NZEB strategies – Mediterranean warm climate in housing buildings

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In this article a detailed analysis of a real case of single-family homes is presented. As a starting point, the building complies with the Spanish regulation DB-HE 2013 and have an Energy Class “A” for the CO_2 emissions indicator and Class “B” for the non-renewable primary energy consumption indicator. Next, different strategies are analysed to convert the building into nZEB according to the ongoing Spanish regulation DB-HE 2018. The objective is to offer strategies that do not involve a significant increase in construction costs or a modification of the construction systems that are currently used.

Keywords: nZEB in single family homes, Mediterranean warm climate, Spanish DB-HE 2018

Introduction

The update of the Spanish building regulation “DB-HE”, which must be finally approved during the year 2018, will be the second review of energy saving requirements that will occur since the first version was published in 2006. This new version of the DB-HE will incorporate the nZEB requirements into the Spanish regulation.

The new requirements are defined within a set of indicators that are based on the standard EN ISO 52000-1, the building that complies with the limits established for each of these indicators will be considered as nZEB.

The standard EN ISO 52000-1 indicators focus on four blocks:

- First indicator: The building envelope (energy needs or energy demand).
- Second indicator: The total primary energy use.
- Third indicator: Non-renewable primary energy use without compensation between energy carriers.
- Fourth indicator: Numerical indicator of non-renewable primary energy use with compensation.

The first three indicators are incorporated into the Spanish new DB-HE, leaving the fourth indicator for its development in future regulations.

In this article we analyse various alternatives applied to a real single-family dwelling, both in the envelope of the building and in its facilities (production of domestic hot water, heating and cooling).

The criterion that has been followed to determine energy improvement strategies follows the following principles:

- The strategies should not imply a significant increase in the construction cost.
- The strategies should not imply a significant modification of the constructive systems that are currently used.

In summary, we look for strategies that have an easy and fast implementation in the building sector in Spain, trying to create the feeling in the promoters of new buildings that nZEB is a feasible objective to achieve.

Description of the dwelling

This analysis is based on a single-family house that is currently on definition phase. The house is close to a group of similar houses which are currently on construction. They are located on the north coast of the province of Alicante (climatic zone B4), with 150.17 m^2 living space distributed over two floors, ground floor with 54.29 m^2 and first floor with 95.88 m^2.

The thermal envelope of the building consists of the elements presented in **Table 1**.

The windows have aluminum frames with thermal break, U = 3.20 W/(m^2·K) and low emissive glasses, U = 1.80 W/(m^2·K) (thermal transmission coefficient) and g = 64% (solar factor).

Regarding the definition of the encounters between the different enclosures that produce thermal bridges, and taking into account the constructive typology of the façade formed by double brick with an isolated air chamber, it has been considered:

- Slab penetrating a wall (façade) and encounter between wall and roof: thermal insulation not continuous.
- Pillar: there are no pillars (load bearing walls).
- Encounter between façade and external floor: thermal insulation above slab.
- Contour of the window: small separation between the thermal insulation of the façade and the window frames.
- Encounter between façade and floor above ground: thermal insulation not continuous.

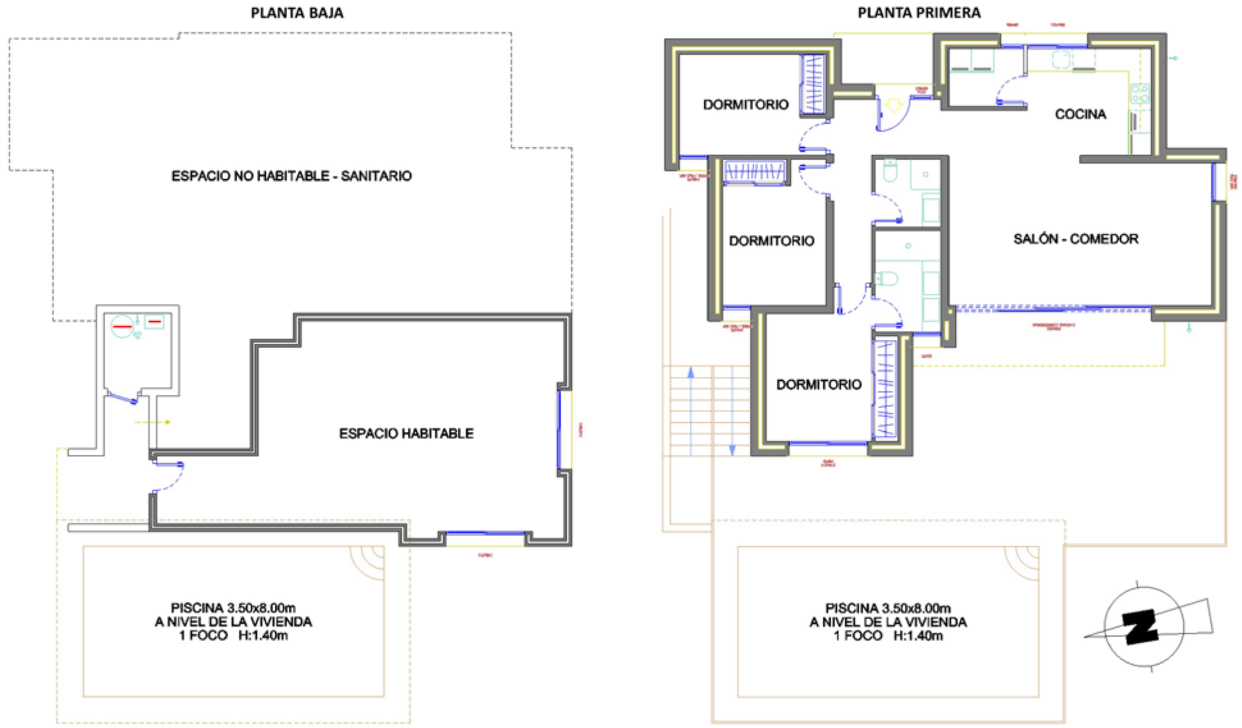

Figure 1. Drawings of the analysed dwelling.

Regarding the installations, the project has an air-water heat pump for the supply of both domestic hot water and heating (underfloor heating) and cooling (fan coils). At EUROVENT nominal conditions, the air-water heat pump has a nominal performance in heat mode COP of 4.29 and in cold mode the SEER seasonal average is 3.04. There is no solar thermal installation for domestic hot water. The ventilation is produced by an impulse / extraction system with a heat recovery of an efficiency of 77%.

Methodology followed

This study has been done using the software "Unified Tool LIDER – CALENER, HULC 2018 (Spanish acronym), version 1.5.1743.1155 of July 19, 2018. HULC is the Spanish official building energy certification tool used for the thermal energy demand assessment. This version of the HULC tool is included in the draft of the DB-HE 2018, which, as indicated above, includes the indicators for the nZEB buildings. It is important to highlight that the HULC tool follows a transitory calculation and hourly base assessment that has been validated through BESTEST and has been used in many recently published studies.

Figure 2. Exterior of similar homes to the analysed one built in the same development.

Table 1. Description of the thermal envelope of the building.

Façades (layers from outside to inside)		**U = 0.28 W/(m^2·K)**
Cement mortar	1.5 cm	
Concrete block (load bearing walls)	20 cm	
Mineral wool – 0.034 W/m·K	5 + 5 cm	
Double air brick	7 cm	
Gypsum plaster	1.5 cm	
Roofs (layers from outside to inside)		**U = 0.20 W/(m^2·K)**
Gravel + geotextile	5 cm	
Extruded polystyrene – 0.034 W/m·K	5 + 5 + 5 cm	
Geotextile + waterproofing	0.4 cm	
Light weight concrete	7 cm	
Unidirectional slab with concrete blocks	25 cm	
Gypsum plaster	1.5 cm	
Interior floor (layers from outside to inside)		**U = 0.96 W/(m^2·K)**
Stoneware	1.5 cm	
Cement mortar	4 cm	
Expanded polystyrene (underfloor heating) – 0.039 W/m·K	2 cm	
Unidirectional slab with concrete blocks	25 cm	
Inside wall. Conditioning to not conditioning spaces		**U = 0.47 W/(m^2·K)**
Concrete block (load bearing walls)	20 cm	
Mineral wool – 0.034 W/m·K	5 cm	
Double air brick	7 cm	
Gypsum plaster	1.5 cm	

For the analysis of the thermal bridges that arise in Case 2, the THERM Finite Element Simulator has been used in its latest version 7.6.01 (version date 17 November 2017). THERM is developed by Lawrence Berkeley National Laboratory (LBNL) to model two-dimensional heat transfer effects and is based on the finite element method and meets the requirements indicated in the UNE-EN ISO 10211 standard "Thermal bridges in buildings. Heat flows and surface temperatures".

In the analysis carried out, six cases are presented:

- Case 1: This is the starting situation in which the solutions described in the previous section are applied.
- Case 2: Starting from Case 1, it includes the necessary measures to comply with the parameter of the global heat transfer coefficient of the thermal envelope K.
- Case 3: From Case 2, the necessary measures are added to comply with the solar control parameter of the thermal envelope, q_{sol}; Cases 2 and 3 allow compliance with the energy demand indicator.
- Case 4: From Case 3, the necessary measures are included so that the building complies with both the total primary energy indicator and the non-renewable primary energy indicator.

From Case 4, the building complies with the Spanish nZEB requirements and, therefore, it is a Nearly Zero Energy Building.

To complement the research, two variations are made in the domestic hot water, heating and cooling installations according to the following:

- Case 5: Solar thermal solar installation and air/water heat pump for domestic hot water production and air/air heat pump for heating and cooling.
- Case 6: Photovoltaic solar installation and air /water heat pump for domestic hot water production and air/air heat pump for heating and cooling.

Results

The results obtained with each of the six cases analysed are shown below. In addition, the limit values established in the DB-HE 2018 draft form the indicators that define a NZEB are shown.

Case 1. Starting situation *(pls. see Table 2)*

Case 2. Comply with the parameter of the global coefficient of heat transmission through the thermal envelope K *(pls. see Table 3)*

The envelope global heat transfer coefficient, K depends on three main components: opaque parts (façades, roofs, outside floors and floors above the ground), windows and thermal bridges. The analysis of the contribution of each one of these three components on the total value will show us where to start the improvement process. The result is: 39% for opaque parts; 30% for windows and 31% for thermal bridges.

Given that the opaque part is already well insulated, with insulation thicknesses of 10 cm on façades and 15 cm on the roof, the analysis was focussed on thermal bridges: the reduction of the façade encounter with flat roofs is proposed, since in that encounter the highest energy losses are produced (54% of the total). It is proposed to replace the concrete blocks of the unidirectional slab by EPS expanded polystyrene blocks obtaining a linear thermal transmittance value, determined with THERM Software, of 0.18 W/m·K (much lower than the standard value of 0.92 W/m·K).

Case 3. Comply with the solar control parameter of the thermal envelope, q_{sol}, $q_{sol;jul}$ *(pls. see Table 4)*

The solar control of the thermal envelope depends on the solar gains, for July 15th, through all windows with the solar protections activated. Therefore, it is proposed to incorporate blinds to all windows (except those in the toilet rooms) and an awning in the window of the living - dining room. The standard EN ISO 52033-1 has been applied to determine the coefficient g_{gl}; s_h; w_i (total energy transmittance through a glass).

Table 2. Results obtained in Case 1.

Energy Demand		**Energy Class**	
Heating kWh/(m^2·year)	Cooling kWh/(m^2·year)	CO_2 emissions Kg CO_2/(m^2·year)	Non-Renewable Primary Energy Consumption. kWh/(m^2·year)
12.80	19.80	5.30 - "A"	31.20 - "B"
First indicator Energy Demand		**Second indicator** Total Primary Energy Consumption	**Third indicator** Non-Renewable Primary Energy Consumption
K = 0.68 > 0.58 Fails	$q_{sol;jul}$ = 17.03 ≤ 2 Fails	51.20 ≤ 56 Comply	31.20 ≤ 28 Comply

Case 4. Comply with all nZEB indicators *(pls. see Table 5)*

Case 3 shows that the building is very close to comply all nZEB requirements. As it can be seen in the house drawings (**Figure 1**), the larger windows are oriented to the West, reducing the absorption of solar radiation in winter. It was proposed to change the orientation of the main bedroom room from West to South.

Case 5. Modification of the facilities: thermal solar installation and air/water heat pump for domestic hot water production and air/air heat pump for heating and cooling *(pls. see Table 6)*

Facilities are now modified: domestic hot water through solar thermal (annual solar coverage of 77.2%) and air-water heat pump (COP under EUROVENT conditions of 3.19); Air conditioning by autonomous air-to-air heat pump (EUROVENT COP 4.28 and EER 3.75). This case does not require the modification of the window orientation proposed in Case 4.

Case 6. Modification of the facilities: photovoltaic solar installation and air/water heat pump for domestic hot water production and air/air heat pump for heating and cooling *(pls. see Table 7)*

Facilities are modified: domestic hot water through photovoltaic solar installation (annual production of 432 kWh/year) and air to water heat pump (EUROVENT nominal COP = 3.19). Air conditioning by autonomous air to air heat pump (EUROVENT nominal COP = 4.28 and EER = 3.75). This case needs the modification of the window indicated in Case 4.

Table 3. Results obtained in Case 2.

Energy Demand		**Energy Class**	
Heating kWh/(m^2·year)	Cooling kWh/(m^2·year)	CO$_2$ emissions Kg CO$_2$/(m^2·year)	Non-Renewable Primary Energy Consumption. kWh/(m^2·year)
9.8	19.4	4.9 - "A"	28.9 - "A"

First indicator Energy Demand		**Second indicator** Total Primary Energy Consumption	**Third indicator** Non-Renewable Primary Energy Consumption
K = 0.57 ≤ 0.58 Comply	$q_{sol;jul}$ = 17.03 ≤ 2 Comply	47.6 ≤ 56 Comply	28.9 ≤ 28 Comply

Table 4. Results obtained in Case 3.

Energy Demand		**Energy Class**	
Heating kWh/(m^2·year)	Cooling kWh/(m^2·year)	CO$_2$ emissions Kg CO$_2$/(m^2·year)	Non-Renewable Primary Energy Consumption. kWh/(m^2·year)
9.8	19.4	4.9 - "A"	28.9 - "A"

First indicator Energy Demand		**Second indicator** Total Primary Energy Consumption	**Third indicator** Non-Renewable Primary Energy Consumption
K = 0.57 ≤ 0.58 Comply	$q_{sol;jul}$ = 2 ≤ 2 Comply	47.6 ≤ 56 Comply	28.9 ≤ 28 Comply

Table 5. Results obtained in Case 4.

Energy Demand		**Energy Class**	
Heating kWh/(m^2·year)	Cooling kWh/(m^2·year)	CO$_2$ emissions Kg CO$_2$/(m^2·year)	Non-Renewable Primary Energy Consumption. kWh/(m^2·year)
8.5	19.1	4.6 - "A"	27.2 - "A"

First indicator Energy Demand		**Second indicator** Total Primary Energy Consumption	**Third indicator** Non-Renewable Primary Energy Consumption
K = 0.57 ≤ 0.58 Comply	$q_{sol;jul}$ = 1.96 ≤ 2 Comply	44.90 ≤ 56 Comply	27.2 ≤ 28 Comply

Conclusions

It has been demonstrated that it is possible to achieve the requirements established in the latest version of the Spanish definition of nZEB, applying strategies that neither imply a significant increase in the construction costs nor a significant modification of the construction systems that are currently used.

Once the building is properly insulated according to current Spanish requirements, incorporating solutions to minimize thermal bridges, installing solar protection systems such as blinds and analysing the correct orientation of the windows, it will be possible to meet the nZEB requirements published in the last draft.

On the other hand, a comparison between different facilities is provided in **Table 8** (Cases 4, 5 and 6), which is interesting because there are significant differences in energy consumption. ■

Table 6. Results obtained in Case 5

Energy Demand		Energy Class	
Heating kWh/(m^2·year)	Cooling kWh/(m^2·year)	CO$_2$ emissions Kg CO$_2$/(m^2·year)	Non-Renewable Primary Energy Consumption. kWh/(m^2·year)
9.8	19.4	4.3 - "A"	25.4 - "A"

First indicator Energy Demand		Second indicator Total Primary Energy Consumption	Third indicator Non-Renewable Primary Energy Consumption
K = 0.57 ≤ 0.58 Comply	$q_{sol;jul} = 2 \leq 2$ Comply	52.0 ≤ 56 Comply	25.4 ≤ 28 Comply

Table 7. Results obtained in Case 6.

Energy Demand		Energy Class	
Heating kWh/(m^2·year)	Cooling kWh/(m^2·year)	CO$_2$ emissions Kg CO$_2$/(m^2·year)	Non-Renewable Primary Energy Consumption. kWh/(m^2·year)
8.4	19.1	5.1 - "A"	24.5 - "A"

First indicator Energy Demand		Second indicator Total Primary Energy Consumption	Third indicator Non-Renewable Primary Energy Consumption
K = 0.57 ≤ 0.58 Comply	$q_{sol;jul} = 1.96 \leq 2$ Comply	49.6 ≤ 56 Comply	24.5 ≤ 28 Comply

Table 8. Comparison between Cases 4, 5 and 6.

Case	**Primary Energy Consumption [kWh/(m^2·year)]**		
	Total	**Renewable**	**Non-Renewable**
Case 4. Air to water heat pump for domestic hot water production, heating and cooling	44.90	17.70	27.20
Case 5. Solar thermal installation and air to water heat pump for DHW production and air to air heat pump for heating and cooling	52.00	26.60	25.40
Case 6. Photovoltaic solar installation and air to water heat pump for DHW production and air to air heat pump for heating and cooling	49.60	25.10	24.50

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