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# Analysis of energy performances of a nZEB kindergarten building in Bisceglie (Apulia region)

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**Abstract.** School buildings would stand as a prime example, among public buildings, of how the dual goal of preserving natural resources, through a sustainable design approach, and the comfort indoor can be reached. The work deals with the analysis of energy performance of the nZEB kindergarten “Sandro Pertini” in Bisceglie, Apulia region. The school, located in a residential area of the town, hosts 180 pupils. Classes offer a first experience to family and teachers of energy efficiency, safety, comfort and saving resources. A monitoring analysis has been done to evaluate the energy performances in the daily life of the young occupants. The architectural design of the envelop, with its rounded shapes, optimally oriented with performing shielding ensures a low energy consumption. Climatization needs are satisfied through nearly full renewable energy system such as photovoltaic plant on the roof and air-to-water heat pump.

## 1. Introduction

The new EPBD revised (Directive 2018/844/EU) requires building to have very low energy demand met by renewable energy (nearly-zero energy) [1]. In Italy the characteristics of a nearly Zero Energy Building (nZEB) are established by the Italian Decree 26 June 2015 “Minimum requirements” [2]: new and existing buildings are considered nZEBs if both the decree's performance requirements and the obligations regarding the integration of renewable sources dictated by Italian Legislative Decree 28/2011 are met. In particular, according to Law 90/2013, a nZEB is “a building characterized by a very high energy performance in which the very low energy demand is significantly covered by RES, produced within the building system boundaries”[3]. In Italy, nZEB has to be implemented by 2019 for public building and by 2021 for all new building, also if some regions (e.g. Lombardy and Emilia Romagna) have set early targets. Considering that the majority of schools in Italy are public, it means that new building schools would be nZEB in a nearly future. In order to boost the construction of innovative school building, the Law 107/2015 promotes new public schools with stricter earthquake-proof reinforcement and innovative energy systems as an extra requirement, increasing the ad-hoc fund of 23.9 million € in 2016 and 126 million €/year from 2017 to 2021. With the following Decree 94/2015, the Ministry of Instruction, University and Research allocated 300 million € to the Italian regions for the construction of 30 new innovative schools [4]. However it is important to remind that more than 66% of school buildings were built without any energy-related regulation (built prior 1976) and less than 10% were built after the adoption of the Law 10/1991, which is the first regulation introducing constrain about energy efficiency [5]. This is the scenario of the present work, focused on the analysis of the first nZEB kindergarten built in Apulia, in the Municipality of Bisceglie.

The school plan won the public competition of the Ministry of Cultural Heritage and Activities and the Ministry of Economic Development jointly with seven regions of southern Italy [6], for

construction of a kindergarten and a place in the outskirts of Bisceglie (BAT, Italy). The innovative approach of the building is an example of nZEB in a Mediterranean Climate. In addition, the square is an example of integration in the social life of the neighbourhood in the Mediterranean culture. The purpose of the study is to compare the numerical data obtained from a model of the building-plant system elaborated with Termolog EpiX9 and the experimental data, monitored during daily life of its young occupants in the heating season. The results will be communicated to all square inhabitants and to the Municipality (owner of the building), in order to explain the meaning of nZEB and put in evidence the right behaviour to adopt in a nZEB. The aim of the research is to put in evidence the necessity of monitoring actions in the nZEB (above all public buildings as school) in order to guarantee its high energy and environment performances foreseen in the design phase also in the daily life of its occupants.

In this direction, the work contributed to the National nZEB Observatory paving the way to the creation of the Regional nZEB Observatory. In 2017, ENEA launched a national nZEB Observatory [7] that allowed statistics on number and type of nZEBs, information on regional policies, public and private initiatives for information and training and the state of research in the sector. Despite the still limited number, there is a rapid increase in nZEBs, also due to the even more stringent obligations imposed in advance with respect to the deadlines of 2019 and 2021 [8].

## 2. Description of the case study

The school “Sandro Pertini” is a kindergarten, it is a public school owned by the Municipality of Bisceglie, a city of about 55000 inhabitants. It is located in a zone destined to social housing, with three stories residential building. The kindergarten provides every day education for about 180 pupils, aged between three and five years old.



**Figure 1.** Bird's eye view [Photo ©Michele Riglietti] **Figure 2.** Bird's eye view [Photo ©Giacomo Richitelli]

The building develops on a single level with a rectangular shape and it opens on the main square, meeting point for the family of the district. Inside, the building is characterized by a curved courtyard bordered by a corridor with large glass windows. The indoor space is organized in rectangular rooms closed at two different heights (2.70 m and 3.40 m), included spaces dedicated to services (locker rooms, toilets, technical room, etc.) and spaces dedicated to teaching. Aligned to the nZEB requirements, the wooden sunshade pergolas shade the large windows of the south-facing classrooms overlooking the didactic garden and the central courtyard.

The construction system consists of load-bearing walls in reinforced brickwork (suitably insulated along the external walls). In this way, the designers assured the characteristics of insulation and thermal inertia, acoustic insulation and the high levels of fire protection and seismic safety, answering to the eco-sustainable material specification. Specifically, the various types of brickwork were made using lightweight 35 cm brick blocks and for internal partitions a thickness of 30 cm. The stratigraphy of insulated external wall is described in Table 1.

The roof, completely flat, is made with concrete slab floor, with joists and interposed blocks. The central annular corridor provides the same stratigraphy of the other floors but with a 16 cm slab in reinforced concrete plate. In the areas destined for classrooms, gymnasium, school canteen and corridor, has a heating systems with radiating panels.

**Table 1.** Stratigraphy of the insulated external wall

<i>Elements</i>	<i>s</i> <i>mm</i>	$\lambda$ <i>W/(mK)</i>	$\rho$ <i>kg/m<sup>3</sup></i>	<i>c</i> <i>kJ/(kgK)</i>
Lime/gypsum plaster	20.0	0.700	1400	0.84
POROTON® - armed brickwork	350.0	0.203	850	1.00
ROFIX EPS - expanded polystyrene panel	80.0	0.031	15	1.45
Plastic plaster	20.0	0.330	1300	0.84

In the table 2, the thermal performances of the envelope are reported. According to the Italian Decree 26.06.2015 (“Minimum requirements”) the maximum threshold limit for  $Y_{IE}$  is 0.10 W/m<sup>2</sup>K for vertical walls and 0.18 W/m<sup>2</sup>K for horizontal and inclined walls. Regarding the thermal transmittance ( $U$ ) of opaque vertical walls, facing outside or rooms without air-conditioning or against ground, the maximum threshold limit is set to 0.34 W/m<sup>2</sup>K, for buildings in climate zone C.

**Table 2.** Building main features

<i>Elements</i>	<i>s</i> <i>mm</i>	$U$ <i>W/(m<sup>2</sup>K)</i>	$Y_{IE}$ <i>W/(m<sup>2</sup>K)</i>
Insulated external wall	470	0.219	0.01
Roof classrooms	525	0.189	0.01
Roof service	485	0.191	0.01
Roof corridor	455	0.196	0.02
Floor classrooms	825	0.263	0.02
Floor service	825	0.307	0.01

Windows are made of aluminum frames with thermal break. They are coupled with double glazing with low-emissivity coating, with thermal transmittance  $U_g$  of 1.653 W/(m<sup>2</sup>K). The limit value of global transmission factor of solar energy through the windowed components,  $g_{gl+sh}$ , is 0.35. Following the UNI EN ISO 10077-1, the calculations of the total transmittances,  $U_w$ , take into account the dispersions through the frame, the glass and the thermal bridge between the glass and the frame. All  $U_w$  calculated are less than the limit of 2.2 W/(m<sup>2</sup>K) as set by the legislation.

The heat generator adopted for the winter central heating system is a heat pump driven by an electric motor. It has a useful heating power of 63 kW and a COP performance coefficient of 3.73. It provides heat to the room heat exchangers, both radiant panels and aluminum radiators. The heat pump is equipped with a storage tank with a capacity of 300 l with a maximum working temperature of 60 °C. For the production of domestic hot water is used a heat pump of 2 kW and COP equals to 3.49.

A photovoltaic system has been installed well integrated in the roof. It consists of six groups, each of 20 monocrystalline silicon photovoltaic panels, with a nominal power of 335 Wp each, for a resulting total electric power of 40.20 kW. The modules are installed on a support, inclined at 20 degrees from the horizontal roof. The PV system was sized to cover the electric energy needs. Two lithium batteries (Sonnen, 2x16 kWh) provided a 32 kWh storage system, in order to store and then reuse the energy that is not directly consumed.

### 2.1. Building's energy performance

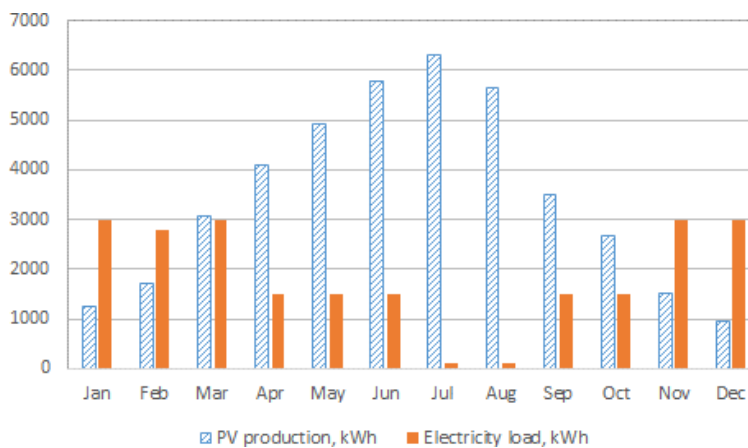
The energy model of the case study was performed by commercial software Termolog Epix9. The building was divided into two thermal zones, characterized by different height (2.70 m and 3.40 m)

and different heating systems (radiating panels and radiators). Two analyses were carried out, one in quasi-steady state condition according to national UNI/TS 11300, and the other in dynamic state, according to hourly method of EN ISO 52016. In both simulation, the model included six different room categories: classrooms (six rooms for 180 pupils), bathroom and dressing rooms, service rooms, canteen and corridor. According to the Italian legislation on the building energy certification, through the quasi-steady state analysis, several parameters like efficiencies, energy performance indexes and the percentage of coverage from renewable sources have been calculated. They meet the requirements for nZEB, with a positive outcome for all items (table 1).

**Table 3.** Main data for the case study, according to Italian Decree (DM 26.02.2015) for nZEB

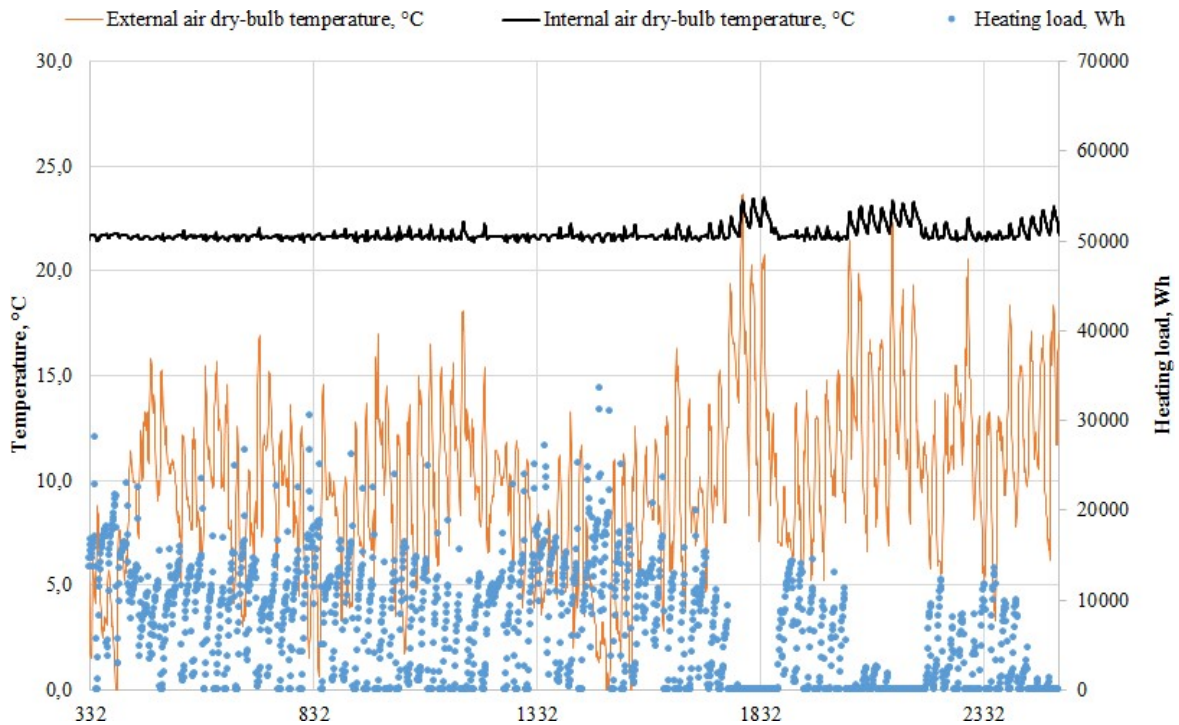
$H'_T$	$0.31 < 0.60 \text{ kWh/m}^2$	$EP_{gl,tot}$	$96.82 < 165.71 \text{ kWh/m}^2$
$A_{sol,est}/A_{sup,utile}$	$0.02 < 0.04$	$\eta_H$	$0.68 > 0.55$
$EP_{H,nd}$	$38.72 < 56.50 \text{ kWh/m}^2$	$\eta_w$	$0.80 > 0.47$
$EP_{C,nd}$	$19.83 < 19.92 \text{ kWh/m}^2$	$PV-prod.$	$69.9 > 55\%$

In figure 3, the photovoltaic system monthly production is compared to the daily electricity needs in the school building. It is clear an over-production in summer while in the winter months load exceed production.



**Figure 3.** Monthly photovoltaic production (PV) vs monthly electricity loads.

An analysis in dynamic conditions was carried out for check the performance of the building with its real HVAC system. An hourly simulation method has been used according to EN ISO 52016-1. The simulation was done with the software Termolog EpiX9. In figure 4 results for the period 1<sup>st</sup> January – 31<sup>st</sup> March are showed. It is clear as comfort conditions (indoor temperature 21.5°C) are met in the entire period of simulation. A slight overheating phenomenon appear when the outdoor temperature rise over 18°C.

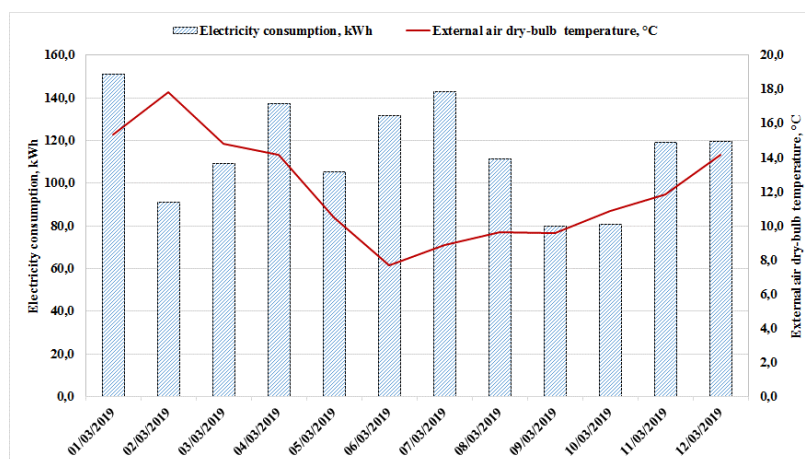


**Figure 4.** Internal and external air temperature vs heating load from 1st January to 31st March (dynamic simulation according to EN ISO 52016-1, Termolog EpiX 9).

## 2.2. Monitoring Campaign

Indoor air dry-bulb temperature, relative humidity, CO<sub>2</sub> and electric energy consumption are collected through Beeta™ device by Tera srl. Beeta™ delivers a cheap smart energy monitoring and consumption optimization system, based on an interoperable and easy-to-install physical gateway, a software interface and an innovative mobile app. It has located in a classroom, on the north face, of about 25 pupils. One more device, the data logger Testo 160 IAQ, has been positioned in a different room of the school. At the moment temperature data, both outdoor and indoor are collecting over the whole year and will be used for the model validation.

Daily electric energy consumption as monitored by the Energy-Meter of Beeta™ device, are showed for the period 1-12 March in figure 5. The comparison with the external air dry-bulb temperature highlights as one would expect, a dependence on external temperature. When the temperature goes down the electric load goes up.



**Figure 5.** Monitored electricity consumption vs External air temperature in the period 1-12 March 2019.

### 3. Conclusion

The work presents a preliminary analysis on the first nZEB kindergarten school in Apulia region, comparing thermal simulation with early real data collected by monitoring campaign started at the end of January 2019. The goal is to understand the behaviour of the building during the “uses phase”. The monitoring campaign will carry on until the end of the year. The results will contribute to collect data useful for covering the gap of information related to non-residential nZEB allowing statistics on number and type of nZEBs.

### Acknowledgements

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