Replicability of nZEBs on real estate market in Mediterranean countries

Original
Replicability of nZEBs on real estate market in Mediterranean countries / Barthelmes, VERENA MARIE; Becchio, Cristina; Corgnati, STEFANO PAOLO; Guala, C.; Lequio, M.. - In: ENERGY PROCEDIA. - ISSN 1876-6102. - 82:(2015), pp. 452-457. [10.1016/j.egypro.2015.11.843]

Availability:
This version is available at: 11583/2641865 since: 2016-05-09T14:01:08Z

Publisher:
Elsevier Ltd

Published
DOI:10.1016/j.egypro.2015.11.843

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 82 (2015) 452 – 457

Energy Procedia

ATI 2015 - 70th Conference of the ATI Engineering Association

Replicability of nZEBs on real estate market in Mediterranean countries

V.M. Barthelmes[a], C. Becchio[a]*, S.P. Corgnati[a], C. Guala[a], M. Lequio[a]

[a]DENERG - Politecnico di Torino, Corso Duca degli Abruzzi 24, Torino 10129, Italy

Abstract

According to the recast of the Energy Performance of Buildings Directive and its target for the large-scale increase of nearly-zero energy buildings, nowadays a challenging task is the definition of standard high performing building types depending on location and specific climate conditions. The widespread replicability of nZEB types on the current real estate market could implement nZEB design scenarios attractive and affordable for construction companies and private investors. In particular, this research focuses on the definition of replicable HVAC system configurations with different features and efficiencies starting from a reference building located in a Mediterranean country. The configurations were applied to CorTau House, an nZEB under construction in Piedmont Region, a typical situation of European Mediterranean country where both winter and summer loads, together with humidity, have to be carefully controlled. Building envelope and HVAC system design were matched in order to optimize energy performance and indoor thermal comfort. The HVAC configurations, able to meet nZEB targets and to ensure optimal indoor comfort conditions, were combined with a performing building envelope, made of local construction materials, in order to assess which of them is more energy effective and economically viable. Cost-optimal types were identified and prospective replicability on building market was speculated. Finally, differences between private investor's and company construction's perspectives were discussed.

Peer-review under responsibility of the Scientific Committee of ATI 2015

Keywords: nZEB replicability; real estate market; cost-optimal evaluation.

1. Introduction

The recast of the Directive on the Energy Performance of Buildings (EPBD) [1] represents a turning point in designing buildings, from both an architectural perspective and technical systems one, including HVAC. Indeed, it requires by the end of 2020 all new buildings to be nearly-zero energy buildings (nZEBs), defining them as buildings characterized by a very high energy performance; the very low amount of required energy should be mainly covered by energy from renewable sources produced on-site or nearby. The EPBD recast also introduces a comparative methodology framework to guide Member States in defining nZEB energy performances with a cost-optimality perspective. Cost-optimal level refers to the primary energy performance leading to the lowest cost during the building lifecycle. Indeed, nowadays considering only investment cost building an nZEB is not so viable, but it reveals to be cost efficient taking into account the costs incurred during whole building life-cycle. Cost-optimal levels can represent a first step towards the achievement of nZEB targets and to the spread of nZEBs on the real estate market.

Currently the implementation of the cost-optimal methodology at national and local levels is a challenging task in the European research landscape, but it emerges the lack of definition of local nZEB types, oriented to different profiles of investors and replicable on the real estate market [2]. For this reason, starting from the analysis of a single-family house under construction in Piedmont region (North Italy), the so-called CorTau House, this paper aims at

* Corresponding author. Tel.: +39 011 447 1778; fax: +39 011 090 4499.
E-mail address: cristina.becchio@polito.it

Peer-review under responsibility of the Scientific Committee of ATI 2015
doi:10.1016/j.egypro.2015.11.843

individuating possible nZEB types for Mediterranean countries, replicable on the market according to building typology, size and climate conditions and to different investors requirements. Indeed CorTau House represents a good example of the refurbishment of a traditional rural building, a sort of canopy designed to house agricultural equipment, which is a widely diffused structure in the Italian countryside. Moreover, the final object of the retrofit intervention is the realization, without new soil consumption, of a single-family house, which represents a widespread building typology in Italy; around 38% of Italian population lives in single-family houses [3]. The final concept of the CorTau House is strongly influenced by the interest of a "green" private investor (which is also the owner of the building) in testing high performing technologies and systems for achieving the nZEB targets. Starting from this real reference building (RB), in the perspective of replicability on real estate market, different HVAC system configurations characterized by lower investment costs and efficiency were assessed in order to counterpose the requirements of a private investor (identified by the real reference building) and those of a construction company.

In particular, in the analysis different HVAC system configurations suitable to be replicated were defined and investigated, while the building envelope with its energy performance represents a fixed parameter. Indeed, all the HVAC configurations (such as water-to-water heat pumps, condensing boilers, mechanical controlled ventilation systems with heat recovery, humidifier/dehumidifier, solar and PV panels) were combined with the high performing envelope of the RB, built with typical local construction materials, typically used in Mediterranean countries due to their high thermal mass. The different HVAC system configurations, hereinafter indicated as Energy Efficiency Measure (EEM), were assessed through cost-optimal analysis. Energy performance and economic feasibility of each EEM were analyzed in the perspective of the diverging interests which move construction companies and individual private investors in realizing nZEBs.

2. The case-study

The so-called CorTau House [4][5] is a single-family house born from the refurbishment of a traditional rural building widely diffused in North Italy; it is located in Piedmont Region (Italian Climate Zone E, 2549 Heating Degree Days), that represents a typical situation of European Mediterranean country characterized by a quite wide range of climatic zones. In particular, nZEB design solutions should aim at achieving the right balance in the minimization of winter heating and summer cooling loads and at ensuring indoor comfort conditions. During the building design phases these goals were accurately evaluated and combined with architectural quality in refurbishing a traditional rural building widely diffused in this Region.

The building spaces are arranged over a single-storey with a net conditioned floor area of 135 m^2 and are designed with particular attention to bioclimatic principles (e.g. orientation of rooms and windows, sun screens). The external vertical envelope, constituted by both structural reinforced concrete bearing-walls and infill masonry walls, offers high thermal inertia. The insulation layer of walls (U_{wall} = 0.15 W/m^{2}K) and slabs ($U_{floor\ slab}$ = 0.19 W/m^{2}K, U_{roof} = 0.15 W/m^{2}K) consists of rock-wool panels and the whole envelope is accurately designed in order to minimize the creation of thermal bridges and the air infiltration and to provide barriers to rising damp. Windows are composed by aluminum frame with thermal break with low-e triple-pane glass with argon (U_{window} = 0.96 W/m^{2}K). The low heating ($Q_{H,nd}$ = 17.2 kWh/m^{2}y) and cooling needs ($Q_{C,nd}$ = 19.7 kWh/m^{2}y), due to the insulated and massive envelope, contribute to limit the total building energy demand.

Fig. 1. (a) CorTau House construction site; (b) distribution manifold and radiant floor details; (c) air handling unit

The house represents a type of all-electric building (the kitchen also is furnished with electric stove and oven); according to nZEB definitions a distinctive element of the building is indeed the possibility to ensure the energy independence from fossil energy sources. The electricity consumptions of the building are totally covered by a 7 kW$_{peak}$ grid-connected photovoltaic (PV) system installed on the southern roof pitch (surface = 56 m^2). Space heating and cooling and Domestic Hot Water (DHW) production are provided by a water-to-water heat pump (COP = 4.78; ESEER= 5.67). Terminal devices are constituted by radiant floors, with the addiction of electric radiators in the bathrooms. A Controlled Mechanical Ventilation (CMV) system, equipped with high efficiency heat recovery exchanger (mean seasonal efficiency = 0.85), guarantees good IAQ and the humidity control, especially in summer when condensation risk, linked to use of radiant floor as terminal devices, is higher.

3. HVAC system configurations

Starting from the type provided by the RB, in the perspective of replicability on real estate market, 11 different system configurations (EEMs), characterized by lower investment costs and different energy efficiencies, were hypothesized.

In the present analysis EEMs were divided into three categories, based on the generation system adopted: water-to-water heat pump (COP = 4.78; ESEER= 5.67), condensing boiler (nominal efficiency = 0.99) and pellet boiler (nominal efficiency = 0.92). As regards the other building system components, three different typologies of terminal devices were assessed: radiant floors, radiators and low temperature radiators. The analyzed EEMs also include alternatively a CMV system with heat recovery, a dehumidifier or multi-split air conditioners. PV systems were sized based on minimum requirements laid down for new buildings in the Italian regulation. Indeed, two different peak power values were considered, 5 kW_{peak} and 3 kW_{peak}, which respectively refer to construction permits required before and after December 2016 [6]. EEMs with generation systems different from electric heat pump were also equipped with thermal solar panels, which cover the 60% of DHW needs [7].

All the HVAC combinations characterizing each EEM are shown in Table 1. The building envelope of the RB instead is fixed, because its high thermal inertia and performing insulation level optimally fits into a Mediterranean country, where both winter and summer loads have to be minimized.

		Generation system											
		Heat pump				**Condensing boiler**				**Pellet boiler**			
		RB	EEM1	EEM 2	EEM 3	EEM 4	EEM 5	EEM 6	EEM 7	EEM 8	EEM 9	EEM 10	EEM 11
Terminal devices	Radiant floors	•	•			•	•	•		•	•	•	
	Radiators								•				•
	Low temp. radiators			•	•								
CMV with heat recovery		•				•				•			
Dehumidifier			•	•	•			•	•			•	•
Multi-split air conditioner							•				•		
PV system	7 kW_{peak}	•											
	5 kW_{peak}		•	•		•	•			•	•		
	3 kW_{peak}				•			•	•			•	•
Solar panels	Around 4 m^2					•	•	•	•	•	•	•	•
Investment cost related to HVAC	[€]	57'804	44'835	41'928	29'485	41'558	41'240	27'454	24'547	48'118	47'799	34'013	31'107
	[€/m^2]	440	341	319	224	316	314	209	187	366	364	259	237

Table 1. Description of the EEMs assessed through cost-optimal analysis and their investment cost

4. Methodology and tools

In the present study, the cost-optimal methodology is exploited as an assessment tool to evaluate the different HVAC system options and to individuate which of them is more energy effective and economically viable and represents the cost-optimal level. The first step of the analysis consisted in the energy evaluation of each EEM according to the European Standard EN 13790:2008 [8]. The annual overall delivered primary energy, calculated using Italian primary energy factors (1.09 for natural gas and 2.17 for electricity [9]), includes energy uses for space heating and cooling, DHW production, lighting, equipment, ventilation and solar panels and PV system production (taking into account on-site consumption and surplus electricity going to the grid). Then, the energy class of each EEM was defined according to the Directive of Piedmont Region [10], which takes into account primary energy consumption only for space heating and DHW. The economic valuation was performed according to global cost method from EN 15459:2007 [11]. For each EEM global cost was valuated; it consists in the estimation of the net-present value of all costs incurring in a defined calculation period, taking into account the residual values of components with longer lifetime. It can be written as (1):

$$C_G(\tau) = C_I + \sum_J \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) * R_d(i) \right) - V_{f,\tau}(j) \right] \quad (1)$$

where $C_G(\tau)$ represents the global cost referred to starting year τ_0, C_I is the initial investment cost, $C_{a,i}(j)$ is the annual cost for the component j at the year i (including running costs and periodic or replacement costs), $R_d(i)$ is the discount rate for year I and $V_{f,\tau}(j)$ is the final value of component j at the end of the calculation period (referred to the starting year τ_0). The analysis refers to a calculation period of 30 years and a discount rate of 4% [12]. In this research, for each EEM, initial investment costs, HVAC systems maintenance costs and energy costs were taken into account, while replacement costs and final values of building components were assumed to be zero in order to simplify the calculation. A future development of the present analysis is surely the introduction of these values in the calculation of global cost. All the assessed investment and maintenance costs are referred to the building system; a significant part of the real investment cost is due to the construction cost, which includes the investment cost for the building envelope. Since this construction cost is a constant value (the building envelope is a fixed element for all the EEMs), it is not evaluated among the costs to be incurred, in line with the aim of this research to focus on the assessment of HVAC system configurations. Based on the obtained results, the cost-optimal graph was drawn; the global cost (€/m^2) on y-axis is plotted versus the primary energy consumption (kWh/m^{2}y) on the x-axis. Each point on the graph represents a different EEM in terms of energy and economic performance. The positions of different scenarios allowed drawing the trend of the dotted broken line representing the cost-curve, the minimum of which constitutes the cost-optimal level.

5. Results

As shown in the graph (Figure 2), the RB (water-to-water heat pump, radiant floors, CMV with heat recovery, 5 kW_{peak} PV system) represents the scenario with the highest global cost and the lowest primary energy consumption since all electric energy consumptions are covered by the PV system.

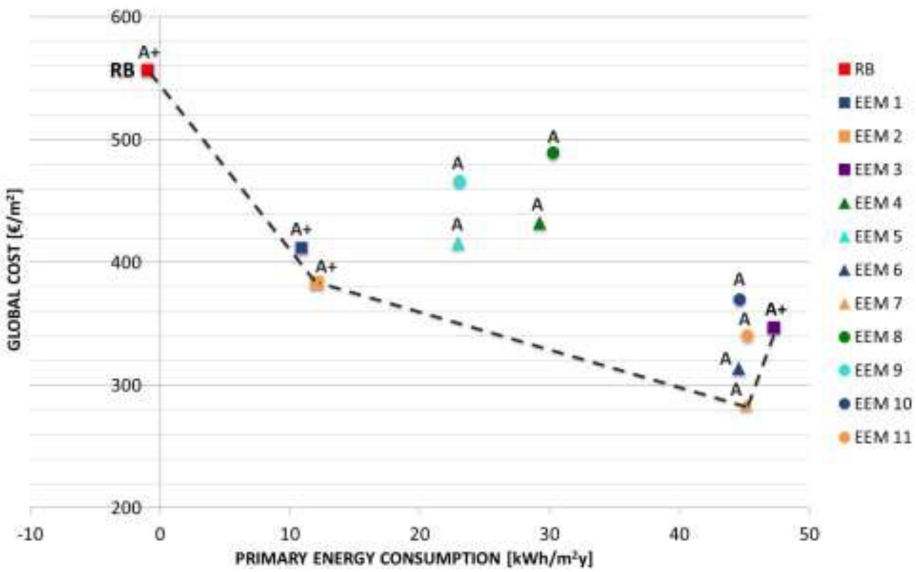

Fig. 2. Cost-optimal graph and nZEB configurations

In line with the aim to test HVAC systems with lower investment cost and efficiency than the ones adopted for the RB, all the EEMs assessed are characterized by higher energy consumptions and lower global costs than the RB ones. The graph shows that primary energy consumptions range from -1 kWh/m²y (RB) to 47 kWh/m²y (EEM 3; water-to-water heat pump, low temperature radiators, dehumidifier, 3 kW_{peak} PV system); the global cost range is between 284 (EEM 7; condensing boiler, radiators, dehumidifier, 3 kW_{peak} PV system, 4 m² of solar panels) and 557 €/m² (RB). The cost-optimal level is given by EEM 7 that represents the system configuration with the lowest global cost (284 €/m²), the lowest investment cost (Table 1) but with a primary energy consumption (45 kWh/m²y) distant from the nZEB targets.

EEM 1 (water-to-water heat pump, radiant floors, dehumidifier, 5 kW_{peak} PV system) and EEM 2 (water-to-water heat pump, low temperature radiators, dehumidifier, 5 kW_{peak} PV system), against a lower global cost than RB (around 400 €/m²), achieve the nZEB targets with around 12 kWh/m²y. EEMs equipped with condensing and pellet boiler do not reach the nZEB target.

A “green” private investor coinciding with the end user of the building is probably moved to support high investment costs in order to achieve enhanced energy performances and high comfort levels; this kind of investor could be interested in realizing a building based on the type of RB. A typical private investor might instead prefer to invest in cost-optimal scenarios, as EEM 7, which is characterized by lower global costs. Cost-optimal EEMs doesn’t allow to achieve nZEB targets but guarantees at the same time quite good energy performances (45 kWh/m²y). In the perspective of a construction company, which has to sell the building on real estate market, the most viable EEMs are those with the lowest investment costs, about 200 €/m² (EEMs 3 with water-to-water heat pump, low temperature radiators, dehumidifier, 3 kW_{peak} PV system; EEM 6 with condensing boiler, radiant panels, dehumidifier, 3 kW_{peak} PV system, 4 m² of solar panels; EEM 7 with condensing boiler, radiators, dehumidifier, 3 kW_{peak} PV system, 4 m² of solar panels), that are related with high energy classes (A for EEM 6 and 7 and A+ for EEM 3).

All the assessed EEMs lead to high energy classes (A or A+) according to Piedmont Region legislation [9]. EEMs equipped with condensing and pellet boiler are class A, while the four A+ configurations refer to solutions equipped with water-to-water heat pump (RB and EEMs 1, 2 and 3). The gap in terms of energy performances among the A+ configurations (from -1 kWh/m²y of RB to 45 kWh/m²y of EEM 3) demonstrates that the highest Italian energy class does not necessarily correspond to high energy performances in terms of primary energy consumptions. In fact, energy consumptions for cooling, lighting and equipment are not taken into account by the national energy labeling, but are fundamental for an accurate off-market evaluation. Nowadays in Italy, the energy class, which is neither a guarantee of low energy consumptions nor of indoor comfort conditions, barely influences the market value of a building to be sold [13]. For these reasons, in choosing the best and most viable energy configuration, a private investor is not influenced by the energy class and the market value of the building, but he should prefer the solution with the lowest energy consumption due to the fact that he will pay the energy bills. On the contrary, the real estate value of a building plays a key role in the perspective of a construction company whose aim is that of selling the building that it fabricated. A construction company should compare the real estate market value, derived from the National Observatory on Real Estate Values [14], with the sale price of a building that represents the sum of the investment costs and its own financial profit. If the sale price is equal or lower than the market value the company can start to construct and enter in the marketplace; if the sale price is higher than the market value it means that there is no profit for the company and the investment cost is not economically sustainable.

6. Conclusion and research future development

The individuation of nZEB types in Mediterranean countries is nowadays a challenging task. Several parameters influence the individuation of the most convenient HVAC configurations both in energy and economic perspective. The replicability of an nZEB type on real estate market is highly dependent on the perspective in which the building is realized and has to take into account the point of view of the investor.

A private investor who coincides with the end user of the building is highly influenced by its own current financial situation and by future energy bills that will have to pay; if he has financial means he is probably willing to support high investment costs in order to achieve enhanced building quality, energy performances and indoor comfort. With the same financial liquidity, a “green” private investor could be interested in realizing a high performing building based on the type of RB (water-to-water heat pump, radiant floors, CMV with heat recovery, 5 kW_{peak} PV system), while a typical private investor might prefer to invest in cost-optimal scenarios (EEM 7; condensing boiler, radiators, dehumidifier, 3 kW_{peak} PV system, 4 m² of solar panels). More generally and differently from a construction company, the choices of a private investor, which is also the building end-user, are not influenced by the real estate value and the energy class of its property but by its real total energy consumptions.

On the other hand, a construction company, which has to sell the building, is especially interested in obtaining a financial profit and in fabricating the most profitable building configuration. In this perspective a key role is played by the real estate market value of a building that represents a parameter with comparing its sale price; if the market value is lower than the sale price, there is no financial profit for the company and the energy configuration is not viable. The EEMs which imply low investment costs and quite good energy performances (EEMs 3, 6 and 7) are thus probably the most suitable ones for a construction company and represent the HVAC system configurations that should be largely replicable on the real estate market.

Nowadays, the issue of how real estate market reflects and enhances the energy features of a building is still pending but in future it's desirable to take into account the energy performance indexes in evaluating the market value of a building.

With the aim to achieve nZEB targets, EEMs 1 and 2, which are characterized by lower global costs than the RB reveal to be the most convenient and replicable ones on the market.

This analysis represents a first step towards the definition of a replicable nZEB type in Mediterranean countries. This kind of analysis could be implemented in future and extended to new building typologies by including combinations of different building system and envelope solutions. Finally, a further development should include the analysis of the system replacement costs, which could be a turning point in the evaluations since the life durability of each building component might determine significant difference in their convenience.

7. References

[1] European Parliament. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast). Belgium: Official Journal of the European Union; 2010.

[2] The Economist Intelligence Unit. Investing in energy efficiency in Europe's buildings. A view from the construction and the real estate sectors. BPIE; 2013

[3] ISTAT. L'abitazione delle famiglie residenti in Italia. Anno 2008. 26 February 2010. Available online: http://www.istat.it.

[4] Barthelmes VM, Becchio C, Bottero MC, Corgnati SP. The Influence of Energy Targets and Economic Concerns in Design Strategies for a Residential Nearly-Zero Energy Building. *Buildings Special Issue Low Carbon Building Design* 2014;4:937-962.

[5] Barthelmes VM, Becchio C, Corgnati SP, Guala C. Towards Nearly Zero Energy Buıldıng: Challenge Of Mediterranean Region. Ulusal Tesisat Mühendisliği Kongresi, Izmir, 8-11 April 2014;1-8.

[6] Governo italiano. D. Lgs. 3 marzo 2011, n. 28, Attuazione della direttiva 2009/28/CE sulla promozione dell'uso dell'energia da fonti rinnovabili, recante modifica e successiva abrogazione delle direttive 2001/77/CE e 2003/30/CE. Italy; 2011.

[7] Giunta Regionale. Deliberazione della Giunta Regionale 4 agosto 2009, n. 46-11968. Turin: Italy; 2009.

[8] European Committee for Standardization (CEN). Standard EN ISO 13790:2008. Energy performance of buildings. Calculation of energy use for space heating and cooling. Brussels: Belgium; 2008.

[9] Autorità per l'Energia Elettrica il Gas e il Sistema Idrico. Available online: http://www.autorita.energia.it/it/index.htm.

[10] Giunta Regionale. L.R. 28 maggio 2007, n. 13, Disposizioni in materia di rendimento energetico nell'edilizia. Turin: Italy; 2007.

[11] European Committee for Standardization (CEN). Standard EN ISO 15459:2007. Energy Performance of Buildings. Economic Evaluation Procedure for Energy Systems in Building. Brussels: Belgium; 2007.

[12] European Commission. Guidelines Accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012. Belgium: Official Journal of the European Union; 2012.

[13] ENEA. RAEE Rapporto annuale Efficienza Energetica 2011. Italy; 2012.

[14] Agenzia delle Entrate, Osservatorio del Mercato Immobiliare (OMI). Available online: http://www.agenziaentrate.gov.it/wps/content/nsilib/nsi/documentazione/omi.

Biography

Cristina Becchio is a grant researcher at the Department of Energy of Politecnico di Torino, where she holds a Ph.D. in Technological Innovation for Built Environment. Her activity focuses on buildings energy performance assessment and economic evaluation, in particular applied to nZEB.