Achieving nearly zero energy buildings in Greece

Maria Bololia, Andreas Androutsopoulos
Buildings Department, Centre for Renewable Energy Sources and Saving, Greece
mbolo@cretes.gr, aandr@cretes.gr

Abstract. Energy consumption of buildings in Europe is still high despite their significant savings potential. The European Union has issued a number of directives to reduce energy consumption in buildings in its Member States. Each country has put in place the best minimum requirements to make its buildings more energy efficient. By the beginning of 2021 at the latest; all new and deep renovated buildings must have almost zero energy consumption. The latter is the subject of this paper, which focuses on identifying Greece's energy requirements for newly built buildings to meet the requirements of a nearly zero energy building (nZEB).

Two categories of building use are considered: a typical single-family house and an office building which apply bioclimatic design principles that all newly built buildings have to take into consideration, while all four climatic zones of Greece were looked into. The work presents the combinations - scenarios of building envelope characteristics, electro-mechanical installations, and RES technologies used in the modeled buildings, first to meet the minimum national requirements and secondly to reach minimum energy consumption. The calculations made use of the national program for the determination of the energy efficiency of the TEE KENAK building. The results show that combinations of a variety of building envelope components, electromechanical systems, and RES technologies meet the country's energy saving targets under its 2030 national energy efficiency plans.

1. Introduction
The characteristics of nearly zero energy buildings have been officially defined years ago in a European effort to reduce the consumption of its buildings [1]. A nearly zero energy building (nZEB) in Greece is a building whose primary energy consumption ranges from 33% to 50% of the primary energy of the reference building, so it is classified as energy class A [2]. The scope of this paper is to present combinations - scenarios of the technical systems’ characteristics (envelope and heating – cooling technologies) of a new building in order to achieve the goal to construct all new buildings with nZEB features.

2. Methodology
In order to determine the conditions that meet the nZEB criteria in Greece, two typical types of building were examined. The first is a residential building - detached house and the second is an office building.

2.1. Calculation program
The calculation program used is the National tool for the Determination of Energy Efficiency (TEE KENAK, version v.1.31.1.9) [3]. The specification regarding the operation of the buildings, the
The calculations were carried out for all 4 climatic zones of Greece and cover all the country’s energy demands. The climatic data of the following representative cities were utilized: Heraklion, Athens, Thessaloniki, and Florina.

2.2. Climatic zones of Greece

According to the Technical Guidelines of the Technical Chamber of Greece [4,6], Greece is divided into four climatic zones based on the Heating Degree Days (DD). The reference temperature is $18^\circ$C. Figure 1 shows the climatic zones on the map and Table 1 shows the DD of the representative cities.

![Figure 1](image_url)

**Figure 1.** The four Climatic Zones of Greece.

**Table 1.** Heating Degree Days of the representative cities.

| Climatic Zone | Representative cities | HDD  |
|---------------|-----------------------|------|
| A             | Heraklion             | 702  |
| B             | Athens                | 947  |
| C             | Thessaloniki          | 1677 |
| D             | Florina               | 2537 |

3. Building characteristics

In this paper a detached house and an office building which have the biggest percentage of the building stock in Greece were examined. There were chosen because the detached houses are the majority of building type use in Greece and the office buildings represent considerable energy consumption.

Their size and construction technique is representative of the building stock of the last decade and the basic principles of energy and bioclimatic design for the exploitation of solar radiation, natural lighting and natural ventilation have been taken into account.

The exterior dimensions of the buildings depend on the thickness of the thermal insulation. In the calculations, two cases were examined. In the first case, the thickness of the thermal insulation is the minimum allowed, for each climate zone, according to the Greek Energy Efficiency Regulation of Buildings [7] (the thickness of the wall thermal insulation in that case is 0.5m, 0.6m, 0.7m and 0.9m respectively for each climate zone starting with zone A). In the second case, the thickness of the wall thermal insulation is 0.13m, which is considered to cover all the adverse conditions throughout Greece.
3.1. Residential house model (detached house)

The building chosen as a representative detached house is a two storey building (ground floor and 1st floor), with an indoor parking space and basement. It is located on a building plot that follows the national building requirements [8] and unshaded by the surrounded buildings. It has southern orientation and its total surface ranges from 398m\(^2\) to 405m\(^2\) depending on the minimum thickness of the thermal insulation for each climate zone (based on the requirements of the Technical Guideline of the Technical Chamber of Greece [4]), as well as the maximum thickness selected (0.13m). Specifically, in climatic zone A, the ground floor area is 134m\(^2\), the 1st floor area is 101m\(^2\), the basement area is 132m\(^2\), while the parking space is 31m\(^2\) [9].

Figure 2 shows the surface area of every floor of the detached house and Table 2 the dimensions for each climatic zone.

![Detached House](image)

**Figure 2.** Detached House (left: ground floor and parking space; centre: 1st floor; right: basement).

**Table 2.** Total detached house area for each climate zone.

| Climatic Zone | A  | B  | C  | D  |
|---------------|----|----|----|----|
| Building area (minimum thickness) [m\(^2\)] | 398 | 399 | 400 | 402 |
| Building area (maximum thickness 0.13m) [m\(^2\)] | 405 |    |    |    |

The basic structure of the building is made of reinforced concrete and brick walls with external thermal insulation. The roof of the building consists of a horizontal reinforced concrete slab with an inverted type of thermal insulation and tiles at the top.

All windows consist of metallic frame with thermal transmittance coefficient \(U_f=2\,W/(m^2\,K)\), double glazing (glass thickness 4mm), low-e, air gap of 8mm, 12mm and 16mm (depending on the climatic zone); and thermal conductivity coefficient 1.1W/(mK). The thermal transmittance coefficient of the glazing is \(U_g=2.8, 2.2, 1.8, \) and \(1.6\,W/(m^2\,K)\), respectively for the 4 climatic zones. The coefficients for the maximum thickness thermal insulation are: \(U_f=1\,W/(m^2\,K)\) and \(U_g=1.4\,W/(m^2\,K)\).

The airtightness of the frame is chosen to have an airtightness class 4 (for certified windows according to EN 12207).

The heating is covered by an underfloor system while the cooling system is equipped with local AC split units. Finally, the domestic hot water (DHW) needs are covered by 80% from a solar collector system.

3.2. Office building model

The selected building is a representative office building the current construction practice; it has an exclusive office use, and consists of 4 storeys and 2 underground floors. On the ground floor there is a multiple use– conference room and the corridor areas, while on the floors there are office rooms, corridors and auxiliary spaces.

All office areas are situated circumferential of the building, while the corridors are on the inner side of the building and extend on the perimeter of a central atrium space. The atrium space helps in the
natural ventilation – cooling, as well as in natural lighting, allowing the solar radiation to enter in
darker areas of the building. Finally, the 2 basements are open space and they are used as car parking
area.

The building plot satisfies the requirement of the New Building Regulation and the building is not
shaded from the surrounded buildings. Its main entrance has a south orientation and its total surface
ranges from 3223 to 3280m$^2$ depending on the minimum thickness of the thermal insulation for each
climatic zone, as well as the maximum (0.13m). More specifically, in climatic zone A, the ground
floor area is 610m$^2$, while the 3 floors are 791m$^2$ each. The surface of the staircase and the closed area
of the 1$^{st}$ basement are 61m$^2$ each, while the 2$^{nd}$ basement is 118m$^2$ [10].

Figures 3 and 4 show the ground floor area and a typical floor area of the office building. In Table
3, the dimensions for each climate zone can be found.

The basic structure of the building is made of reinforced concrete and brick walls with external
thermal insulation. The roof of the building consists of a horizontal reinforced concrete slab with an
inverted type thermal insulation and tiles.

Table 3. Total office building area for each climatic zone.

| Climatic Zone | A   | B   | C   | D   |
|---------------|-----|-----|-----|-----|
| Building area (minimum thickness) [m$^2$] | 3223 | 3231 | 3238 | 3252 |
| Building area (maximum thickness 0.13m) [m$^2$] |       |       |       | 3280 |

In this building too, the windows structure consist of metallic frame with thermal transmittance
coefficient $U_f=2W/(m^2K)$, double glazing (glass thickness 4mm), low-e, air gap of 6mm, 8mm,12mm
and 16mm (depending on the climatic zone); and thermal conductivity coefficient 1.1W/(mK). The
thermal transmittance coefficient of the glazing is $U_g=2.8$, 2.2, 1.8, and 1.6W/(m$^2$K), respectively for
the 4 climatic zones. The coefficients for the maximum thickness thermal insulation are:
$U_f=1W/(m^2K)$ and $U_g=1.4W/(m^2K)$.

The airtightness of the frame is chosen to have an airtightness class 4 (for certified windows
according to EN 12207).

The shading system of the building consists of horizontal and vertical exterior blinds (horizontal
blinds on the south side of the stairwell, vertical blinds on the east and west side of the building, at the
office floors).

The artificial lighting system of the building is equipped with LED lamps, and the mechanical
ventilation works with a 75% efficiency exchanger. Finally, the building has an Energy Management
System (BMS) and the terminal units for the heating and cooling systems are fan coils (FCU).
4. Scenarios studied

The aim of the scenarios was to examine the basic combinations of the building envelope with electromechanical systems and RES, so the building to be classified as energy class A. It is noted that the selected scenarios are in accordance with the usual practices followed in Greece.

In the detached house case, the combinations – scenarios examined for the 4 climatic zones, are:

- Scenario [1]: minimum thermal insulation thickness in the building envelope, heating system with condensing natural gas boiler, cooling system with AC split units and solar collector for DHW needs.
- Scenario [2]: maximum thermal insulation thickness (0.13m) in the building envelope, heating system with air to water heat pump, cooling system with split units and solar collector for DHW needs.
- Scenario [3]. All possible combinations between scenario [1] and scenario [2]. In particular, the combinations that arise between different thicknesses of the thermal insulation with different heating systems.

In the case of the office building, the combinations – scenarios examined for 4 climatic zones are:

- Scenario [1]: minimum thermal insulation thickness in the building envelope, heating system with condensing natural gas boiler and cooling system with chiller.
- Scenario [2]: minimum thermal insulation thickness in the building envelope, heating – cooling system with air to water heat pump.
- Scenario [3]. Combined scenarios with maximum thermal insulation thickness and different heating – cooling systems, and an additional photovoltaic system for electricity production.

5. Results

In this chapter, the results of the combinations – scenarios for the detached house and the office building are presented. The following Tables and Figures, present the primary energy consumption and energy use, the CO₂ emissions, as well as the primary energy saving and an economic evaluation of technologies of the various scenarios studied.

5.1. Detached house

The data used in the national tool TEE KENAK are presented in Table 4.

Table 4. Characteristics of residential building.

| Building Use                              | Detached house                                      |
|-------------------------------------------|----------------------------------------------------|
| Number of thermal zones                   | 3                                                  |
| Number of unheated zones                  | 2                                                  |
| Surface of Building/ Thermal zone/ Unheated zones | Depending on the climate zone                      |
| Airtightness class                         | Thermal zone 4                                     |
|                                           | Unheated zone According to [4]                     |
| Thermal transmittance coefficient         | Minimum thickness of thermal insulation            |
|                                           | Maximum thickness of thermal insulation            |
| Heating system                            | Natural gas boiler: SCOP=1.02                       |
|                                           | Air to water Heat pump: SCOP=3.5                   |
| Cooling system                            | Split units SEER=4                                 |
| DHW                                       | Solar collectors (80%) – 20% from the heating system during the heating period |
5.1.1. Scenario [1]: Scenario [1] uses minimum thermal insulation thickness in the building envelope is applied, a heating system with condensing natural gas boiler, cooling system with split units and a solar collector for DHW needs.

Figures 5 and 6 show the primary energy consumption and the energy use for the 4 climate zones. In scenario [1], in climate zone A, B and C, the building meets the requirements of nZEB, and it is classified in energy class A. However, this is not the case in climate zone D where the primary energy consumption is the 50.4% of the reference building consumption, and it is classified in energy class B+. In climate zone D, in order to cover the requirements of an nZEB, a more efficient natural gas boiler (SCOP>1.02) or an automation system (e.g. BMS) should be implemented.

![Figure 5. Primary energy consumption for all climatic zones (scenario 1).](image1)

![Figure 6. Energy use for all climatic zones (scenario 1).](image2)

5.1.2. Scenario [2]. It uses maximum thermal insulation thickness (0.13m) in the building envelope, a heating system with air to water heat pump, a cooling system with split units and a solar collector for DHW production.

The following figures 7 and 8 show the primary energy consumption and the energy use for all climatic zones in Greece, respectively. The building, in all climatic zones (A to D), meets the requirements of nZEB and specifically is classified as energy class A+ with primary energy consumption of only 20.9kWh/m², 30.1kWh/m², 42.7kWh/m² and 56.9kWh/m² respectively.

![Figure 7. Primary energy consumption per climatic zone (scenario 2).](image3)

![Figure 8. Energy use per climatic zone (scenario 2).](image4)

5.1.3. Scenario [3]. It is the combination scenario of scenarios [1] and [2]. Particularly, the 4 combinations studied are presented below:
• Scenario [3.1]: minimum thermal insulation thickness in the building envelope, heating system with condensing natural gas boiler, cooling system with split units and solar collector for DHW.
• Scenario [3.2]: minimum thermal insulation thickness in the building envelope, heating system with air to water heat pump, cooling system with split units and solar collector for DHW needs.
• Scenario [3.3]: maximum thermal insulation thickness (0.13m) in the building envelope, heating system with condensing natural gas boiler, cooling system with split units and solar collector for DHW production.
• Scenario [3.4]: maximum thermal insulation thickness (0.13m) in the building envelope, heating system with air to water heat pump, cooling system with split units and solar collector for DHW.

It should be noted that in the following tables that follow, the financial difference is the additional cost of the technologies in scenarios [3.2], [3.3] and [3.4], when compared to scenario [3.1]. Also, the negative results of CO$_2$ emissions signify that the emissions in scenarios [3.2], [3.3] and [3.4] are increased due to different technology. The same note applies to the office building as well. The results for each climatic zone are:

**Climatic zone A**

As shown in the Table 5 below, all scenarios meet the nZEB requirements and primary energy saving reaches 47.6% (scenario [3.4]).

|                  | Sc[3.1] | Sc[3.2] | Sc[3.3] | Sc[3.4] |
|------------------|---------|---------|---------|---------|
| Energy class     | A       | A       | A+      | A+      |
| Primary energy saving (%) | -   | 15.3    | 42.6    | 47.6    |
| CO$_2$ (kg/m$^2$) | 9.7    | 11.9    | 6.2     | 7.1     |
| Reduction of CO$_2$ emissions (%) | -   | -22.7   | 36.1    | 26.8    |
| Cost difference (€) | -    | 13.200  | 5.164   | 18.364  |

Figures 9 and 10 show the primary energy consumption and energy use for the 4 scenarios. It can be seen that scenario [3.3] has a primary energy consumption of 22.9kWh/m$^2$ which corresponds to energy use consumption for heating 10.3kWh/m$^2$, for cooling 2.8kWh/m$^2$, for DHW 6.3kWh/m$^2$, since the solar energy for DHW is 6.3kWh/m$^2$.

**Figure 9.** Primary energy consumption in climatic zone A.

**Figure 10.** Energy use consumption in climatic zone A.

**Climatic zone B**

Table 6 shows the results for climate zone B. The primary energy saving is approximately 45% in scenario [3.4]. Depending on the scenario the building is classified in energy classes A and A+. 

![Climate Zone A](image1.png) ![Energy Use Consumption](image2.png)
Table 6. Climate zone B.

|                | Sc[3.1] | Sc[3.2] | Sc[3.3] | Sc[3.4] |
|----------------|---------|---------|---------|---------|
| Energy class   | A       | A       | A+      | A+      |
| Primary Energy saving (%) | -       | 16,0    | 37,6    | 44,8    |
| $\text{CO}_2$ (kg/m$^2$)   | 12,8    | 16,0    | 8,6     | 10,3    |
| Reduction of $\text{CO}_2$ emissions (%) | -       | -25,0   | 32,8    | 19,5    |
| Cost difference (€)    | -       | 13,200  | 4,514   | 17,714  |

In Figures 11 and 12, the primary energy consumption and the energy use consumption are shown. More specifically, in scenario [3.2] the primary energy consumption is 45.8kWh/m$^2$ which corresponds to energy use consumption for heating 11.6kWh/m$^2$, for cooling 4.3kWh/m$^2$, for DHW 0.4kWh/m$^2$, since the solar energy for DHW is 6.4kWh/m$^2$.

Climatic zone C

Table 7 shows that the primary energy consumption is 40.4% (scenario [3.4]) and all scenarios meet the nZEB requirements in climatic zone C.

Table 7. Climate zone C.

|                | Sc[3.1] | Sc[3.2] | Sc[3.3] | Sc[3.4] |
|----------------|---------|---------|---------|---------|
| Energy class   | A       | A       | A       | A+      |
| Primary Energy saving (%) | -       | 17,2    | 31,0    | 40,4    |
| $\text{CO}_2$ (kg/m$^2$)   | 16,2    | 21,1    | 11,8    | 14,9    |
| Reduction of $\text{CO}_2$ emissions (%) | -       | -38,3   | 34,4    | 10,2    |
| Cost difference (€)    | -       | 13,200  | 3,899   | 17,099  |

As shown in Figures 13 and 14, in scenario [3.4] which is the only one that the building is classified as energy class A+, the primary energy consumption is 42.7kWh/m$^2$ and corresponds to energy use consumption for heating 11.8kWh/m$^2$, for cooling 2.4kWh/m$^2$, for DHW 0.5kWh/m$^2$, and the solar energy for DHW is 6.3kWh/m$^2$. 
Figure 13. Primary energy consumption in climatic zone C.

Figure 14. Energy use consumption in climatic zone C.

Climatic zone D

From Table 8 it can be seen that all scenarios, except the first one, meet the nZEB requirements and primary energy savings reach approximately 39% (scenario [3.4]).

Table 8. Climatic zone D.

| Scenario | Energy class | Primary Energy saving (%) | CO₂ (kg/m²) | Reduction of CO₂ emissions (%) | Cost difference (€) |
|----------|--------------|---------------------------|--------------|-------------------------------|-------------------|
| Sc[3.1]  | B+           | -                         | 19.3         | -                             | -13.2000          |
| Sc[3.2]  | A            | 18.5                      | 26.6         | -57.0                        | 3.0080            |
| Sc[3.3]  | A            | 26.9                      | 14.7         | 35.9                         | 16.2080           |
| Sc[3.4]  | A+           | 39.5                      | 19.5         | -1.6                         |                   |

Through Table 8 and Figures 15 and 16 it is seen that in scenario [3.3], the building is classified in energy class A and the primary energy consumption is 68.7kWh/m² which corresponds to energy use consumption of 58.6kWh/m². The primary energy saving is approximately 27% and the reduction of CO₂ emissions is 36% compared to scenario [3.1].

Figure 15. Primary energy consumption in climatic zone D.

Figure 16. Energy use consumption in climatic zone D.

5.2. Office Building

The characteristics data used in the national calculation tool TEE KENAK are presented in Table 9.

Table 9. Characteristics of the office building.

| Building Use | Office building |
|--------------|-----------------|
| Number of thermal zones | 11 |
| Number of unheated zones | 9 |
Surface of Building/ Thermal zone/ Unheated zone

Airtightness class

Thermal transmittance coefficient

Heating system

Cooling system

Lighting system

Automation class

Mechanical ventilation

Photovoltaic system

Depending on the climate zone

Thermal zone 4

Unheated zone According to [4]

Minimum thickness of thermal insulation

Maximum thickness of thermal insulation

Natural gas boiler SCOP=1.02

Air to water Heat pump

Climate zone A, B: SCOP=3.5

Climate zone C: SCOP=3.0

Climate zone D: SCOP=2.8

Chiller SEER=3.5

Air to water Heat pump SEER=3.5

LED lamps with dimming control

A (BMS)

75% efficiency exchanger

Climate zone A: 25kWp

Climate zone B, C, D: 30kWp

5.2.1. Scenario [1]. Scenario [1] uses minimum thermal insulation thickness in the building envelope, heating system with a condensing natural gas boiler and a cooling system with chiller.

The following Figures 17 and 18, show the primary energy consumption and the energy use for the 4 climate zones. Specifically, in all climatic zones, the building meets the nZEB requirements and is classified as energy class A.

5.2.2. Scenario [2]. The building uses minimum thermal insulation thickness in the building envelope and heating - cooling system with air to water heat pump. Figures 19 and 20 show the primary energy consumption and energy use for the 4 climatic zones. More specifically, the building is classified as energy class A and the energy use for heating in climatic zone A and B is 3.7kWh/m², in climatic zone C is 6.7kWh/m², while in climatic zone D is 10.2kWh/m².
5.2.3. Scenario [3]. It is a combination scenario and more specifically it presents the following 4 subcategories:

- Scenario [3.1]: Maximum thermal insulation thickness (0.13m) in the building envelope, heating system with condensing natural gas boiler and cooling system with chiller.
- Scenario [3.2]: Maximum thermal insulation thickness (0.13m) in the building envelope and heating - cooling system with air to water heat pump.
- Scenario [3.3]: Maximum thermal insulation thickness (0.13m) in the building envelope, heating system with condensing natural gas boiler, cooling system with chiller and a photovoltaic system.
- Scenario [3.4]: Maximum thermal insulation thickness (0.13m) in the building envelope, heating - cooling system with air to water heat pump and a photovoltaic system.

The results for each climate zone are presented below.

**Climatic zone A**

As shown in Table 10, all scenarios meet the nZEB requirements and maximum primary energy saving is approximately 86% (scenario [3.4]).

| Sc[3.1] | Sc[3.2] | Sc[3.3] | Sc[3.4] |
|---------|---------|---------|---------|
| Energy class | A | A | A+ | A+ |
| Primary Energy saving (%) | - | 0,3 | 81,8 | 86,1 |
| CO₂ (kg/m²) | 22,2 | 22,3 | 4,7 | 4,5 |
| Reduction of CO₂ emissions (%) | - | -0,5 | 78,8 | 79,7 |
| Cost difference (€) | - | 75,500 | 11,500 | 100,500 |

Figures 21 and 22 show the primary energy consumption and the energy use for each scenario. Particularly, in scenario [3.4], the primary energy consumption is 9.1kWh/m² which corresponds to energy use consumption for heating 3.1kWh/m², for cooling 6.7kWh/m², for lighting 12.8kWh/m², while the energy from PV system is 20.5kWh/m².
Figure 21. Primary energy consumption in climatic zone A.

Figure 22. Energy use consumption in climatic zone A.

Climatic zone B
From Table 11 it is shown that the building meets the nZEB requirements and the primary energy savings reach the 95% (scenario [3.4]).

Table 11. Climate zone B.

| Sc[3.1] | Sc[3.2] | Sc[3.3] | Sc[3.4] |
|---------|---------|---------|---------|
| Energy class | A | A | A+ | A+ |
| Primary Energy saving (%) | - | 0,9 | 85,4 | 94,7 |
| CO₂ (kg/m²) | 23,2 | 23,4 | 5,1 | 4,5 |
| Reduction of CO₂ emissions (%) | - | -0,9 | 78,0 | 80,6 |
| Cost difference (€) | - | 75.500 | 16.500 | 105.500 |

In Figures 23 and 24, the primary energy consumption and the energy use consumption are shown, respectively. More specifically, in scenario [3.4] the primary energy consumption is only 3.7kWh/m² which corresponds to energy use consumption for heating 3.7kWh/m², for cooling 7.3kWh/m², for lighting 12.8kWh/m², while the energy production from PV system reaches 23.8kWh/m².

Figure 23. Primary energy consumption in climatic zone B.

Figure 24. Energy use consumption in climatic zone B.

Climatic zone C
Table 12 shows that the primary energy consumption is approximately 83% (scenario [3.4]) and all scenarios meet the nZEB requirements.
Table 12. Climate zone C.

| Energy class          | Sc[3.1] | Sc[3.2] | Sc[3.3] | Sc[3.4] |
|-----------------------|---------|---------|---------|---------|
| Primary Energy saving (%) | A       | A       | A+      | A+      |
| CO₂ (kg/m²)           | 23.4    | 24.4    | 6       | 4.5     |
| Reduction of CO₂ emissions (%) | -       | -4.3    | 74.4    | 80.8    |
| Cost difference (€)   | -       | 75,500  | 16,500  | 105,500 |

From Figures 25 and 26 it can be seen that, in scenario [3.1] the primary energy consumption is 70.7kWh/m² which corresponds to energy use consumption for heating 10.7kWh/m², for cooling 6.0kWh/m², while for lighting is 12.8kWh/m².

Figure 25. Primary energy consumption in climatic zone C.

Figure 26. Energy use consumption in climatic zone C.

Climatic zone D

Table 13 presents the results for climate zone C, and it can be seen that all scenarios meet the nZEB requirements and primary energy savings reach approximately 81% (scenario [3.4]).

Table 13. Climatic zone D.

| Energy class          | Sc[3.1] | Sc[3.2] | Sc[3.3] | Sc[3.4] |
|-----------------------|---------|---------|---------|---------|
| Primary Energy saving (%) | -       | -0.1    | 77.8    | 81.3    |
| CO₂ (kg/m²)           | 22.8    | 25.4    | 7.5     | 4.5     |
| Reduction of CO₂ emissions (%) | -       | -11.4   | 67.1    | 80.3    |
| Economical difference (€) | -       | 75,500  | 16,500  | 105,500 |

Table 13 and Figures 27 and 28 show that in scenario [3.4], the building is classified as energy class A+ and the primary energy consumption is 13.7kWh/m² which corresponds to energy use consumption of 25.4kWh/m². The primary energy saving is approximately 81% and the reduction of CO₂ emissions is 80% when compared to scenario [3.1].
6. Conclusions

In this paper, various possible combinations – scenarios in order to meet the national requirements that define a typical residential building (detached house) and an office building as a nearly zero energy building, have been investigated. The scenarios combined the building envelope with electromechanical systems and RES. Two cases of building envelope were examined: the first one used minimum thermal insulation thickness, according to the national energy efficiency regulation of buildings and the other a maximum thermal insulation thickness (0.13m). In addition, the basic natural gas boiler heating system used and split units cooling system or chiller, as well as air to water heat pump, were combined with the cases of the building envelope. The calculations were carried out by the use of the national buildings energy efficiency tool TEE KENAK. From the results the following can be derived:

Regarding the detached house:

- The combination of minimum thermal insulation thickness with every heating and cooling system, for all climate zones, classifies the building in energy category A. The only exception is climatic zone D, where a very high efficiency condensing natural gas boiler must be selected (SCOP > 1.02).
- The building, when combining the maximum thermal insulation thickness (0.13m) with any heating system, for all climate zones, meets the requirements of nZEB. In addition, the building, in every climatic zone, when the heating system is an air-to-water heat pump, is classified in energy class A+.
- The maximum primary energy saving is achieved in climatic zone A (scenario [3.4] - primary energy saving of 47.6%).
- The maximum reduction of CO₂ emissions is found in climatic zone A (scenario [3.3] – reduction of CO₂ emissions by 36.1%).
- Scenario [3.3] shows the lowest investment cost in all climatic zones. In particular, with a maximum cost of 5,000€, a minimum primary energy savings of 26.9% is achieved.

Regarding the office building:

- The building, in all combinations of building envelope with heating – cooling systems, in every climatic zone, meets the requirements of nZEB and is classified in energy class A.
- Comparing the results from the combinations with minimum thermal insulation thickness and both cases of heating – cooling systems, it is found that the primary energy consumption in climatic zone A and B is similar (the primary energy consumption is reduced only by 8.7% and 8.4% respectively for each zone, when the heating system is an air-to-water heat pump).
- In climatic zones C and D, the difference is significantly higher (22.5% and 32.3%)
respectively). It is clear that in climatic zones C and D, in order to reduce the primary energy consumption, the electromechanical systems are equally important to the building envelope.

- The primary energy consumption, when the maximum thermal insulation thickness is combined with the cases of heating – cooling systems, in all climatic zones, is reduced at a minimum. The difference in primary energy consumption between scenarios [3.1] and [3.2] is only 0.3%, 0.9%, 0.7% and 0%, respectively for each climate zone. This results show that when there is a maximum thermal insulation thickness in the building envelope, any electromechanical system can be selected.

- The building, in scenarios with maximum thermal insulation thickness with 2 cases of heating – cooling system and PV system, in all climate zones, is classified as energy class A+.

- The maximum primary energy saving is achieved in climatic zone B (primary energy saving 94.79% comparing with scenario [3.1]).

- The maximum reduction of CO₂ emissions is in climatic zone C (scenario [3.4] – reduction of CO₂ emissions: 80.8%).

- Scenario [3.3] shows the lowest investment cost in all climatic zones. More specifically, at a cost ranging from 11,500€ to 16,500€, the energy savings achieved lay between 77.8% and 85.4%.

The paper presents the conditions for the newly detached houses and office buildings to meet the requirements of a nearly zero energy building in Greece. Scenarios of building envelope and electromechanical systems were examined without being exclusive and unique. The results contribute to facilitate the increase the nZEB buildings in Greece.

References
[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast). OJEU L.153.
[2] Ministerial Decision YPEN/DEPEA/85251/242 (2018). Approval of national plan for the increase of the number of nearly zero energy buildings. Government Gazette 5447/B/5.12.2018), National Printing Office, Athens. [in Greek].
[3] National Program for the Determination of Energy Efficiency TEE KENAK version 1.31: user manual (2018). [in Greek].
[4] Technical Guide, TOTEE 20701-1 (2017). Analytic National Specifications of the Parameters for the Calculation of the Energy Performance of Buildings and the Issue of the Energy Certificate of Buildings., 1st Edition, Technical Chamber of Greece, (Government Gazette 4003/B/17.11.2017), National Printing Office, Athens. [in Greek].
[5] Technical Guide, TOTEE 20701-2 (2017) Analytic Thermo-Physical Properties of Structural Materials and Insulation Building Efficiency Control. 1st Edition, Technical Chamber of Greece. (Government Gazette 4003/B/17.11.2017), National Printing Office, Athens. [in Greek].
[6] Technical Guide, TOTEE 20701-3 (2012). Climatic Data of Greek Areas. 2nd Edition, Technical Chamber of Greece, Athens. [in Greek].
[7] Governmental Decision DEPEA/178581/2017 (Issue Number 2367/B/12.7.2017) Approval of the Regulation on the Energy Performance of Buildings. Athens, National Printing office. [in Greek].
[8] Law 4067. New Buildings Regulation. Government Gazette 79/A/9.4.2012), National Printing Office, Athens. [in Greek].
[9] Aristotele University of Thessaloniki (2018). Study of detached house to the direction of a characterization as a nearly zero energy building.Thessaloniki.
[10] Aristotele University of Thessaloniki (2018). Study of office building to the direction of a characterization as a nearly zero energy building.Thessaloniki.