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Heiselberg, Per Kvols

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Towards nZEBs: experiences in Italy

C. Becchio[#1], A. Buonomano[*2], F. Cappelletti[**3], S. P. Corgnati[#4], T. Dalla Mora[**5], A. Palombo[*6], F. Peron[**7], P. Romagnoni[**8]

[#] *DENERG, Politecnico di Torino*

Italy, Corso Duca degli Abruzzi 24, 10129 Turin

[1]cristina.becchio@polito.it

[4]stefano.corgnati@polito.it

[*] *DII, University of Naples Federico II*

Italy, P.le Tecchio 80, 80125 Naples

[2]annamaria.buonomano@unina.it

[6]adolfo.palombo@unina.it

[**] *Department of Design and Planning in Complex Environments, University IUAV of Venice*

Venezia – Italy, Santa Croce, 191, 30135 Tolentini Venice

[3]francesca.cappelletti@iuav.it

[5]tiziano.dallamora@iuav.it

[7]fabio.peron@iuav.it

[8]pierca@iuav.it

Abstract

Nowadays in the European framework the good practices for high-performing buildings realization and retrofitting are copious, but what emerges is the lack of information and data sharing about them. There are indeed no official sources for notes deriving from this kind of buildings and, moreover, there is shortage of quantitative and comparable data. In a process oriented to a large-scale diffusion of nZEBs on the market, the existing good practices of actual case studies of high-performing buildings should be kept as market benchmarks and reveal to be precious sources of information. In the light of the above, the need of a harmonized database to collect and share data deriving from different building typologies and climatic zones plays a fundamental role.

Due to the weakness of the existing databases and to the necessity of having practical guidelines to design nZEBs, at Italian level, an AiCARR teamwork is targeting the development of a design guide for nZEBs in Mediterranean region, based on different national experiences. In order to reach this target the workgroup has created a detailed database, useful to collect and share information about single high-performing buildings. Its main purpose is to record nZEBs, which have been already built, with available monitored data and that represent concrete models for future designing. Because of the still scarcity of monitored nZEBs, the database is suitable not only for realized monitored buildings but also for those that are still in a design phase. Actually, three different Italian case studies are catalogued in the database.

Keywords* – *Database; high-performing buildings; energy efficiency retrofit; good practices

1. Introduction

In the last years significant progresses have been made in reaching a widespread realization of new nearly-zero energy buildings (nZEBs) and application of nZEB retrofit interventions. This has been feasible because a lot of good practices for reaching energy high-performing targets currently exist. Nevertheless there are some obstacles to a large-scale dissemination of intervention towards nZEBs: financial, technical and information barriers. In the case of information ones, still now not all citizens in Europe are well-informed about the availability of energy efficiency solutions and incentive programs available in their territory. Information, when available, is still scattered and results into a wide range of options that are difficult to compare and understand for the final user. Key stakeholders (e.g. building administrators) and professionals should be regularly updated (importance of continuous professional education programs) about innovative solutions and progresses in national and local policies.

The achievement of nZEB targets requires a wide range of technologies, systems and solutions with different degrees of complexity and sophistication, depending on the location and environment conditions, but also on local legislation and market situation. Starting from the sharing of envelope technologies and system solutions, the creation of a database could reveal to be a crucial tool to spread and engage the good practices to reach nZEB goals on a wide scale.

Up to now various practices attempting to collect data about nZEBs can be identified; it is possible to recognize two principal types of database related to different levels of data collection. A first type database, which collects general information about a great number of buildings (requiring few and perfunctory information), reveals to be useful to provide statistical overviews at a large-scale. While a second type database collects data (regarding to climate conditions, building geometrical information, envelope features, systems configurations and operational parameters) of single building in a detailed way so that the energy modelling could be performed.

Due to the weakness of the existing databases and to the necessity of having practical guidelines to design nZEBs, at Italian level, an AiCARR teamwork and, at the European level, a current REHVA task-force are targeting the development of a design guide for nZEBs in Mediterranean region, based on different national experiences. In order to reach this target they created a second type database, useful to collect and share detailed information about single high performing buildings, with the aim of filling the lack of quantitative and comparable information, in a process towards nZEBs diffusion. The main purpose is to record nZEBs, which have been already built, with available monitored data and that represent concrete models for future designing.

The database was developed as a MS Office Excel tool in order to be easily modified and implemented, covering most of the building typologies and features. Indeed, because of the still scarcity of monitored nZEBs, the format as it is allows collecting data both of new and existing buildings (monitored or not), belonging to different categories of end uses in order to be utilized for the whole building stock [1].

The database is made of seventeen thematic sections, each one corresponding to a different spreadsheet: general information, geometrical data, building envelope, building system, space heating system, space cooling system, domestic hot water system, storage, ventilation, lighting & appliances, renewable energy sources, energy calculated data, energy monitored data, conversion factors, economic valuation, sustainable and green features, references.

Each section is structured in different consecutive columns (Figure 1). In the first column, the required information are reported; in the second one, the instructions detail precisely which kind of data is necessary to specify; in the third one, there is the space to fill in the data; in the fourth one, a space for notes is provided. In some specific sections, there are other columns dedicated to figures, drawings and schemes inclusion. Some of these data have to be filled, while others can be selected from drop-down menu.

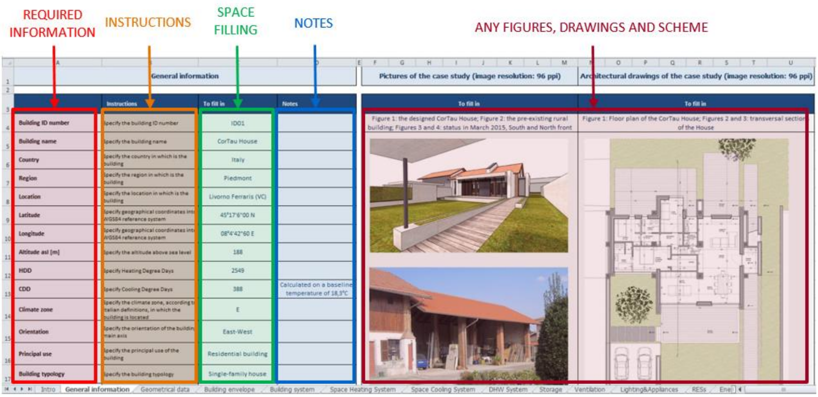

Fig. 1 Database structure

Actually, three different Italian case studies are catalogued in the database. The first consists in a single family house arisen from the refurbishment of a traditional rural building, widely diffuse in Piedmont Region (North Italy). The second one, located in Treviso (North Italy) is a historical edifice (a convent) transformed in a residential building. The third case study is referred to a public demonstrative non-residential NZEB. This multi-zone building will be built up in Naples (South-Italy) and it will host office, conference and expo spaces. This paper describes these three successful case studies of nZEB in Mediterranean climate. In particular in these climate conditions, the nZEB design challenge can be summarized in a careful building planning that permits to obtain indoor comfort conditions both in winter and summer with very low energy consumptions.

2. A residential nZEB in Piedmont Region (North-West Italy)

CorTau House (Figure 2) represents a significant experience of nZEB design and construction in Mediterranean climate. This single-family house, located in Northern Italy combines bioclimatic architectural principles for cutting down building energy needs with the use of high-performing systems technologies in order to achieve the nZEB targets. In particular, in the preliminary design phase all design team and owners' choices were guided by cost-optimal methodology. This method was followed in order to identify nZEB configuration that represents the most energy and economic solution [2]. Building construction started in March 2014 and is bringing to an end. The single-family house is all-electric and supplies its energy demand through self-generation of electricity from a photovoltaic (PV) system, that ensures the building energy independence from fossil energy sources.

Fig. 2 CorTau House

The house (net floor area = 130 m²; net conditioned volume = 390 m³) is realized by refurbishing a traditional rural building, "curmà", widely diffuse in Piedmont Region and, for this reason, represents a good nZEB model at regional and national levels. The new single-storey volume is inserted under the preexisting roof, whose wooden structure and tiles covering were maintained, so as the brick columns. The traditional rural framework surely influenced the architectural project. As the preexisting rural building presented a fully-open southern façade and a blind northern façade, the new volume is characterized by a mostly glazing southern façade while the northern one presents little windows. On the southern side windows are equipped with exterior horizontal overhangs carefully designed in order to maximize useful solar gains in winter and to avoid overheating in summer; the arrangement of some trees and hedges was accurately studied with the dual function of acoustic protection and solar control. Rooms are located to maximize indoor comfort during use; the living room, the kitchen and the master bedroom facing South, while a single bedroom, the study and the bathrooms facing North.

The 16-cm external insulation layer of rock-wool panels covers the reinforced concrete cast on-site bearing walls and the infill masonry walls which enclose the heated spaces and are part of the gross heated volume of the building (U_{wall} = 0.15 W $m^{-2}K^{-1}$); on the contrary the brick columns placed along the perimeter of the house are outside the insulating layer. This clear separation between heated and unheated structures allows thermal bridges elimination. Rock-wool insulation is adopted also for the slabs ($U_{floor\ slab}$ = 0.19 W $m^{-2}K^{-1}$, $U_{ceiling}$ = 0.15 W $m^{-2}K^{-1}$), having the wisdom to choose high-density compression resistant panels. The floor slab consists of a concrete casting which incorporates disposable formworks in recycled plastic realizing a ventilated under-floor cavity for one portion; in the remaining part the casting is realized on a gravel layer. The thermal bridge between external infill masonry walls and floor slab is eliminated with an intermediate 8-cm cellular-glass insulation layer, which also provides excellent barrier to rising damp. Windows are characterized by aluminum frame with thermal break and low-e triple-pane glass with argon (U_{window} = 0.96 W $m^{-2}K^{-1}$); thermal bridges are eliminated through a careful study of anchoring and joints between the external insulation layer and window wooden sub-frames. Plasterboard internal partitions placed between living and sleeping areas provide the acoustic insulation among these two macro-areas.

With regard to the building primary system, a controlled mechanical ventilation (CMV) system with heat recovery and dehumidifier is combined with radiant floors for space heating and cooling in all areas with the addiction of electric radiators in the bathrooms. Space heating and cooling is provided by a water-to-water heat pump that supplies also domestic hot water (DHW) production. All electricity needs of the building for space heating and cooling, ventilation, lighting, equipment, cooking (the kitchen is equipped with electric stove and oven) is covered by a 7 kW_{peak} grid-connected PV system installed on the roof.

Table 1. Annual energy uses of CorTau house

<table>
<tr><td>Space heating [kWh_{el}/m^2]</td><td>Space cooling [kWh_{el}/m^2]</td><td>DHW production [kWh_{el}/m^2]</td><td>Lighting [kWh_{el}/m^2]</td><td>Equipment [kWh_{el}/m^2]</td><td>Fans&Pumps [kWh_{el}/m^2]</td></tr>
<tr><td>3.94</td><td>2.62</td><td>5.78</td><td>11.17</td><td>31.9</td><td>5.76</td></tr>
<tr><td colspan="6">Total energy uses [kWh_{el}/m^2]</td></tr>
<tr><td colspan="6">61.17</td></tr>
<tr><td colspan="6">PV production [kWh/m^2]</td></tr>
<tr><td colspan="6">44.47</td></tr>
</table>

During design phase, the building energy evaluation was developed by means of the dynamic simulation software EnergyPlus in order to estimate the annual energy uses and the PV system production (Table 1).

Moreover, not only a careful design of envelope and HVAC systems but also the presence of trained manpower on construction site is fundamental in reaching nZEB targets. Indeed, it still proves difficult to find on the market manpower and technicians trained in the construction of high performing buildings. The construction company involved in the CorTau House realization provides not only for skilled manpower but also for suggestions and planning support to the designers. Indeed, in order to achieve the nZEB quality there is a strong necessity of collaboration and cooperation between designers, construction companies, foreman and all the actors involved in the building design and construction.

3. An historical nZEB in Treviso (North-Est Italy)

Ca' S. Orsola case study shows how an historical building could achieve nZEB targets with a deeply renovation in respect of heritage requirements. In fact the building was the old seat of Polish Institute and now it's a listed building by Historical and Architectural Heritage Superintendence of Veneto Region. The whole building (a gross volume of 6300 m^3) was a convent and it was inhabited for 40 years until 2000 and then in 2007 it was converted in a prestigious residential building (Fig.3).

Fig. 3 General view of the building a) before and b) after the intervention.

Before renovation, the state of conservation was quite ruined: the traditional construction system, based on bearing masonry with covered solid bricks, presented crooked walls and different kinds of stratification, moisture affected wooden elements in the floors and in the roof, therefore there wasn't no insulation in the structure. Heating or cooling system was not installed. Heating was provided by a fireplace, also used for cooking, occasionally an electric heater or portable fan coil was placed in any room. The domestic hot water was supplied by electric heaters with storage tank; there wasn't a ventilation system, so ventilation was made by natural means.

The building refurbishment was aimed to transform it in a residence with all comforts, acting a consolidation of the structure and improving an energetic retrofitting that meet the nZEB goals.

The building refurbishment was developed with a particular regards on thermal and acoustic insulation of building envelope improving indoor quality; special attention has been paid also to mechanical ventilation and renewable energy utilization (both solar thermal and photovoltaic system).

Technologies measures aimed to achieve A class energy classification according to Italian regulations in force until 2015 [3]; several design topics were adopted among which high insulated windows, high level of opaque walls insulation, mechanical ventilation system with heat recovery, solar thermal panels and PV systems, water to water heat pumps and chillers.

Due to heritage architectural restriction in the envelope, the insulation is placed on the inner part of the external walls and this solution meet the requirements of the Superintendence of Veneto Region, preserving the existing materials and the external architectural identity of the building. Specifically, two types of insulating are used: an expanded polystyrene (EPS) foam, placed directly on masonry, and a rigid mineral wool panel with a plasterboard cover. Roof was replaced with a new wooden structure and it was insulated with wood fiber panel and water tight covering. All existing windows are replaced with a low-energy double layer ones within wooden frames.

About technical systems, the HVAC generation system is a water to water centralized heat pump/chiller. The underlying well is the hot/cold water source and internal comfort is achieved exploiting a radiant system installed in the floor together with a dehumidification system for the summer period. Heating and cooling system adopted is a 32 kW heat pump with a distribution by radiant floor system; another heat pump (20 kW) is installed for domestic hot water requirement (DHW); mechanical ventilation is provided by heat recovery box (95% efficiency).

Renewable energy systems have been installed: thermal solar panels for DHW production (20 m^2) are located in vertical position and a photovoltaic power plant (18.85 m^2). These panels are installed on the roof and oriented to the south. The contribution of renewable energy resources is given in 6.56 kWh $m^{-2}a^{-1}$: calculation and monitoring gives a production of about 3300 kWh for photovoltaic system and 8500 kWh for solar thermal.

Energy needs values before renovation are calculated by a simulation and they are presented for comparing thermal comfort conditions after retrofit measures. It should be stressed that values for DHW need already include the solar thermal contribution and also that the amount of renewable energy was zero before renovation (

Table 2).

Table 2. Energy savings and CO_2 reduction

Energy need		**Before renovation**	**After renovation**	**Saving**
Heating	kWh $m^{-2}a^{-1}$	342.7	42.3	88%
DHW	kWh $m^{-2}a^{-1}$	44.4	33.6	24%
Electricity	kWh $m^{-2}a^{-1}$	45.0	20.0	56%
Total	kWh $m^{-2}a^{-1}$	432.1	95.9	92,5%
Energy label		G	A+	
Carbon emissions	kg CO_{2Eq} $m^{-2}a^{-1}$	29.8	5.8	81%

4. A non-residential NZEB in Naples (South Italy)

This building prototype will be the first non-residential NZEB in the Mediterranean area. It will be located in Naples (Southern Italy, 40°20'N - 14°15'E), which features a Mediterranean temperate climate with dry hot summers (CDD = 185 Kd) and mild winters (HDD = 1163 Kd). During winter, outdoor air temperatures are not excessively low (design and average outdoor temperature: 2 and 10°C, respectively), while quite high outdoor air temperatures and humidity occur in several summer days (design temperature and humidity: 32°C and 60%). The building project initiative stems from the action ED6 of the Sustainable Energy Action Plan (SEAP, Covenant of Majors of the European Community, August 3rd 2012) and from an explicit Resolution (n. 517 on April 21st 2011) of the Municipality of Naples. The building will be built up on three floors, two of them above the ground level. It will host offices (at the ground floor) and conference and exposition spaces (at the first floor). In order to obtain suitable criteria for passive heating and cooling techniques, the building, shown in Figure 4, is conceived with a rectangular shape (15.0 × 24.5 m, East-West oriented longitudinal axis). The indoor space is subdivided in ten different thermal zones. The S/V ratio is 0.38.

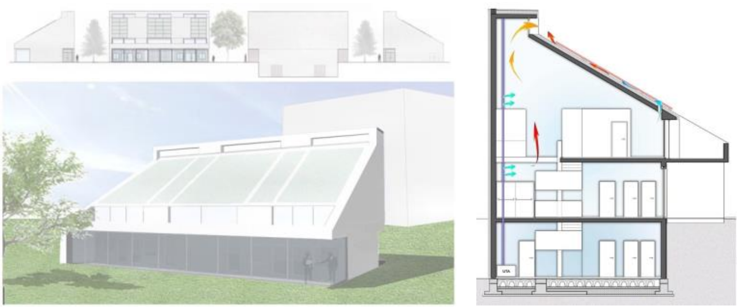

Fig. 4 NZEB prototype in Naples (South-Italy)

The energy and economic performances of this NZEB were assessed by means of a detailed Building Energy Performance Simulation code called

DETECt. By such tool (now including also an innovative indoor air temperature/humidity control) a complete dynamic simulation procedure of multi-zone building-plant systems (also including indoor comfort) can be carried out [4]. For the design of NZEBs, several useful subroutines were implemented in DETECt for modelling: attached sunspaces; smart daylighting (for varying windows shadings and artificial lights); building integrated PCM (in both the opaque envelope and windows glazing) also coupled to BIPV/T (or BIPV) system [5]. It is worth noting that, parametric, multi-criteria and/or multi-objective analyses can be carried out through DETECt from energy, economic and environmental points of views.

For the presented NZEB a number of design and operating parameters was optimized from the energy point of view. For the optimized NZEB configuration, the results of the energy analysis are reported in Table 3.

Table 3. Energy analysis results

Energy demands [kWh/m^2·y]	Heating	DHW	Cooling	Ventilation	Light	Appliances	Fans, pumps and cooling tower
Electricity	0.13	0.21	0.19	2.50	3.51	5.96	2.18
Solar	3.47	1.21	5.62				

Renewable energy [kWh/m^2·y]	Thermal	Cooling	Electricity
Produced on site	38.9	30.9	45.2
Exported	30.4	22.1	30.6

Primary energy [kWh/m^2·y]	Produced on site	Produced and used on site	Exported	Imported	RESs
	153.9	45.9	108.0	32.0	235%

Energy needs and label (Italian release of EN 13790 and Italian guidelines)	Primary energy for heating [kWh/m^3·y] (label)	Energy for cooling (not primary) [kWh/m^2·y] (label)
	1.92 (A$^+$)	9.39 (I)

Note that, the heating and cooling energy demands are very low resulting almost entirely covered by solar energy. Lighting is optimized through a suitable system control (by modulating the windows shadings according to the optimal visual comfort). Electricity for appliances is rather high according to the occurring building uses. The contribution on the overall balance of renewable energies is remarkable (given the need to supply energy to a large existing public building adjacent to this NZEB). Note that, the produced PV electricity is first supplied to the grid and then partly recovered from it. For the primary energy assessment, a reference electric heat pump/chiller COP of 3/2.5 and a national average electricity efficiency of 0.46 are taken into account. According to Italian rules, the heating and cooling energy efficiency labels achieved by the NZEB correspond to the best ones. Note that, by comparing the adopted BIPV/T plant (with an underlying PCM layer) vs. a standard BIPV system, an increase of more than 8% of the yearly electricity production and a decrease of 18.6% of primary energy for heating and cooling are obtained. If no solar energy technologies are applied to the NZEB, an increase of the heating demand of 22.8% and a decrease of the cooling one of 7.8% are detected. At last, a simplified economic analysis was also carried out. It refers only to the extra-costs to be taken into account for optimizing the initial NZEB design (i.e. by the initial NZEB layout all the requirements of the Italian rules regarding the buildings energy efficiency are fulfilled). The total extra-cost for all the accounted enhancements reaches 48.2 k€, while without PCM it decreases to 1.6 k€. The resulting SPB period (optimized layout without PCM) is of 14 years without national funding for energy saving (assuming a a feed-in tariff of 0.08 €/kWh for the exported electricity to the grid). With PCM the resulting SPB is presently too long. Details are reported in [5].

5. Conclusion

The main goal of the database is to provide as complete and detailed as possible an overview of the presence of high efficient buildings in different Mediterranean countries. In a process oriented to a large-scale diffusion of nZEBs on the market, the main function of this tool is to collect and share quantitative and detailed data referred to good practices of energy efficient buildings in order to compare and assess the most important information on the available solutions, on the results obtained in terms of energy and monetary savings, and also on local market and legislation conditions. The availability of a large number of comparable data from different case studies would surely help to draw on the lessons learnt from good practices in Mediterranean climate. In order to serve as a guide for investors, designers and policy makers, it is necessary to collect inside the specified database as many as possible of the buildings in question.

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