Project Documentation

1 Abstract

Apartment 03 in Nafplio, Argolis, Greece

1.1 Data of building

Year of construction	2021	**Space heating**	**13 kWh/(m^{2}a)**
U-value external wall	0.225 W/(m^{2}K)		
U-value floor slab	0.833 W/(m^{2}K)	**Primary Energy Renewable (PER)**	47 kWh/(m^{2}a)
U-value roof / ceiling	0.138 W/(m^{2}K)	**Generation of renewable energy**	4 kWh/(m^{2}a)
U-value window	0.98 W/(m^{2}K) Including thermal bridges	**Non-renewable Primary Energy (PE)**	91 kWh/(m^{2}a)
Heat recovery	80 % Ground floor 78 % First floor	Pressure test n_{50}	0.6 h-1
Special features	Solar collectors and heat pump for hot water generation, heat recovery taking advantage of geothermal energy for the residence.		

1.2 Brief Description

Passive House in Nafplio, Argolis

The project concerns the renovation of an existing house from the 60s to which an addition by extension and in height was made. The residence is located at the base of the Acronafplia Castle walls in Nafplio, Greece.

The purpose of the proposal was the implementation of a project with a proper architectural design, with respect to the history of the place but at the same time a project with a low energy footprint, which would meet the Passive House certification standards.

Due to the location of the project, which is classified as an archaeological site, there were limitations both during the planning and the implementation.

There were restrictions on the form, permitted heights and choice of building materials by the archeology department. There were difficulties in accessing the project and transporting materials and equipment. There were static problems in the existing part of the building but also limitations in the energy design due to the northern orientation of the building and the shading of the southern face.

The result of the completion of the project was two independent apartments, one on the ground floor and one on the first floor with an area of 128 and 80 m^2 respectively. Each property has its own independent system for heating and cooling, and mechanical ventilation systems. A subsoil heat exchanger has been introduced to reduce the cooling needs during the summer season. The domestic hot water production system is shared and consists of a heat pump and solar panels.

The project was completed in 2021 and certified in August 2023 by the Hellenic Passive Building Institute.

1.2 Σύντομη περιγραφή έργου

Παθητικό κτήριο στο Ναύπλιο, Αργολίδα

Το έργο αφορά την ανακαίνιση υφιστάμενης κατοικίας της δεκαετίας του 60, στην οποία έγινε προσθήκη κατ' επέκταση και προσθήκη καθ' ύψος. Η κατοικία βρίσκεται στην παλαιά πόλη του Ναυπλίου, στους πρόποδες των τειχών του κάστρου της Ακροναυπλίας.

Σκοπός της πρότασης, ήταν η υλοποίηση ενός έργου με άρτιο αρχιτεκτονικά σχεδιασμό, με σεβασμό στην ιστορία του τόπου αλλά παράλληλα και ένα έργο με χαμηλό ενεργειακό αποτύπωμα, το οποίο θα πληρούσε τα κριτήρια πιστοποίησης ενός Παθητικού Κτηρίου.

Λόγω της θέσης του έργου, η οποία είναι χαρακτηρισμένη ως αρχαιολογικός χώρος, υπήρξαν περιορισμοί τόσο κατά την διάρκεια του σχεδιασμού αλλά και της υλοποίησης.

Υπήρξαν περιορισμοί στη μορφή, στα επιτρεπόμενα ύψη και στην επιλογή των δομικών υλικών του κτηρίου από το τμήμα αρχαιολογίας. Υπήρξαν δυσκολίες πρόσβασης στο έργο και στην μεταφορά υλικών και εξοπλισμού. Υπήρξαν στατικά προβλήματα στο υφιστάμενο τμήμα του κτηρίου αλλά και περιορισμοί στον ενεργειακό σχεδιασμό λόγω του βόρειου προσανατολισμού του κτηρίου και την σκίαση της νότιας όψης.

Με την ολοκλήρωση του έργου, προέκυψαν δύο ανεξάρτητα διαμερίσματα, ένα στο ισόγειο και ένα στον όροφο με εμβαδά 128 και 80 m^2 αντίστοιχα. Η κάθε ιδιοκτησία διαθέτει ανεξάρτητο σύστημα θέρμανσης και ψύξης και ανεξάρτητο σύστημα μηχανικού αερισμού με ανάκτηση θερμότητας. Έχει εφαρμοστεί σύστημα αεροθερμίας για την μείωση των αναγκών σε ψύξη κατά την θερινή περίοδο. Το σύστημα παραγωγής ζεστού νερού χρήσης είναι κοινόχρηστο και αποτελείται από αντλία θερμότητας και ηλιακούς συλλέκτες.

Το έργο ολοκληρώθηκε το 2021 και πιστοποιήθηκε τον Αύγουστο του 2023 από το Ελληνικό Ινστιτούτο Παθητικού Κτηρίου.

1.3 Responsible project participants

Architect	Panagiotis (Panos) Papasotiriou, Studio 2Pi Architecture https://www.s2pia.com/
Implementation planning	Panagiotis (Panos) Papasotiriou, Studio 2Pi Architecture https://www.s2pia.com/
Building systems	Pavlos Michos, 02 Architecture & Mech. Engineering https://www.0-2.gr/
Structural engineering	Giorgos Taraviras
Building physics	Pavlos Michos, 02 Architecture & Mech. Engineering https://www.0-2.gr/ , Aggeliki Stathopoulou, NetZero https://www.netzero.gr/
Passive House project planning	Pavlos Michos, 02 Architecture & Mech. Engineering https://www.0-2.gr/
Construction management	Panagiotis (Panos) Papasotiriou, Studio 2Pi Architecture https://www.s2pia.com/

Certifying body	Hellenic Passive House Institute https://eipak.org/		
Certification ID	38998-38999_HPHI_PH_20230623_SPA	Project-ID (www.passivehouse-database.org)	6346

Author of project documentation	Pavlos Michos, 02 Architecture & Mech. Engineering https://www.0-2.gr/
Date, Signature	Nafplio, 19/12/2023

2 Elevation view of the building (photo)

2.1 Existing building

Picture 1: North view of the existing building.

Picture 2: East view of the existing building.


Picture 3: West view of the existing building.

2.2 New construction


Picture 4: North view of the new construction.

Picture 5: North - West view of the new construction.

Picture 6: North - East view of the new construction.

Picture 7: South - East view of the new construction.

Picture 8: Top view of the new construction.

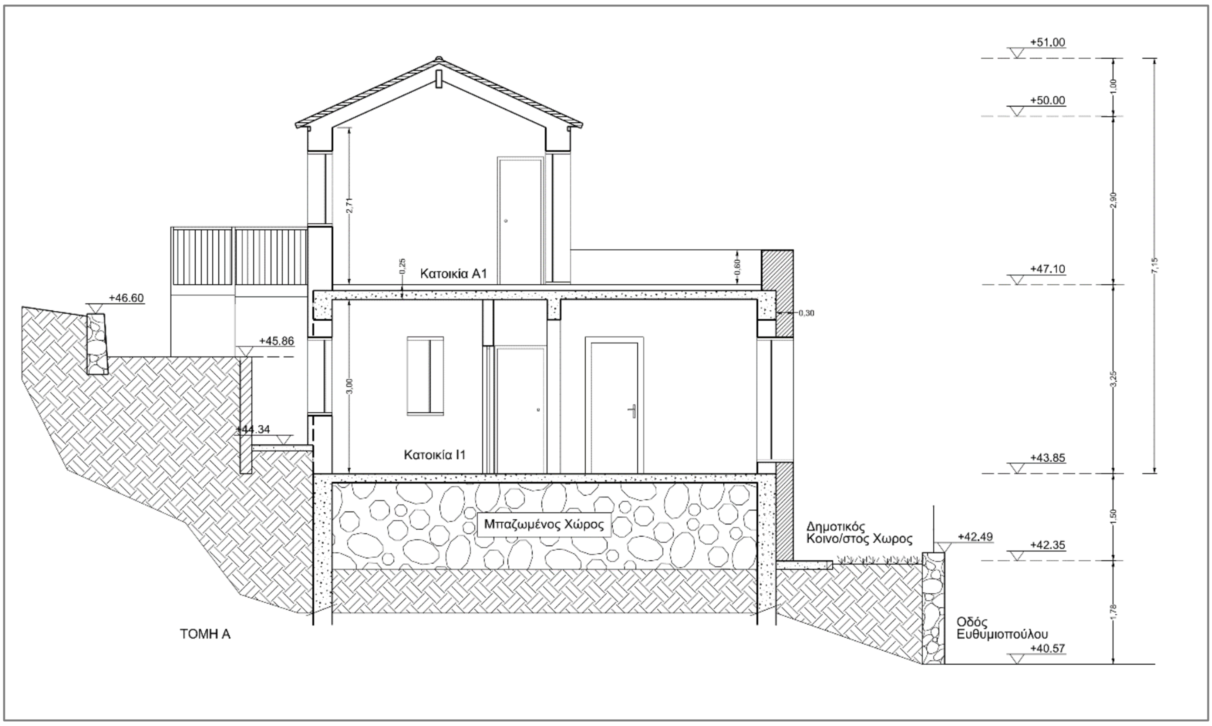
3 Exemplary photo from the inside of the building

Picture 9: Kitchen, first floor

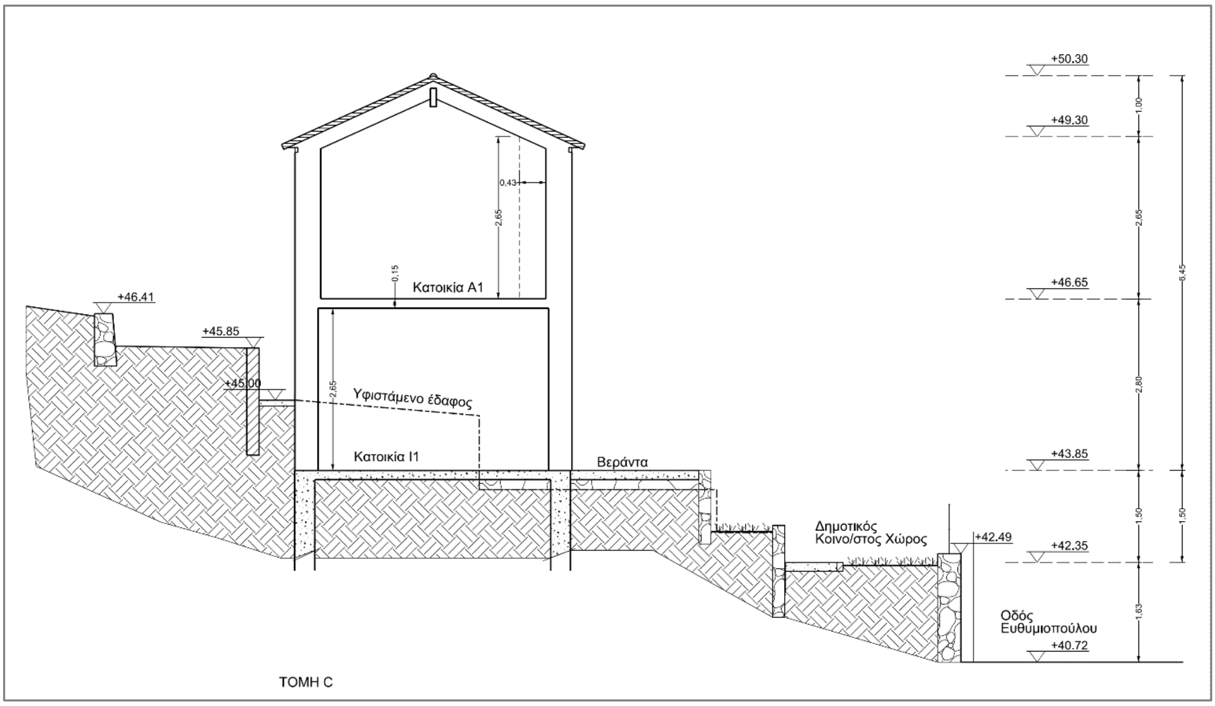
Picture 10: Bedroom 1, first floor

4 Project Sections

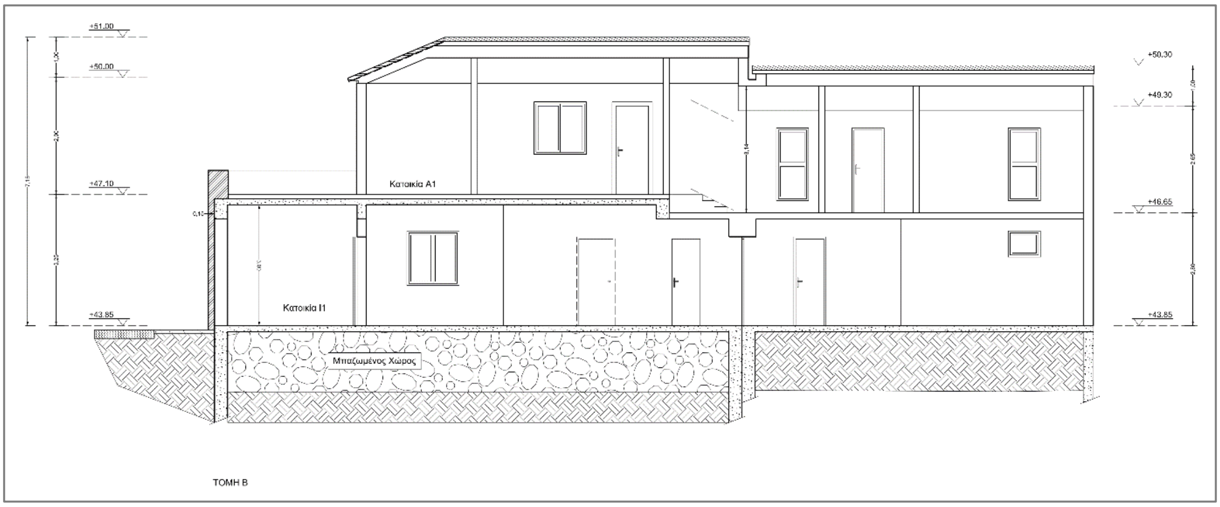
The renovated part of the building on the ground floor and the new extension in height of the first floor are shown in section A (Picture 11). The two-story new construction to the left is shown in section C (Picture 12).



Picture 11: Section A.



Picture 12: Section C.

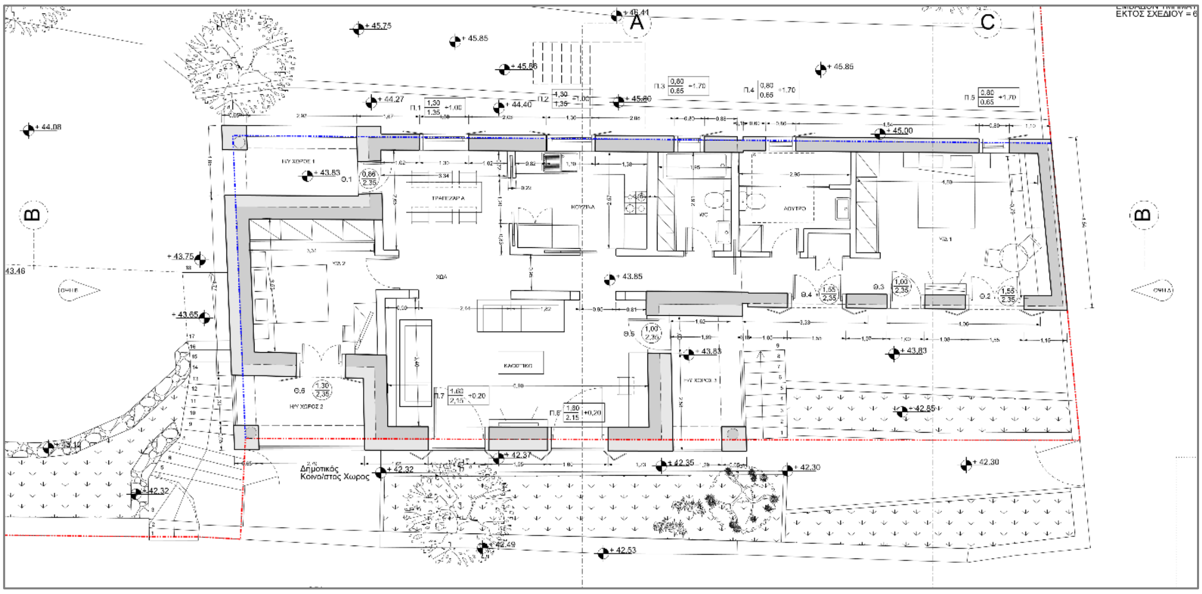


Picture 13: Section B.

The renovated existing part of the building and the new construction are shown in section B (Picture 13). The insulation was implemented on the walls and roofs externally without any interruption. On the other hand, the insulation of the ground floor slab is placed above the slab due to the existing status. Measures have been taken to minimize thermal bridges.

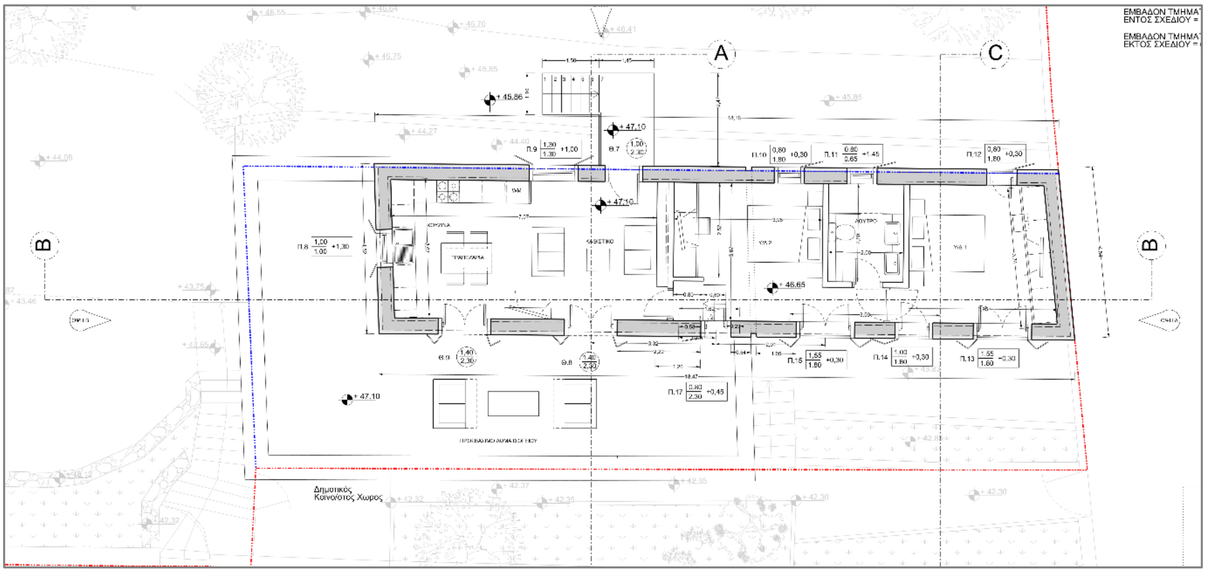
5 Project Floor Plans

The ground floor apartment of the building comprises of the renovated existing building on the left and the new ground floor extension to the right. It consists of a living room, a dining room, a kitchen, two bedrooms, and two bathrooms. The total floor area is 128 m^2. The apartment has two entrances: one on the east and another one on the west.



Picture 14: Ground floor plan.

The apartment of the first floor is a new construction and consists of a kitchen, a living room, two bedrooms, and a bathroom. The total floor area is 80 m^2. The main entrance is located on the south.



Picture 15: First floor plan.

6 Construction of floor slab / basement ceiling

Internal insulation of 3 cm thick eps 250 (λ=0.033 W/mK) has been applied to the ground floor of the building due to the existing construction. The final U-value of the ground floor is 0.833 [W/m2K].

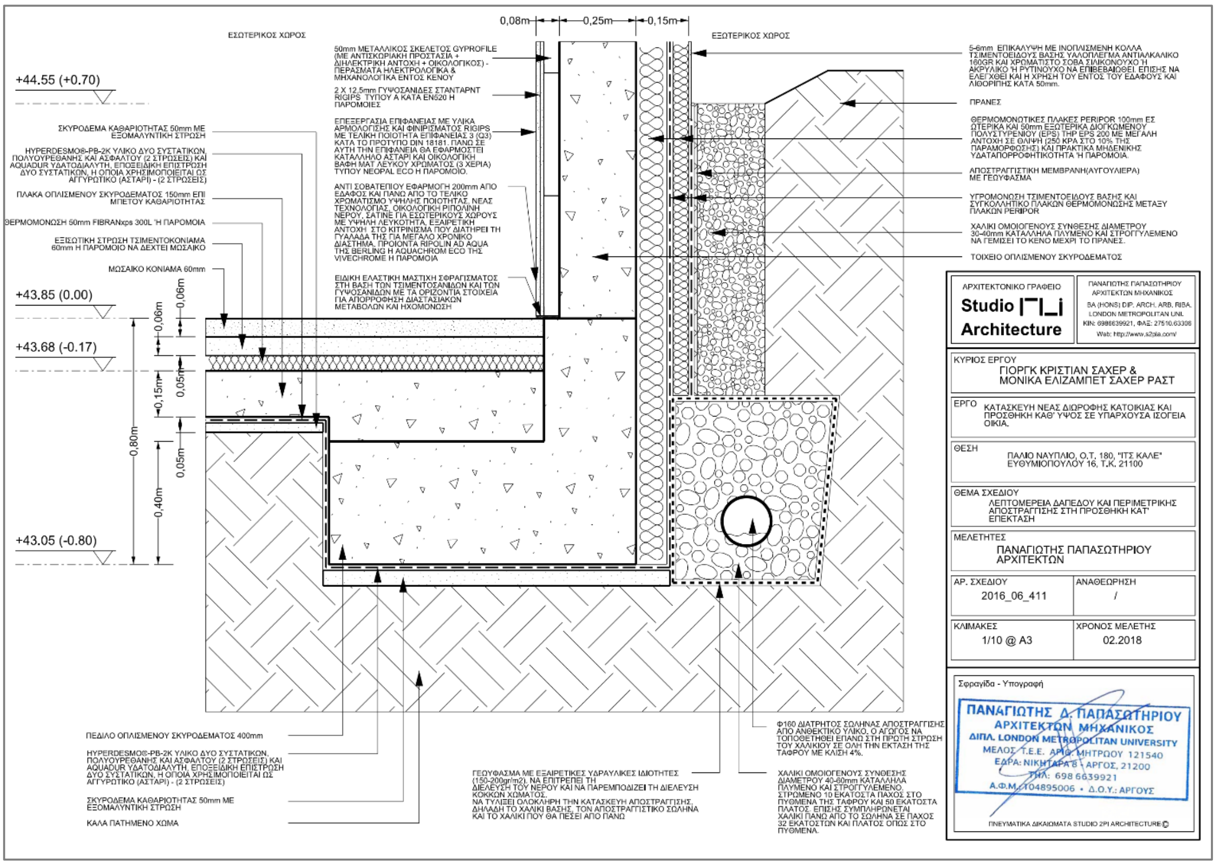
Picture 16: Ground floor insulation, existing building.

Picture 17: Ground floor insulation, new construction.

Insulation of 10 cm eps 250 (λ=0.033 W/m^{2}K) applied to the basement walls of the new construction to minimize the thermal bridges of the assembly between the floor slab and the and the external walls.

Picture 18: Basement wall insulation, north view new construction.

The picture below shows a section detail drawing of the new ground floor attached to the ground.



Picture 19: Section detail, new construction.

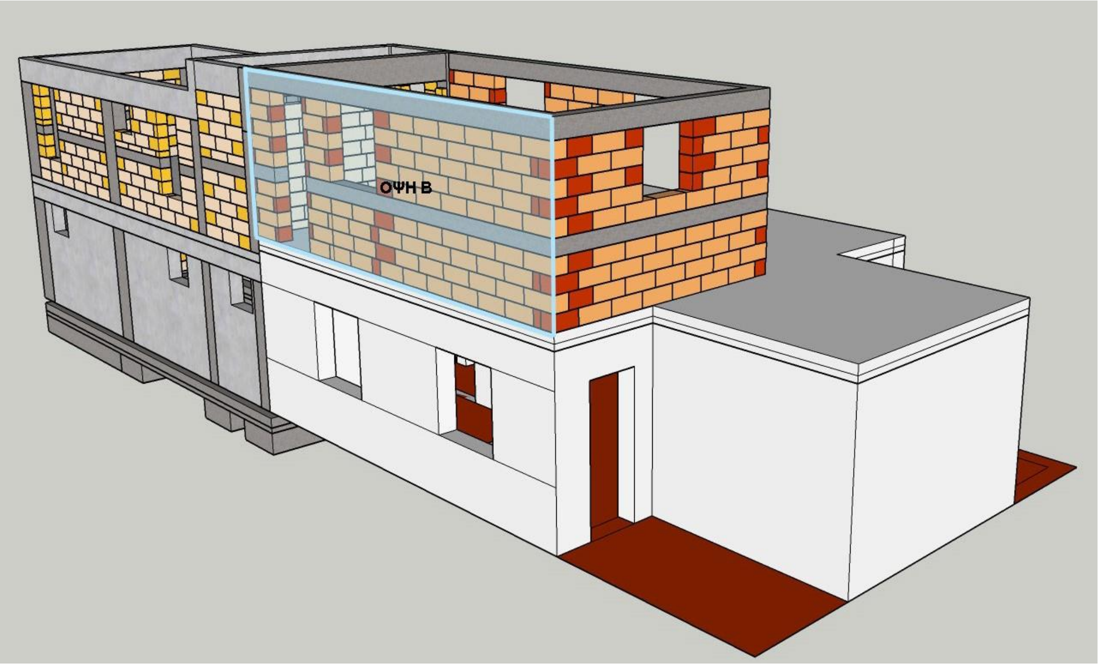
7 Construction of the exterior walls

The existing construction had a typical exterior wall assembly consisting of 25 cm thick uninsulated brick walls plastered on each side with an estimated U-value at 2.20 [W/m^{2}K]. The existing walls were renovated and insulated externally with 10 cm eps graphite insulation (λ=0.030 W/m^{2}K) and cladded with 20 cm stone, giving a final U-value of 0.233 [W/m^{2}K]. Insulation also applied to the reinforced concrete structure of the building, giving a final U-value of 0.283 [W/m^{2}K] for beams and columns.

Picture 20: External brick walls renovation.

Picture 21: External brick walls.

The wall assemblies of the new construction vary as shown on the picture below:



Picture 22: Wall assemblies of both existing and new construction, south view.

Thermal blocks (YTONG) 25 cm thick used for the extension in height above the existing building, and 10 cm eps graphite applied externally, giving a U-value of 0.180 [W/m^{2}K].

Thermal blocks 20 cm thick are filling the walls of the two-story extension and 10 cm eps graphite applied externally, giving a U-value of 0.181 [W/m^{2}K]. The new construction has a reinforced concrete frame as well as a concrete wall to the south view of the ground floor where 10 cm eps graphite applied externally, giving a U-value of 0.261 [W/m^{2}K].

Picture 23: Thermal blocks extension in height, south view.

Picture 24: Wall insulation, south view.

Internal insulation has been applied to the part of the south wall of the existing building which is attached to the ground. The insulation has been expanded 70 cm above the ground level to minimize thermal bridges. The final U-value of the assembly is 0.248 [W/m^{2}K].

Picture 25: Basement wall insulation, internal insulation existing construction.

8 Construction roof / ceiling of the top floor

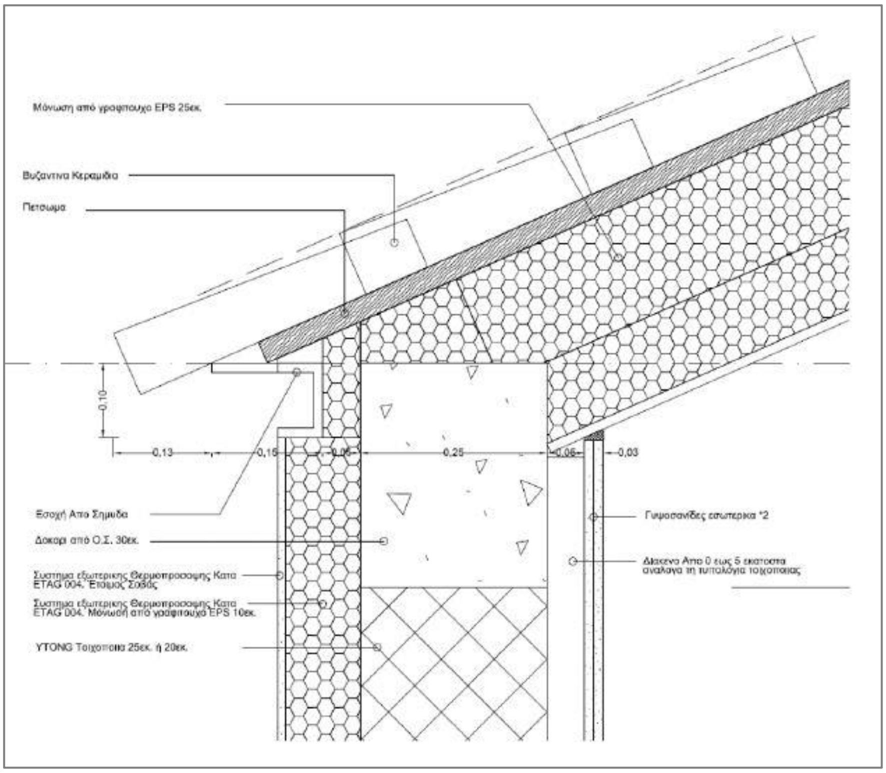
Thermal insulation 15 cm thick eps graphite (λ=0.030 W/mK) has been applied to the exposed ceiling of the ground floor apartment, giving a U-value of 0.187 [W/m^2K]. The projected elements of the building have been covered with 5 cm xps insulation (λ=0.035 W/mK) to minize thermal bridges.

Picture 26: Ceilng, ground floor, existing building.

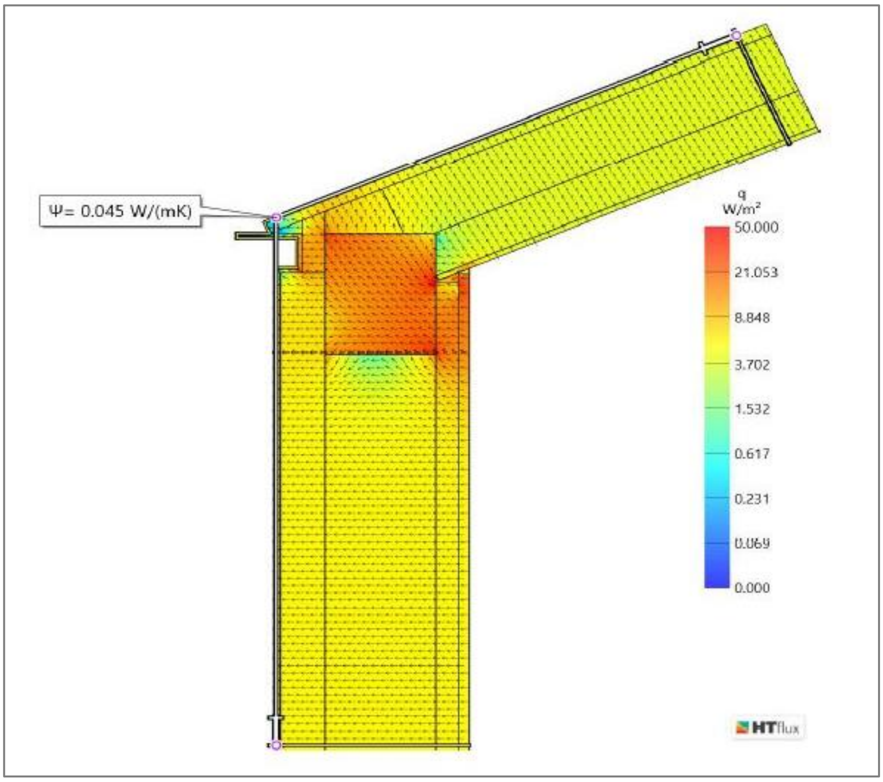
Thermal insulation of 25 cm thick eps graphite (λ=0.030 W/mK) has been applied to the roof of the first floor apartment, giving a U-value of 0.111 [W/m^2K].

Picture 27: Roof, first floor apartment.

A reduction of insulation thickness at the upper part of the external wall is shown on the section detail drawing below. The thermal bridge has been calculated (Picture 30) and has been considered during phpp calculations.



Picture 28: Section detail, roof.



Picture 29: Thermal bridge calculation, roof.

9 Windows

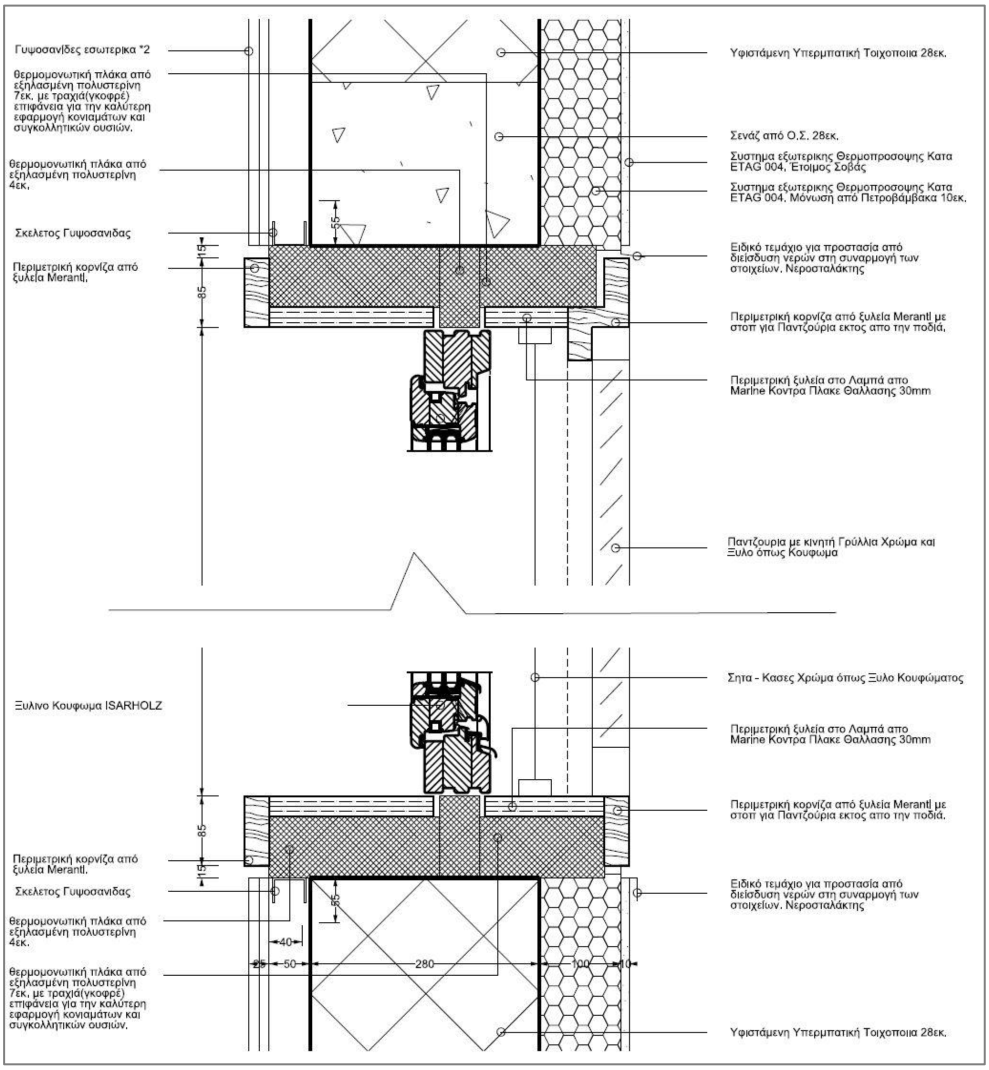
Wooden framed, triple glazed, single or double opening windows ISARHOLZ FENSTER INO-80 (4/14/4/14/4) have been chosen due to the historical location of the building. The windows technical specifications are as follows: Uf=1.20 [W/m^{2}K], Ug=0.60 [W/m^{2}K]. The total window surface of the building is 23.64 m^2 where more than 75% of the windows surface is facing the north, leading to unwanted heat losses during the winter period. Hence, to increase the solar radiation, the highest available g-value in the market for three glazed windows has been chosen (i.e. g=0.60).

Wooden opaque doors INO-80 have been installed with a U-value of 0.865 [W/m^{2}K].

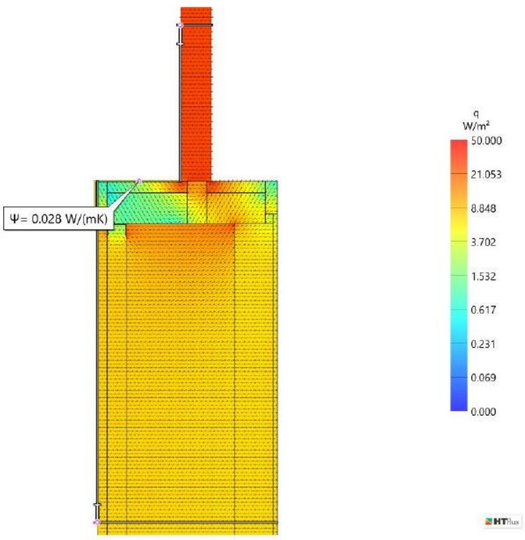
The heat gains increased, although the transmission losses through the windows during the heating period remain higher than gains. The average U-value of the windows, including thermal bridges due to installation, equals 0.98 [W/m^{2}K].

Picture 30: Triple glazed, wooden framed windows and opaque wooden door.

A section detail of the windows installation is shown below. The thermal bridges have been calculated and are included in the phpp calculations.



Picture 31: Section detail of windows installation.



Picture 32: Windows thermal bridge calculation.

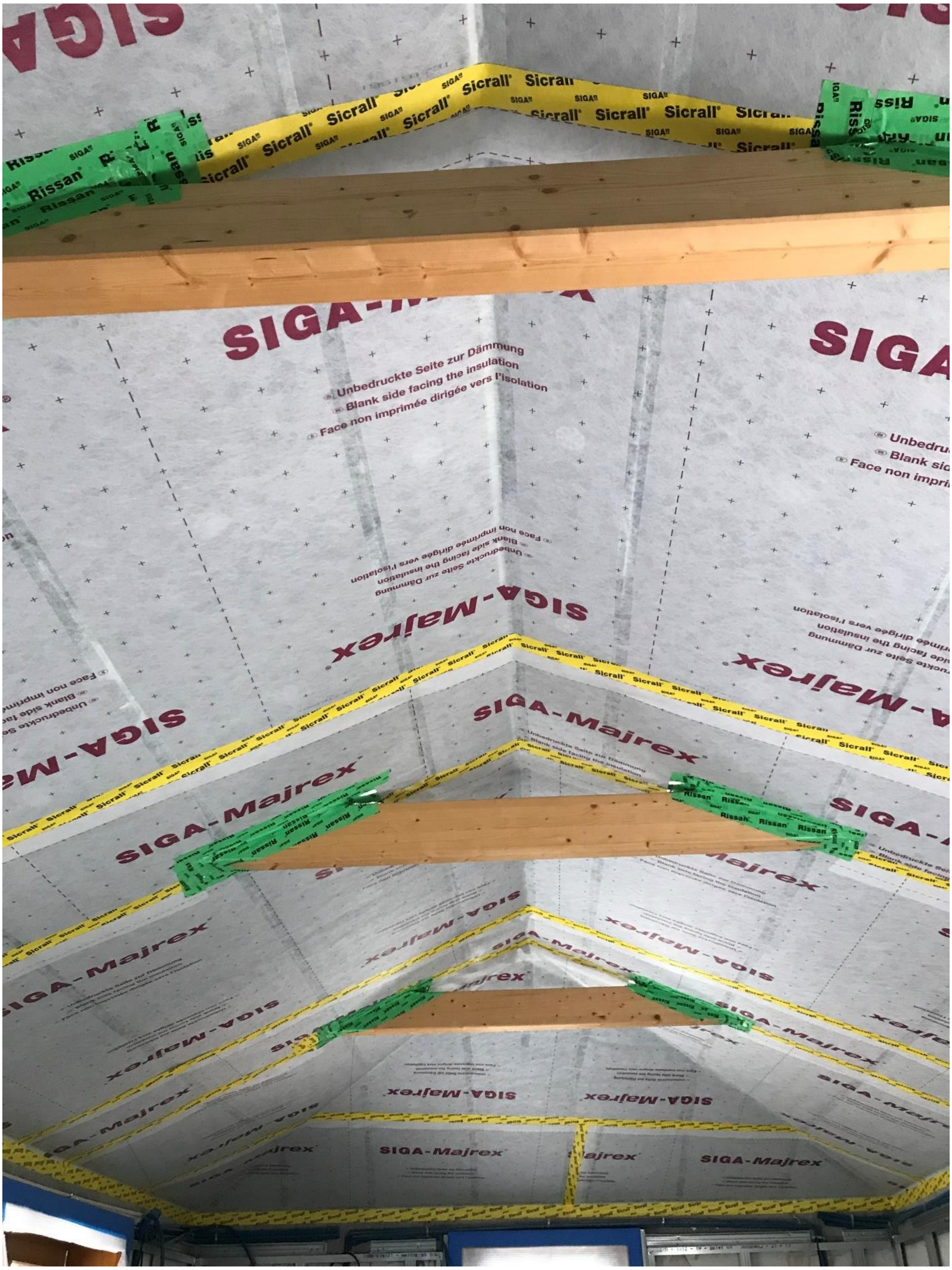
10 Airtight building envelope

Airtightness in a passive house is crucial to minimize infiltration and therefore to avoid unexpected heat losses. The reinforced concrete frame is considered airtight construction. Plaster applied to the existing building brick walls internally as airtight material. A special material named Aerosana applied on all the walls of the new construction, and a membrane applied on the wooden roof to achieve the desirable airtightness. Tapes are used for windows and doors, and for any other leak caused by penetration.

Picture 33: Plaster applied on the brick walls as an airtight layer.

Picture 34: Aerosana, airtight material used on thermal block walls.

Picture 35: Special tapes applied around the window frame before installation.



Picture 36: Special tapes applied around the window frame before installation.

An average value of 0.64 1/h at n50 has been achieved. The blow door test results are shown below.

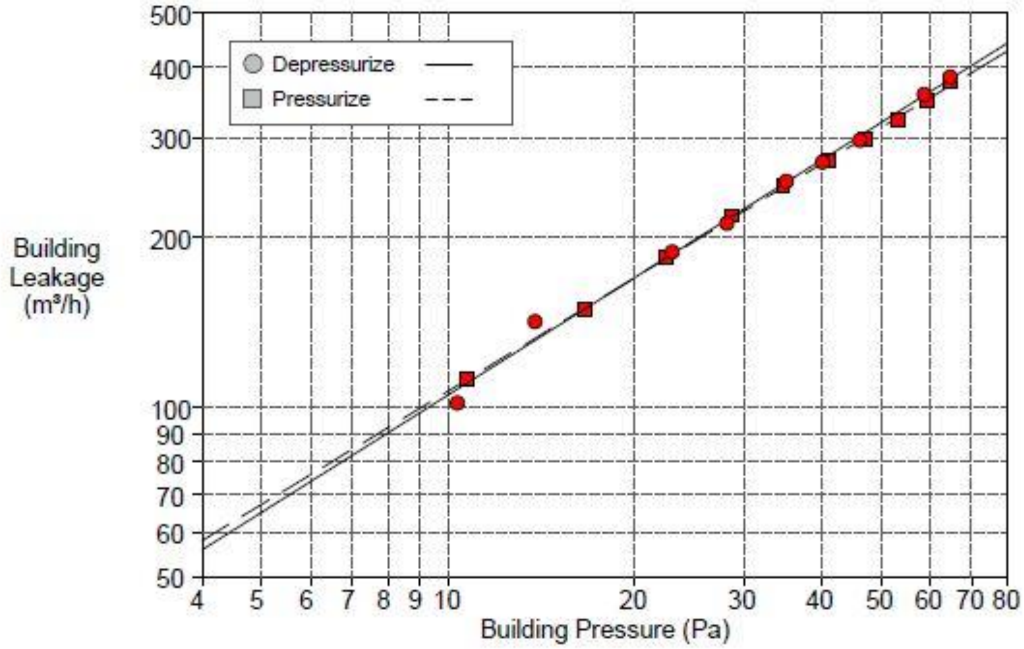
BUILDING LEAKAGE TEST

Hellenic Passive House Institute
Testing-Certification Department
Anastaseos 112
Papagou , Attiki 15669
Phone: +30 211 4081109 Fax: +30 211 4081109
Email: info@eipak.org Website: www.eipak.org

Date of Test: 11/12/2019		Technician:	Stefanos Pallantzas
Test File: sacher3		Project Number:	Apartment03
Customer:	Christian Sacher Efthimiopoulou 16 Nafplion, Argolis 2100 Phone: Fax:	Building Address:	Masonry Efthimiopoulou 16 Nafplion, Argolis 21100

	Depressurization	Pressurization	Average
Test Results at 50 Pascals:			
V50: m³/h Airflow	320 (+/- 3.8 %)	313 (+/- 0.9 %)	316
n50: 1/h (Air Change Rate)	0.65	0.63	0.64
w50: m³/(h·m² Floor Area)	2.02	1.98	2.00
q50: m³/(h·m² Envelope Area)	0.70	0.68	0.69
Leakage Areas:			
Canadian EqLA @ 10 Pa (cm²)	117.4 (+/- 6.3 %)	119.2 (+/- 1.8 %)	118.3
cm²/m² Surface Area	0.26	0.26	0.26
LBL ELA @ 4 Pa (cm²)	60.3 (+/- 10.6 %)	62.5 (+/- 2.9 %)	61.4
cm²/m² Surface Area	0.13	0.14	0.13
Building Leakage Curve:			
Air Flow Coefficient (Cenv) m³/(h·Paⁿ)	21.4 (+/- 17.3 %)	23.0 (+/- 4.8 %)	
Air Leakage Coefficient (CL) m³/(h·Paⁿ)	21.5 (+/- 17.3 %)	23.0 (+/- 4.8 %)	
Exponent (n)	0.690 (+/- 0.050)	0.667 (+/- 0.013)	
Correlation Coefficient	0.99675	0.99969	

Test Standard:	EN 13829
Test Mode:	Depressurization and Pressurization
Type of Test Method:	B
Regulation complied with:	passive house standard n50 ≤ 0.6 1/h

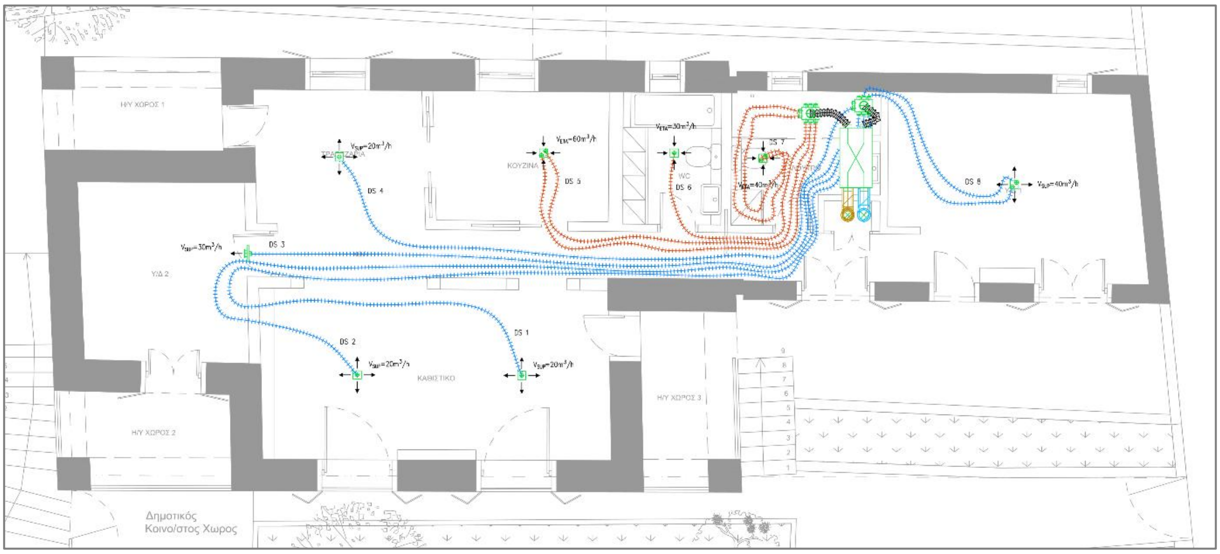


Picture 37: Blow door test results, Hellenic Passive House Institute.

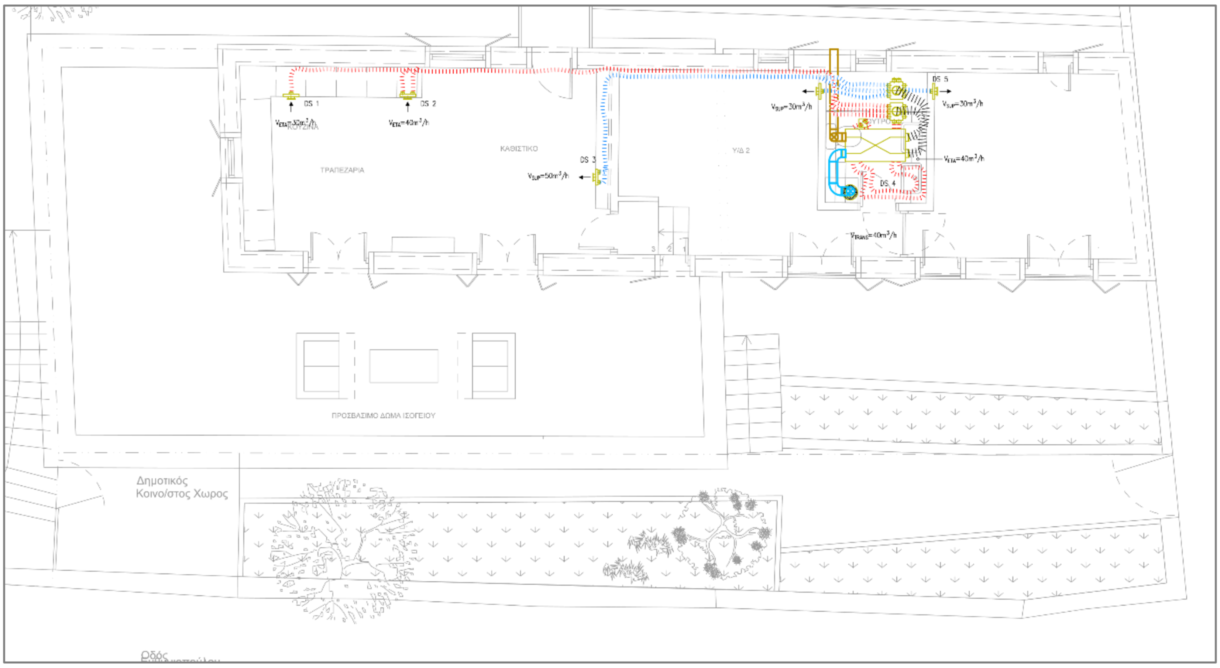
11 Layout of the ventilation system ducting

The design proposed a decentralized ventilation system for each apartment. Two units has been installed, one for each apartment, while the main duct system is shared. The layout of the ventilation system with flexible duct pipes Φ75 is shown below.

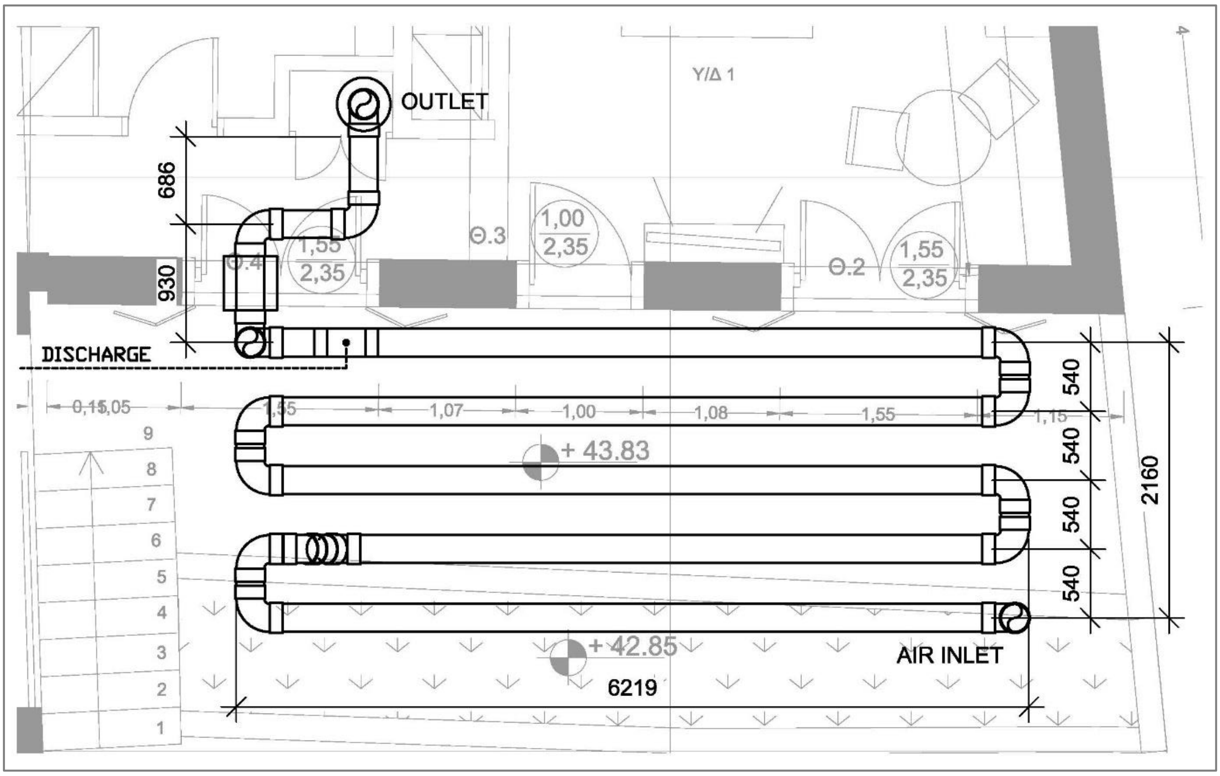
As mentioned, the windows g-value increased to improve the solar gains during heating period. As a result, the solar gains during the summer period also increased. Therefore, a subsoil heat exchanger was introduced to meet the passive house standards. An efficiency of 65% was estimated for an installation length of 34.0 m in an installation depth between 1.50 and 1.80 m. The overall efficiency is estimated at 80 and 78% for the ground floor and first floor respectively. The cooling demand decreased significantly from 17 [Wh/m^{2}a] to 12 [Wh/m^{2}a].



Picture 38: Ventilation layout, ground floor



Picture 39: Ventilation layout, first floor



Picture 40: Subsoil heat exchanger layout.

Picture 41: Subsoil heat exchanger during installation.

12 Ventilation unit

A mention two ventilation units have been installed in the bathroom false ceiling of each apartment. The design proposed the Wolf - CWL-F-300 Excellent model with an effective heat recovery efficiency at 85%, an electrical efficiency at 0.31 Wh/m^3, and finally an effective range of 66 – 226 m^3/h.

Picture 42: Ventilation unit, ground floor

13 Heating, Cooling, and DHW Systems

The heating and cooling demands of the building are met by the installation of two air to air heat pumps, one for each aparment. The heat pump of the ground floor has a nominal heating and cooling capacity of 6.80 and 5.40 kW respectively. The heat pump of the first floor has a nominal heating and cooling capacity of 4.10 and 3.50 kW respectively. Ceiling concealed ducted units have been installed as terminal units, one for the first floor and two for the ground floor.

Picture 43: Air to air heat pumps outdoor units for heating and cooling.

The design proposed a heat pump for the production of DHW with a maximum heating output of 2.5 kW. The storage tank has a capacity of 195l. Two selective solar collectors of a total surface area of 4.58 m^2 have been installed. The solar contribution for the production of DHW reaches 66% during the year. An electrical resistance of 1.80 kW is used as an auxiliary power.

Picture 44: DHW heat pump during installation.

Picture 45: DHW heat pump pipe insulation.


Picture 46: Sollar collectors facing south.

14 Short documentation of PHPP results

The data have been exported to the PHPP v9.6a to verify that the building has met the Passive House standards.

Passive House Verification

Building:	Apartment 03
Street:	Efthimiopoulou 18 str
Postcode/City:	21100 Nafplio
Province/Country:	Peloponnese GR-Greece
Building type:	Residential
Climate data set:	GR0002b-Athen
Climate zone:	5: Warm — Altitude of location: 44 m
Home owner / Client:	Christian Sacher, Monika Sacher
Street:	Schlagstrasse 49
Postcode/City:	6430 Schwyz
Province/Country:	Schwyz SZ-Swaziland

Architecture:	Panagiotis Papasotiriou	**Mechanical engineer:**	Pavlos Miohos
Street:	Nikitara 8	Street:	Papanikolaou 22
Postcode/City:	21200 Argos	Postcode/City:	21100 Nafplio
Province/Country:	Peloponnese GR-Greece	Province/Country:	Argolis GR-Greece
Energy consultancy:	Pavlos Miohos / Aggeliki Stat	**Certification:**	Stefan Pallantzas
Street:	Papanikolaou 22 / Ethnikis Anti	Street:	Tzanni Alevizatou 84
Postcode/City:	21100 Nafplio / Vrilissia 1628	Postcode/City:	16889 Athens
Province/Country:	Peloponnese GR-Greece / Attica GR-Greece	Province/Country:	Attica GR-Greece

Year of construction:	2021	Interior temperature winter [°C]:	20,0	Interior temp. summer [°C]:	25,0
No. of dwelling units:	2	Internal heat gains (IHG) heating case [W/m²]:	2,7	IHG cooling case [W/m²]:	2,8
No. of occupants:	4,0	Specific capacity [Wh/K per m² TFA]:	188	Mechanical cooling:	x

Specific building characteristics with reference to the treated floor area

				Criteria	Alternative criteria	Fulfilled?[2]
	Treated floor area m²	157,9				
Space heating	Heating demand kWh/(m²a)	13	≤	15	-	yes
	Heating load W/m²	12	≤	-	10	
Space cooling	Cooling & dehum. demand kWh/(m²a)	12	≤	17	17	yes
	Cooling load W/m²	10	≤	-	11	
	Frequency of overheating (> 25 °C) %	-	≤	-		-
	Frequency of excessively high humidity (> 12 g/kg) %	1	≤	10		yes
Airtightness	Pressurization test result n_{50} 1/h	0,6	≤	0,6		yes
Non-renewable Primary Energy (PE)	PE demand kWh/(m²a)	91	≤	-		-
Primary Energy Renewable (PER)	PER demand kWh/(m²a)	47	≤	60	60	yes
	Generation of renewable energy (in relation to projected building footprint) kWh/(m²a)	4	≥	-	-	

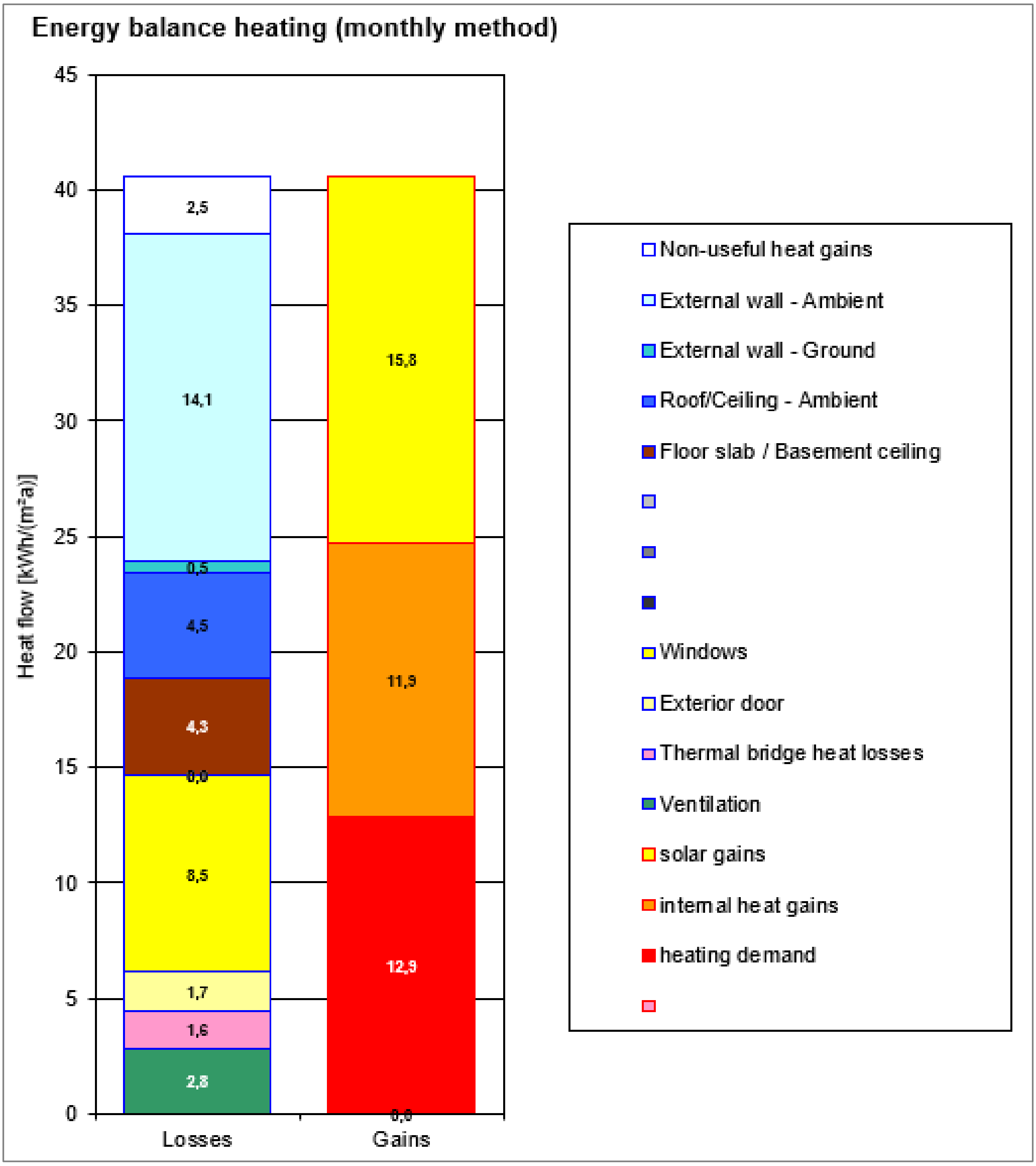
[2] Empty field: Data missing; '-': No requirement

I confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification.

Passive House Classic? yes

Task:	First name:	Surname:	Signature:
2-Certifier	Stefanos	Pallantzas	
Certificate ID	Issued on:	City:	
	23.08.2023	Athens	

Picture 47: PHPP Verification results.



Picture 48: PHPP results, energy balance (monthly method).

The results show that most of the heat losses take place through the walls and windows. On the other hand, the solar and the internal gains are 15.8 and 11.3 kW/m^{2}a respectively, while the remaining heating demand reaches 12.9 kW/m^{2}a.

The project was completed in 2021 and certified in Aug. 2023 by the Hellenic Passive Building Institute.

Certificate

Certified Passive House Classic

HELLENIC PASSIVE HOUSE INSTITUTE

Authorised by: Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Apartment 03
Efthimiopoulou 16 str, 21100 Nafplio, Greece

Certified Passive House
Passive House Institute
| classic | plus | premium |

Client	Christian Sacher, Monika Sacher Schlagstrasse 49 6430 Schwyz, Switzerland	
Architect	Panagiotis Papasotiriou Nikitara 8 21200 Argos, Greece	
Building Services	Pavlos Michos Papanikolaou 22	
Energy Consultant	Pavlos Michos Papanikolaou 22 21100 Nafplio	Aggeliki Stathopoulou Ethnikis Antistaseos 17 Vrilissia 15235, Greece

Passive House buildings offer excellent thermal comfort and very good air quality all year round. Due to their high energy efficiency, energy costs as well as greenhouse gas emissions are extremely low.

The design of the above-mentioned building meets the criteria defined by the Passive House Institute for the 'Passive House Classic' standard:

Building quality		This building		Criteria	Alternative criteria
Heating					
Heating demand	[kWh/(m²a)]	13	≤	15	-
Heating load	[W/m²]	12	≤	-	10
Cooling					
Cooling + dehumidification demand	[kWh/(m²a)]	12	≤	17	17
Cooling load	[W/m²]	10	≤	-	11
Frequency of excessively high humidity	[%]	1	≤	10	
Airtightness					
Pressurization test result (n_{50})	[1/h]	0,6	≤	0,6	
Renewable primary energy (PER)					
PER-demand	[kWh/(m²a)]	47	≤	60	60
Generation (reference to ground area)	[kWh/(m²a)]	4	≥	-	-

The associated certification booklet contains more characteristic values for this building.

Athens
26.06.2023

Certifier: Stefanos Pallantzas, Hellenic Passive House Institute

www.passivehouse.com **38998-38999_HPHI_PH_20230623_SPA**

Picture 49: Passive House Certificate, Hellenic Passive House Institute

15 Construction cost

The building owner does not wish to display this information.

16 Year of construction

The project was completed in 2021.

17 Information about the design / architecture

Panos Papasotiriou studied Architecture at the UNL, BA (Hons) and London Metropolitan University, Dip. Arch, where he completed RIBA III and ARB registration. He was an award-winning student with building projects and publications. Following 4 years working at PCKO and gaining a vast amount of experience in various aspects of architectural practice Panos decided to establish S2PiA (Studio 2Pi Architecture) in Argos.

The practice is concerned with many aspects of the design disciplines. We undertake work that spans between various sectors such as architectural design, interior design, master planning, sustainable and bioclimatic applications.

We are driven by the constant and ever-changing architectural philosophies that provide our starting point. We aim to enhance the environment by incorporating specifically designed buildings that correspond to their surroundings socially as well as environmentally.

We believe that through constant discussion amongst the profession and the construction industry as a whole we could establish the necessary measures that could fulfil our role in the modern world. We have to answer questions that go beyond the realm of form and function, questions that will fundamentally affect the future of our planet and our species.

The practice is collaborating with various UK architects creating dynamic relationships that exchange ideas and promote a constant architectural dialogue on issues both current and enduring. Issues that span between the synthesis of architectural components to the formality of modern architectural concepts. In this collaboration we seek to enhance our understanding of the architectural profession and development as well as the systematic production of information that exists on the continent.

18 Information about the building services

Pavlos studied Mechanical Engineering with Energy at the Higher Technological Educational Institute of Patras, in Greece (2005). He holds a BEng (Hons) and an MSc in Mechanical Engineering from the University of Sussex (2010) as well as an MSc in Sustainable Building Technology from the University of Nottingham (2011), in the United Kingdom.

His academic background and professional experience give him the opportunity to offer a wide range of services combining the traditional building services engineering with cement awareness of building sustainability, creating an integrated understanding that considers the whole building in order to deliver comfortable, energy efficient solutions.

He is a registered engineer with the Technical Chamber of Greece, an Energy Assessor certified by the Hellenic Energy Inspectorate, and a certified Passive House Designer since 2018. He is a cofounder of the architectural and engineering practice 02 | Architecture & Mech. Engineering since 2013.

19 References

1. Passive House Database: https://passivehouse-database.org/index.php?lang=en#d_6346
2. Studio 2Pi Architecture: https://www.s2pia.com/s2pia-villagarifallia