Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 38 (2017) 115 – 120

Procedia Environmental Sciences

International Conference on Sustainable Synergies from Buildings to the Urban Scale, SBE16

The Role of the Building Envelope in Achieving Nearly-Zero Energy Buildings (nZEBs)

Stergiani Charisi[a,]*

[a]*Department of Mathematical Science and Technology, Norwegian University of Life Sciences, Box 5003, 1432, Ås, Norway*

Abstract

The 2010 Energy Performance of Buildings Directive (EPBD) requires all new buildings to be nearly-zero energy buildings (nZEBs) by 2020. A strict definition of nZEB is yet to be defined by the legal framework of each European country. However, the basic principles of nZEBs are the reduction of their energy demands to minimum and, subsequently, the coverage of their low energy demands in a great extent by renewable energy sources.
This study focuses on the potential reduction of energy demands in a typical Greek residential building. A model building, representative to the average Greek residential building was designed and used as model. The effect of various parameters on the energy demand of the building, such as insulation, openings and shading devices, was investigated and evaluated. The model building was examined in all four climate zones of Greece using dynamic simulation software tools to define the energy demands. The results suggest that the most efficient constructive solutions for every climate zone lay on various combinations of parameters. The right combination for each climate zone can contribute to a significant energy saving that rises up to 30% and reduce the total annual energy demand of the building to less than 50 kWh/m^2.

Peer-review under responsibility of the organizing committee of SBE16.

Keywords: nZEB, energy performance, building envelope

1. Introduction

Building sector is responsible for 40% of energy consumption and 36% of CO_2 emissions in the EU. The 2010 Energy Performance of Buildings Directive (EPBD) and the 2012 Energy Efficiency Directive (EED) are the EU's main legislation regarding reduction of energy consumption of buildings. Under the EPDB all new buildings must be nearly-zero energy buildings (nZEBs) by 31 December 2020. A strict definition of nZEB is yet to be defined by the legal framework of each European country, however the Directive defines the greater picture of nZEB concept, providing considerable flexibility to state members to refine it and implement it in their national legislation. According to EPBD, nearly-zero energy buildings have very high energy performance and their nearly-zero or very

Peer-review under responsibility of the organizing committee of SBE16.
doi:10.1016/j.proenv.2017.03.092

low amount of energy demands should, to a very significant extent, be covered by energy from renewable sources, including renewable energy produced on-site or nearby[1].

According to the Technical Chamber of Greece, building sector is responsible for 34% of the total energy consumption within Greece. Building sector consumes approximately 67% of the total electrical power produced and contributes to the total emission of CO_2 by approximately 43%[2]. The need for energy upgrade of the building sector, as well as the alignment with the directive of European Union, lead to the issue of the Hellenic Regulation on the Energy Performance in the Building Sector (K.Eν.A.K), which constitutes the implementation of EPBD in Greece. The strict legal definition of nZEB in Greece, based on current energy efficiency calculation tools, available renewable sources and existing energy legislation, is yet to be defined.

The increasing trend of reconstruction, combined with climate changes and the need for energy efficiency, render nearly-zero energy buildings as a promising solution for energy saving and sustainability. This study investigates the role of the building envelope in achieving nearly-zero energy buildings. Specifically, the basic parameters that influence greatly the energy performance of the building were examined, such as insulation layer, openings and shading devices. A model building was designed and a transient simulation software was used to define its energy demands. The results suggest solutions that contribute significantly to the decrease of the energy demands of the building. The reduction of the energy demands of a building constitutes the first essential step in achieving nearly-zero energy buildings, as the low energy demands can later be covered by renewable sources.

2. Methodology

2.1. Model building

The model building designed is representative to the average Greek residential building. The official data of the 2011 Population-Housing Census, provided by the Hellenic Statistical Authority (ΕΛ.ΣΤΑΤ.), were used to define the typologies and the materials of the model building. The architectural composition was aligned with the basic principles of energy-saving building design (passive house design).

The model building (Fig. 1) is a two-storey detached house with basement and roof terrace. The load bearing structure consists of reinforced concrete. The total area of the residential spaces of the house is approximately 180 m^2 and corresponds to a residential building destined to host a family of 4 members. The main façade of the building is facing South.

The building elements of the model building were dimensioned according to the Hellenic Regulation on the Energy Performance in the Building Sector (K.Eν.A.K) and fulfil its minimum requirements. The insulation layer is placed on the external side of all building elements. The thickness of the insulation layer was calculated so that the thermal transmittance U-value of every building element fulfills the minimum requirements of the regulation. The insulation thickness was defined at 8 cm for most vertical building elements (shear walls, infill walls, columns), the terrace and the balcony floor, and at 5 cm for all building elements adjacent to ground and non-heated spaces. The insulation material selected was expanded polystyrene, which represents the most used insulation material within Greece.

The opening type corresponds also to the most used opening type in Greece and abide by the minimum standards of the regulation. All the openings in the model building dispose aluminum frame with thermal break and double glazing. The thermal transmittance of the frame and the glazing was calculated at U_f=2,799 W/m^2K and U_g=1,793 W/m^2K respectively and the Solar Heat Gain Coefficient (SHGC) at 0,595.

2.2. Modelling and dynamic simulation

The software DesignBuilder was used to run hourly dynamic simulations and define the energy demands of the building. Initially, the model building was designed in the 3d drawing interface of the software and the input data for all simulations were set. The profile correspond to a typical residential building and was determined at 16 hours/day, 7 days/week and 12 months/year. The occupation rate was set at 0,016 persons/m^2, which corresponds to 4 persons for the given area of the model building. The comfort temperatures for winter and summer were set at 20 ^oC and 26 ^oC respectively, the natural ventilation at 4,17 l/(s·person) and the infiltration rate at 0,7 ac/h. Moreover a simple

HVAC system was created for the simulations and includes an oil generator for heating (PR=0,935) and air conditioning unit for cooling (EER=3,000). All input data were defined based on the Hellenic regulation standards.

According to the Hellenic regulation, Greece is divided in four different climate zones, based on the amount of heating degree days[4]. The model building was examined in all four climate zones of Greece. As a result, the climate data files of a representative city for every climate zone was used for the simulations. The cities, whose climate file were used, are Heraklion, Athens, Thessaloniki and Kozani and correspond to the climate zones A, B, C and D respectively.

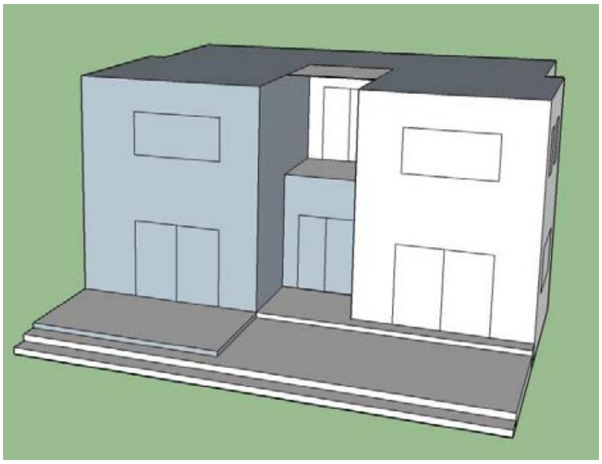

Fig. 1. Perspective drawing of the model building

Table 1. Insulation layer thickness and U-value of the building elements in all climate zones of Greece

Building elements	Zone A, B, C		Zone D	
	thickness *(cm)*	U-value *(W/m²K)*	thickness *(cm)*	U-value *(W/m²K)*
shear wall	8	0,377	8	0,377
wall	8	0,337	8	0,337
wall adjacent to ground	5	0,581	5	0,581
floor over ground	5	0,565	5	0,565
terrace	8	0,376	9	0,340
floor over non-heated space	5	0,510	5	0,510
balcony floor	8	0,338	9	0,338

2.3. Parametrical analysis

Primarily, the energy demands of the model building, that was designed based on the minimum requirements of the regulation, were calculated in every climate zone. A series of simulations, where various parameters were differentiated, were run in order to minimize the energy demands of the building in every climate zone. The parameters that were examined, relate to the building envelope and specifically to the insulation layer, openings and shading devices.

The thickness of the insulation layer and its effect on the energy demands of the building was examined first. The typical insulation material used within Greece is expanded polystyrene. As it is described above, the thickness of the insulation layer in the model building, according to the minimum standards of the Hellenic regulations, starts at 8 cm for all vertical building elements and the flat terrace. In every simulation, the U-value of the building elements was gradually decreased as the thickness of the insulation layer was increased every 2 cm till the final thickness examined of 20 cm. Only the thickness of the vertical building elements and the terrace was differentiated during the simulations.

The second parameter that was investigated was an innovative type of insulation. The energy demands of the building were calculated for the use of Vacuum Insulation Panels instead of conventional insulation materials. Vacuum Insulation Panels feature significantly low thermal conductivity (λ=0,007 W/mK) and small thickness of 5 cm [3].

Furthermore, two more energy efficient opening types were tested. The type of openings investigated dispose lower thermal transmittance of frame and glazing, as well as lower solar heat gain coefficient (SHGC).

Last but not least, the impact of shading devices on the energy performance of the building was examined. Horizontal aluminum overhangs were placed on the south façade of the building, while louvres with high-reflectivity blades were placed on the west and east façades. The louvres were tested under two different protocols: the blades were always steady at 45° angle and the blades were adjusted by the users.

The impact of each separate parameter, as well as all the possible combinations of the parameters, were examined and compared to the model building constructed based on the minimum standards of the regulation. The 12 different scenarios that resulted are presented briefly on Table 2.

Table 2. Scenarios examined

Scenario	
Scenario 0	Model building – insulation layer 8cm
Scenario 1	Insulation layer 10cm
Scenario 2	Insulation layer 12cm
Scenario 3	Insulation layer 14cm
Scenario 4	Insulation layer 16cm
Scenario 5	Insulation layer 18cm
Scenario 6	Insulation layer 20cm
Scenario 7	Vacuum Insulation Panels (VIP)
Scenario 8	Opening type 2 – U_f=2 W/m^{2}K, U_g=1,269 W/m^{2}K, SHGC=0,419
Scenario 9	Opening type 3 – U_f=1 W/m^{2}K, U_g=0,719 W/m^{2}K, SHGC=0,385
Scenario 10	Overhangs
Scenario 11	Overhangs + louvres (user operated)
Scenario 12	Overhangs + louvres (steady)

3. Results

The energy demands of every scenario simulated were compared with the energy demands of the model building, which was designed based on the minimum standards of the Hellenic Regulation on the Energy Performance in the Building Sector (K.Ev.A.K). The comparative analysis was performed in every climate zone of Greece. It is reminded that the climate zones descend from the warmest to the coldest, where zone A corresponds to the warmest and D to the coldest climate zone.

The results indicate that the increase of the insulation layer thickness of conventional materials, such as expanded polystyrene, reduce significantly the heating demand of the building. Alongside, the increase of the insulation thickness seems to have a negligible reduction of cooling demand for the low occupation rate of a residential building. The increase of the insulation thickness can be a simple efficient solution for cold climate zones, such as zones C and D. The simulation findings suggest that an insulation layer 20cm of convective materials (expanded polystyrene) reduce the total annual energy demand of the building by 13,65% in the cold climate zones C and D, and by 11,77% and 13,12% in the climate zones A and B respectively.

According to the simulation results, the innovative Vacuum Insulation Panels (VIP) contribute immensely to the decrease of heating and cooling demands of the building, compared to conventional insulation materials. The total annual energy savings was calculated at 13,56% for the warm climate zone A and at approximately 15,69% for the rest three climate zones of Greece. Moreover, VIP feature the extra advantage of thin insulation layer and keep the construction 'elegant' while providing high energy performance.

The simulation results regarding the improved opening types, suggest that openings with low SHGC have great impact on the decrease of cooling demand. The Solar Heat Gain Coefficient affects the amount of the solar radiation inserting the interior of the building and thus, the reduction of the SHGC leads to reduced solar gains and it is considered beneficial for the warmer climate zones with high cooling demands, such as zones A and B. For example, the two improved opening types decrease the total annual energy demand of the building in the warm climate zone A by 8,46% and 10,83% respectively, whereas the same opening types contribute only by 2,61% and 4,67% respectively at the energy savings of the building in the cold climate zone D.

The shading devices are proven to be extremely favorable for warm climate zones, as they reduce significantly the solar gains and subsequently the cooling demand of the building. In the warm climate zone A, the results showed that the shading devices as the only solution can yield energy savings of 8,63%. However, shading devices contribute to the surcharge of the heating demand. As a result, they can only be beneficial for the warm climate zones A and B, where the cooling demand has a definite role on the total energy demand. On the contrary, for the cold climate zones C and D, where the cooling demand consists a small percentage of the total energy demand, the shading devices surcharge the total annual energy demand of the building. Characteristically, in the coldest climate zone D, it is found that the shading devices surcharge the total annual energy demands of the building by 1,05%. It worth mentioning that the louvres with steady blades were proven to be more efficient compared to the ones operated by the users, probably because of the improper schedule followed by the users.

Last but not least, the series of simulations conducted showed that there is an optimal combination of parameters for every climate zone that can maximize the energy savings of the building in apiece zone. For the warmest climate zone A, only the use of improved opening types along with shading devices on the façades of the building can lead to energy savings up to 14%. For the rest three colder climate zones, the increase of the insulation layer thickness at 20 cm, combined with the use of more efficient opening types and shading devices may lead to energy savings up to 30%.

Table 3. Total annual energy savings and energy consumption based on the optimal combination for every climate zone

Climate zone	Annual energy saving *(%)*	Annual energy consumption *(kWh/m²)*
A	14	29,05
B	24	41,07
C	20	55,23
D	30	55,25

4. Conclusions

This study presents the potential of minimizing the total energy demands of a building within Greece in order to achieve nearly-zero energy buildings. The dynamic simulation analysis indicates that the increased thickness of the insulation layer consists a simple and very effective solution for decreasing the total annual energy demands of a building. Furthermore, other simple constructive solution, such as the application of openings with improved thermal characteristics and the use of shading devices, may lead to significant energy savings in the warm climate zones. The use of innovative insulation materials with low thermal conductivity, such as the VIP, establish a very promising constructive solution that can combine high energy performance and aesthetics.

The climatic characteristics of Greece compose a complicated map that leads the way to the achievement of nearly-zero energy buildings. The temperate climate of Greece provides plenty of renewable energy sources that can be exploited for the coverage of the low energy demands. However, the demand for both heating and cooling throughout a year complicates the achievement of the goal. The simulation analysis results highlight that the total energy demand depends on multiple factors that can affect the energy performance of the building. A set of various parameters is necessary to be investigated in order to determine the right combination of parameters that can optimize the energy performance of the building and minimize its energy demands, accomplishing thus the first crucial step in achieving nearly-zero energy buildings.

References

1. Ecofys. Towards nearly zero-energy buildings. Definition of common principles under the EPBD. *Final report for Europen Commission*; February 2013.
2. Technical Chamber of Greece. Introduction on Energy Field. Educational material for energy consultants; June 2011
3. Institutions and Author. Study on VIP components and Panels for Service Life Prediction of VIP in Building Applications (Subtask A). *HiPTI IEA/ECBCS Annex 39*; September 2005
4. Technical Chamber of Greece. Hellenic Regulation on the Energy Performance in the Building Sector. *TOTEE 20701-1/2010*; April 2012