. The average value for a residence of 50-75m^2 is 137.20€/m^2, and for a residence of 75-100m^2 is 117.00€/m^2. [37]

Table 3.4.2.1.4: Average cost of intervention per square meter of residence

Square meter	Average value	Standard deviation	Lower value	Maximum value
25-50	168.70€/m^2	93.50€/m^2	25.60€/m^2	499.80€/m^2
50-75	137.20€/m^2	63.80€/m^2	15.40€/m^2	345.40€/m^2
75-100	117.00€/m^2	43.30€/m^2	12.20€/m^2	256.30€/m^2
100-125	101.50€/m^2	33.10€/m^2	11.40€/m^2	283.10€/m^2
125-150	90.10€/m^2	25.20€/m^2	17.60€/m^2	195.10€/m^2
150-175	78.60€/m^2	22.30€/m^2	19.00€/m^2	183.90€/m^2
175-200	68.80€/m^2	19.10€/m^2	24.00€/m^2	145.00€/m^2
200-225	62.60€/m^2	21.90€/m^2	23.10€/m^2	157.00€/m^2
225-250	64.00€/m^2	26.90€/m^2	21.80€/m^2	173.10€/m^2
>250	59.60€/m^2	34.10€/m^2	1.10€/m^2	210.10€/m^2

Source: [37]

The Table 3.4.2.1.5 presents the average cost of intervention per square meter of residence, per region. [37]

Table 3.4.2.1.5: Average cost of intervention per square meter of residence per region

Region	Average value	Standard deviation	Lower value	Maximum value
Central Macedonia	110.70€/m^2	51.00€/m^2	1.10€/m^2	499.80€/m^2
Attica	110.40€/m^2	52.40€/m^2	14.80€/m^2	479.90€/m^2
Thessaly	107.50€/m^2	48.00€/m^2	22.60€/m^2	407.30€/m^2
East Macedonia and Thrace	118.60€/m^2	51.820€/m^2	16.60€/m^2	272.10€/m^2
West Macedonia	111.70€/m^2	44.20€/m^2	19.00€/m^2	276.90€/m^2
West Greece	117.90€/m^2	45.50€/m^2	20.70€/m^2	323.60€/m^2
Central Greece	108.10€/m^2	51.70€/m^2	7.50€/m^2	348.30€/m^2
Crete	114.60€/m^2	43.00€/m^2	31.50€/m^2	286.60€/m^2
Peloponnesus	106.20€/m^2	45.00€/m^2	1.60€/m^2	367.60€/m^2
Epirus	111.30€/m^2	50.50€/m^2	14.00€/m^2	390.50€/m^2
North Aegean	122.60€/m^2	49.60€/m^2	23.60€/m^2	333.30€/m^2
South Aegean	113.40€/m^2	47.50€/m^2	15.90€/m^2	472.10€/m^2
Ionian Islands	112.70€/m^2	47.10€/m^2	12.20€/m^2	273.30€/m^2

Source: [37]

The Table 3.4.2.1.6 presents the average cost of intervention per square meter of residence, per decade of construction. The average cost of intervention for a residence constructed at the period 1971-1980 is 109.30€/m^2, and for a residence constructed at the period 1981-1990 is 106.50€/m^2. [37]

Table 3.4.2.1.6: Average cost of intervention per square meter of residence per decade of construction

Decade of construction	Average value	Standard deviation	Lower value	Maximum value
1931-1940	123.70€/m^2	54.90€/m^2	40.20€/m^2	333.30€/m^2
1941-1950	129.70€/m^2	63.00€/m^2	37.90€/m^2	499.80€/m^2
1951-960	121.50€/m^2	55.20€/m^2	7.50€/m^2	472.10€/m^2
1961-1970	117.20€/m^2	54.00€/m^2	10.10€/m^2	427.00€/m^2
1971-1980	109.30€/m^2	47.30€/m^2	12.20€/m^2	347.10€/m^2
1981-1990	106.50€/m^2	44.00€/m^2	1.60€/m^2	479.90€/m^2
1991-2000	106.70€/m^2	49.20€/m^2	15.40€/m^2	312.50€/m^2
2001+	100.20€/m^2	53.60€/m^2	1.10€/m^2	443.80€/m^2

Source: [37]

The Table 3.4.2.1.7 presents the average cost of intervention per square meter of residence, per energy category. [37]

Table 3.4.2.1.7: Average cost of intervention per square meter of residence per energy category

Energy category	Average value	Standard deviation	Lower value	Maximum value
D	95.80€/m^2	43.80€/m^2	15.40€/m^2	326.90€/m^2
E	101.70€/m^2	46.20€/m^2	12.50€/m^2	443.80€/m^2
F	105.50€/m^2	47.30€/m^2	11.40€/m^2	479.90€/m^2
G	117.40€/m^2	50.40€/m^2	1.10€/m^2	499.80€/m^2

Source: [37]

3.4.2.2 Cost of the energy savings

The average cost of interventions per primary energy savings [€/kWh] of the refurbished buildings is 110.45€/kWh. The Table 3.4.2.2.1 shows the average cost of interventions per primary energy savings. The average value is 116.44€/kWh. [37]

Table 3.4.2.2.1: Average cost of interventions per primary energy savings

	Primary energy savings [€/kWh]
Average value	116.44€/kWh
Standard deviation	245.69€/kWh
Lower value	1.12€/kWh
Maximum value	18,750.00€/kWh

Source: [37]

The Table 3.4.2.2.2 presents the average cost of interventions per primary energy savings, per region. [37]

Table 3.4.2.2.2: Average cost of interventions per primary energy savings, per region

Region	Average value	Standard deviation	Lower value	Maximum value
Central Macedonia	90.00€/kWh	79.10€/kWh	1.10€/kWh	1,070.50€/kWh
Attica	98.70€/kWh	150.80€/kWh	5.90€/kWh	2,933.80€/kWh
Thessaly	81.10€/kWh	151.30€/kWh	7.60€/kWh	3,169.90€/kWh
East Macedonia and Thrace	148.50€/kWh	232.30€/kWh	3.60€/kWh	1,750.30€/kWh
West Macedonia	130.40€/kWh	143.60€/kWh	3.00€/kWh	1,591.40€/kWh
West Greece	150.30€/kWh	149.30€/kWh	16.10€/kWh	1,958.90€/kWh
Central Greece	160.00€/kWh	504.90€/kWh	2.70€/kWh	18,750.00€/kWh
Crete	127.60€/kWh	106.00€/kWh	3.50€/kWh	970.80€/kWh
Peloponnesus	89.10€/kWh	84.70€/kWh	2.90€/kWh	1,602.60€/kWh
Epirus	154.70€/kWh	169.00€/kWh	8.20€/kWh	1,721.30€/kWh
North Aegean	122.10€/kWh	111.70€/kWh	9.50€/kWh	805.90€/kWh
South Aegean	171.90€/kWh	164.10€/kWh	4.30€/kWh	1,391.70€/kWh
Ionian Islands	139.90€/kWh	158.00€/kWh	15.60€/kWh	1,137.40€/kWh

Source: [37]

The Table 3.4.2.2.3 presents the average cost of interventions per primary energy savings, per decade of construction. [37]

Table 3.4.2.2.3: Average cost of interventions per primary energy savings, per decade of construction

Decade of construction	Average value	Standard deviation	Lower value	Maximum value
1931-1940	85.20€/kWh	59.20€/kWh	18.10€/kWh	294.70€/kWh
1941-1950	109.70€/kWh	142.40€/kWh	3.60€/kWh	1,026.90€/kWh
1951-960	92.10€/kWh	98.20€/kWh	2.70€/kWh	1,137.90€/kWh
1961-1970	95.10€/kWh	125.50€/kWh	1.10€/kWh	2,884.30€/kWh
1971-1980	107.60€/kWh	127.10€/kWh	1.80€/kWh	2,366.00€/kWh
1981-1900	143.50€/kWh	458.60€/kWh	1.90€/kWh	18,750.00€/kWh
1991-2000	137.80€/kWh	114.70€/kWh	1.70€/kWh	1,390.80€/kWh
2001+	133.80€/kWh	123.10€/kWh	1.50€/kWh	1,721.30€/kWh

Source: [37]

The Table 3.4.2.2.4 presents the average cost of interventions per primary energy savings, per energy category. [37]

Table 3.4.2.2.4: Average cost of interventions per primary energy savings, per energy category

Energy category	Average value	Standard deviation	Lower value	Maximum value
D	184.70€/kWh	213.30€/kWh	1.90€/kWh	3,993.00€/kWh
E	170.10€/kWh	538.60€/kWh	1.70€/kWh	18,750.00€/kWh
F	128.80€/kWh	138.10€/kWh	1.10€/kWh	3,169.90€/kWh
G	84.10€/kWh	101.10€/kWh	1.80€/kWh	2,884.30€/kWh

Source: [37]

4 Case study

In this part, a case study will be presented in order to discuss the effectiveness of Eksikonomisi kat' Oikon Program. The case study considers a Polykatoikia studied for the climatic zone C of Greece. Using "EnergyPlus" program, different intervention scenarios will be studied, so as to examine the cost effectiveness of these scenarios, the financial charge of the owner and the energy savings of the building.

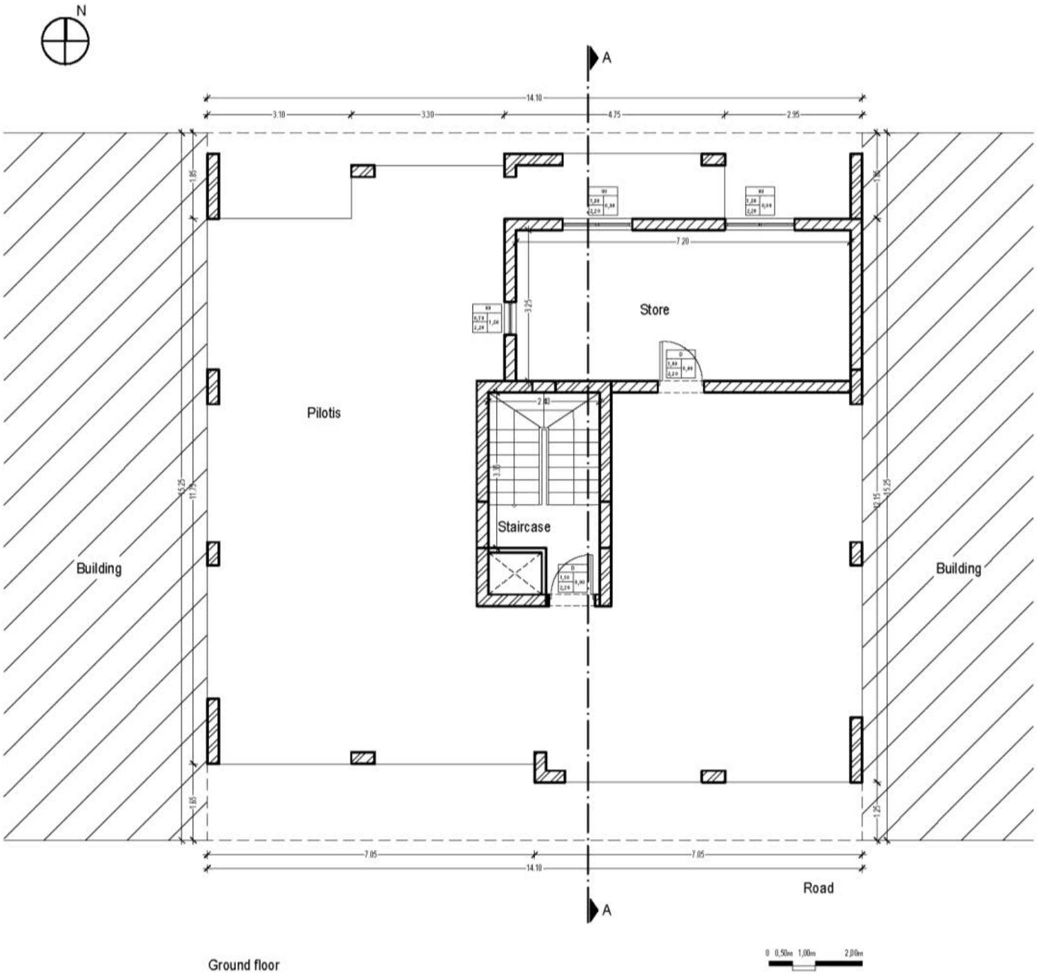
The polykatoikia that will be discussed at the case study is hypothetical. It is assumed that it was built at 1980s, with the same typological characteristics as polykatoikies which were constructed at this period. As said in Chapter 2.3.2.4, most of the polykatoikies, which were built at the period 1950-1980, were constructed with antiparochi system. At 1950-1980 more than 35,000 polykatoikies were built, with most of their apartments having 3 rooms and an average of 75 sq.m. [11]

The building regulation of 1985 introduced the concept of the ideal solid. The morphology of the buildings could be designed freely, and it was also proposed the induction of new spaces at the polykatoikies, the Pilotis, a shared space and also semi-outdoor spaces and balconies, which could be designed extra at the maximum percentage of 40% on the surface (20% on the surface for semi-outdoor spaces and 20% on the surface for balconies). The Pilotis is an open space at the ground floor of polykatoikies, which is used mainly as parking. Also, the building could be constructed at any place in the plot, without necessarily “touching” the building line. In order to have an extra floor, the building was placed as much as possible at the back of the plot, and keeping as a base the ideal solid, an extra floor was added, but the uncovered area of the plot got smaller. The balconies were also larger. The coverage ratio remained at 70%. The maximum height was defined according to structure factor of each area. [9]

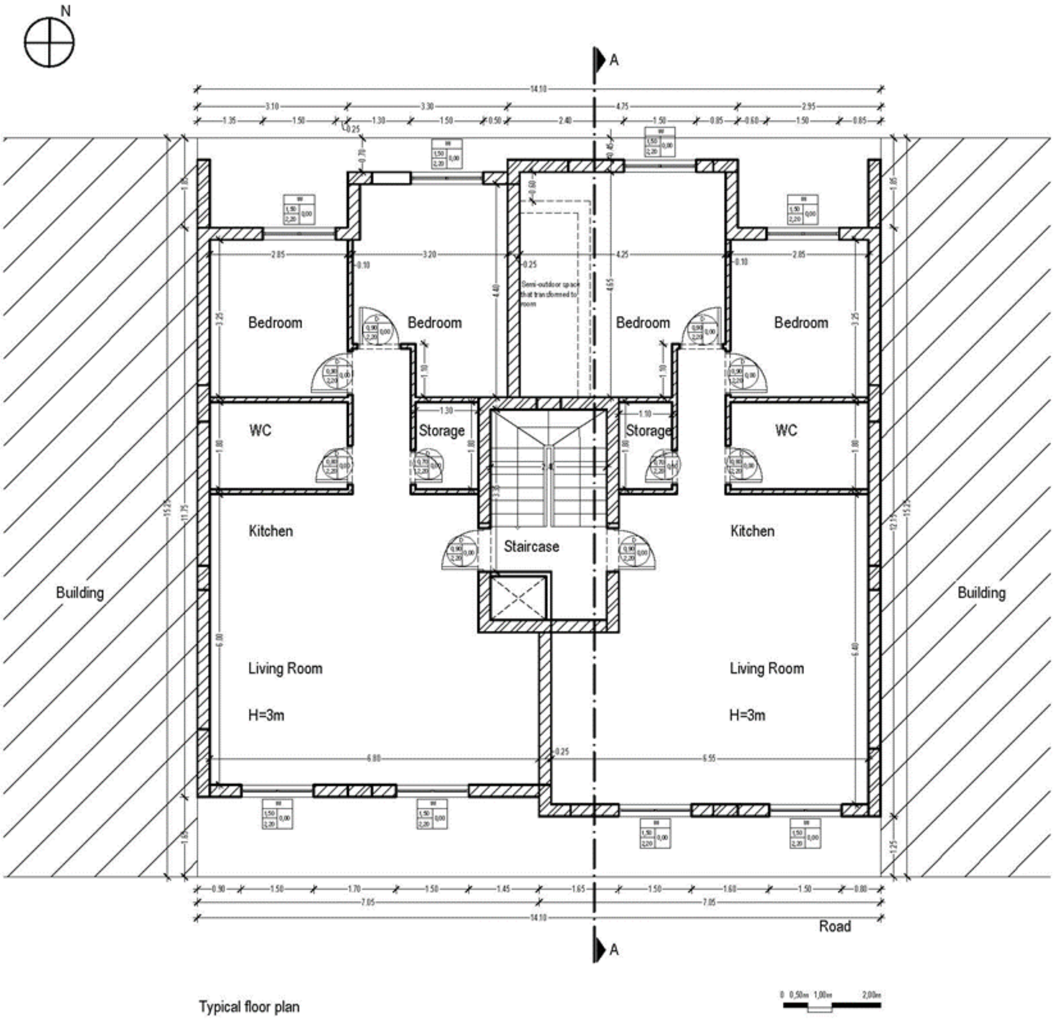
The floor plans of polykatoikies of this period are typical. The living room were designed on the front view towards the road, the kitchen and the toilet were located in the middle, and the bedrooms were located at the back. At small apartments, it was designed an open kitchen due to lack of space. The most semi-outdoor spaces that were designed were transformed at rooms. The openings were small, and usually were divided by a canvas. The balconies usually had 1m width. [9]

The introduction of Thermal Insulation Regulations in Greece was initiated in 1979, and remained the same until 2010, when the new Energy Regulation, KENAK, was implemented. Although the Thermal Insulation Regulation was implemented, only a small percentage of new buildings applied thermal insulation until 2000. So, polykatoikies of this period are partially insulated. [17] According to ELSTAT, 45.6% of the residential stock affords no thermal insulation, and the rest 54.5% presents some thermal insulation.

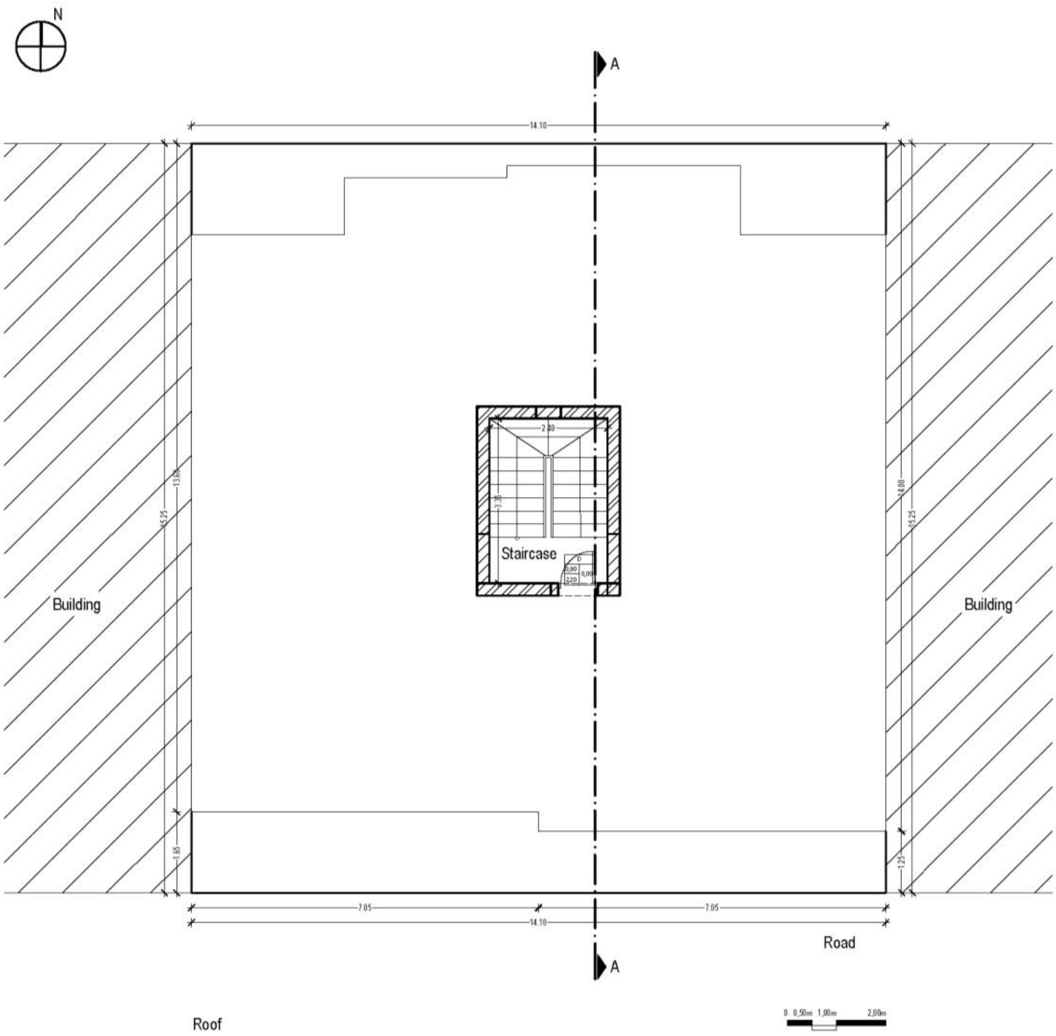
The floor plan of the case study is typical, and it is repeated at all floors. The polykatoikia has 5 floors, and it also has a Pitotis on the ground floor that is used as a parking. There is also a store at the ground floor. The height of each floor is 3m and the area 178.94m^2. Each floor has two apartments of total area 168.41m^2 (one of 88.20m^2 and one of 80.21m^2), and the semi-outdoor space that were designed at the back of the staircase was transformed into a room. All apartments and the store are heated spaces The staircase and the Pilotis are unheated spaces. The west and east façade of the building are tanged to neighbor buildings, and the north and south facades are free. The road is located towards the south façade.



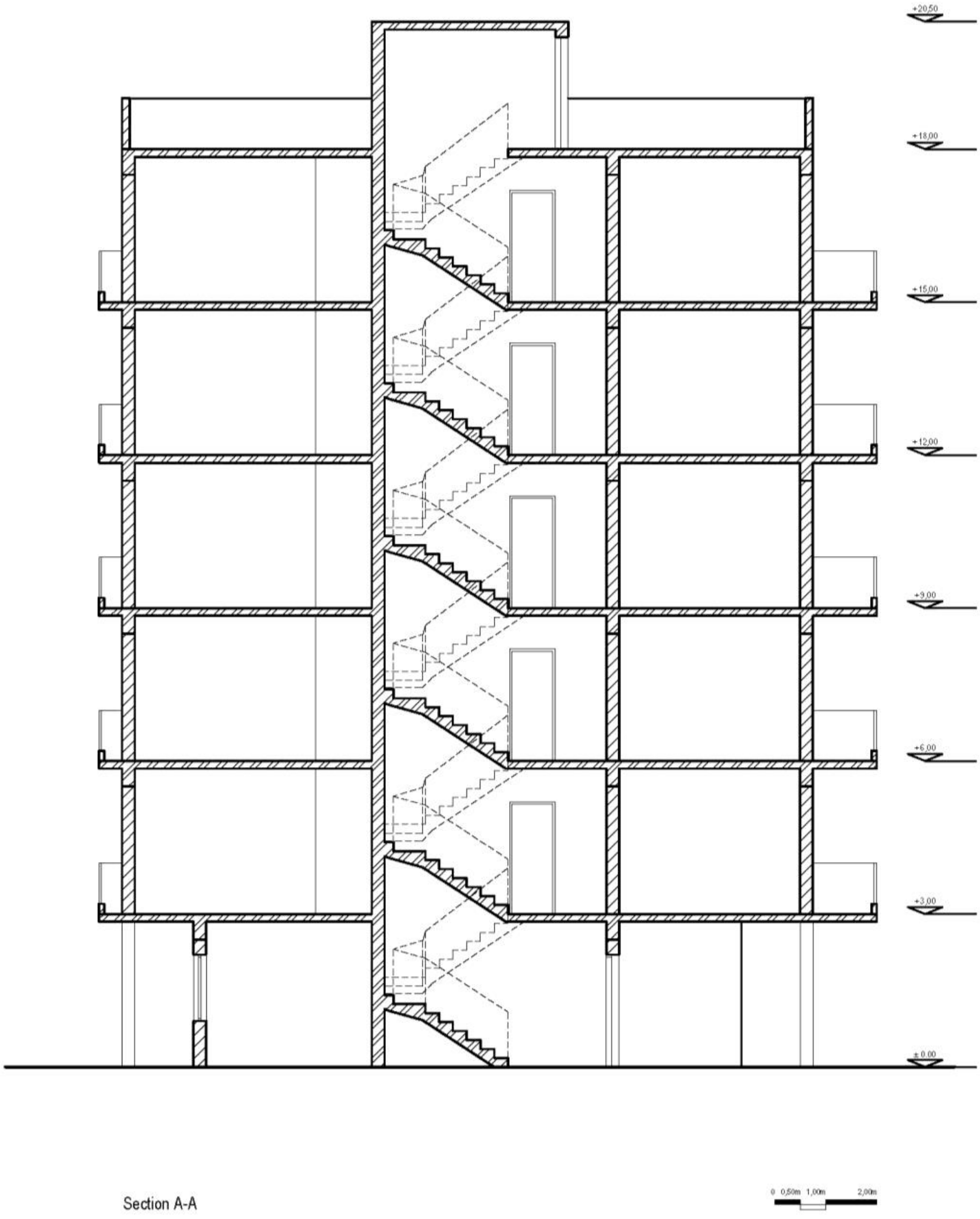
Picture 4.1: Ground Floor Plan



Picture 4.2: Typical Floor Plan



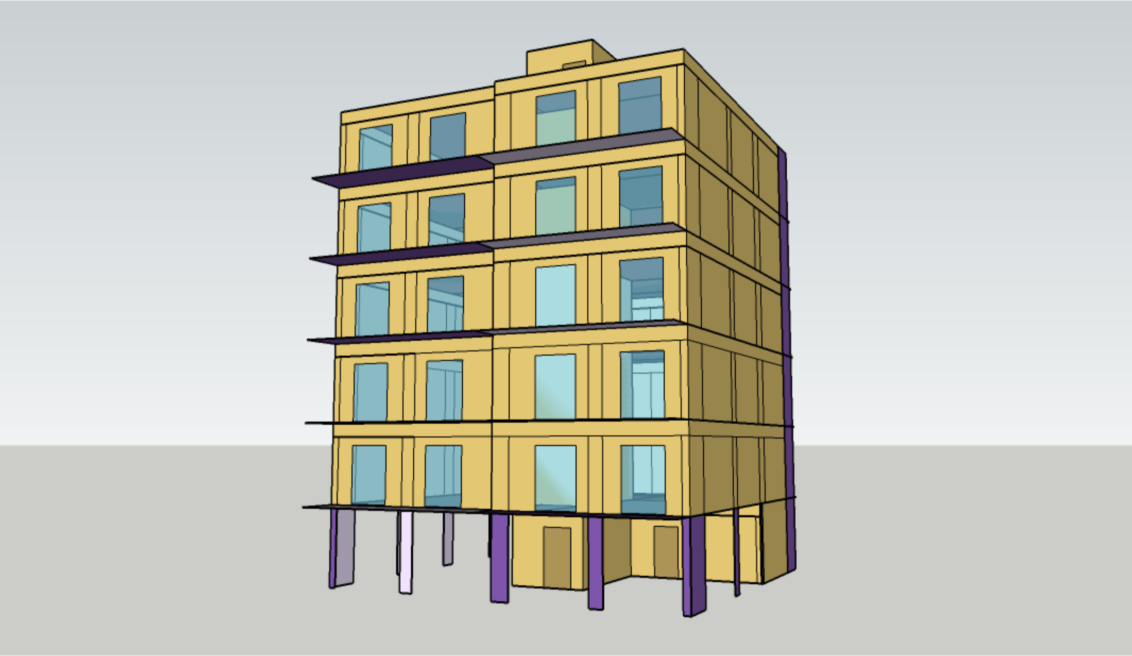
Picture 4.3: Roof Plan



Picture 4.4: Section

4.1 Energy Performance Simulation and Analysis

The software used for the energy calculations is Energy Plus. For the calculations, the assumptions made were in accordance with the Technical Directions of Technical Chamber of Greece. From now on, the model will be called as “Reference Building”, to distinguish it from the retrofitting proposals that will be discussed later in this chapter. The pictures below show the simulation model in Energy Plus Program.



Picture 4.1.1: Energy Plus Model, South Facade

Picture 4.1.2: Energy Plus Model, North Facade

The walls of the polykatoikia are made of bricks, and they are uninsulated. The bearing structure is made of concrete, and is also uninsulated. The construction of the roof is conventional and uninsulated. The windows are single glazed with metal frames, without shutters. The Pilotis is also uninsulated. The heating system is a central oil boiler. For the domestic hot water, each apartment uses its own electric water heater.

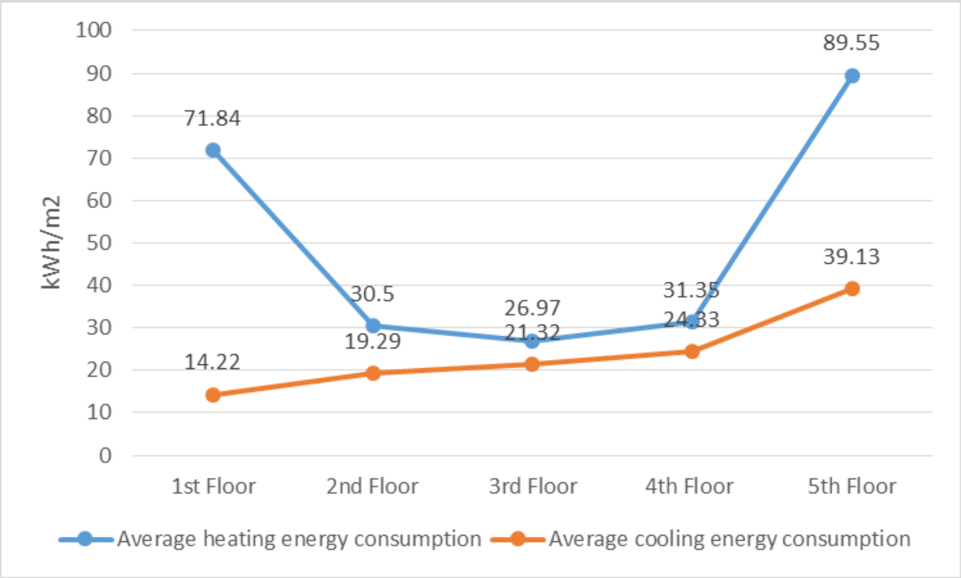
Table 4.1.1: U-value factor of opaque envelope

	U-Factor with Film [W/m²-K]	U-Factor no Film [W/m²-K]
Exterior wall	1.672	2.231
Exterior column	3.519	7.436
Exterior beam	3.519	7.436
Interior ceiling	2.793	4.533
Interior floor	2.793	4.533
Floor to unheated space	2.424	4.533
Floor to the ground	3.001	5.840
Wall to unheated space	1.976	2.806
Ceiling over unheated space	2.700	4.533
Exterior door	5.008	20.000

Table 4.1.2: U-value factor of windows

	Glass U-Factor [W/m²-K]	Frame Conductance [W/m²-K]
Windows	2.859	2.000

The results of the simulation analysis are presented analytically at the Tables 43-49 at the Appendix. Each Table presents the simulation results for one floor of the building, the store at the Pilotis and the unheated space of the staircase. The Graph 4.1.1 sum up the information for the heating and cooling needs of the building.



Graph 4.1.1: Average heating and cooling energy consumption per square meter.

By studying the simulation results, it is noticed that the polykatoikia has high energy consumption as expected. The apartments of the 1st Floor have annual heating energy consumption of 71.84kWh/m^2. The apartments of the 2nd Floor have annual heating energy consumption of 30.50kWh/m^2. On the 2nd Floor the heating energy consumption is quite less that the one of the 1st Floor, as the 1st Floor is over the Pilotis. The apartments of the 3rd Floor have heating annual energy consumption of 26.97kWh/m^2, which is lower that the energy consumption of the 2nd Floor. The apartments of the 4th Floor have annual heating energy consumption of 31,35kWh/m^2. The apartments of the 5th Floor have annual heating energy consumption of 79.55kWh/m^2. The 5th Floor has the highest heating energy consumption because of the heat losses of the roof.

Concerning the cooling energy consumption, the apartments of the 1st Floor have 14.22kWh/m^2, the apartments of the 2nd Floor 19.29kWh/m^2, the apartments of the 3rd Floor 21.32kWh/m^2, the apartments of the 4th Floor 24.31kWh/m^2, and the apartments of the 5th Floor 39.13kWh/m^2. The 5th Floor has the highest cooling energy consumption, almost double than the one at the 1st Floor, because of the losses of the roof. The 1st Floor has the lowest cooling energy consumption, followed by the 2nd Floor.

4.2 Retrofitting Proposals

Three scenarios are proposed as retrofitting measures for the polykatoikia of the case study. The three scenarios are: the basic scenario, the optimistic scenario, and the upgraded building scenario.

Basic scenario: this scenario applies all the retrofitting interventions that are proposed by Eksikonomisi kat' Oikon Program.

Optimistic scenario: this scenario applies the interventions of the basic scenario, and also applies sustainable energy sources and innovative energy saving technologies.

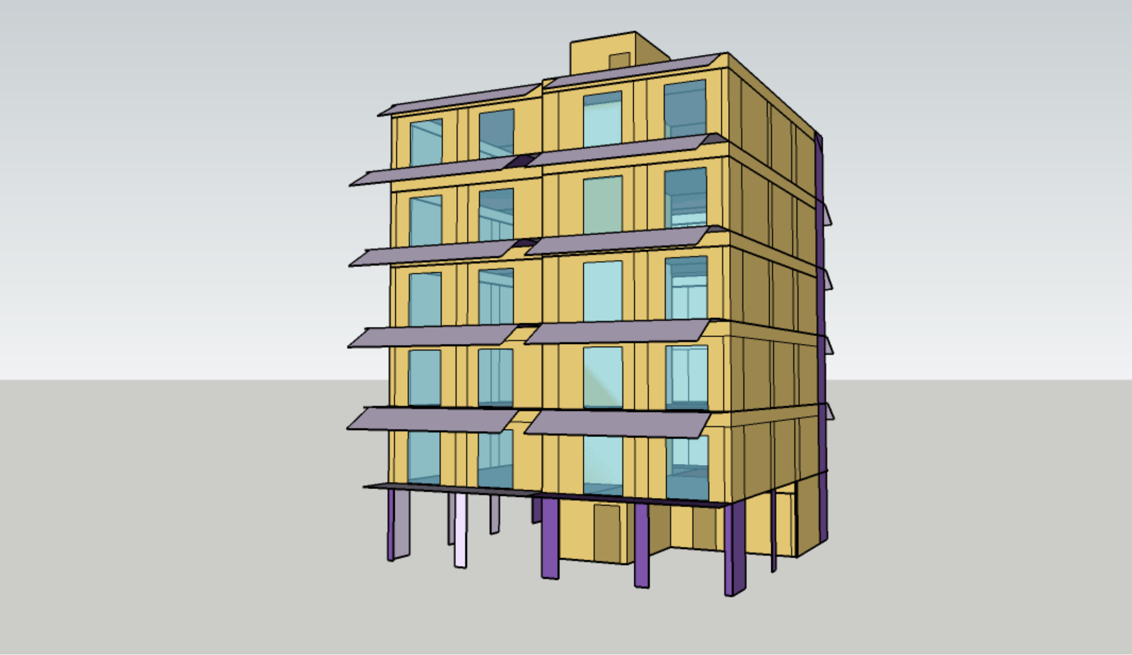
Upgraded building scenario: this scenario proposes even lower thermal conductivity coefficient (u-value) on the envelope of the building, by at least 0.05 W/m^2K. The transparent surfaces are proposed to have 20% lower u-value compared to Eksikonomisi kat' Oikon Program. The heating system proposed for the climatic zone of the case study, the climatic zone C, is the heat pump, for space heating. Domestic Hot Water is proposed 75% to be heated by solar thermal, and 25% to be heated from the heat pump.

According to the energy regulation for the residences, the domestic hot water supply, for all the scenarios, is calculated at 50lt per person per day, and 27.38m^3 per room per year. These values refer to the typical domestic hot water consumption at the temperature of 45^oC.

4.2.1 Basic scenario

This scenario applies all the retrofitting interventions that are proposed by Eksikonomisi kat' Oikon Program. The intervention applied are:

- Thermal insulation on the building's envelope (on the external walls, on the roofs and on the Pilotis);
- Replacement of the windows with energy efficient ones;
- Iinstallation of shading systems;
- Upgrade of the heating system, by replacing it with a heat pump and of the system of the hot water supply.



Picture 4.2.1.1: Energy Plus Model, South Facade

Picture 4.2.1.2: Energy Plus Model, South Facade

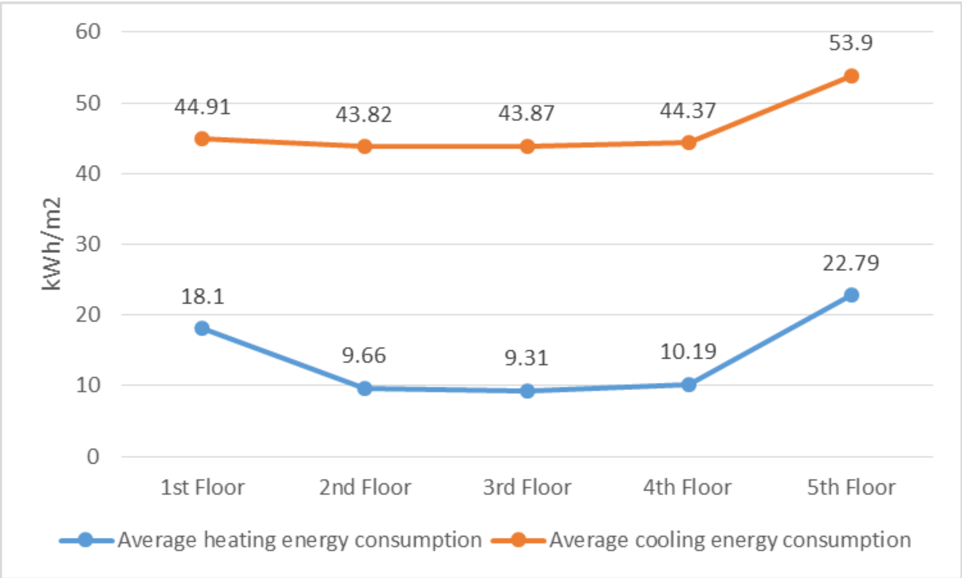
The simulation results are presented at the Tables below, and analytically at the Tables 50-56 at the Appendix.

Table 4.2.1.1: U-value factor of opaque envelope

	U-Factor with Film [W/m²-K]	U-Factor no Film [W/m²-K]
Exterior wall	0.365	0.386
Exterior column	0.412	0.439
Exterior beam	0.412	0.439
Interior ceiling	0.56	0.606
Interior floor	0.56	0.606
Floor to unheated space	0.391	0.423
Floor to the ground	0.404	0.432
Wall to unheated space	0.517	0.56
Ceiling over unheated space	0.56	0.606
Exterior door	5.008	20.000

Table 4.2.1.2: U-value factor of windows

	Glass U-Factor [W/m²-K]	Frame Conductance [W/m²-K]
Windows	1.754	2.000

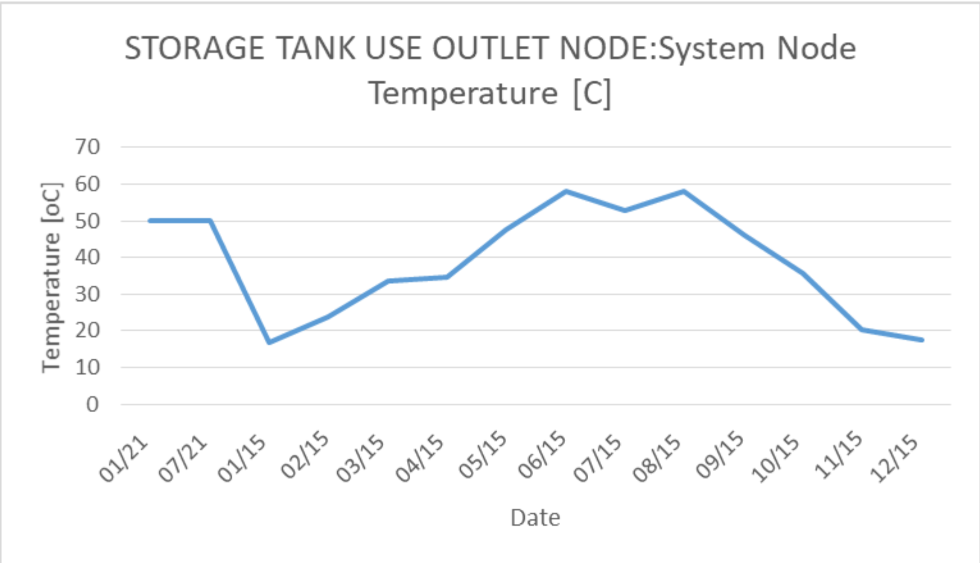


Graph 4.2.1.1: Average heating and cooling energy consumption per square meter.

By studying the simulation results of the Basic scenario, it is noticed that the polykatoikia has less heating energy consumption than the reference building, as expected. The apartments of the 1st Floor have annual heating energy consumption of 18.10kWh/m². The apartments of the 2nd Floor have annual heating energy consumption of 9.66kWh/m². On the 2nd Floor the heating energy consumption is quite less that the one of the 1st Floor, as the floor of the apartments of the 1st Floor is over the Pilotis. The apartments of the 3rd Floor have the lowest annual heating energy consumption of 9.31kWh/m^2. The apartments of the 4th Floor have annual heating energy consumption of 10.19kWh/m^2. The apartments of the 5th Floor have annual heating energy consumption of 22.79kWh/m^2. The 5th Floor has the highest heating energy consumption because of the heat losses of the roof.

Concerning the cooling energy consumption, the apartments of the 1st Floor have 43.90kWh/m^2, the apartments of the 2nd Floor 43.82kWh/m^2, the apartments of the 3rd Floor 43.87kWh/m^2, the apartments of the 4th Floor 44.37kWh/m^2, and the apartments of the 5th Floor 53.90kWh/m^2. So, it is noticed that the 5th Floor has the highest cooling energy consumption, and the 2nd Floor has the lowest. This happens due to air's density. The warm air is lighter, so it goes up and the cold air is heavier so it stays down. At summer months, the warm air goes up at the 5th level of the polykaytoikia, so the cooling needs at this floor are greater.

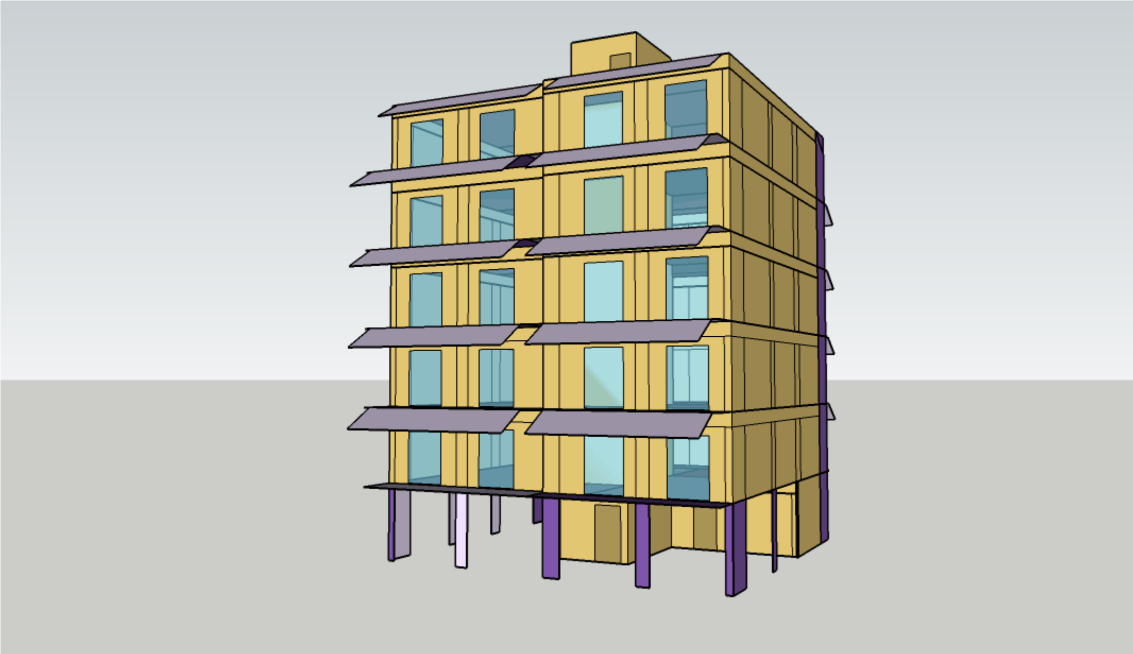
The graph 4.2.1.1 presents the fluctuation of the temperature of the domestic hot water throughout the year. It is noticed that the storage tank contains water at higher temperatures at summer months.



Graph 4.2.1.1: Domestic Hot Water Equipment Use

4.2.2 Optimistic scenario

This scenario applies the interventions of the basic scenario, and also implements renewable energy sources (central domestic hot water system) and a passive system (green roof).



Picture 4.2.2.1: Energy Plus Model, South Facade

Picture 4.2.2.2: Energy Plus Model, North Facade

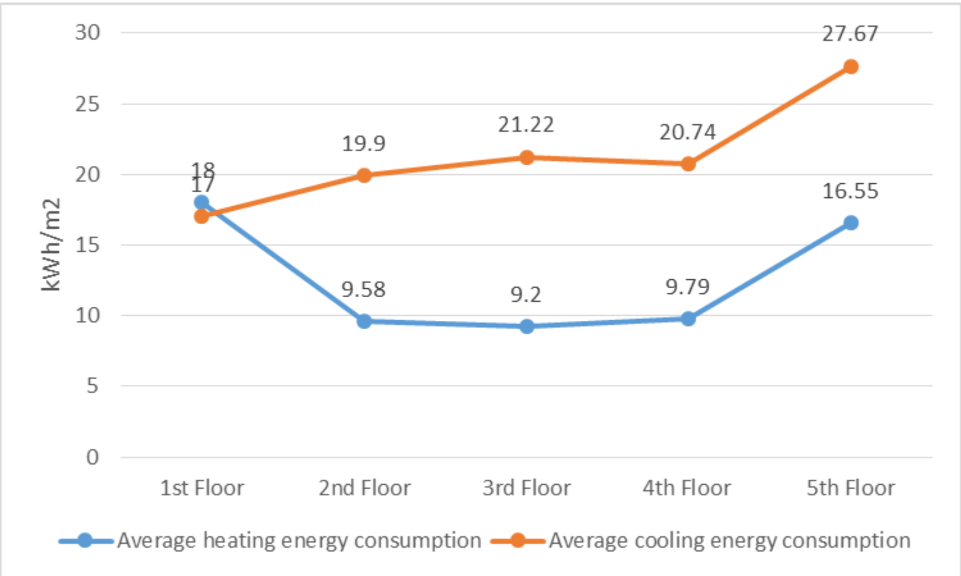
The simulation results are presented at the Tables below, and analytically at the Tables 57-63 at the Appendix.

Table 4.2.2.1: U-value factor of opaque envelope

	U-Factor with Film [W/m²-K]	U-Factor no Film [W/m²-K]
Exterior wall	0.365	0.386
Exterior column	0.412	0.439
Exterior beam	0.412	0.439
Interior ceiling	0.56	0.606
Interior floor	0.56	0.606
Floor to unheated space	0.391	0.423
Floor to the ground	0.404	0.432
Wall to unheated space	0.517	0.56
Ceiling over unheated space	0.56	0.606
Green Roof	0.484	0.519
Exterior door	5.008	20.000

Table 4.2.2.2: U-value factor of windows

	Glass U-Factor [W/m²-K]	Frame Conductance [W/m²-K]
Windows	1.754	2.000



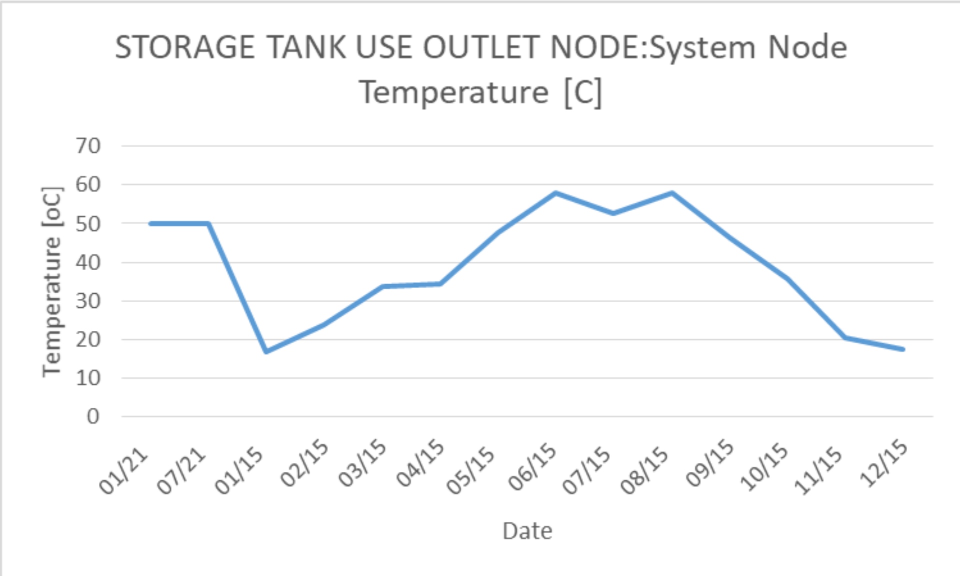
Graph 4.2.2.1: Average heating and cooling energy consumption per square meter.

By studying the simulation results of the Optimistic scenario, it is noticed that the polykatoikia has less heating energy consumption than the one at the basic scenario, as expected. The apartments of the 1st Floor have annual heating energy consumption 18.00Wh/m². The apartments of the 2nd Floor have annual heating energy consumption of 9.58kWh/m². The apartments of the 3rd

Floor have the lowest annual heating energy consumption of 9.20kWh/m^2. The apartments of the 4th Floor have annual heating energy consumption of 9.79kWh/m^2. The apartments of the 5th Floor have annual heating energy consumption of 16.54kWh/m^2. The 5th Floor has no longer the highest heating energy consumption because of the green roof. The 1st Floor has the highest heating energy consumption because of the Pilotis.

Concerning the cooling energy consumption, the apartments of the 1st Floor have 16.99kWh/m^2, the apartments of the 2nd Floor 19.90kWh/m^2, the apartments of the 3rd Floor 20.22kWh/m^2, the apartments of the 4th Floor 20.74kWh/m^2, and the apartments of the 5th Floor 27.67kWh/m^2. The 5th Floor has the higher cooling energy consumption, and the 1st Floor the lower. Therefore, the differences are quite small at this scenario, between the levels of the building. At this scenario also, the reason for the higher cooling needs at the 5th floor are the same as at the basic scenario. It happens due to air's density. The warm air is lighter, so it goes up and the cold air is heavier so it stays down. At summer months, the warm air goes up at the 5th level of the polykaytoikia, so the cooling needs at this floor are greater.

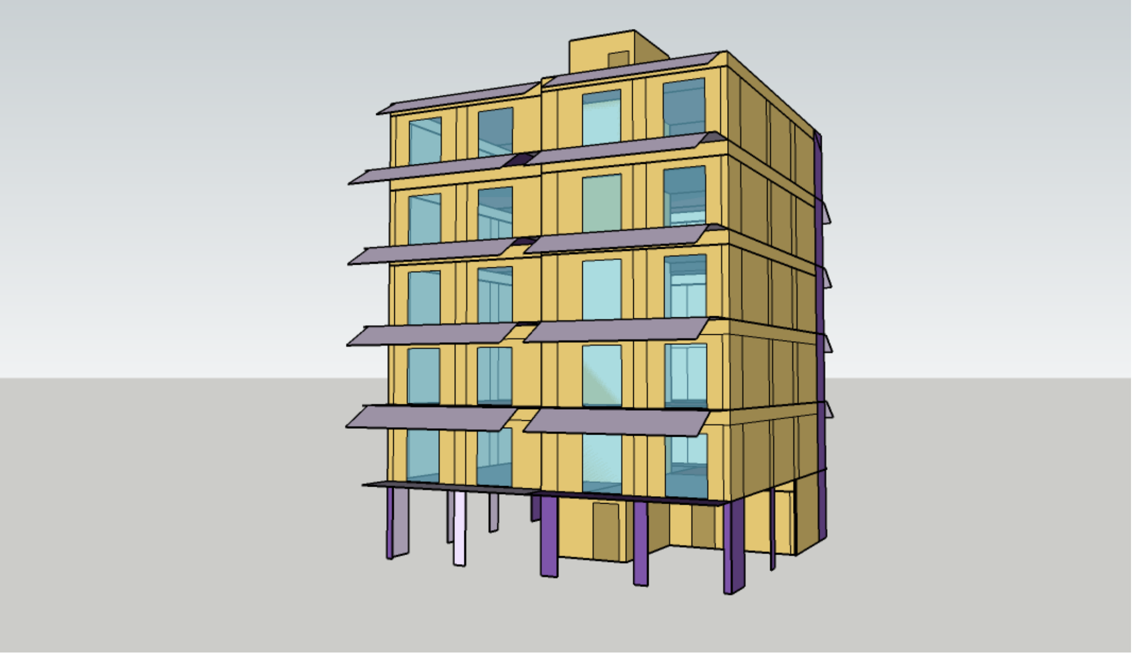
The graph 4.2.2.1 presents the fluctuation of the temperature of the domestic hot water throughout the year. It is noticed that the storage tank contains water at higher temperatures at summer months.



Graph 4.2.2.1: Domestic Hot Water Equipment Use

4.2.3 Upgraded building scenario

This scenario proposes even lower thermal conductivity coefficient (u-value) on the envelope of the building, by at least 0.05 W/m^2K. The transparent surfaces have energy efficient glazing with low-e coating. The heating system proposed for the climatic zone of the case study, the climatic zone C, is the heat pump, for space heating. Domestic Hot Water is proposed 75% to be heated by solar thermal, and 25% to be heated from the heat pump.



Picture 4.2.3.1: Energy Plus Model, South Facade

Picture 4.2.3.2: Energy Plus Model, North Facade

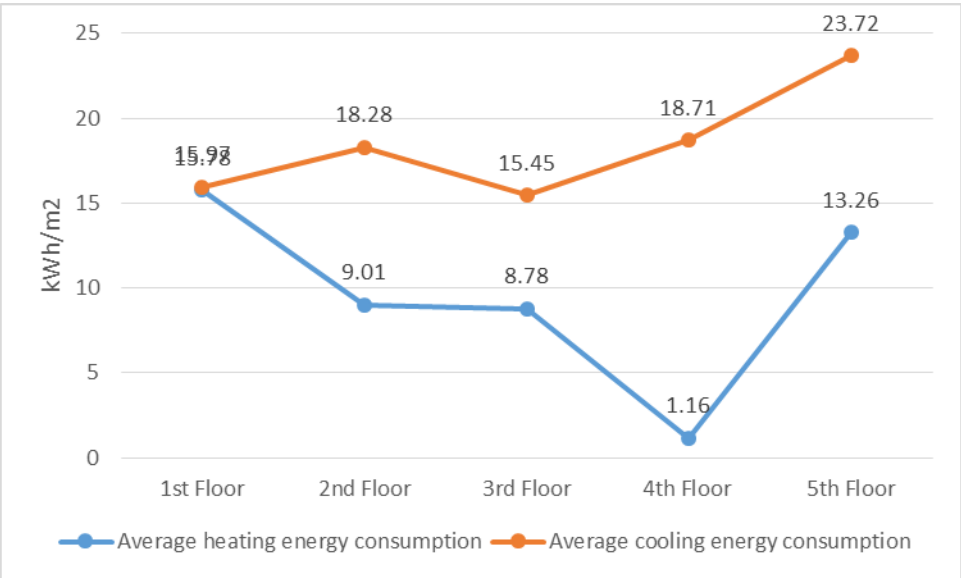
The simulation results are presented at the Tables below, and analytically at the Tables 64-70 at the Appendix.

Table 4.2.3.1: U-value factor of opaque envelope

	U-Factor with Film [W/m^2-K]	U-Factor no Film [W/m^2-K]
Exterior wall	0.289	0.303
Exterior column	0.318	0.334
Exterior beam	0.318	0.334
Interior ceiling	0.4	0.423
Interior floor	0.4	0.423
Floor to unheated space	0.306	0.325
Floor to the ground	0.313	0.33
Wall to unheated space	0.378	0.4
Ceiling over unheated space	0.4	0.423
Green Roof	0.286	0.298
Exterior door	5.008	20

Table 4.2.3.2: U-value factor of windows

	Glass U-Factor [W/m^2-K]	Frame Conductance [W/m^2-K]
Windows	1.683	2.000

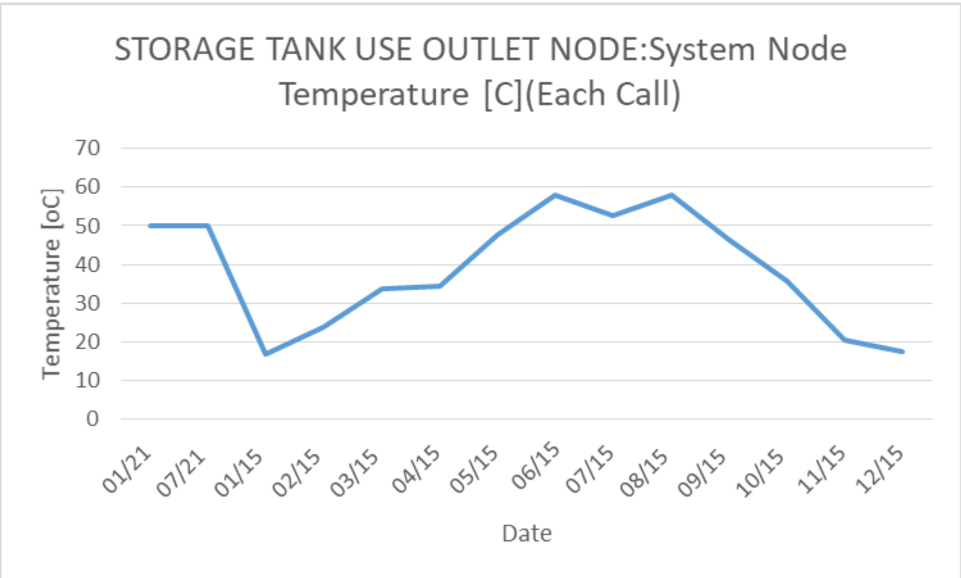


Graph 4.2.3.1: Average heating and cooling energy consumption per square meter.

By studying the simulation results of the Upgraded building scenario, it is noticed that the polykatoikia has the lowest heating energy consumption of all scenarios proposed, as expected. The apartments of the 1st Floor have annual heating energy consumption of 15.78Wh/m^2. The apartments of the 2nd Floor have annual heating energy consumption of 9.00kWh/m^2. The apartments of the 3rd Floor have the lowest annual heating energy consumption of 8.78kWh/m^2. The apartments of the 4th Floor have annual heating energy consumption of 9.16kWh/m^2. The apartments of the 5th Floor have annual heating energy consumption of 13.26kWh/m^2. At this scenario also, the 5th Floor has not the highest heating energy consumption because of the green roof. The 1st Floor has the highest heating energy consumption because of the Pilotis, even though the floor is insulated.

Concerning the cooling energy consumption, the apartments of the 1st Floor have 15.97kWh/m^2, the apartments of the 2nd Floor 18.28Wh/m^2, the apartments of the 3rd Floor 18.45kWh/m^2, the apartments of the 4th Floor 18.71kWh/m^2, and the apartments of the 5th Floor 23.72kWh/m^2. The differences at this scenario are also quite small, between the levels of the building. At this scenario also, the reason for the higher cooling needs at the 5th floor are the same as at the basic and the optimistic scenario. It happens due to air's density. The warm air is lighter, so it goes up and the cold air is heavier so it stays at the bottom. At summer months, the warm air goes up at the 5th level of the polykaytoikia, so the cooling needs at this floor are greater.

The graph 4.2.3.1 presents the fluctuation of the temperature of the domestic hot water throughout the year. It is noticed that the storage tank contains water at higher temperatures at summer months.



Graph 4.2.3.1: Domestic Hot Water Equipment Use

5 Results – Discussion

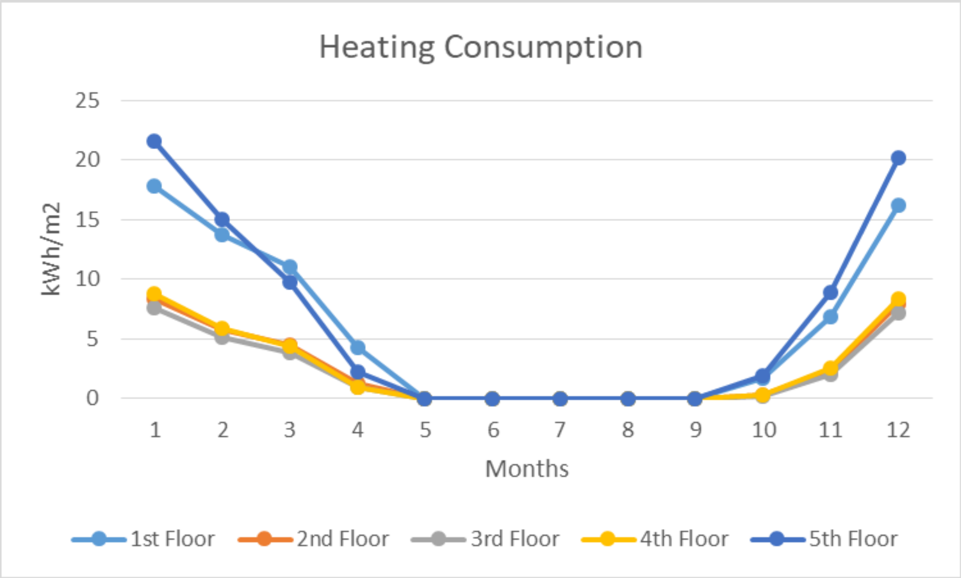
The findings of the case study concern the energy consumption of a typical polykatoikia constructed at the climatic zone C, at the decade of 1980. The results of the energy simulation of the case study will be further analyzed and the findings will be discussed and extrapolated to the other three climatic zones of Greece.

5.1 Analysis of the case study's results

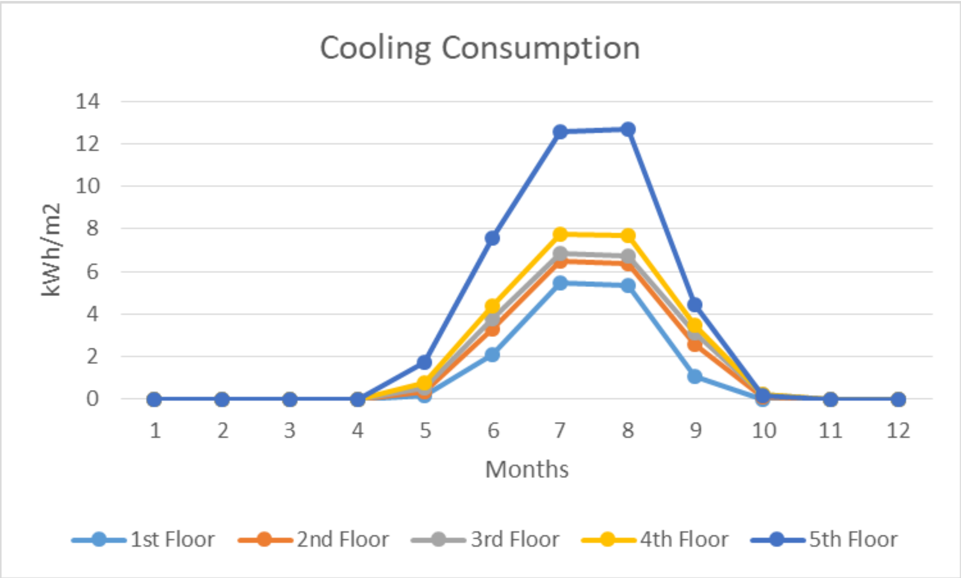
5.1.1 Reference building

The buildings constructed before the energy related regulation have high energy demand. The reference building has very high heating energy consumption at winter months, and high cooling energy consumption at summer months. It is also noticed very high difference on the primary energy consumption between the levels of polykatoikia. The first and the last floor have the highest energy consumption, and the third floor that is the medium floor has the lowest heating energy consumption. The apartments at the first floor have the lowest cooling energy consumption, and at the last floor the highest cooling energy consumption. The reason for this difference is the lack of insulation at the floor of the first level and the ceiling of the fifth level. The heat losses to the ambient are very high for these floors. The levels in between are surrounded by heated spaces, so their heat losses are lower.

The graphs below present the primary energy consumption of the five levels, where the residences of the polykatoikia are located, throughout the year.



Graph 5.1.1: Heating energy consumption per square meter.



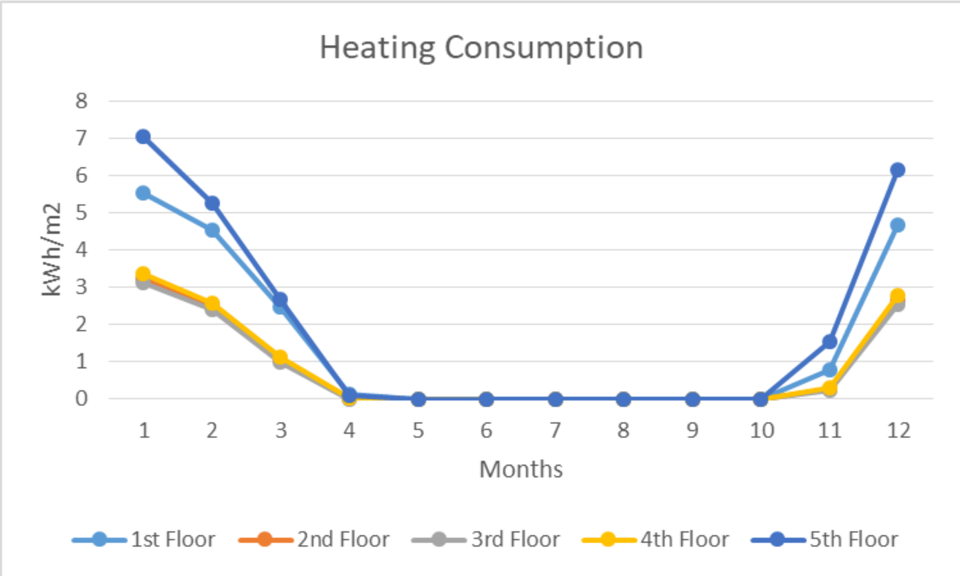
Graph 5.1.2: Cooling energy consumption per square meter.

5.1.2 Basic scenario

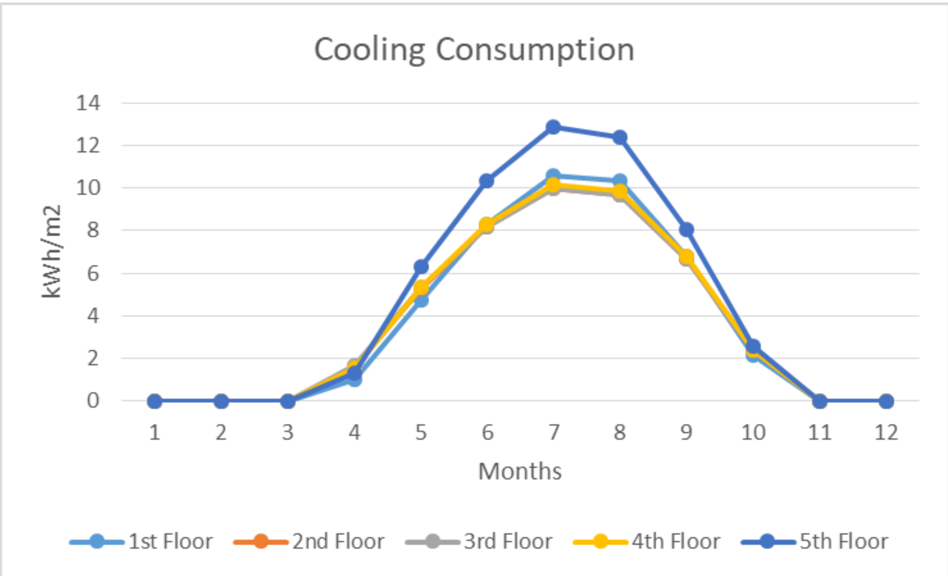
At the basic scenario, the energy savings of the polykatoikia in heating are quite obvious. At all levels, the primary energy consumption for heating is lower. Nevertheless, the difference at the energy consumption of the first and the fifth floor and the medium levels is still high. The external insulation at the first level floor and the fifth level ceiling succeed to eliminate the heat losses, but not at the desired levels.

In the contrary to what expected, the cooling needs are higher at the retrofitting scenario that the reference building. By implementing shading elements and thermal insulation on the buildings's envelope, the cooling load was increased instead of decreased.

The graphs below present the primary energy consumption of the five levels, where the residences of the polykatoikia are located, throughout the year.



Graph 5.1.3: Heating energy consumption per square meter.



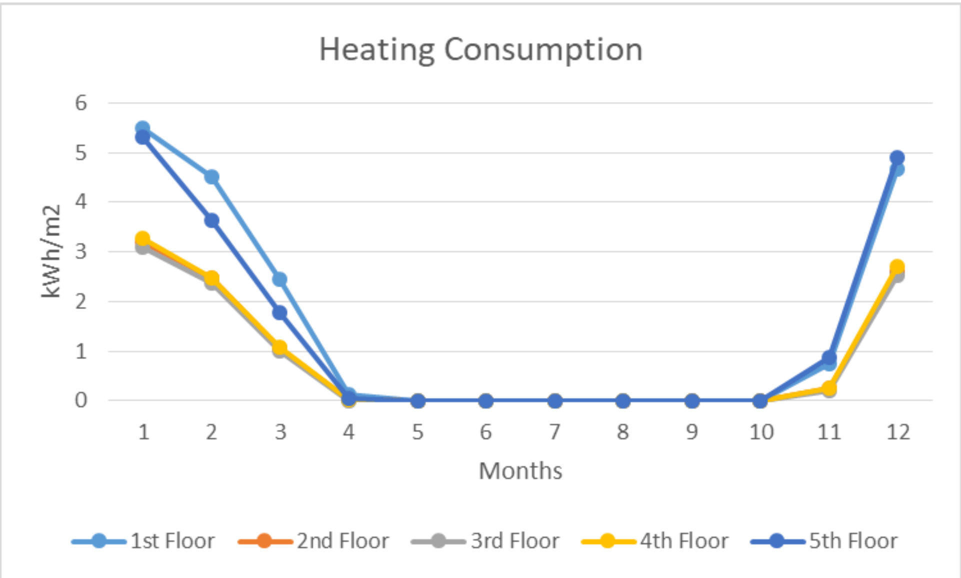
Graph 5.1.4: Cooling energy consumption per square meter.

5.1.3 Optimistic scenario

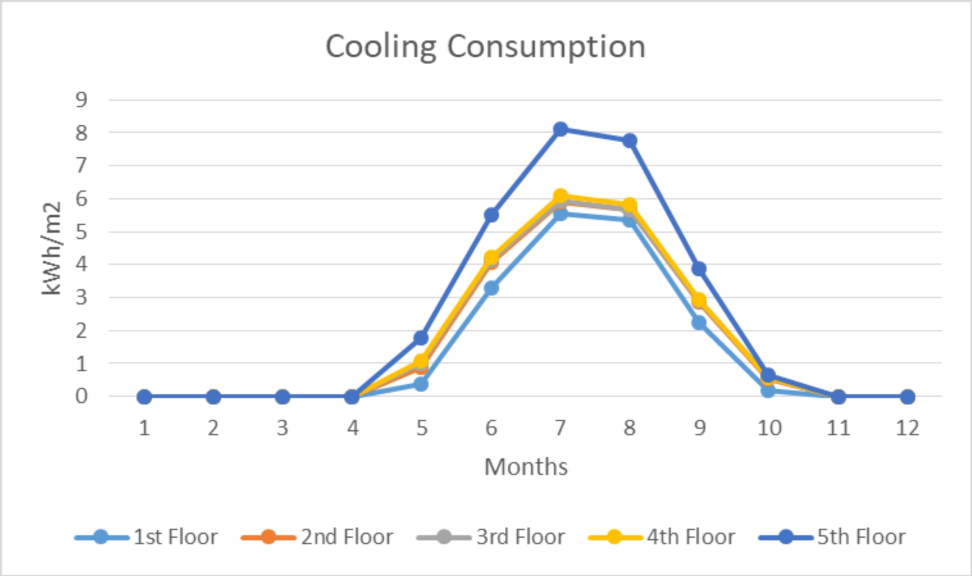
At optimistic scenario, all the retrofitting measures of the basic scenario were implemented, and also were implemented sustainable technologies. So, the energy consumption of the building is lower, as expected. The passive design implementation that was selected is the green roof. Also, the domestic hot water supply system was upgraded, by using solar flat plate collectors.

The combination of all these retrofitting measures had positive results on the building, especially on the fifth floor. At the reference building and the basic scenario, the fifth floor had the higher heat losses. But at the optimistic scenario, because of the implementation of the green roof, the high temperatures of the building were reduced during the day at summer months. It is also a very effective cooling technique. The cooling loads at this scenario were reduced in compare to the basic scenario, but still in general at the first, second and third floor are at the same level as the reference building. Nevertheless, the use of the cooling system at summer months would be very minimum for the apartments of the fifth floor.

The graphs below present the primary energy consumption of the five levels, where the residences of the polykatoikia are located, throughout the year.



Graph 5.1.5: Heating energy consumption per square meter.



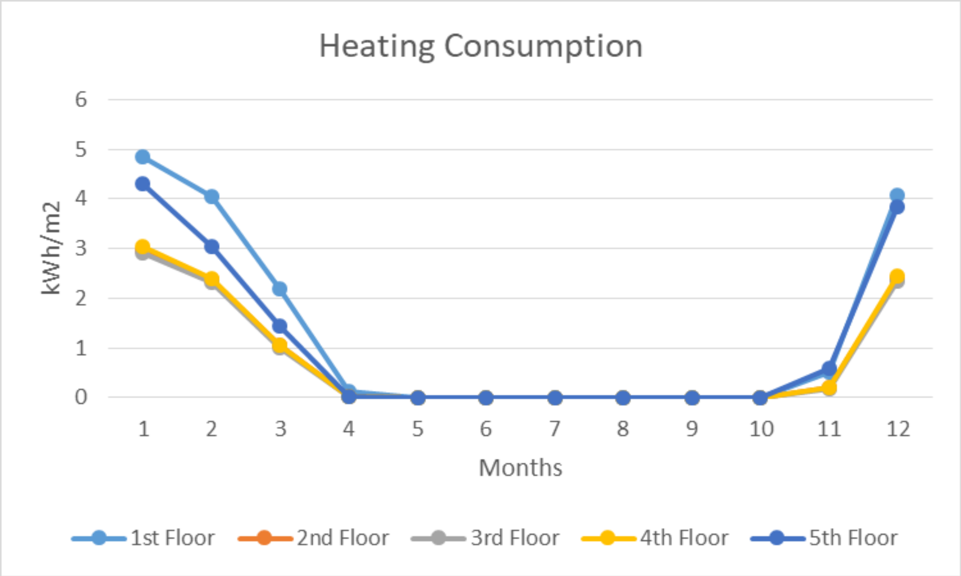
Graph 5.1.6: Cooling energy consumption per square meter.

5.1.4 Upgraded building scenario

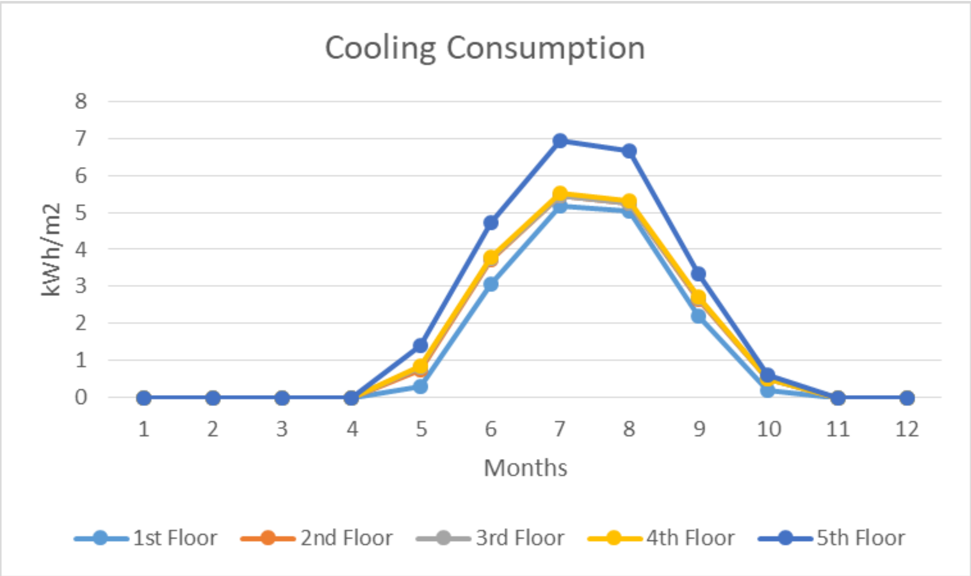
This scenario proposes the refurbished building to achieve even lower energy consumption levels than the energy related regulation suggests. Those energy saving levels were achieved with the upgrade of the heating system, the installation of windows with low-e coating, and the implementation of external thermal insulation of higher thickness.

The results of the simulation were satisfied, as the heat losses were eliminated. The energy consumption for heating and cooling is at the lower level in compare with all scenarios applied. The fifth floor has extremely low energy consumption in compare to the reference building. The third floor has at all scenarios proposed the lowest heating energy consumption level, and at this scenario the lowest of all. The cooling energy is also lowest in compare to the reference building and the previous retrofitting scenarios. Finally, the first floor has the highest heat losses at this scenario because of the pilotis, as expected.

The graphs below present the primary energy consumption of the five levels, where the residences of the polykatoikia are located, throughout the year.



Graph 5.1.7: Heating energy consumption per square meter.



Graph 5.1.8: Cooling energy consumption per square meter.

5.2 Extrapolation of the case study at the four climatic zones of Greece

Because of time limitation, the energy simulation analysis was implemented only for one climatic zone. However, a theoretical discussion about the implementation of the retrofitting scenarios to the other three climatic zones will be made, and can be the basis for future expansion.

The case study was implemented at climatic zone C, as said at previous chapters. The northern part of Greece belongs to climatic zones C and D, and these areas have colder winters. The climatic zones A and B cover the southwest part of Greece, where the winter months are milder.

The Graph 3.4.1.2 presents the primary energy consumption for the last decade, for the four climatic zones of Greece. By studying the graph, it is noticed that the climatic zone A contains the residential buildings with the lowest energy consumption, followed by climatic zone B. The climatic zone D contains the buildings with the highest energy consumption. Also, the Graphs 3.4.1.7, 3.4.1.8 and 3.4.1.9 present the average annual primary energy consumption of the building stock per climatic zone. By studying the graphs, it is noticed that climatic zone D contains the majority of uninsulated buildings in Greece.

So, if the refurbishment measures were applied on a polykatoikia located on climatic zone A, where the winters are mild and rainy, and the summers are hot, the scenario that would be recommended would be the basic scenario. This scenario would be recommended because these regions have mild winter, and there is no need for very low u-values on the envelope. The external insulation of the building, the shading elements and the replacement of the windows would cover the needs of the envelope. Also, because of the sunny summers, the solar flat plate collectors that are connected with the hot water supply system would be very useful.

If the refurbished building was located on climatic zone B, the proposed scenario would be the optimistic scenario. The decisive intervention of this scenario is the upgraded heating system, as the winters are not so mild as at the climatic zone A. Also, because of the sunny summers, the solar flat plate collectors that are connected with the hot water supply system would be very useful, and the green roof would be ideal for the heat losses during hot summers. It would restrain the rainwater as well. So the retrofitting measures of this scenario are suitable for this climatic zone.

At climatic zone C, where the case study was carried out, the scenario that would be selected would be the optimistic or the upgraded. The winters are cold and the summers are hot. So, both of these scenarios would be suitable. An important parameter that would induce the selection, is the height of the region. Climatic zones C and D are characterized by differences due to high latitude and the morphology of the ground. So, at high latitudes would be preferred the upgraded building scenario, and at lower latitudes would be recommended the optimistic scenario.

Finally, at climatic zone D, the scenario that would be selected would be the upgraded building scenario. The winters are cold and rainy, with a lot of humidity at these areas, and the summers are not very hot. The upgraded envelope and heating system of this scenario would be suitable for these climatic conditions.

5.2.1 Extrapolation of the case study at climatic zone C

The parts of Greece that belong to climatic zone C have cold winters and hot summers. Most of the northern part of Greece and a part of central Greece belong to this climatic zone. Also, according to Table 2.1.1, more than 32% of the residential building stock of Greece belongs to climatic zone C.

Regarding the residential building stock, according to Graph 3.4.3, 40.40% of the residential building stock was constructed at the decade 1971-1980, and 23.00% was constructed at the decade 1981-1990. These percentages indicate that over 60.00% of the residential building stock is built before the energy regulation. So, the majority of the building stock has on average the same typological and structural characteristics as the polykatoikia of the case study.

According to Table 2.1.1, the climatic zone C has over 800,000 residential buildings (until 2011). Also, according to Graph 3.4.1.1, the majority of the EPCs at climatic zone C indicate energy categories G, E and D. So, if we consider that 60.00% of the residential buildings of climatic zone C need to be refurbished, there are about 480,000 buildings at this climatic zone that could be fund by Eksikonomisi kat' Oikon Program.

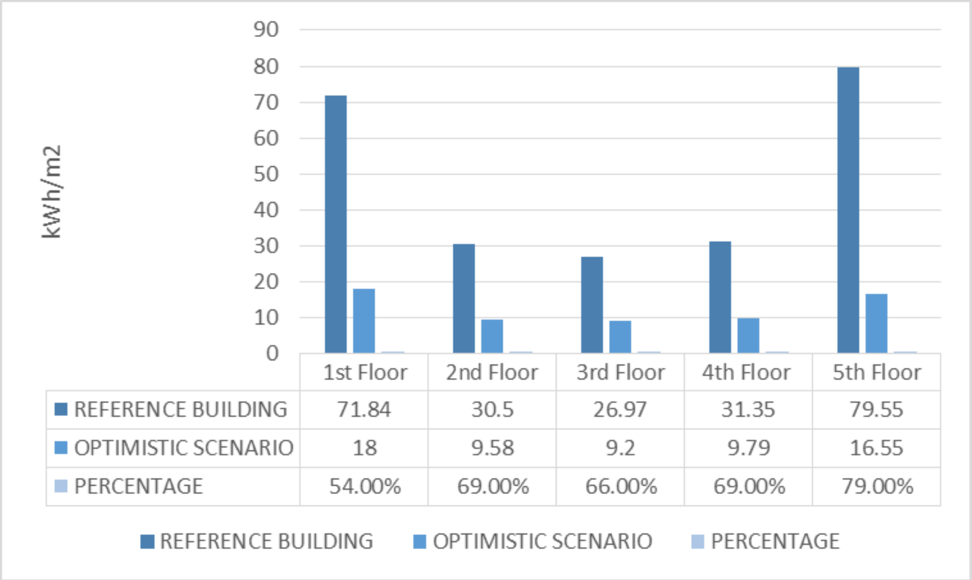
The average annual primary energy consumption for polykatoikies at climatic zone C is 332.36kWh/m^2 (Graph 3.4.1.6). Therefore, the energy consumption of the buildings is characterized by huge fluctuations. For instance, the highest consumption is noticed at energy category G, at the value of 546.32kWh/m^2, followed by energy category F, at the value of 327.90kWh/m^2 (Graph 3.4.1.9). The lowest energy consumption is noticed at energy category A+, at the value of 36.07 kWh/m^2, followed by energy category A, at the value of 40.50 kWh/m^2 (Graph 3.4.1.9). It is also important to mention, that according to Graph 3.13, the buildings of the regions of climatic zone C could have energy savings of 47% after the refurbishment.

In case of energy refurbishment, the average cost of interventions per primary energy savings is 116.44€/kWh (Table 3.4.2.2.1). According to Table 3.4.2.1.4, the average cost of interventions per square meter (m^2) of residence is 137.20€/m^2 for residences of 50-75m^2, and 117.00€/m^2 for residences of 75-100m^2. Finally, the average cost of intervention per m^2 per region is 115.75€/m^2, for climatic zone C (Table 3.4.2.1.5).

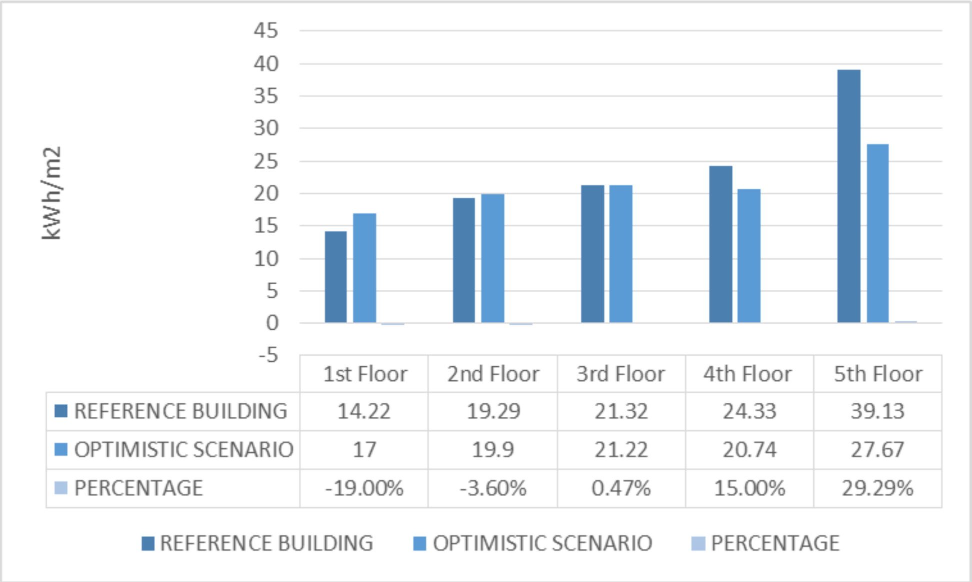
The initial cost of interventions for polykatoikies was estimated at 26,789€ (Table 3.4.2.1.1). Eksikonomisi kat' Oikon Program distributed over 300 million€ at climatic zone C (Table 3.12).

So, if all 480,000 buildings of climatic zone C could be refurbished with the optimistic scenario, the energy savings for heating would be over 60% (Graph 5.2.1.1), and for cooling would be around to 2.50% (Graph 5.2.1.2). If the polykatoikies were refurbished with the upgraded building scenario, the energy savings for heating would be over 70% (Graph 5.2.1.3), and for cooling would be over 16.60% (Graph 5.2.1.4).

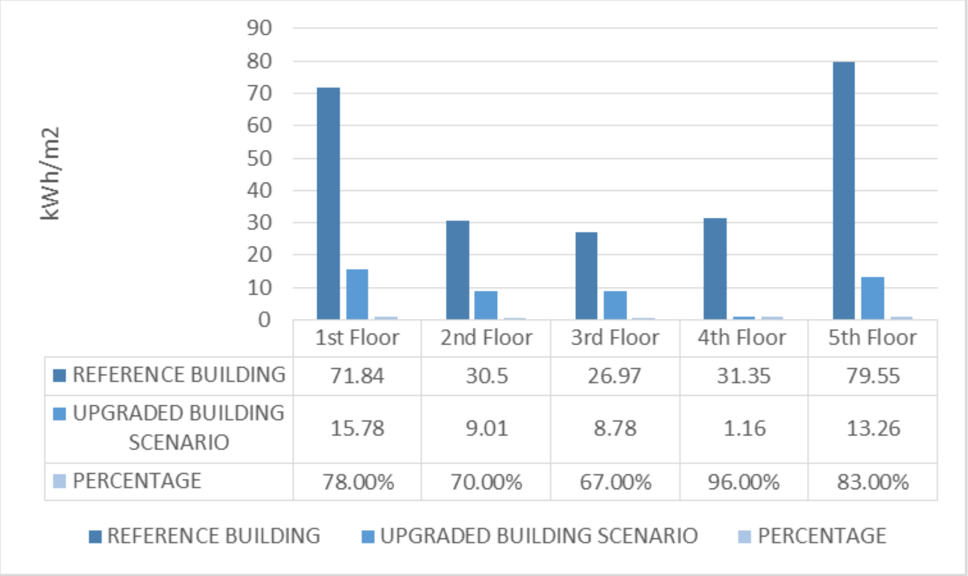
But if we do the calculations, we will notice that the funds needed are more than the resources of the repository of Eksikonomisi kat' Oikon Program. So, the program is not able to fund the retrofitting of all the residences at once.



Graph 5.2.1.1: Comparison of the reference building with the optimistic scenario_ Average annual heating energy consumption before and after the refurbishment

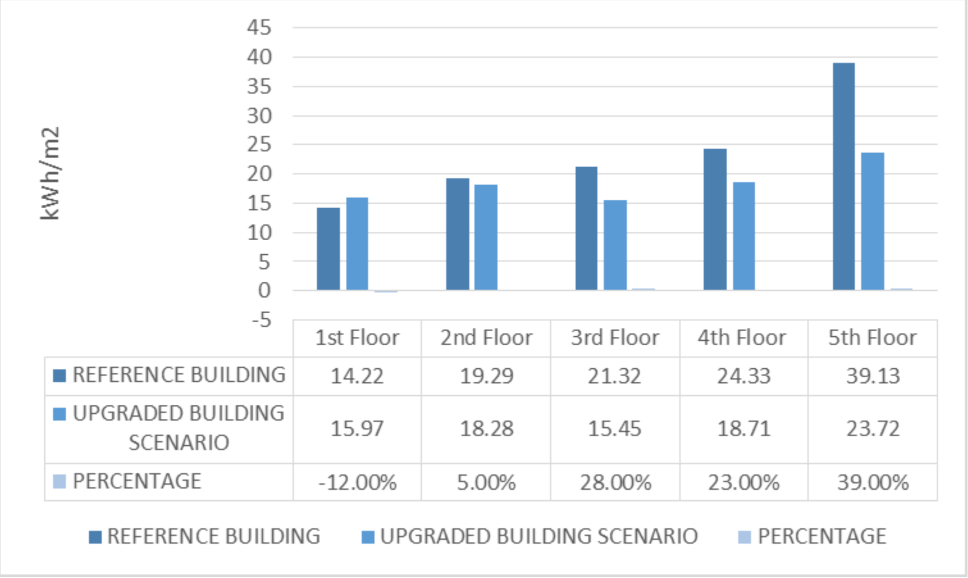


Graph 5.2.1.2: Comparison of the reference building with the optimistic scenario_ Average annual cooling energy consumption before and after the refurbishment



	1st Floor	2nd Floor	3rd Floor	4th Floor	5th Floor
REFERENCE BUILDING	71.84	30.5	26.97	31.35	79.55
UPGRADED BUILDING SCENARIO	15.78	9.01	8.78	1.16	13.26
PERCENTAGE	78.00%	70.00%	67.00%	96.00%	83.00%

Graph 5.2.1.3: Comparison of the reference building with the upgraded building scenario_ Average annual heating energy consumption before and after the refurbishment



	1st Floor	2nd Floor	3rd Floor	4th Floor	5th Floor
REFERENCE BUILDING	14.22	19.29	21.32	24.33	39.13
UPGRADED BUILDING SCENARIO	15.97	18.28	15.45	18.71	23.72
PERCENTAGE	-12.00%	5.00%	28.00%	23.00%	39.00%

Graph 5.2.1.4: Comparison of the reference building with the upgraded building scenario_ Average annual cooling energy consumption before and after the refurbishment

6 Economic Analysis of Retrofit

Introduction to the Economic Analysis Method

The economic analysis method of retrofitting measures assesses the investment payback period for each energy-saving scenario. The shorter the payback period, the most cost effective the scenario implemented. The methodology and the economic criteria are presented at the next paragraphs. Unfortunately, due to time limitations it hasn't been further developed.

6.1 Net Present Value (NPV)

"The Net Present Value (NPV) is the sum of the present values of all cash flows from the project (including initial investment)". [PSYCHOGIOS, 2019] More specifically, "it is the difference between the present value of the cash inflows and the present value of cash outflows over a period of time". [42] The Net Present Value is usually used to analyze if the investment is profitable.

To understand the NPV, we should consider that there is a difference in the worth of money in the present and in the future. An amount of money in the present worth more than the same amount of money in the future. The reason for this difference is the inflation and the possible earnings of different investments during the investment period. The discount rate in the formula accounts for these differences. [42]

The formula of calculation is the following:

NPV = $\sum_{t=0}^{n} \frac{CF_t}{(1+R)^2}$

When t=0

Where:

C_t = net cash flow during t years

C_o = total initial investment cost

r = discount rate and

t = number years

The initial cost CF_0 is an outflow.

NPV = $\sum_{t=1}^{n} \frac{CF_t}{(1+R)^2} - CF_0$

The acceptance of the investment is decided by a decision rule:

NPV > 0, accept the investment

NPV < 0, do not accept the investment

NPV = 0, viable investment with average internal rate of return equal to r

The NPV is used to “find today’s value of a future stream of payments”. [42] So, if the NPV is positive, the investment is accepted, as the earnings exceed the anticipated costs. It is assumed that the investment will be profitable, unlike an investment with a negative NPV, that is considered an investment with net loss. The highest the NPV, the more viable the investment. Also, the NPV formula could be used to compare similar projects or a project’s alternatives. [42]

It is important to mention that this method is based on estimates and assumptions, so the results could be inaccurate.

6.2 Internal Rate of Return (IRR)

“The Internal Rate of Return (IRR) is the discount rate that sets the net present value equal to zero. It is the percentage rate of return, based upon incremental time-weighted cash flows”. [PSYCHOGIOS, 2019] It estimates the profitability of investments. The calculation relies on the same formula as NPV does. [43]

$NPV_{r=IRR}=0$

The decision rule for IRR acceptance is:

IRR>r, acceptable investment

IRR<r, not acceptable investment.

The higher the IRR, the more desirable the investment. IRR is widely used as it is based entirely on the cash flows and it is completely independent of interest rates. Therefore, it is usually considered “inferior to NPV”, because it makes too many assumptions about “reinvestment risk and capital allocation”. [42] It could be misleading if used alone. [43] Finally, this method is usually used to compare investments or projects with different lifespans or amount of required capital. [42]

6.3 Payback Period (PBP)

“The Payback Period (PBP) is an indicator of the time needed to recover the initial cost of a project”. [PSYCHOGIOS, 2019] However, the Payback Period doesn’t take into consideration the value of money over time. For this reason, the payback period that is calculated for a long investment has higher possibility to be inaccurate. [42]

The payback period refers to the amount of time needed to recover the cost of the initial investment. The shorter the payback period, the more attractive the investment. The longer the payback period, the less desirable the investment. It is an easy and quick method to value investments. To calculate the payback period, we divide the investment cost by the annual cash flow.

The decision rule for the acceptance of the Payback Period is to be less than some preset limit.

It is also important to mention that the payback period is limited to the period of time needed to recover the initial cost of the investment, and it does not take into consideration a discount rate or possible future investments. So, it is not usually used for long-term investments, of for alternative investments. [42]

The formula given below is for the calculation of PBP:

$$PBP = C/R$$

Where:

C: the investment cost,

R: yearly cost savings after the investment.

In our case study, the investment cost (C) would be the cost of refurbishment measures, and the annual cash flows (R) would be the annual energy cost savings after the refurbishment.

6.4 Comparison of retrofitting proposals

The method chosen for the economic analysis of the three scenarios is the Payback Period. Using this method, it will be calculated the period of time needed to recover the cost of the initial investment. The part of the initial investment that is covered by the Eksikonomisi kat; Oikon

Program is removed from the cash flows, so it is not taken into consideration for the calculation of the payback period.

The Tables below present the cost of interventions for the whole polykatoikia, for the three different scenarios proposed at the case study.

Table 6.4.1: Cost of interventions for the Basic Scenario

Costs of various interventions	Initial investment (€/m²)	Initial investment (€)	Overall investment (€)
ETICS	45		37,573.20
Roof	45		8,010.00
Pilotis	45		8,010.00
Windows	220		29,040.00
Shading Systems	25		3,500.00
Heating System		5,000 x 10	50,000.00
Cooling system: Split unit A/C (inverter A++)		330 x 10	3,300
DHW: Solar Thermal		300 x 100	3,000
TOTAL COST			142,433.20

Table 6.4.2: Cost of interventions for the Optimistic Scenario

Costs of various interventions	Initial investment (€/m²)	Initial investment (€)	Overall investment (€)
ETICS	45		37,573.20
Roof	45		8,010.00
Pilotis	45		8,010.00
Windows	220		229,040.00
Shading Systems	25		3,500.00
Heating System		5,000 x 10	50,000.00
Cooling system: Split unit A/C (inverter A++)		330 x 10	3,300
DHW: Solar Thermal + storage tank		300 x 10 12,000	15,000.00
Green Roof	45		8,010.00
TOTAL COST			162,443.20

Table 6.4.3: Cost of interventions for the Upgraded Building Scenario

Costs of various interventions	Initial investment (€/m^2)	Initial investment (€)	Overall investment (€)
ETICS	55		45,922.80
Roof	55		9,790.00
Pilotis	55		9,790.00
Windows	300		39,600.00
Shading Systems	35		4,900.00
Heating System		6,000 x 10	60,000.00
Cooling system: Split unit A/C (in-verter A++)		450 x 10	4,500
DHW: Solar Ther-mal + storage tank		300 x 10 12,000	15,000.00
Green Roof	45		8,010.00
TOTAL COST			197,512.80

The Tables that follow present the Payback Period calculated for the three scenarios. The annual energy costs reduction is calculated based on the energy savings of each scenario, and the price of fuels in Greece for this time of period.

Table 6.4.4: Payback Period for the Basic Scenario

Overall investment cost (€)	142,433.20€
Eksikonomisi kat' Oikon Funding	35%/ 30%
Annual energy costs reduction (€)	37,702.11€
Pay-back period (years)	2.46/ 2.64

Table 6.4.5: Payback Period for the Optimistic Scenario

Overall investment cost (€)	162,443.20€
Eksikonomisi kat' Oikon Funding	35%/ 30%
Annual energy costs reduction (€)	40,359.44€
Pay-back period (years)	2.62/ 2.82

Table 6.4.6: Payback Period for the Upgraded Building Scenario

Overall investment cost (€)	197,512.80€
Eksikonomisi kat' Oikon Funding	35%/ 30%
Annual energy costs reduction (€)	42,068.53€
Pay-back period (years)	3.05/ 3.29

By studying the results, it is noticed that the Basic Scenario has the shorter payback period, and the Upgraded Building Scenario has the longest payback period. Nevertheless, the differences at the payback periods are quite small. The reason for payback periods being so short, is mainly the upgrade of the heating systems, but also the different price of fuels that the systems use. For instance, the price of oil in Greece is double the price of natural gas. The difference on the price, the system's energy efficiency and the reduction of losses of the envelope explain the short payback period of the proposed retrofitting scenarios.

Moreover, the upgraded building scenario, that has the higher energy savings of the three scenarios, has also the longer payback period. It presents the higher annual energy reduction costs, but it also has the highest overall investment cost.

Finally, it is important to mention that the funding of the program was considered on average 35%/ 30% for all scenarios, as it refers to the retrofitting of the same building. Those percentages were used as the majority of citizens that choose Eksikonomisi kat' Oikon Program to refurbish their residence, belong to categories 4 and 5 of the beneficiaries. (Table 3.1.1)

7 Conclusions

In this thesis, it is described the existing residential building stock of Europe, and the funding schemes available which fund the energy refurbishment of those buildings. The Greek Polykatoikia was chosen to be examined in detail, as well as the Greek funding program Eksikonomisi kat' Oikon. A case study was carried out, examining a Greek Polykatoikia in climatic zone C of Greece, and three retrofitting scenarios were proposed. The scenarios proposed were compared according to their energy savings and their payback period.

The European building stock is at its majority aged, uninsulated and so, energy inefficient, as it was built before EU energy regulations. Buildings are responsible for 40% of final energy consumption. Most of the European buildings will remain in use by 2050, so the need for energy refurbishment is crusial. To achieve EU 2050 energy targets, 97% of the residential building stock in Europe needs to be refurbished. At this point, less than 3% of the buildings qualify an EPC of A-label. According to BPIE, 75% of the European building stock can be upgraded and be 'energy efficient'. It is a fact that European cities are responsible for about 70% of the overall primary energy consumption. European Union policy initiatives aim to fund public and private energy efficient projects, and also contribute to the reduction of energy poverty. Therefore, the amount of EU funds available is not enough for all these expectations, so the contribution of the private sector is necessary. The private sector finances the majority of energy efficiency projects in European buildings.

For Greece, the launch of Eksikonomisi kat' Oikon Program is an innovative initiative. The program is co-financed by the European Regional Development Fund, from the National Financial Resources and Environment and Sustainability of ESPA 2007-2013, and ESPA 2014-2020. It financed the energy refurbishment of over 60,000 residences with a total budget of 396 million€ at the first stage, and 778.01 million€ at the second stage of the program. The program also covers the cost of the inspection, before and after the retrofitting. It is important to mention that the most vulnerable financially citizens were benefited the most, as the criteria of election for the funding are mainly financial. The energy category of the building is also an important criteria for the election of the beneficiaries, as well as the location of the building. Eksikonomisi kat' Oikon Program is still facing some issues, mainly at the election part, and at the distribution of the funding at the beneficiaries. Nevertheless, many owners were benefited by the program and refurbished their residence.

Eksikonomisi kat' Oikon II Program has no significant differences to Eksikonomisi kat' Oikon I Program. The differences concern at most the budget of the program and the economic situation of the applicants, but they do not concern the energy performance of the existing building stock. Social aspects should be considered, as well as the elimination of fuel poverty. The intervention proposed aim to reduce the energy consumption of the residential buildings, and improve the thermal comfort of the residents. The residential building stock of Greece is enlisted at its majority to the lower energy categories. The retrofitting of the buildings could contribute, to a very large extend, to the upgrade of the energy categories of the existing buildings and the increase of the energy savings. The energy refurbishment would also consist to meet the energy targets, set by the energy regulations. The program aims to contribute to reach the energy and environmental targets, and also achieve energy savings up to 1 billion kWh/year. Also, it contributes to enrich public awareness related to environmental issues, and improve the living conditions of the residential building stock. Finally, it contributed to the creation of more than 2,500 jobs (engineers, energy inspectors, bank accountants etc.).

The energy simulation of a typical polykatoikia at the case study presented high energy consumption at the reference building, but also high percentages of energy savings at the proposed scenarios. The three scenarios proposed presented different results, but all scenarios improved at a significant degree the energy performance of the polykatoikia. The heating energy consumption presents the higher possibility for improvement, followed by the cooling energy consumption. It is also important to mention that the implementation of those scenarios at buildings which belong to lower energy categories would present higher energy savings. The age, the location and the construction of the building are significant parameters that affect its energy performance.

More specifically for the results of the case study, at climatic zone C, by studying the optimistic scenario the energy savings for heating would be over 60%, and for cooling would be around to 2.50%. Respectively, by studying the upgraded building scenario, the energy savings for heating would be over 70%, and for cooling would be over 16.60%. Those percentages are promising, but the cost for the implementation of these scenarios is not cost affordable for all the existing buildings at this climatic zone at once. The available funds of the program can not cover the demand. A viable solution could possibly be for the program to be co-financed by the private sector.

Regarding the recovery of the cost of the investment, the payback periods calculated are shorter than 10 years, so the investments are profitable.

The energy refurbishment of the existing residential building stock reduces the energy consumption, improves the thermal comfort and also has a short payback period. People spend most of their time inside the buildings, so indoor thermal comfort is a significant factor that affects their everyday life. Buildings are responsible for 40% of final energy consumption, but they present large potential for energy savings. The energy packages set high standards so as all European countries to meet the climate and energy targets. The retrofitting of the building stock will upgrade the energy categories and improve the energy performance of the buildings. Retrofitting all polykatoikies at once is not essential. Therefore, Eksikonomisi kat' Oikon Program can contribute significantly to the energy refurbishment of the residential building stock in the near future.

To conclude, the program should be continued and evolved at the years to come. It could implement more interventions and change the eligibility of the beneficiaries from the owner's financial statement to the building's needs, based on the energy performance and the location of each building. The implementation of this funding program in Greece is an innovative initiative that can assist to eliminate the climate change and energy poverty.

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Appendix

List of Tables

Table 1: Buildings by type of building, year of construction and type of ownership in Austria

Topics	Buildings	of which			
		Residential buildings	of which		Other buildings[1]
			with one or two conventional dwellings	with three or more conventional dwellings	
Total	2,191,280	1,973,979	1,727,129	246,850	217,301
	Year of construction (in %)				
Before 1919	14.9	14.4	13.4	21.2	19.9
1919 to 1944	7.6	7.7	7.4	9.8	6.4
1945 to 1970	24.0	24.2	24.1	24.6	22.8
1971 to 1990	28.8	28.8	29.8	21.2	28.8
1991 or later	24.7	25.0	25.2	23.2	22.1
	Type of ownership (in %)				
Private person(s)	88.7	92.1	96.6	60.7	58.3
Public bodies	4.0	2.5	1.1	11.9	17.5
Limited profit housing associations	3.3	3.6	1.2	20.0	0.5
Other legal entities	4.0	1.8	1.0	7.4	23.6

Source: STATISTICS AUSTRIA, Register-based Census 2011.

[1]Other buildings include residences for communities and buildings designed for commercial, industrial or cultural purposes or for the provision of services.

Table 2: Number of residential buildings and square meters useful floor area in Austria

Construction period		Single Family Houses (SFH)	Terrassed and Multi-Family Houses* (TRH & MFH)	Apartment Blocks (AB)
Until 1918	Number of res.-bui.	171,291	34,790	15,203
	square meters	24,775,075	14,003,842	16,947,540
1919 to 1944	Number of res.-bui.	97,794	18,033	5,020
	square meters	11,920,467	6,069,886	4,326,033
1945 to 1960	Number of res.-bui.	158,417	19,763	7,771
	square meters	20,047,041	7,049,862	7,367,726
1961 to 1980	Number of res.-bui.	419,848	37,356	21,732
	square meters	59,755,244	14,943,948	28,868,193
1981 to 1990	Number of res.-bui.	224,692	17,845	6,114
	square meters	32,463,527	7,879,064	8,410,398
1991** to 2000**	Number of res.-bui.	170,966	18,446	4,510
	square meters	24,491,315	8,159,392	5,185,161
2001 to 2010	Number of res.-bui.	179,083	19,137	5,038
	square meters	27,605,363	8,384,987	6,178,288
2011 to 2013	Number of res.-bui.	25,714	2,873	1,345
	square meters	4,262,240	1,343,948	1,707,848
Missing**	Number of res.-bui.	36,371	3,354	2,144
	square meters	4,335,113	1,563,331	3,346,185
Subtotal	Number of res.-bui.	1,483,812	171,597	68,877
	square meters	209,655,385	69,398,260	82,337,372
Total	Number of res.-bui.	1,724,286		
	square meters	361,391,017		

Source: Statistik Austria 2014

* In the statistical data the terraced houses are included in the category multi-family houses.

** Due to a gap in the data collection the construction period 1991-2000 is slightly under-recorded. These cases are included in the construction period "missing".

Last updated: 15.03.2016

Table 3: Percentage of Thermally Refurbished Envelope Areas

Renovations rates between 2000–2010 in Austria

% of total stock of dwellings per year	Rehabilitation of windows in major parts of the building	Rehabilitation of facades including thermal insulation	Change of boilers	Insulation of the upper ceiling	Combination of three out of four renovation activities
Residential buildings	2.4 %	1.8 %	1.8 %	1.5 %	0.9 %

Source: Environment Agency Austria 2013

Last updated: 15.03.2016

Table 4: Number of dwellings in Bosnia and Herzegovina

Construction	SFH	TH	MFH	AB	Sum	Fraction
Year class	**Number of dwellings (1000)**					
Before 1945	12.1	1.6	5.5	0.1	19.3	1.19%
1946 to 1960	30.6	2.2	37.6	17.2	87.6	5.41%
1961 to 1970	110.4	10.5	68.2	51.3	240.4	14.84%
1971 to 1980	244.5	14.9	73.2	105.0	437.6	27.03%
1981 to 1991	306.9	8.9	14.0	40.5	370.3	22.87%
1992 to 2014	323.6	10.2	72.0	58.3	464.1	28.66%
Sum	1,028.1	48.3	270.5	272.4	1,619.3	100.00%
Fraction	63.49%	2.98%	16.71%	16.82%	100.00%	

Source: Survey carried out by Ipsos Strategic Marketing in cooperation with Faculty of Architecture and Faculty of Mechanical Engineering - University of Sarajevo and Faculty of Architecture, Civil Engineering and Geodesy and Faculty of Mechanical Engineering - University of Sarajevo as well as independent experts for the TABULA projecta data base of a representative survey of Bosnia and Herzegovina residential building stock (2015), pondered in relevance to the official statistical data from Statistical Office of the Republic of Bosnia and Herzegovina. Results published in form of internal report, 2016.

Last updated: 14.02.2017

Table 5: Aggregation for Building Stock Model in Bosnia and Herzegovina

		Construction period	Number of buildings	Number of apartments	Living space
			1000	1000	Million m²
"Single Family Houses" (<=3 apartments)	**SFH I**	**Before 1970**	134.8	167.4	10.53
	SFH II	**1971 to 1980**	203.3	259.4	21.6
	SFH III	**1981 to 1991**	242	315.8	30.38
	SFH IV	**1992 to 2014**	261.5	333.8	32.96
"Multi Family Houses" (>=4 apartments)	**MFH I**	**Before 1970**	10.4	179.9	8.57
	MFH II	**1971 to 1980**	4.4	178.2	10.77
	MFH III	**1981 to 1991**	2.1	54.5	3.44
	MFH IV	**1992 to 2014**	4.4	130.3	6.76
Sum			862.9	1,679.3	125.89

Source: Survey carried out by Ipsos Strategic Marketing in cooperation with Faculty of Architecture and Faculty of Mechanical Engineering - University of Sarajevo and Faculty of Architecture, Civil Engineering and Geodesy and Faculty of Mechanical Engineering - University of Sarajevo as well as independent experts for the TABULA project a data base of a representative survey of Bosnia and Herzegovina residential building stock (2015), pondered in relevance to the official statistical data from Statistical Office of the Republic of Bosnia and Herzegovina. Results published in form of internal report, 2016.

Last updated: 14.02.2017

Table 6: Insulation thickness – Walls in Bosnia and Herzegovina

	Year class				
Insulation in exterior walls (%)	**Before 1970**	**1971-1980**	**1981-1991**	**1992-2014**	**Total**
Yes	16.26	21.78	26.78	41.46	28.07
No	82.74	78.22	73.22	58.5	71.9
Unknown	0.15			0.04	0.03
Insulation thickness (%)	**Before 1970**	**1971-1980**	**1981-1991**	**1992-2014**	**Total**
< 5 cm	52.27	61.97	64.16	57.62	59.32
5 cm	9.88	22.75	28.01	31.59	27.16
6-10 cm	3.81	6.14	5.68	6.62	6.22
Unknown	29.04	2.15	2.15	4.17	7.3
	average wall insulation thickness 7 cm				

Source: Survey carried out by Ipsos Strategic Marketing in cooperation with Faculty of Architecture and Faculty of Mechanical Engineering - University of Sarajevo and Faculty of Architecture, Civil Engineering and Geodesy and Faculty of Mechanical Engineering - University of Sarajevo as well as independent experts for the TABULA projecta data base of a representative survey of Bosnia and Herzegovina residential building stock (2015), pondered in relevance to the official statistical data from Statistical Office of the Republic of Bosnia and Herzegovina. Results published in form of internal report, 2016.

Last updated: 14.02.2017

Table 7: Frequency of Building Types of the National Building Stock in Belgium

Frequencies of 6 aggregated, representative dwelling types in Belgian stock for the year 2006

		Building period	**Number of housing units**
Single Family Houses	**SFH I**	Until 1970	2,126,913
	SFH II	1970 to 1990	810,024
	SFH III	1991 to 2006	392,813
Multi Family Houses	**MFH I**	Until 1970	656,743
	MFH II	1970 to 1990	319,895
	MFH III	1991 to 2006	216,397
Total			4,552,784

Source: TABULA Project

Table 8: Cadastral statistics of the buildings, Belgium and regions, built-up area, 2018

		Houses in closed buildings	Houses in semi-open buildings	Houses in open buildings, hooves and castles
Number of buildings with built-up area of less than 45 m²	**Flemish region**	25,659	4,151	1,431
	Brussels Capital Region	5,332	506	33
	Walloon Region	30,166	10,193	1,638
Number of buildings with built-up area from 45 m² to 64 m²	**Flemish region**	121,607	21,875	3,278
	Brussels Capital Region	30,168	4,161	91
	Walloon Region	102,501	48,602	6,263
Number of buildings with built-up floor space from 65 m² to 104 m²	**Flemish region**	337,810	211,838	66,109
	Brussels Capital Region	54,779	7,492	942
	Walloon Region	190,335	142,577	97,232
Number of buildings with built-up land area larger than 104 m²	**Flemish region**	165,345	344,914	825,019
	Brussels Capital Region	16,322	3,382	4,727
	Walloon Region	95,589	166,919	400,878

Source: Statbel (Directorate-General Statistics - Statistics Belgium)

Table 9: Cadastral statistics of the buildings park, Belgium and regions, buildings and housing, 2018

		Houses in closed buildings	Houses in semi-open buildings	Houses in open buildings, hooves and castles	Buildings and apartment buildings with apartments
Number of buildings	**Flemish region**	650,421	582,778	895,837	127,983
	Brussels Capital Region	106,601	15,541	5,793	35,608
	Walloon Region	418,591	368,291	506,011	40,344
Number of buildings erected after 1981	**Flemish region**	80,399	164,113	391,373	53,881
	Brussels Capital Region	3,687	1,728	904	3,916
	Walloon Region	21,850	41,515	187,660	12,419
Number of housing units	**Flemish region**	695,272	588,648	901,692	820,989
	Brussels Capital Region	188,795	17,401	6,158	318,290
	Walloon Region	455,905	380,010	515,871	263,988

Source: Statbel (Directorate-General Statistics - Statistics Belgium)

Table 10: Percentage of Thermally Refurbished Envelope Areas in Bulgaria

Building period	Total number of buildings		Heated area (m^2)
	Single family houses and terrace houses (1000)	Apartment blocks and multifamily houses (1000)	All type of buildings (1000 m^2)
Until 1949	433.859	4.194	3,209.74
1950 to 1959	347.473	4.679	3,065.49
1960 to 1969	381.145	12.234	3,424.37
1970 to 1979	240.816	14.162	2,219.59
1980 to 1989	198.857	13.125	1,845.31
1990 to 1999	96.922	7.913	912.591
2000 to 2011	74.144	13.023	758.791
Total	1,773.216	69.397	15,435.886

Source: National Statistical Institute, Census 2011

Table 11: Percentage of Thermally Refurbished Envelope Areas in Bulgaria

Dwellings	Occupied dwellings	Dwellings with external thermal insulation	Dwellings with energy saving windows
Total (number)	2,666,733	428,473	937,574
Refurbished dwellings (%)		16.1	35.2

Source of data: National Statistical Institute, Census 2011

Table 12: Frequency of Building Types of the National Building Stock in Cyprus

Construction period	SFH Single family houses		TH Terrace houses		MFH Multi-family houses	
	No. of Buildings	National sq. meters.	No. of Buildings	National sq. meters.	No. of Buildings	National sq. meters.
Until 1980	58,524	7485,301	7,874	773,464	13,524	1447,645
1981 to 2006	98,025	17,975,224	8,277	928,174	39,366	4088,088
2007 to 2013	19,278	3,762,191	1,670	201,056	17,236	1,537,614
Total	175,827	29,222,716	17,821	1,902,694	70,126	7,073,347

Last updated: 08.11.2013

Source: Cyprus Statistical Service, Census 2011, and

Source: Cyprus Land Development Corporation, Statistical data.

Table 13: Frequency of Building Types of National Building Stock in Czech Republic

Single-unit housing

Building period		Number of houses (1000)						
		Until 1920	1920 to 1945	1946 to 1960	1961 to 1980	1981 to 1994	1995 to 2011	Total
Total		199.8	271.5	113.6	370.3	277.0	294.1	1,554.8
Number of dwellings in houses	**1**	164.5	210.8	90.6	259.5	219.5	256.3	1,226.8
	2	32.7	56.1	22.3	108.3	55.9	36.0	314.0
	3	2.6	4.6	0.7	2.5	1.6	1.8	14.1
Number of storeys in houses	**1**	122.4	115.1	53.0	116.8	74.4	99.6	584.1
	2	65.1	137.2	56.1	238.9	188.0	174.4	861.8
	3	4.7	11.7	1.4	7.3	9.3	11.4	46.0

Source: Czech Statistical Office, CSU 2001

Last updated: 18.11.2013

Table 14: Multi-unit housing in Czech Republic

Building period		**Number of houses (1000)**						
		Until 1920	**1920 to 1945**	**1946 to 1960**	**1961 to 1980**	**1981 to 1994**	**1995 to 2011**	**Total**
Total		26.1	27.8	30.6	71.4	31.7	19.0	211.3
Number of dwell-ings in houses	**2**	2.1	1.4	0.7	0.9	0.8	0.9	7.0
	3	3.1	2.3	0.5	0.6	0.6	1.1	8.5
	4	4.9	4.9	5.3	6.9	2.8	1.8	27.0
	5-9	11.7	11.1	16.6	21.8	8.1	6.2	77.1
	10-19	3.9	6.4	6.2	26.9	10.3	5.8	60.9
	20 and more	0.4	1.7	1.3	14.3	9.2	3.2	30.8
Number of sto-reys in houses	**1**	1.2	0.6	0.5	0.6	0.4	0.7	3.9
	2	7.9	5.7	6.9	9.7	3.8	3.4	37.7
	3	7.7	8.9	11.2	12.2	4.8	4.9	49.9
	4	4.8	5.4	7.3	19.1	6.7	4.5	48.0
	5	3.2	3.9	2.9	8.6	2.5	2.2	23.4
	6 and more	0.8	2.4	1.2	19.0	12.3	3.0	38.7

Source: Czech Statistical Office, CSU 2001

Table 15: Frequency of building types of the national building stock in Germany

Construction	**SFH**	**TH**	**MFH**	**AB**	**Sum**	**Fraction**
Year class	**Number of dwellings (1000)**					
Until 1859	399	181	214	11.1	806	2 %
1860 to 1918	1,213	617	2177	525.8	4,533	12 %
1919 to 1948	1,389	840	1,911	126.0	4,265	11 %
1949 to 1957	1,060	546	2,003	307.5	3,915	10 %
1958 to 1968	1,948	749	3,348	817.7	6,863	17 %
1969 to 1978	1,915	685	2,313	1,366.3	6,279	16 %
1979 to 1983	881	374	852	355.7	2,463	6 %
1984 to 1994	1,397	722	1,826	605.3	4,550	12 %
1995 to 2001	1,204	674	1,390	407.7	3,675	9 %
2002 to 2009	858	409	461	151.4	1,880	5 %
Sum	12,263	5,796	16,495	4,674	39,228	100 %
Fraction	31 %	15 %	42 %	12 %	100 %	

Source: "Basisdaten für Hochrechnungen mit der Deutschen Gebäudetypologie des IWU", Institut Wohnen und Umwelt, Darmstadt, October 2013. In this paper data from the German census 2011 was analysed. For assigning the building typology's size classes (SFH, TH, MFH, AB) to the statistical data the following definitions were used: SFH: detached buildings with 1-2 apartments, TH: other types of buildings with 1-2 apartments (terraced houses, double houses, others) , MFH: buildings with 3-12 apartments, AB: buildings with 13 or more apartments.

Last updated: 31.10.2013

Table 16: Aggregation for Building Stock Model in Germany

			Number of buildings	Number of dwellings	Living space
			1000	1000	million m^2
Single Fami-ly Houses (<=2 dwell-ings)	SFH I	until 1978	9,342	11,541	1,270
	SFH II	1979 - 1994	2,852	3,373	418
	SFH III	1995 - 2009	2,813	3,144	409
Multi Family Houses (>=3 dwell-ings)	MFH I	until 1978	2,377	15,120	1,024
	MFH II	1979 - 1994	498	3,639	253
	MFH III	1995 - 2009	358	2,411	179
Sum			18,239	39,228	3,552

Source: "Basisdaten für Hochrechnungen mit der Deutschen Gebäudetypologie des IWU", Institut Wohnen und Umwelt, Darmstadt, October 2013. In this paper data from the German census 2011 was analysed. For assigning the building typology's size classes (SFH, TH, MFH, AB) to the statistical data the following definitions were used: SFH: detached buildings with 1-2 apartments, TH: other types of buildings with 1-2 apartments (terraced houses, double houses, others) , MFH: buildings with 3-12 apartments, AB: buildings with 13 or more apartments.

Last updated: 31.10.2013

Table 17: Percentage of Thermally Refurbished Envelope Areas in Germany

Percentages related to building numbers of the respective classes SFH I - MFH II				
Percentage of modernized element area (with improved thermal protection)				
Building classes	SFH I	SFH II	MFH I	MFH II
	until 1978	1979-1994	until 1978	1979-1994
Walls	20 %	7 %	26 %	15 %
Roofs/ upper floor ceilings	47 %	24 %	48 %	23 %
Basement/ cellar ceiling	10 %	3 %	11 %	7 %
Windows*	35 %	12 %	44 %	24 %

Modernization of buildings erected after 1995 (SFH III and MFH III) neglected

*percentage of thermal protection glazing (window installation after 1995)

Source: Analysis carried out by IWU 2011 for the TABULA project with "Datenbasis Gebäudebestand", a data base of a representative survey of the German residential housing stock (project report: "Datenbasis Gebäudebestand", Institut Wohnen und Umwelt, 9.12.2010)

Table 18: Frequency of building types of the national building stock in Denmark

Building period	Total number of buildings. Excluded listed buildings and buildings without heating installation		
	Single-family houses	Terrace houses	Apartment Blocks
Until 1850	35,803	3,632	1,714
1851 to 1930	297,832	24,873	41,672
1931 to 1950	134,001	14,204	16,659
1951 to 1960	108,299	15,608	5,574
1961 to 1972	273,139	31,965	6,594
1973 to 1978	147,183	24,163	2,102
1979 to 1998	127,005	81,801	8,647
1999 to 2006	48,836	24,895	3,385
After 2007	31,525	13,531	1,642
Total	1,203,623	234,672	87,989

Source: Danish Enterprise and Construction Authority, The Building Stock Register (BBR - Bygnings- og Bollgregistret), 2012

Table 19: Frequency of Building Types of the National Building Stock in Spain

	Single unit houses (1 apartment)	Multi-unit houses (≥ 2 apartments)		Building Stock total	
	Number of build-ings= Number of apartments	**Number of buildings**	**Number of apartments**	**Number of buildings**	**Number of apartments**
Before 1900	767,656	132,086	554,412	899,742	554,412
	11%	7%	4%	10%	4%
1900 to 1920	354,954	71,292	369,027	426,246	369,027
	5%	4%	3%	5%	3%
1921 to 1940	405,196	91,147	498,539	496,343	498,539
	6%	5%	4%	6%	4%
1941 to 1950	435,942	102,782	548,948	538,724	548,948
	7%	5%	4%	6%	4%
1951 to 1960	679,882	205,484	1,305,565	885,366	1,305,565
	10%	11%	9%	10%	9%
1961 to 1970	761,201	327,792	2,910,774	1,088,993	2,910,774
	11%	17%	21%	13%	21%
1971 to 1980	1,084,141	418,935	3,888,633	1,503,076	3,888,633
	16%	22%	27%	17%	27%
1981 to 1990	1,096,051	262,965	1,781,978	1,359,016	1,781,978
	16%	14%	13%	16%	13%
1991 to 2001	1,097,568	318,342	2,282,988	1,415,910	2,282,988
	16%	16%	16%	16%	16%
Total	6,682,591	1,930,825	14,140,864	8,613,416	20,823,455

2011 data

Building TYPE	Number of buildings	Number of apartments
Building stock total	9,804,090	25,208,623

Source: INE (National Statistical Institute)

Last updated: 07.11.2013

Table 20: Frequency of Building Types of the National Building Stock in France

Construction year class	SFH	TH	MFH	AB	Sum	Fraction
	Number of dwellings (1000)					
Before 1915	2,568	683	1,078	609	4,938	21%
1915 to 1948	1,445	384	604	452	2,886	12%
1949 to 1967	1,456	387	865	1,714	4,422	19%
1968 to 1974	1,188	316	418	1,515	3,436	14%
1975 to 1981	1,470	391	208	944	3,012	13%
1982 to 1989	1,452	386	246	555	2,640	11%
1990 to 1999	1,134	301	261	732	2,428	10%
2000 to 2005						
2006 to 2012						
Sum	10,713	2,848	3,679	6,521	23,762	100%
Fraction	45%	12%	15%	27%	100%	

Source: INSEE 1999_LOG1 - Logements par catégorie selon l'époque d'achèvement (France métropolitaine) www.recensement-1999.insee.fr/default.asp

Last updated: 08.11.2013

Table 21: Aggregation for Building Stock Model in France

		Construction period	Number of buildings (x1000)	Number of apartments (x1000)	Living space (106 m²)
Single Family Houses	**SFH I**	Until 1975	8,207.5	8,207.5	743.8
	SFH II	1976 to 2000	5,308.6	5,308.6	512.4
Multi Family Houses	**MFH I**	Until 1975	1,178.5	7,023.4	433.7
	MFH II	1976 to 2000	222.0	2,986.3	176.5

Source: INSEE 1999_LOG1 - Logements par catégorie selon l'époque d'achèvement (France métropolitaine) www.recensement-1999.insee.fr/default.asp

Table 22: Percentage of thermally refurbished envelope areas in France

percentages related to building numbers of the respective classes SFH I - MFH II				
Percentage of modernized element area (with improved thermal protection)				
Building classes	**SFH I**	**SFH II**	**MFH I**	**MFH II**
	until 1975	1975-2000	until 1975	1975-2000
Walls	37	88	19	52
Roofs/ upper floor ceilings	62	90	25	65
Basement/ cellar ceiling	12	42	10	30
Windows*	35	75	23	57

Source: ADEME: SOFRES (10000 ménages survey) + OPEN

Table 23: Frequency of Building Types of the National Building Stock in Great Britain

	estimated number of buildings (1000)	number of dwell-ings (1000)	living space in 1000 m²
SFH pre 1919	615	615	117,528
SFH 1919-44	567	567	81,900
SFH 1945-64	746	746	95,836
SFH 1965-80	1,206	1,206	142,846
SFH 1981-90	767	767	91,836
SFH 1991-2003	785	785	103,807
SFH post 2004	214	214	30,281
Terraced house pre 1919	3,259	3,259	318,723
Terraced house 1919-44	2,811	2,811	246,106
Terraced house 1945-64	3,026	3,026	248,479
Terraced house 1965-80	2,291	2,291	184,076
Terraced house 1981-90	695	695	47,710
Terraced house 1991-2003	716	716	53,674
Terraced house post 2004	293	293	26,630
MFH pre 1919	373	982	66,539
MFH 1919-44	108	314	18,963
MFH 1945-64	168	595	33,802
MFH 1965-80	222	952	53,172
MFH 1981-90	106	459	22,455
MFH 1991-2003	73	391	20,698
MFH post 2004	48	296	16,835
Apartment pre 1919	*	*	701
Apartment 1919-44	*	*	1,131
Apartment 1945-64	2	82	4,556
Apartment 1965-80	4	188	10,789
Apartment 1981-90	*	*	723
Apartment 1991-2003	*	*	1,252
Apartment post 2004	1,401	49	2,981
Total		22,359	2,044,031

* indicates that sample size for this group of dwellings from the raw survey data is too small for reliable estimate

Base: Total dwelling stock - sample size of 24,642 dwellings

Source: English House Survey 2009 (https://www.gov.uk/government/organisations/department-for-communities-and-local-government/series/english-housing-survey)

Last updated: 18.11.2013

Table 24: Information on Insulation Level and Window Types in Great Britain

	Walls			Roof/ upper floor ceilings				Windows	
	cavity walls with insula-tion	unin-sulat-ed cavity walls	non cavi-ty wall	no loft at dwell-ing	non-insu-lated	under 150 mm	150 mm or more	none or partial double glazing	100% double glazing
SFH pre 1919	7.4	13.7	78.8		11.7	52.3	36.1	61.1	38.9
SFH 1919-44	31.2	34.6	34.2		*	60.6	34.2	50.8	49.2
SFH 1945-64	56.6	36.2	7.1		*	60.0	36.6	29.4	70.6
SFH 1965-80	60.0	37.0	3.0		*	55.4	43.6	18.3	81.7
SFH 1981-90	44.4	50.5	*		*	61.0	38.7	13.7	86.3
SFH 1991-2003	44.7	51.3	4.0		*	37.0	62.9	*	96.2
SFH post 2004	81.2	*	*		*	*	85.5	*	97.7
Ter-raced house pre 1919	3.7	11.5	84.8		11.2	57.7	31.2	46.3	53.7
Ter-raced house 1919-44	28.3	28.2	43.5		4.7	54.4	41.0	33.1	66.9
Ter-raced house 1945-64	56.2	32.7	11.1		2.7	50.6	46.7	20.4	79.6
Ter-raced house 1965-80	49.5	44.8	5.8		1.7	56.9	41.4	13.9	86.1
Ter-raced house 1981-90	37.2	60.9	*		*	63.6	35.7	16.3	83.7

Ter-raced house 1991-2003	41.5	57.3	*		*	38.4	61.4	4.2	95.8
Ter-raced house post 2004	82.8	14.6	*		*	12.0	88.0	*	99.0
MFH pre 1919	*	8.6	89.5	57.8	8.8	25.3	8.1	58.6	41.4
MFH 1919-44	9.4	22.3	68.2	54.0	*	26.9	11.3	38.4	61.6
MFH 1945-64	36.9	38.1	25.0	57.2	6.6	23.1	13.1	19.1	80.9
MFH 1965-80	35.1	56.3	8.7	59.6	*	26.0	12.3	16.0	84.0
MFH 1981-90	33.3	63.3	*	59.2	*	24.7	16.0	17.4	82.6
MFH 1991-2003	35.4	61.3	*	64.5	*	15.8	19.7	8.8	91.2
MFH post 2004	84.2	12.9	*	69.8	*	*	24.6	*	96.8
Apart-ment pre 1919	*	*	*	*	*	*	*	*	*
Apart-ment 1919-44	*	*	*	*	*	*	*	*	*
Apart-ment 1945-64	*	33.5	53.1	86.0	*	*	*	*	78.1
Apart-ment 1965-80	*	34.3	55.9	88.0	*	*	*	20.8	79.2
Apart-ment 1981-90	*	*	*	*	*	*	*	*	*
Apart-ment 1991-2003	*	*	*	*	*	*	*	*	*
Apart-ment post 2004	64.6	*	*	84.5	*	*	*	*	97.9
All dwell-ings	35.7	33.3	31.0	12.1	4.2	47.0	36.7	26.5	73.5

* indicates that sample size for this group of dwellings from the raw survey data is too small for reliable estimate

Total dwelling stock - sample size of 24,642 dwellings

Source: English House Survey 2009

https://www.gov.uk/government/organisations/department-for-communities-and-local-government/series/english-housing-survey

Last updated: 18.11.2013

Table 25: Frequency of building types of the national building stock in Hungary

<table>
<tr><th></th><th>SFH
below 80 m²
(1-3 flats)</th><th>SFH
above 80 m²
(1-3 flats)</th><th>MFH
4-9 flats</th><th>MFH
10+ Flats, traditional</th><th>MFH
10+ Flats, industrialized technology, "panel"</th><th>MFH
10+ Flats, industrialized technology, other</th></tr>
<tr><td>Before 1944</td><td>400,537</td><td>269,508</td><td rowspan="5">43,981</td><td>10,819</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>1945-1960</td><td rowspan="2">449,213</td><td rowspan="2">672,128</td><td rowspan="4">16,825</td></tr>
<tr><td>1961-1979</td><td>11,502</td><td rowspan="2">10,575</td></tr>
<tr><td>1980-1989</td><td colspan="2">378,942</td><td>9,635</td></tr>
<tr><td>1990-2001</td><td colspan="2">198,938</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>After 2001</td><td colspan="2">157,885</td><td>6,285</td><td>3,770</td></tr>
<tr><td>Total</td><td colspan="2">2,527,151</td><td>50,266</td><td>31,414</td><td>21,137</td><td>10,575</td></tr>
<tr><td colspan="7">2,640,543</td></tr>
</table>

Source: Hungarian Statistic Office, 2012, based on the census 2001 and questionnaires for the period after 2001

Last updated: 31.10.2013

Table 26: Frequency of building types of the national building stock in Ireland

	All house holds	De-tached houses	Semi-de-tached houses	Ter-raced houses	Flat or apart-ment in a pur-pose-built block	Flat or apart-ment in a con-verted house or com-mercial build-ing	Bed-sit	Not stated
Before 1919	149,939	80,020	16,176	37,923	2,975	9,977	1,818	1,050
1919 to 1945	114,817	49,308	25,586	33,120	2,503	2,947	652	701
1946 to 1960	127,691	42,961	39,045	39,047	3,573	1,735	569	761
1961 to 1970	114,510	42,235	42,258	23,621	4,307	1,131	331	627
1971 to 1980	214,197	98,913	70,422	37,081	5,292	1,161	241	1,087
1981 to 1990	172,413	87,782	48,914	24,626	8,754	1,080	257	1,000
1991 to 2000	238,724	111,618	79,107	19,021	25,626	1,962	293	1,097
2001 to 2005	266,110	103,994	77,125	33,883	47,196	2,081	260	1,571
2006 or later	171,397	69,646	39,852	21,032	37,763	1,588	210	1,306
Not stat-ed	79,610	13,392	18,166	12,471	11,932	4,004	1,064	18,581
Total	1,649,408	699,869	456,651	281,825	149,921	27,666	5,695	27,781

Source: Census 2011, Table CD432

Last updated: 31.10.2013

Table 27: Percentage of Thermally Refurbished Envelope Areas in Ireland

Wall measures summary	Wall measures (warmer home scheme)	Wall measures (better energy homes)	Total wall measures	Wall measures as % of hous-ing stock
2007	1,229		1,229	0.08%
2008	1,236		1,236	0.08%
2009	4,372	12,628	17,000	1.06%
2010	10,620	35,209	45,829	2.86%
2011	11,517	39,168	50,685	3.17%
2012	7,990	20,096	28,086	1.76%
Total	36,964	107,101	144,065	9.00%

Source: Sustainable Energy Authority of Ireland (SEAI), Department of Community Energy & Local Government (DCELG)

Last updated: 15.11.2013

Table 28: Frequency of Building Types of the National Building Stock in Italy

Middle climatic regions

Construction age	SFH 1 apartment		MFH ≥ 2 apartments	
	Number of buildings	Number of apartments	Number of buildings	Number of apartments
Before 1919	546,667	546,667	364,782	1,252,383
1919-1945	330,754	330,754	232,776	885,486
1946-1960	372,840	372,840	345,000	1,506,876
1961-1970	415,190	415,190	486,783	2,331,452
1971-1980	399,082	399,082	459,929	2,099,946
1981-1990	242,287	242,287	265,212	1,239,523
1991-2000	175,838	175,838	189,973	919,465
2001-2005	102,964	102,964	118,095	648,027
After 2005	87,824	87,824	97,659	560,992
Total	2,673,446	2,673,446	2,560,209	11,444,150

Source: National Institute of Statistics, ISTAT, Census 2011.

Table 29: Percentage of Thermally Refurbished Envelope Areas in Italy

Middle climatic regions

Construction age	Not refurbished apartments	Refurbished apartments
Before 1919	46.6 %	53.4 %
1919-1945	44.9 %	55.1 %
1946-1961	41.8 %	58.2 %
1962-1971	40.6 %	59.4 %
1972-1981	43.1 %	56.9 %
1982-1991	57.0 %	43.0 %
After 1991	77.1 %	22.9 %
On the whole	47.5 %	52.5 %

Source: National Institute of Statistics, ISTAT, Census 2001.

No available data on thermally refurbished envelope areas but on type of intervention for age of construction.

Table 30: Frequency of Building Types of the National Building Stock in The Netherlands

Number of dwellings (x 1000) on 1-1-2012	Detached house	Semi-detached house	Terraced house, mid-row	Terraced house, end-row	Flat with common staircase and galleries	Flat with common staircase, no galleries*	Marionette*	Other multi-family dwellings*	Total
Before 1946	441	285	337	186	69	256	226	99	2,644
1946 to 1964			296	182		267			
1965 to 1974	119	142	375	231	174	112	22	125	1,300
1975 to 1991	221	224	572	307	109	142	94	125	1,794
1992 to 2005	178	173	241	112	113	70	40	136	1,063
2006 to 2011	78	76	106	48	49	31	17	60	465
Total	1,037	900	1,927	1,066	514	878	399	545	7,266

Source: AgentschapNL, Voorbeeldwoningen 2011; bestaande bouw

* As for the 2006-2011 period, the flats with common staircase and no galleries, the maisonnettes and the other multi-family dwellings belong to the same class. Nevertheless, the numbers of dwellings are given per building type.

Last updated: 01.09.2014

Table 31: Percentage of Thermally Refurbished Envelope Area in The Netherlands

Percentage of dwellings in 2012	Total
Ground floor	56%
Wall	70%
Roof	79%
Glazing	86%

Source: Housing Survey 2012, Energy module / Cijfers over Wonen en Bouwen 2013, p. 136

Last updated: 08.11.2013

Table 32: Frequency of Building Types of the National Building Stock in Norway

	Number of buildings (#)				Number of dwellings (#)			
Age classes	**SFH**	**TH**	**AB**	**Total**	**SFH**	**TH**	**AB**	**Total**
1955 and before	371,183	69,020	26,955	467,158	401,482	143,241	179,666	724,389
1956-1970	209,324	56,769	7,419	273,512	227,929	81,577	121,358	430,864
1971-1980	194,861	49,848	4,546	249,255	219,673	72,521	91,387	383,581
1981-1990	178,291	44,391	5,296	227,978	202,228	70,619	57,471	330,318
1991-2000	91,914	30,924	6,319	129,157	109,696	55,632	65,056	230,384
2001-2010	83,819	40,468	10,450	134,737	98,808	67,624	126,975	293,407
2011 and after	16,695	9,623	2,280	28,598	19,144	13,929	23,194	56,267
Sum	1,146,087	301,043	63,265	1,510,395	1,278,960	505,143	665,107	2,449,210

Source: Statistics Norway: Table: 06266: Dwellings, by type of building and year of construction (M) and

Population and housing census, dwellings, 19 November 2011

Last updated: 04.04.2016

Table 33: Frequency of Building Types of the National Building Stock in Poland

Construction period		**Number of buildings**	**Number of apartments**	**Living space (1000 m^2)**
Up to 1944	**SFH**	865,913	865,913	69,424,228
1945-1970		1,168,340	1,168,340	95,621,198
1971-2002		1,831,142	1,831,142	218,138,583
2002-2010		496,269	496,269	59,552,280
Up to 1944	**TH**	156,206	312,412	20,486,590
1945-1970		114,042	228,084	14,889,989
1971-2002		108,890	217,780	16,676,935
2002-2010		4,487	308,974	27,807,660
Up to 1944	**MFH I**	176,859	867,558	46,506,695
1945-1970		42,166	200,347	10,343,469
1971-2002		32,310	160,784	9,487,010
2002-2010		33,370	286,507	21,488,025
Up to 1944	**MFH II**	42,444	700,719	35,462,223
1945-1970		42,994	1,574,491	67,325,934
1971-2002		85,965	3,585,142	185,664,884
2002-2010		13,931	617,800	43,246,000
Total		5,215,328	13,422,262	942,121,703

Where:

SGH	single family house with 1 apartment
TH	terrace house with 2 apartments
MFH I	small multifamily house with 3-9 apartments
MFH II	large multifamilty house with over 9 apartments

Source: TABULA Project

Table 34: Percentage of Thermally Refurbished Envelope Areas in Poland

Construction period	**percent of thermos-modernized buildings**
Up to 1945	7%
1946-1966	52%
1967-1985	60%
1986-1992	41%
1193-2002	30%
2002-2008	new buildings fulfilled as obligatory energy efficient standards
After 2008	new buildings fulfilled as obligatory energy efficient standards

Source: TABULA Project

Table 35: Frequency of the buildings of national building stock in Serbia

Construction	**SFH**	**TH**	**MFH**	**AB**	**Sum**	**Fraction**
Year class	**Number of dwellings (1000)**					
Before 1919	118	17	4	0,6	140	4.39%
1919-1945	196	11	31	2,5	240	7.52%
1946-1960	290	12	37	16	354	11.10%
1961-1970	380	23	91	48	542	17.00%
1971-1980	495	22	133	131	781	24.50%
1981-1990	435	23	122	91	672	21.06%
1991-2011	291	14	113	42	460	14.43%
Sum	2,205	123	530	331	3,188	100.00%
Fraction	69.14%	3.86%	16.62%	10.37%	100.00%	

Source: Analysis carried out by Faculty of Architecture - University of Belgrade for the TABULA project, a data base of a representative survey of Serbian residential building stock (Survey by Ipsos 2012 and 2011), pondered in relevance to the official statistical data from Statistical Office of the Republic of Serbia. Main results published in National Typology of Residential Buildings in Serbia, 2013.

Last updated: 01.09.2014

Table 36: Aggregation for Building Stock Model in Serbia

		Construction period	Number of buildings	Number of apartments	Living space
			1,000	**1,000**	**Million m^2**
Single Family Houses (<= 4 apartments)	**SFH I**	Before 1970	1,039	1,047	75
	SFH II	1971-1980	476	517	40
	SFH III	1981-1990	407	458	36
	SFH IV	1991-2011	265	305	25
Multi Family Houses (>= 5 apartments)	**MFH I**	Before 1970	18	229	26
	MFH II	1971-1980	15	264	33
	MFH III	1981-1990	14	213	31
	MFH IV	1991-2011	13	155	24
Sum			2,246	3,188	290

Source: Analysis carried out by Faculty of Architecture - University of Belgrade for the TABULA project, a data base of a representative survey of Serbian residential building stock (Survey by Ipsos 2012 and 2011), pondered in relevance to the official statistical data from Statistical Office of the Republic of Serbia. Main results published in National Typology of Residential Buildings in Serbia, 2013.

Last updated: 01.09.2014

Table 37: Information on Insulation Level in Serbia

	Year class					
Insulation in exterior walls (%)	**Until 1945**	**1946-1970**	**1971-1980**	**1981-1990**	**1991-2011**	**Total**
Yes	5	12	15	26	43	16.3
No	95	88	84	74	56	83.2
Unknown		1	1	0	1	0.5
Insulation thickness	**Until 1945**	**1946-1970**	**1971-1980**	**1981-1990**	**1991-2011**	**Total**
<5cm	20	29	6	12	13	16.1
5cm	63	58	60	40	48	48
6-10cm	18	10	26	43	24	24
Unknown		4	7	5	16	7.8
	average wall insulation thickness 5cm					

Last updated: 01.09.2014

Source: Survey carried out by Ipsos Strategic Marketing in cooperation with Faculty of Architecture - University of Belgrade for the TABULA project, a data base of a representative survey of Serbian residential building stock (2011), pondered in relevance to the official statistical data from Statistical Office of the Republic of Serbia. Results published in form of internal report, 2011.

Table 38: Frequency of Building Types of the National Building Stock in Sweden

		Construction period	Number of buildings	Number of apartments
			x1000	
Single family house	SFH I	Up to 1960	846	
Single family house	SFH II	1961-1975	500	
Single family house	SFH III	1976-1985	313	
Single family house	SFH IV	1986-1995	154	
Single family house	SFH V	1996-2005	77	
Multifamily house	MFH I	Up to 1960	77	1,031
Multifamily house	MFH II	1961-1975	32	768
Multifamily house	MFH III	1976-1985	12	130
Multifamily house	MFH IV	1986-1995	31	364
Multifamily house	MFH V	1996-2005	12	102

Source: BETSI, Boverket 2010

Table 39: Percentage of Thermally Refurbished Envelope Areas in Sweden

Percentage of building type that have modernized building elements 2007-2010

	SFH	MFH
	%	%
Floor	6±6	4±3
Window/ Door	10±4	8±4
Wall	11±4	11±7
Roof	9±6	4±2

Source: BETSI, Boverket 2010

Table 40: Percentage of one- and two-dwelling buildings in 2009 by types of energy efficiency measures taken during 1998-2008 and year of completion in Sweden, x1000

	SFH	SFH	SFH	SFH	SFH	SFH	SFH
	Up to 1940	**1941-1960**	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-…**
Single family houses (1000)	508	258	259	416	201	98	86
Percent of houses completed action 98-08 (1000)	54.0	56.0	39.0	46.0	36.0	22.0	4.0
Insulation walls/ roof	23.0	21.0	11.0	6.0	2.0	1.0	1.0
Insulating glass, at least 50%	18.0	25.0	18.0	15.0	1.0	1.0	

Source: BETSI, Boverket 2010

Table 41: Frequency of building types of the national building stock in Slovenia

Building type (condensed)	Number of build-ings	Number of apart-ments	Living space in 1,000 m^2
SUH I	153,579	165,180	14,689
SUH II	102,546	111,813	10,103
SUH III	90,189	96,958	9,718
SUH IV	122,862	128,048	12,981
SUH V	23,961	24,668	2,844
SUH VI	146	158	14
MUH I	11,623	104,214	5,830
MUH II	6,027	74,676	3,514
MUH III	3,165	66,905	3,216
MUH IV	3,074	57,282	2,909
MUH V	1,408	21,630	1,274
MUH VI	18	1,161	71
Building stock total	518,598	852,693	67,164

Where:

SUH	Single Unit Houses
MUH	Multi Unit Houses

Source: Registry of buildings, 2009, http://e-prostor.gov.si/?id=601

Table 42: Percentage of thermally refurbished envelope areas in Slovenia

Building classes	Walls	Roofs	Upper floor ceilings	Windows
SUH I	38%	74%	38%	84%
SUH II	45%	74%	48%	74%
SUH III	38%	58%	49%	46%
SUH IV	35%	34%	31%	31%
SUH V	20%	7%	9%	0%
SUH VI	0%	0%	0%	0%
MUH I	14%	55%	17%	77%
MUH II	16%	56%	21%	52%
MUH III	14%	38%	20%	49%
MUH IV	26%	34%	18%	27%
MUH V	17%	0%	0%	0%
MUH VI	0%	0%	0%	0%

Where:

SUH	Single Unit Houses
MUH	Multi Unit Houses

Source: REUS survey, 2011

Table 43: Simulation Analysis Results of the Reference Building, of the Store

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	18.846	918.906	0	0	0	0	0	92.366	0	62.164
February	6.612	18.849	790.799	0	0	0	0	0	81.347	0	55.481
March	9.497	18.892	687.374	0	0	0	0	0.01	70.14	0.005	47.358
April	13.216	19.1	330.905	0	0	0	0	0.545	44.551	0.314	30.956
May	18.437	19.917	0	0	0	0	0	6.184	22.343	3.615	16.746
June	23.335	22.839	0	0	0	0	0	9.425	14.636	5.386	11.65
July	25.786	24.96	0	9.631	0	0	0	11.492	14.381	6.871	11.316
August	25.455	24.919	0	12.106	0	0	0	9.732	14.818	5.736	11.606
September	21.294	22.683	0	0	0	0	0	4.226	22.494	2.352	17.212
October	15.952	20.029	110.179	0	0	0	0	1.793	36.833	1.01	26.425
November	11.085	19.061	438.208	0	0	0	0	0.008	58.813	0.006	40.568
December	7.369	18.871	741.717	0	0	0	0	0	84.477	0	56.612
Annual Sum or Average	15.4	20.761	4018.087	21.737	0	0	0	43.415	557.2	25.295	388.095

Table 44: Simulation Analysis Results of the Reference Building, of the 1st Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	18.862	3,004.184	0	610.274	391.076	726.237	0	540.856	0	353.308
February	6.612	18.883	2,313.748	0	808.817	327.289	907.804	0	477.409	0	316.043
March	9.497	19.008	1,863.74	0	684.914	276.738	787.864	0.058	415.273	0.026	272.792
April	13.216	19.371	721.697	0	546.057	183.593	611.293	1.745	271.513	0.906	184.023
May	18.437	22.361	0	30.525	616.099	150.223	649.585	11.937	215.437	6.832	152.989
June	23.335	25.476	0	357.513	685.141	116.718	677.886	21.179	139.638	12.04	101.596
July	25.786	26.34	0	924.692	697.419	105.441	658.469	55.432	78.02	32.894	56.095
August	25.455	26.341	0	904.029	677.478	111.449	640.715	45.491	78.088	26.612	54.876
September	21.294	25.304	0	177.306	743.375	169.469	749.098	6.18	207.079	3.526	145.451
October	15.952	21.685	291.165	0	794.761	213.94	820.195	2.006	278.709	1.081	193.925
November	11.085	19.266	1164.712	0	671.557	261.466	730.972	0	352.422	0	236.541
December	7.369	18.89	2739.262	0	515.119	359.781	624.572	0	494.426	0	321.624
Annual Sum or Average	15.4	21.834	12,098.509	2,394.065	8,051.01	2,667.182	8,584.692	144.027	3,548.87	83.918	2,389.262

Table 45: Simulation Analysis Results of the Reference Building, of the 2nd Floor

	SITE OUTDOOR AIR DRY-BULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	18.996	1,408.785	0	598.668	425.209	726.237	0	547.934	0	358.786
February	6.612	19.074	972.096	0	794.56	356.319	907.804	0	485.928	0	322.669
March	9.497	19.273	751.772	0	669.179	304.292	787.864	0.009	427.618	0.004	282.506
April	13.216	19.896	213.323	0	529.629	208.392	611.293	0.702	293.949	0.342	201.061
May	18.437	23.487	0	63.499	584.373	179.191	649.585	7.238	260.646	4.314	182.213
June	23.335	25.871	0	558.156	667.669	129.85	677.886	18.914	147.316	10.891	106.078
July	25.786	26.451	0	1,098.093	690.762	110.762	658.469	55.126	79.67	32.71	56.896
August	25.455	26.455	0	1,077.313	671.405	117.47	640.715	45.202	79.716	26.442	55.693
September	21.294	25.847	0	434.468	724.725	192.575	749.098	6.049	203.635	3.462	141.36
October	15.952	23.03	58.808	17.323	765.51	263.165	820.195	0.884	334.038	0.48	229.913
November	11.085	19.723	398.847	0	658.728	292.872	730.972	0	372.276	0	251.293
December	7.369	19.039	1332.406	0	505.016	392.7	624.572	0	501.866	0	327.453
Annual Sum or Average	15.4	22.282	5,136.037	3,248.851	7,860.224	2,972.796	8,584.692	134.125	3,734.592	78.644	2,515.92

Table 46: Simulation Analysis Results of the Reference Building, of the 3rd Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.05	1,280.255	0	596.131	432.163	726.237	0	550.986	0	361.109
February	6.612	19.13	858.718	0	791.232	362.442	907.804	0	488.789	0	324.846
March	9.497	19.362	654.969	0	665.056	310.743	787.864	0.003	432.185	0.001	285.941
April	13.216	20.082	159.828	0	524.144	215.838	611.293	0.501	302.509	0.24	207.226
May	18.437	23.867	0	93.216	572.657	190.417	649.585	6.023	275.97	3.662	192.006
June	23.335	25.99	0	634.263	662.126	134.443	677.886	18.395	149.773	10.629	107.456
July	25.786	26.495	0	1158.096	688.572	113.038	658.469	54.819	80.958	32.526	57.704
August	25.455	26.499	0	1137.23	669.219	119.96	640.715	44.915	80.948	26.272	56.467
September	21.294	25.952	0	524.441	720.116	198.397	749.098	5.982	201.778	3.423	139.866
October	15.952	23.366	35.451	42.422	757.161	276.914	820.195	0.793	344.036	0.431	235.74
November	11.085	19.829	333.818	0	655.508	299.662	730.972	0	377.465	0	255.037
December	7.369	19.088	1218.572	0	502.733	399.33	624.572	0	504.668	0	329.581
Annual Sum or Average	15.4	22.413	4,541.612	3,589.668	7,804.654	3,053.347	8,584.692	131.431	3,790.065	77.185	2,552.979

Table 47: Simulation Analysis Results of the Reference Building, of the 4th Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	18.999	1,479.753	0	596.799	428.361	726.237	0	549.545	0	359.831
February	6.612	19.089	1,000.615	0	791.597	360.204	907.804	0	487.874	0	324.007
March	9.497	19.342	730.607	0	664.551	310.066	787.864	0.001	432.112	0	285.744
April	13.216	20.184	163.894	0	520.93	219.144	611.293	0.295	307.549	0.139	210.637
May	18.437	24.172	0	128.879	562.592	200.02	649.585	5.4	288.181	3.347	199.79
June	23.335	26.068	0	737.884	656.953	138.766	677.886	18.308	150.967	10.567	108.111
July	25.786	26.604	0	1309.238	682.451	118.567	658.469	54.515	83.927	32.343	59.574
August	25.455	26.614	0	1297.033	663.245	126.25	640.715	44.63	84.021	26.104	58.411
September	21.294	26.01	0	585.021	717.02	202.114	749.098	5.916	201.858	3.385	139.837
October	15.952	23.246	58.563	39.474	758.573	273.138	820.195	0.855	339.589	0.465	232.723
November	11.085	19.742	438.456	0	656.638	295.465	730.972	0	374.505	0	252.737
December	7.369	19.039	1406.982	0	503.249	395.737	624.572	0	503.361	0	328.401
Annual Sum or Average	15.4	22.447	5,278.87	4,097.529	7,774.598	3,067.832	8,584.692	129.921	3,803.488	76.351	2,559.803

Table 48: Simulation Analysis Results of the Reference Building, of the 5th Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	18.856	3,631.446	0	639.87	401.946	763.083	0	543.362	0	354.879
February	6.612	18.924	2,528.711	0	888.461	344.469	992.034	0	481.558	0	318.98
March	9.497	19.212	1,635.813	0	922.661	303.422	1,024.063	0.002	427.1	0.001	281.804
April	13.216	20.407	380.804	0.152	833.017	230.815	902.979	0.008	318.251	0.004	218.306
May	18.437	24.535	0	293.523	833.639	222.738	909.979	4.977	299.966	3.125	208.534
June	23.335	26.483	0	1277.412	864.797	170.281	884.955	18.621	156.921	10.675	111.775
July	25.786	27.197	0	2117.248	921.531	158.01	898.803	54.219	100.792	32.162	71.064
August	25.455	27.196	0	2132.99	1023.01	166.831	988.435	44.35	100.744	25.938	69.745
September	21.294	26.097	0	744.5	1040.981	218.677	1,051.062	5.851	202.519	3.347	140.342
October	15.952	22.44	322.934	24.129	943.383	252.986	978.242	1.188	306.88	0.636	212.264
November	11.085	19.323	1493.946	0	712.871	275.804	776.422	0	357.557	0	240.196
December	7.369	18.88	3,403.278	0	538.459	369.213	655.244	0	496.775	0	323.05
Annual Sum or Average	15.4	22.485	13,396.932	6589.954	10,162.681	3,115.193	10,825.302	129.217	3,792.422	75.888	2,550.938

Table 49: Simulation Analysis Results of the Reference Building, of the Staircase _ Unheated space

	SITE OUT-DOOR AIR DRY-BULB TEM-PER-ATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYS-TEM SENSI-BLE HEAT-ING ENER-GY [kWh]	ZONE AIR SYS-TEM SEN-SIBLE COOL-ING ENER-GY [kWh]	ZONE WIN-DOWS TO-TAL HEAT GAIN EN-ERGY [kWh]	ZONE WIN-DOWS TOTAL HEAT LOSS EN-ERGY [kWh]	ZONE WIN-DOWS TOTAL TRANS MITTED SOLAR RADIA-TION ENER-GY [kWh]	ZONE INFIL-TRA-TION SENSI-BLE HEAT GAIN ENER-GY [kWh]	ZONE INFIL-TRA-TION TOTAL HEAT LOSS ENER-GY [kWh]	ZONE VENTI-LATION SENSI-BLE HEAT GAIN ENER-GY [kWh]	ZONE VENTI-LATION TOTAL HEAT LOSS ENER-GY [kWh]
January	6.151	14.803	0	0	0	0	0	0	0	0	0
February	6.612	15.411	0	0	0	0	0	0	0	0	0
March	9.497	16.395	0	0	0	0	0	0	0	0	0
April	13.216	18.39	0	0	0	0	0	0	0	0	0
May	18.437	22.695	0	0	0	0	0	0	0	0	0
June	23.335	25.773	0	0	0	0	0	0	0	0	0
July	25.786	27.413	0	0	0	0	0	0	0	0	0
August	25.455	27.439	0	0	0	0	0	0	0	0	0
September	21.294	25.374	0	0	0	0	0	0	0	0	0
October	15.952	21.245	0	0	0	0	0	0	0	0	0
November	11.085	17.226	0	0	0	0	0	0	0	0	0
December	7.369	15.204	0	0	0	0	0	0	0	0	0
Annual Sum or Average	15.4	20.645	0	0	0	0	0	0	0	0	0

Table 50: Simulation Analysis Results of the Basic Scenario, of the Store

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	**ZONE MEAN AIR TEMPERATURE [C]**	**ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]**	**ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]**	**ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]**	**ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]**	**ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]**	**ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]**	**ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]**	**ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]**	**ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]**
January	6.151	18.925	374.198	0	0	0	0	0	91.092	0	60.974
February	6.612	18.942	333.225	0	0	0	0	0	80.557	0	54.652
March	9.497	19.081	269.257	0	0	0	0	0.01	70.414	0.005	47.502
April	13.216	19.391	111.451	0.858	0	0	0	0.509	46.414	0.285	32.378
May	18.437	20.967	0	50.751	0	0	0	4.486	28.644	2.639	21.17
June	23.335	24.934	0	161.652	0	0	0	4.345	25.549	2.48	19.568
July	25.786	27.641	0	255.589	0	0	0	4.519	31.848	2.637	23.916
August	25.455	28.365	0	254.722	0	0	0	2.157	38.178	1.254	28.267
September	21.294	25.956	0	140.734	0	0	0	0.491	44.254	0.27	32.147
October	15.952	21.768	6.498	32.627	0	0	0	0.435	48.306	0.237	34.766
November	11.085	19.396	141.704	0	0	0	0	0	60.48	0	41.902
December	7.369	19.04	315.507	0	0	0	0	0	83.966	0	56.124
Annual Sum or Average	15.4	22.055	1551.84	896.933	0	0	0	16.952	649.701	9.806	453.366

Table 51: Simulation Analysis Results of the Basic Scenario, of the 1st Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.127	929.189	0	176.34	235.714	233.91	0	542.831	0	354.385
February	6.612	19.121	763.697	0	229.248	194.476	277.448	0	479.906	0	317.428
March	9.497	19.429	413.733	0	350.789	161.085	375.949	0.009	430.122	0.004	284.322
April	13.216	20.627	22.026	169.088	400.839	113.069	395.17	0.341	323.904	0.159	221.999
May	18.437	24.204	0	796.306	393.774	95.822	381.887	4.471	296.734	2.672	206.196
June	23.335	28.824	0	1392.352	438.094	88.348	415.206	2.23	309.359	1.242	216.372
July	25.786	31.729	0	1786.207	423.681	98.981	410.584	1.501	366.241	0.763	253.456
August	25.455	32.446	0	1739.994	371.592	115.709	371.349	0.031	411.017	0.021	281.901
September	21.294	29.705	0	1142.4	280.593	140.849	300.551	0	425.426	0	289.987
October	15.952	24.343	0	367.9	278.393	156.86	294.455	0.264	366.444	0.147	249.746
November	11.085	20.554	129.821	0	215.218	168.737	241.745	0	405.428	0	274.02
December	7.369	19.222	789.498	0	159.316	220.85	212.94	0	500.261	0	326.121
Annual Sum or Average	15.4	24.143	3047.963	7394.246	3717.878	1790.5	3911.192	8.847	4857.672	5.008	3275.933

Table 52: Simulation Analysis Results of the Basic Scenario, of the 2nd Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.295	542.075	0	173.3	245.447	233.987	0	552.605	0	362.145
February	6.612	19.3	417.538	0	225.051	203.205	277.525	0	489.456	0	325.036
March	9.497	19.808	179.582	0	342.761	172.234	376.085	0	449.248	0	298.512
April	13.216	21.619	2.501	272.295	385.527	128.765	395.303	0.036	367.657	0.015	251.126
May	18.437	25.29	0	888.652	374.495	111.653	381.887	2.007	346.758	1.268	238.849
June	23.335	29.888	0	1374.426	418.249	102.715	415.206	0.939	357.988	0.513	248.054
July	25.786	32.757	0	1684.984	404.025	114.006	410.584	0.309	415.756	0.146	285.709
August	25.455	33.429	0	1631.249	354.058	131.369	371.349	0	458.791	0	312.978
September	21.294	30.668	0	1128.04	266.132	157.84	300.551	0	470.216	0	319.121
October	15.952	24.898	0	400.714	269.698	170.549	294.531	0.148	381.163	0.074	258.833
November	11.085	21.29	42.612	0	207.012	185.663	241.828	0	438.886	0	296.565
December	7.369	19.39	443.174	0	156.357	230.788	213.017	0	510.074	0	333.907
Annual Sum or Average	15.4	24.836	1627.482	7380.359	3576.665	1954.236	3911.852	3.439	5238.596	2.016	3530.835

Table 53: Simulation Analysis Results of the Basic Scenario, of the 3rd Floor

	SITE OUTDOOR AIR DRY-BULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.306	526.155	0	171.771	248.165	233.884	0	554.021	0	363.16
February	6.612	19.314	404.343	0	222.854	205.689	277.423	0	490.832	0	326.028
March	9.497	19.841	169.774	0	339.586	174.765	375.904	0	451.578	0	300.142
April	13.216	21.752	1.56	284.164	381.462	131.901	395.142	0.024	374.153	0.01	255.362
May	18.437	25.484	0	896.117	369.466	115.589	381.887	1.71	356.314	1.101	245.043
June	23.335	30.093	0	1373.793	412.643	106.434	415.206	0.752	367.942	0.409	254.5
July	25.786	32.956	0	1680.596	398.41	117.91	410.584	0.201	425.893	0.093	292.266
August	25.455	33.612	0	1625.814	348.999	135.405	371.349	0	468.23	0	319.068
September	21.294	30.829	0	1125.873	261.877	161.932	300.551	0	478.264	0	324.307
October	15.952	24.958	0	401.398	266.943	173.763	294.429	0.141	383.527	0.07	260.329
November	11.085	21.394	37.984	0	204.433	189.489	241.718	0	444.223	0	300.085
December	7.369	19.403	428.305	0	154.815	233.664	212.914	0	511.577	0	334.989
Annual Sum or Average	15.4	24.946	1568.122	7387.754	3533.26	1994.707	3910.99	2.827	5306.554	1.683	3575.28

Table 54: Simulation Analysis Results of the Basic Scenario, of the 4th Floor

	SITE OUTDOOR AIR DRY-BULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.285	568.924	0	168.412	249.499	231.539	0	553.57	0	362.654
February	6.612	19.291	434.029	0	219.032	206.704	275.094	0	490.472	0	325.619
March	9.497	19.779	191.327	0	326.648	174.905	366.122	0	449.409	0	298.519
April	13.216	21.566	2.805	261.38	355.016	130.3	372.555	0.041	366.774	0.017	250.564
May	18.437	25.467	0	903.746	368.309	116.366	382.104	1.668	356.33	1.074	245.053
June	23.335	30.132	0	1395.251	410.446	107.859	415.426	0.709	370.417	0.385	256.1
July	25.786	32.98	0	1710.681	396.346	119.222	410.751	0.186	427.744	0.085	293.459
August	25.455	33.601	0	1655.982	347.637	136.335	371.641	0	468.428	0	319.189
September	21.294	30.725	0	1141.822	261.734	161.452	300.716	0	474.198	0	321.673
October	15.952	24.855	0	403.474	264.038	173.371	292.137	0.14	380.851	0.071	258.648
November	11.085	21.181	49.849	0	202.278	186.845	239.212	0	435.5	0	294.274
December	7.369	19.377	469.3	0	151.49	234.883	210.566	0	510.893	0	334.304
Annual Sum or Average	15.4	24.887	1716.234	7472.337	3471.385	1997.741	3867.865	2.744	5284.586	1.632	3560.056

Table 55: Simulation Analysis Results of the Basic Scenario, of the 5th Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.05	1183.928	0	219.08	237.691	268.669	0	543.21	0	354.213
February	6.612	19.096	885.726	0	289.184	198.937	324.901	0	482.559	0	319.176
March	9.497	19.491	450.473	0	436.469	166.451	452.301	0	436.378	0	288.614
April	13.216	21.007	16.292	223.777	461.909	120.917	454.856	0.063	343.199	0.026	235.057
May	18.437	25.448	0	1066.679	428.768	115.093	434.698	1.574	356.176	1.01	245.083
June	23.335	30.148	0	1738.241	465.891	107.937	463.488	0.526	371.808	0.282	257.188
July	25.786	32.943	0	2165.909	445.323	118.059	453.362	0.153	426.585	0.071	292.86
August	25.455	33.357	0	2090.469	397.33	132.065	412.069	0	457.383	0	312.193
September	21.294	30.004	0	1357.266	338.549	149.102	360.325	0	441.929	0	300.902
October	15.952	24.112	0	435.398	353.257	157.482	357.315	0.299	359.183	0.17	245.205
November	11.085	20.215	262.609	0	265.069	166.249	279.7	0	393.232	0	265.418
December	7.369	19.139	1038.595	0	195.477	222.83	243.45	0	500.099	0	325.494
Annual Sum or Average	15.4	24.536	3837.623	9077.739	4296.307	1892.814	4505.134	2.615	5111.742	1.558	3441.404

Table 56: Simulation Analysis Results of the Basic Scenario, of the Staircase _ Unheated space

	SITE OUT-DOOR AIR DRY-BULB TEM-PER-ATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYS-TEM SENSI-BLE HEAT-ING ENER-GY [kWh]	ZONE AIR SYS-TEM SEN-SIBLE COOL-ING ENER-GY [kWh]	ZONE WIN-DOWS TO-TAL HEAT GAIN EN-ERGY [kWh]	ZONE WIN-DOWS TOTAL HEAT LOSS EN-ERGY [kWh]	ZONE WIN-DOWS TOTAL TRANSMITTED SOLAR RADIA-TION ENER-GY [kWh]	ZONE INFIL-TRA-TION SENSI-BLE HEAT GAIN ENER-GY [kWh]	ZONE INFIL-TRA-TION TOTAL HEAT LOSS ENER-GY [kWh]	ZONE VENTI-LATION SENSI-BLE HEAT GAIN ENER-GY [kWh]	ZONE VENTI-LATION TOTAL HEAT LOSS ENER-GY [kWh]
January	6.151	17.321	0	0	0	0	0	0	0	0	0
February	6.612	17.536	0	0	0	0	0	0	0	0	0
March	9.497	18.372	0	0	0	0	0	0	0	0	0
April	13.216	20.423	0	0	0	0	0	0	0	0	0
May	18.437	24.311	0	0	0	0	0	0	0	0	0
June	23.335	28.884	0	0	0	0	0	0	0	0	0
July	25.786	31.816	0	0	0	0	0	0	0	0	0
August	25.455	32.538	0	0	0	0	0	0	0	0	0
September	21.294	29.688	0	0	0	0	0	0	0	0	0
October	15.952	24.18	0	0	0	0	0	0	0	0	0
November	11.085	19.97	0	0	0	0	0	0	0	0	0
December	7.369	17.553	0	0	0	0	0	0	0	0	0
Annual Sum or Average	15.4	23.586	0	0	0	0	0	0	0	0	0

Table 57: Simulation Analysis Results of the Optimistic Scenario, of the Store

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	18.926	373.641	0	0	0	0	0	91.098	0	60.979
February	6.612	18.943	332.67	0	0	0	0	0	80.563	0	54.657
March	9.497	19.082	268.603	0	0	0	0	0.01	70.424	0.005	47.511
April	13.216	19.395	109.913	0	0	0	0	0.506	46.431	0.283	32.393
May	18.437	21.02	0	0	0	0	0	4.397	28.96	2.587	21.394
June	23.335	24.992	0	0.412	0	0	0	4.233	25.897	2.415	19.814
July	25.786	27.697	0	49.442	0	0	0	4.416	32.211	2.576	24.163
August	25.455	28.424	0	54.183	0	0	0	2.087	38.613	1.214	28.561
September	21.294	26.005	0	1.449	0	0	0	0.47	44.626	0.258	32.395
October	15.952	21.793	6.143	0	0	0	0	0.426	48.489	0.232	34.894
November	11.085	19.401	140.481	0	0	0	0	0	60.52	0	41.935
December	7.369	19.041	315.044	0	0	0	0	0	83.973	0	56.13
Annual Sum or Average	15.4	22.081	1546.495	105.485	0	0	0	16.547	651.803	9.571	454.827

Table 58: Simulation Analysis Results of the Optimistic Scenario, of the 1st Floor

	SITE OUTDOOR AIR DRY-BULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.128	925.965	0	176.331	235.765	233.91	0	542.913	0	354.452
February	6.612	19.123	760.389	0	229.235	194.523	277.448	0	479.984	0	317.493
March	9.497	19.433	410.844	0	350.743	161.173	375.949	0.009	430.309	0.003	284.462
April	13.216	20.661	20.798	0	400.417	113.546	395.17	0.322	325.233	0.15	222.878
May	18.437	24.284	0	61.261	392.572	96.832	381.887	4.234	300.308	2.539	208.518
June	23.335	28.906	0	553.441	436.841	89.311	415.206	2.105	313.046	1.171	218.75
July	25.786	31.806	0	936.284	422.471	99.968	410.584	1.391	369.736	0.703	255.695
August	25.455	32.528	0	903.741	370.426	116.842	371.349	0.018	414.881	0.011	284.392
September	21.294	29.775	0	377.799	279.763	141.912	300.551	0	428.599	0	292.039
October	15.952	24.367	0	29.683	278.116	157.333	294.455	0.259	366.898	0.144	250.015
November	11.085	20.579	126.274	0	215.007	169.225	241.745	0	406.548	0	274.78
December	7.369	19.223	786.394	0	159.308	220.905	212.94	0	500.346	0	326.19
Annual Sum or Average	15.4	24.183	3030.664	2862.208	3711.23	1797.337	3911.192	8.336	4878.801	4.722	3289.664

Table 59: Simulation Analysis Results of the Optimistic Scenario, of the 2nd Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.297	538.832	0	173.289	245.51	233.987	0	552.714	0	362.235
February	6.612	19.303	414.454	0	225.028	203.281	277.525	0	489.589	0	325.144
March	9.497	19.815	177.323	0	342.678	172.38	376.085	0	449.583	0	298.753
April	13.216	21.668	2.164	0	384.9	129.452	395.303	0.031	369.665	0.012	252.416
May	18.437	25.39	0	150.741	372.992	113	381.887	1.856	351.328	1.183	241.807
June	23.335	29.987	0	686.638	416.701	103.95	415.206	0.853	362.537	0.465	250.983
July	25.786	32.852	0	995.444	402.53	115.271	410.584	0.262	420.098	0.123	288.491
August	25.455	33.529	0	951.555	352.617	132.821	371.349	0	463.552	0	316.046
September	21.294	30.753	0	479.933	265.115	159.186	300.551	0	474.092	0	321.624
October	15.952	24.924	0	87.813	269.407	171.099	294.531	0.148	381.805	0.074	259.231
November	11.085	21.328	40.881	0	206.689	186.383	241.828	0	440.553	0	297.67
December	7.369	19.392	439.832	0	156.343	230.881	213.017	0	510.217	0	334.023
Annual Sum or Average	15.4	24.887	1613.486	3352.124	3568.288	1963.213	3911.852	3.149	5265.732	1.857	3548.421

Table 60: Simulation Analysis Results of the Optimistic Scenario, of the 3rd Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.308	521.94	0	171.755	248.25	233.884	0	554.166	0	363.278
February	6.612	19.317	400.327	0	222.824	205.794	277.423	0	491.014	0	326.176
March	9.497	19.851	166.76	0	339.468	174.972	375.904	0	452.05	0	300.481
April	13.216	21.821	1.227	0	380.578	132.884	395.142	0.018	377.037	0.007	257.22
May	18.437	25.619	0	170.233	367.417	117.446	381.887	1.534	362.501	1.003	249.047
June	23.335	30.224	0	699.633	410.591	108.085	415.206	0.648	373.903	0.351	258.341
July	25.786	33.079	0	1000.086	396.433	119.589	410.584	0.156	431.61	0.071	295.936
August	25.455	33.743	0	954.906	347.09	137.341	371.349	0	474.461	0	323.081
September	21.294	30.939	0	487.064	260.539	163.707	300.551	0	483.302	0	327.56
October	15.952	24.992	0	93.084	266.554	174.504	294.429	0.141	384.43	0.07	260.89
November	11.085	21.446	35.867	0	203.98	190.485	241.718	0	446.513	0	301.599
December	7.369	19.406	423.796	0	154.796	233.795	212.914	0	511.777	0	335.151
Annual Sum or Average	15.4	25.013	1549.917	3405.006	3522.022	2006.852	3910.99	2.497	5342.764	1.502	3598.762

Table 61: Simulation Analysis Results of the Optimistic Scenario, of the 4th Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	**ZONE MEAN AIR TEMPERATURE [C]**	**ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]**	**ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]**	**ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]**	**ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]**	**ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]**	**ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]**	**ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]**	**ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]**	**ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]**
January	6.151	19.294	550.907	0	168.342	249.853	231.539	0	554.158	0	363.136
February	6.612	19.305	417.545	0	218.909	207.104	275.094	0	491.153	0	326.173
March	9.497	19.812	180.098	0	326.246	175.614	366.122	0	450.997	0	299.665
April	13.216	21.734	1.668	0	352.848	132.716	372.555	0.024	373.962	0.01	255.234
May	18.437	25.767	0	183.614	363.721	120.524	382.104	1.328	370.058	0.883	253.938
June	23.335	30.385	0	713.647	406.438	111.092	415.426	0.52	381.905	0.28	263.514
July	25.786	33.234	0	1023.815	392.216	122.722	410.751	0.108	439.7	0.049	301.165
August	25.455	33.865	0	980.284	343.751	140.254	371.641	0	480.932	0	327.245
September	21.294	30.943	0	498.033	259.03	165.013	300.716	0	484.201	0	328.133
October	15.952	24.942	0	94.077	263.067	175.254	292.137	0.136	383.389	0.069	260.239
November	11.085	21.284	44.264	0	201.366	188.891	239.212	0	440.112	0	297.335
December	7.369	19.386	454.539	0	151.43	235.249	210.566	0	511.462	0	334.765
Annual Sum or Average	15.4	25.031	1649.022	3493.469	3447.362	2024.287	3867.865	2.117	5362.027	1.29	3610.54

Table 62: Simulation Analysis Results of the Optimistic Scenario, of the 5th Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.13	894.443	0	218.095	241.161	268.669	0	548.755	0	358.75
February	6.612	19.187	612.087	0	287.831	202.256	324.901	0	488.035	0	323.67
March	9.497	19.734	298.793	0	433.162	171.674	452.301	0	448.275	0	297.27
April	13.216	21.729	7.241	0	452.476	130.905	454.856	0	374.815	0	255.989
May	18.437	26.518	0	299.108	411.93	129.627	434.698	0.706	405.695	0.505	277.35
June	23.335	30.941	0	930.225	452.997	117.842	463.488	0.025	408.306	0.012	280.931
July	25.786	33.864	0	1364.424	429.969	130.448	453.362	0.004	470.756	0.002	321.564
August	25.455	34.233	0	1304.99	383.954	144.588	412.069	0	498.665	0	338.872
September	21.294	30.763	0	651.008	329.034	160.915	360.325	0	476.961	0	323.703
October	15.952	24.481	0	110.443	348.634	164.721	357.315	0.2	367.947	0.11	250.556
November	11.085	20.528	148.806	0	262.119	172.803	279.7	0	407.757	0	275.446
December	7.369	19.197	825.259	0	194.826	225.483	243.45	0	504.219	0	328.845
Annual Sum or Average	15.4	25.063	2786.629	4660.198	4205.027	1992.423	4505.134	0.934	5400.187	0.63	3632.945

Table 63: Simulation Analysis Results of the Optimistic Scenario, of the Staircase _ Unheated space

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	17.378	0	0	0	0	0	0	0	0	0
February	6.612	17.6	0	0	0	0	0	0	0	0	0
March	9.497	18.449	0	0	0	0	0	0	0	0	0
April	13.216	20.611	0	0	0	0	0	0	0	0	0
May	18.437	24.632	0	0	0	0	0	0	0	0	0
June	23.335	29.144	0	0	0	0	0	0	0	0	0
July	25.786	32.096	0	0	0	0	0	0	0	0	0
August	25.455	32.817	0	0	0	0	0	0	0	0	0
September	21.294	29.919	0	0	0	0	0	0	0	0	0
October	15.952	24.301	0	0	0	0	0	0	0	0	0
November	11.085	20.086	0	0	0	0	0	0	0	0	0
December	7.369	17.597	0	0	0	0	0	0	0	0	0
Annual Sum or Average	15.4	23.756	0	0	0	0	0	0	0	0	0

Table 64: Simulation Analysis Results of the Upgraded Building Scenario, of the Store

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	18.978	330.358	0	0	0	0	0	91.479	0	61.289
February	6.612	18.981	295.411	0	0	0	0	0	80.818	0	54.862
March	9.497	19.136	235.905	0	0	0	0	0.01	70.888	0.005	47.891
April	13.216	19.432	93.806	0	0	0	0	0.491	46.636	0.272	32.559
May	18.437	21.06	0	0	0	0	0	4.337	29.226	2.553	21.585
June	23.335	25.03	0	0.6	0	0	0	4.178	26.155	2.386	19.992
July	25.786	27.781	0	54.705	0	0	0	4.265	32.798	2.486	24.564
August	25.455	28.622	0	59.578	0	0	0	1.883	40.132	1.099	29.583
September	21.294	26.355	0	3.033	0	0	0	0.336	47.275	0.184	34.174
October	15.952	22.15	1.726	0	0	0	0	0.324	51.14	0.177	36.749
November	11.085	19.491	115.017	0	0	0	0	0	61.199	0	42.479
December	7.369	19.096	279.4	0	0	0	0	0	84.382	0	56.467
Annual Sum or Average	15.4	22.198	1351.624	117.916	0	0	0	15.826	662.126	9.162	462.194

Table 65: Simulation Analysis Results of the Upgraded Building Scenario, of the 1st Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.184	814.137	0	128.38	228.805	188.099	0	545.231	0	356.297
February	6.612	19.164	682.506	0	169.309	187.963	222.472	0	481.435	0	318.634
March	9.497	19.471	367.896	0	266.709	154.823	300.914	0.009	432.229	0.004	285.995
April	13.216	20.648	19.648	0	311.69	107.832	316.221	0.371	323.88	0.173	221.956
May	18.437	24.117	0	49.237	309.278	90.125	305.996	4.857	292.876	2.889	203.764
June	23.335	28.693	0	514.127	345.441	81.75	332.699	2.532	303.395	1.412	212.561
July	25.786	31.632	0	873.546	333.045	92.307	328.975	1.748	361.403	0.898	250.333
August	25.455	32.47	0	847.969	288.65	109.456	297.486	0.049	411.977	0.033	282.561
September	21.294	29.933	0	370.097	212.607	136.585	240.634	0	435.877	0	296.835
October	15.952	24.552	0	35.09	212.126	153.466	235.809	0.219	371.669	0.119	252.971
November	11.085	20.823	87.568	0	160.977	165.65	194.246	0	417.221	0	282.106
December	7.369	19.275	685.312	0	116.078	214.627	171.293	0	502.691	0	328.065
Annual Sum or Average	15.4	24.195	2657.066	2690.066	2854.291	1723.388	3134.844	9.786	4879.885	5.529	3292.079

Table 66: Simulation Analysis Results of the Upgraded Building Scenario of the 2nd Floor

	SITE OUTDOOR AIR DRY-BULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.324	500.79	0	126.034	237.167	188.161	0	553.939	0	363.208
February	6.612	19.32	400.146	0	166.024	195.677	222.534	0	490.131	0	325.565
March	9.497	19.804	176.94	0	259.996	164.593	301.023	0	449.293	0	298.656
April	13.216	21.54	2.665	0	298.659	121.748	316.328	0.054	363.19	0.022	248.144
May	18.437	25.145	0	123.872	292.36	104.964	305.996	2.318	340.115	1.446	234.641
June	23.335	29.685	0	624.43	328.112	94.828	332.699	1.157	348.675	0.634	242.098
July	25.786	32.568	0	918.592	316.09	105.713	328.975	0.468	406.422	0.223	279.694
August	25.455	33.333	0	881.356	273.998	123.131	297.486	0	454.036	0	309.955
September	21.294	30.742	0	447.466	200.766	150.96	240.634	0	473.683	0	321.467
October	15.952	24.973	0	82.676	205.423	164.361	235.871	0.147	383.657	0.073	260.45
November	11.085	21.492	32.707	0	154.055	180.854	194.312	0	447.719	0	302.538
December	7.369	19.424	403.573	0	113.759	223.511	171.355	0	511.8	0	335.288
Annual Sum or Average	15.4	24.812	1516.82	3078.392	2735.277	1867.508	3135.373	4.143	5222.661	2.398	3521.705

Table 67: Simulation Analysis Results of the Upgraded Building Scenario, of the 3rd Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	**ZONE MEAN AIR TEMPERATURE [C]**	**ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]**	**ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]**	**ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]**	**ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]**	**ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]**	**ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]**	**ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]**	**ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]**	**ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]**
January	6.151	19.33	491.346	0	124.718	239.794	188.079	0	555.136	0	364.046
February	6.612	19.329	392.139	0	164.104	198.082	222.452	0	491.276	0	326.371
March	9.497	19.826	170.636	0	257.185	166.909	300.878	0	451.096	0	299.904
April	13.216	21.646	1.874	0	295.231	124.459	316.198	0.04	368.514	0.016	251.617
May	18.437	25.31	0	137.022	288.108	108.464	305.996	2.015	348.39	1.272	240.005
June	23.335	29.86	0	632.44	323.399	98.073	332.699	0.979	357.259	0.535	247.656
July	25.786	32.73	0	920.141	311.358	109.049	328.975	0.349	414.808	0.165	285.121
August	25.455	33.479	0	881.727	269.742	126.564	297.486	0	461.703	0	314.906
September	21.294	30.862	0	450.236	197.11	154.395	240.634	0	479.907	0	325.483
October	15.952	25.009	0	85.28	203.068	167.118	235.789	0.141	385.371	0.07	261.541
November	11.085	21.574	29.69	0	151.893	184.288	194.224	0	452.074	0	305.403
December	7.369	19.433	393.545	0	112.458	226.326	171.273	0	513.123	0	336.223
Annual Sum or Average	15.4	24.899	1479.23	3106.845	2698.373	1903.52	3134.682	3.524	5278.657	2.058	3558.275

Table 68: Simulation Analysis Results of the Upgraded Building Scenario, of the 4th Floor

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.32	510.291	0	121.961	241.701	186.199	0	555.34	0	364.073
February	6.612	19.321	402.626	0	160.875	199.676	220.586	0	491.635	0	326.542
March	9.497	19.799	179.348	0	246.328	167.911	293.089	0	450.65	0	299.523
April	13.216	21.582	2.24	0	272.788	124.646	298.36	0.047	366.477	0.019	250.3
May	18.437	25.416	0	145.637	285.258	110.91	306.17	1.795	354.021	1.146	243.649
June	23.335	29.993	0	639.935	319.956	100.625	332.874	0.851	363.989	0.463	252.008
July	25.786	32.845	0	931.405	307.964	111.565	329.108	0.281	421.013	0.132	289.134
August	25.455	33.562	0	893.42	267.082	128.847	297.716	0	466.384	0	317.926
September	21.294	30.855	0	455.243	195.749	155.532	240.766	0	480.287	0	325.723
October	15.952	24.969	0	85.527	200.103	168.105	233.952	0.135	384.783	0.067	261.185
November	11.085	21.453	35.215	0	149.563	183.669	192.215	0	447.471	0	302.336
December	7.369	19.418	413.393	0	109.77	228.155	169.391	0	513.112	0	336.083
Annual Sum or Average	15.4	24.912	1543.112	3151.167	2637.397	1921.342	3100.427	3.109	5295.163	1.827	3568.484

Table 69: Simulation Analysis Results of the Upgraded Building Scenario, of the 5th Floor

	SITE OUTDOOR AIR DRY-BULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	19.207	724.974	0	160.033	235.107	216.125	0	552.3	0	361.573
February	6.612	19.247	513.439	0	214.218	195.888	260.649	0	490.468	0	325.577
March	9.497	19.805	244.414	0	330.468	166.016	361.925	0	451.878	0	300.095
April	13.216	21.724	5.248	0	350.664	125.125	363.768	0.002	373.711	0.001	255.317
May	18.437	26.205	0	239.401	321.138	120.04	348.293	0.884	391.229	0.617	268.131
June	23.335	30.612	0	796.219	354.78	107.969	371.362	0.185	393.076	0.095	271.209
July	25.786	33.464	0	1170.248	336.653	118.861	363.221	0.027	451.485	0.013	309.227
August	25.455	33.904	0	1124.621	298.583	132.714	330.071	0	483.366	0	329.182
September	21.294	30.693	0	563.901	251.402	151.834	288.347	0	473.817	0	321.842
October	15.952	24.592	0	100.286	267.296	159.294	286.151	0.16	373.472	0.085	254.194
November	11.085	20.799	100.039	0	196.768	169.96	224.823	0	419.656	0	283.687
December	7.369	19.283	645.739	0	142.523	220.54	195.878	0	508.441	0	332.232
Annual Sum or Average	15.4	24.997	2233.853	3994.678	3224.525	1903.349	3610.611	1.257	5362.899	0.811	3612.265

Table 70: Simulation Analysis Results of the Upgraded Building Scenario, of the Staircase _ Unheated space

	SITE OUTDOOR AIR DRYBULB TEMPERATURE [C]	ZONE MEAN AIR TEMPERATURE [C]	ZONE AIR SYSTEM SENSIBLE HEATING ENERGY [kWh]	ZONE AIR SYSTEM SENSIBLE COOLING ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT GAIN ENERGY [kWh]	ZONE WINDOWS TOTAL HEAT LOSS ENERGY [kWh]	ZONE WINDOWS TOTAL TRANSMITTED SOLAR RADIATION ENERGY [kWh]	ZONE INFILTRATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE INFILTRATION TOTAL HEAT LOSS ENERGY [kWh]	ZONE VENTILATION SENSIBLE HEAT GAIN ENERGY [kWh]	ZONE VENTILATION TOTAL HEAT LOSS ENERGY [kWh]
January	6.151	17.671	0	0	0	0	0	0	0	0	0
February	6.612	17.842	0	0	0	0	0	0	0	0	0
March	9.497	18.618	0	0	0	0	0	0	0	0	0
April	13.216	20.632	0	0	0	0	0	0	0	0	0
May	18.437	24.441	0	0	0	0	0	0	0	0	0
June	23.335	28.921	0	0	0	0	0	0	0	0	0
July	25.786	31.878	0	0	0	0	0	0	0	0	0
August	25.455	32.699	0	0	0	0	0	0	0	0	0
September	21.294	30.032	0	0	0	0	0	0	0	0	0
October	15.952	24.52	0	0	0	0	0	0	0	0	0
November	11.085	20.451	0	0	0	0	0	0	0	0	0
December	7.369	17.875	0	0	0	0	0	0	0	0	0
Annual Sum or Average	15.4	23.834	0	0	0	0	0	0	0	0	0