#### **PAPER • OPEN ACCESS**

# Analysis of monitoring data for a nZEB in Mediterranean climate

To cite this article: F Ascione et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 609 072038

View the article online for updates and enhancements.

## You may also like

- Awareness, benefits and drawbacks of net zero energy building practices: construction industry professional's perceptions D O Nduka, A N Ede, K D Oyeyemi et al.
- Dormitory thermal retrofitting to nZEB standard J Kwiatkowski, J Sowa, A Trzski et al.
- Business models for nZEB renovation of small wooden buildings Ann Kristin Kvellheim, Sigrid Damman and Anne Gunnarshaug Lien





DISCOVER how sustainability intersects with electrochemistry & solid state science research



This content was downloaded from IP address 18.119.253.93 on 26/04/2024 at 22:18

**IOP** Publishing

# Analysis of monitoring data for a nZEB in Mediterranean climate

### F Ascione<sup>1</sup>, M Borrelli<sup>2</sup>, R F De Masi<sup>3,\*</sup>, F De Rossi<sup>3</sup> and G P Vanoli<sup>4</sup>

<sup>1</sup> University of Naples Federico II, Department of Industrial Engineering, P.le Tecchio 80, 80125, Naples, Italy

<sup>2</sup>University of Bergamo, Department of Engineering, via Marconi 5, Dalmine, 24044, Bergamo, Italy

<sup>3</sup> University of Sannio, Department of Engineering, Piazza Roma 21, 82100, Benevento, Italy

<sup>4</sup>University of Medicine, via Francesco De Sanctis 1, 86100 Campobasso, Italy

\*rfdemasi@unisannio.it,

Abstract. The proposed paper is focused on some of the main conceptions, design criteria and expected energy performance of a new nZEB built in Benevento, a middle-size city of South Italy with typical Mediterranean climate. It is the result of an Italian research project – SMARTCASE – promoted under the umbrella of the European Regional Development Fund. The paper discusses the results of the wintertime monitoring campaign. Measurements on building envelope are shown as well as monitoring of energy uses and indoor microclimatic conditions. The discussion about the hourly energy balance evidences the effectiveness of selected solutions to reach the zero objective also during the winter and to evaluate the incidence of PV-production.

#### 1. Introduction

The ambitious long-terms energy and climate targets cannot be achieved without a strong reduction of energy needs in the building sector. The EU Directive 2018/844/EU [1] requires to identify and develop long-term national strategies to promote the efficiency of building sector. According to the current regulatory framework, all new buildings must be Nearly Zero Energy Buildings by 31 December 2020 (for public buildings by 31 December 2018). According to the EPBD Directive [2], the nZEB is defined as "a building that has a very high energy performance... [] The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby".

As reported by D'agostino et al. [3], the nZEB topic is still under discussion and not uniformly implemented; the most important problem is the mismatching between the expected energy performance and the measured energy consumption in real conditions [4]. Li et al. [5] have suggested a generic framework of energy monitoring, analysis and modelling, which provides feedback for nZEB operation, and yields information for future designing. Moreover, it is very important to focus how different occupant behavior and adaptation measures can influence the performance [6]. For this reason, it is important the analysis of monitoring data. However, at present time, in Mediterranean area where the energy demand for summer cooling is comparable or sometimes higher than for winter heating, there are few examples of monitored nZEBs [7]. The knowledge-transfer and exchange of experiences resulting from pilot programmes is crucial to avoid further mismatch. Basing on this consideration, the proposed paper is aimed to discuss the real performance of an existing nZEB during the winter period that could be critical for the greater uncertainty of renewable sources availability. More in detail the results of an experimental campaign on energy consumption for heating, ventilation, lighting, electric loads, water use are discussed as well as the monitored microclimate variables are shown in real operational conditions. The energy balance with daily or hourly time step is not



Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

#### IAQVEC

IOP Conf. Series: Materials Science and Engineering 609 (2019) 072038 doi:10.1088/1757-899X/609/7/072038

available for other existing but for improving load matching and for reducing grid interaction and energy bills, it is important a balanced design also for the winter period.

#### 2. Case study: the BNZEB

The case-study (Figure 1a), named BNZEB, is a single-storey dwelling built in Benevento (Figure 2a), for which the design phase has been described in [8]. For what concerning the geometrical features, the net conditioned area is 70 m<sup>2</sup>, the window/wall ratio is 22.5 % and the surface to volume ratio is equal to 1.03 m<sup>-1</sup>. The cross laminated wood (X-Lam technology) is the structural frame; it is coupled with two layers of fibre-wood insulation, with an overall thickness of 33 cm for the external walls, and about 50 cm for the roof. The insulation level has been chosen considering as benchmark, values imposed by Italian normative (DM 26/06/2015a) for typical Mediterranean zone (Italian Climatic Zone "C"). Double-glazing systems with low emissivity are installed, using PVC frames. On the south façade it has been installed an electrochromic glass whit wooden frame.

A	B	BENEVENTO				
		Latitude		41° 7' 55''		
16.46.40	Longitude		gitude	14° 46' 40''		
			Elevation (m)		135	
elistres		Heating period		15/11 - 31/03		
Pearly Zero	Heating Degree-Days		ys 1316			
		[20°C baseline]				
Building B		Project winter		Project summer		
		data		data		
and the second s	Т	ext [°C]	-2	T <sub>ext</sub> [°C]	32	
A CONTRACTOR OF THE OWNER	đ	• <sub>ext</sub> [%]	48.8	$\Phi_{\text{ext}}[\%]$	50	
	7	/ [m/s]	4.4	$\Delta T_{d}$ [°C]	11	

Figure 1. a) External view of BNZEB building; b) Benevento site.

An aerothermal heat pump has been installed with a nominal heating power of 3.18 kW and cooling power of 2.14 kW. It satisfies requests of hot water, heating, cooling, dehumidification and mechanical ventilation, with an active thermo-dynamic heat recovery. In order to have a backup capacity, a direct expansion additional heating/cooling system has been installed.

Horizontal geothermal probes, at a depth of 2 meters and with a total length of 100 meters, are used to pre-cool the ventilation air before the handling in the aerothermal heat pump. A solar thermal collector, with area equal to  $2.16 \text{ m}^2$  has two functions: on one side, this is used to produce domestic hot water and on the other, during the winter, this system can supply hot water to the ventilation air, in order to pre-heat this. The circulation pump is activated from the solar control unit, which manages the temperatures of the solar collector, the storage, also by means of a dedicated tank with a net volume of 196 litres. Finally, a photovoltaic system is installed on the roof. This is composed of 16 monocrystalline silicon panels with an area about 1.63 m<sup>2</sup>/each and a peak power of 330 Wp each one. The PV modules are oriented to the south (i.e., azimuth angle of 0°) with a tilt angle of 5°. Moreover, there is a lithium battery for the electricity storage.

#### 3. Building envelope analysis

Some investigations (figure 2a) with IR thermography have been done during this winter for evaluating local phenomena as thermal bridge, insulation losses and for choosing the proper position of the sensors for the in-situ measurement of thermal transmittance according to ISO 9869 [9].

More in detail, the measuring of thermal transmittance has been done from  $17^{\text{th}}$  to  $22^{\text{nd}}$  January 2019 using an Optivelox Thermozig, a wireless heat flow meter; the obtained result is reported in Figure 2b. The measured thermal transmittance is equal to 0.19 W/m<sup>2</sup>K, 10 % greater than the calculated value.

The same analysis has been performed for other walls of the building and for one window. In detail, the measures on the glass have been made from  $18^{th}$  to  $23^{th}$  December 2018 and the result has shown that thermal transmittance is equal to 1.5 W/m<sup>2</sup>K. Indeed, regarding the walls the measured value of thermal transmittance is equal to 0.19 W/m<sup>2</sup>K for a wall on the east side (measures performed

from  $11^{\text{th}}$  to  $18^{\text{th}}$  December) and equal to 0.17 for the wall with north exposure (from  $5^{\text{th}}$  to  $11^{\text{th}}$  December).



Figure 2. a) Outdoor thermography of West wall; b) results of measurement of thermal transmittance.

#### 4. Daily monitoring results

The 14<sup>th</sup> February 2019 has been selected as representative winter day since the value of external temperature and solar radiation (Figure 2c) are typical according to monitored data during 2019; during this day, two students have occupied the building and their activities are reported in Figure 3b.



Figure 3. a) Hourly energy consumptions; b) activity performed during the day; c) daily climate.

The incidence of each type of energy request (heating, ventilation, cooking devices, computers, lighting) can be obtained in Figure 3a where it is clear that the air-conditioning with a set-point temperature of 20°C affects for the 48% the daily energy balance.

Figure 4 shows the hourly energy balance; more in detail, the electric energy consumptions, the PVsystem production and the electricity available in the battery. In the early morning the battery is discharged and the energy request is satisfied by national grid meanwhile during the evening hours, the battery allows to cover the whole energy demand.

Two indexes are introduced for evaluating the interaction between the building request and the PVproduction: the first, named RenEl, is the ratio between the amount of electricity from renewable source used to satisfy the requests and total daily request of building; the second one, PVin, is the ratio between the generation from the photovoltaic system and the daily consumption. For the considered day, these indices are 79% and to 96% respectively. This means that the renewable production, due to the battery adoption, allows the covering of a large amount of consumptions and only around 15% of electricity has to be exported. This is an optimum result for the achievement of nZEB standard.



Figure 4. Total energy consumption and global electricity available by PV-system

Moreover, indoor parameters (CO<sub>2</sub> concentration, lighting level, air temperature and relative humidity) have been continually monitored through some embedded sensors. In particular, Figure 5 shows the variation of the indoor air temperature and relative humidity in the living room and in one bedroom, while the trend of CO<sub>2</sub> concentration for the same zones and outside the building is in Figure 6. Also the limit values proposed by the EN 15251 Standard [9] are evidenced in the figures. In particular, it results that the air temperature in the bedroom is always in the comfort range, while in the living room, it resulted in the range for 84% of the time. During the early hours of the day the temperature is lower presumably due to the energy losses through the glazed components, while during the afternoon the temperature rises above the recommended threshold due to the solar gains. Instead regarding the relative humidity values, it must be considered that the air conditioning system does not operate on this variable for which reason the relative humidity inside the rooms is highly variable during the day and remains within the comfort range established by the EN 15251 only for 53% of the hours in the living room.

Moreover, the CO<sub>2</sub> concentration is always lower than the limits proposed by EN 15251 (350 ppm and 500 ppm above outdoor concentration for category I and for category II respectively).



Figure 5. a) Indoor air temperature; b) indoor relative humidity – 14<sup>th</sup> Frebruary.



**Figure 6.**  $CO_2$  concentration inside and outside the building –  $14^{th}$  February.

Finally, regarding the visual comfort conditions, some punctual measurements of the luminance level have been performed in correspondence of working plane considering different natural and artificial scenarios. Table 1 shows results of measurements considering 10 minutes of continuous acquisition.

	Illuminance level at 10:15 a.m					
	avg [lux]	max [lux]	min [lux]			
Living room	2800	2840	2750			
Bedroom N	819	827	795			
Bedroom S	1037	1042	1006			
	Illuminance level at 17:00 p.m					
	avg [lux]	max [lux]	min [lux]			
Living room	1084	1429	1081			
<b>Bedroom</b> N	208	357	208			
<b>Bedroom S</b>	338	357	337			

Table 1. In-field measured of lighting level.

In this study has been considered suitable an illuminance level of at least of 300-500 lux for reading and writing activity (according to UNI EN 12464-1 Standard [10]). The measured values are usually within the considered range, and the two students were satisfied in terms of visual comfort condition and they could arbitrarily choose when to turn on the installed lamps, their colour temperature and luminous intensity. Starting from 17:00 in the afternoon, they have chosen to turn on the lamps at maximum light intensity but with a colour temperature of 4000K for the bedrooms and 6500K for the living room. The measures indicate good performance in term of natural and artificial lighting.

#### 5. Monthly energy balance

Figure 6 shows the daily energy balance for February and also the indication of the difference between the average external temperature and the internal set point temperature as reference.

The trend suggests that also in the winter period with favourable external climatic conditions, a large amount of the energy consumptions can be satisfied by energy production from the photovoltaic system. Globally, during February about the 56% of the total energy needs are covered by photovoltaic generation and the PVin in some days results very high, but, briefly, it varies between 7.89% on 4<sup>th</sup> February to 100% 26<sup>th</sup> February. Furthermore, the coupling with the storage system maximizes self-consumption, minimizing the impact of the surplus energy produced and not use for self- consumption.



Figure 6. Daily energy balance and difference between external and internal set point temperature.

#### 6. Conclusion

The monitoring results demonstrate the effectiveness of the choices made during the design phase. Indeed also during favourable days of the winter season, in terms of external climatic conditions, the great part of the energy consumption can be satisfied by energy production from the photovoltaic system. Globally, during February about the 56% of the total energy needs are covered by photovoltaic plant. However, monitoring also shown the possibility to increase the energy performance of the building by acting on the control and management logic of the installed devices.

#### References

- [1] European Parliament, Directive 2018/844 of the European Parliament and of Council of 30 May 2018 on amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. *Official Journal of the European Union*. pp. 75-91.
- [2] European Parliament, Directive 2010/31/EU of the European Parliament and of Council of 19 May 2010 on the energy performance of buildings (recast). Official Journal of the European Union. pp. 13-25.
- [3] D'Agostino D and Mazzarella L 2019 J. Build. Eng. 21 200-212
- [4] Sijanec Zavrl and Stegnar G 2017 Procedia Environ. Sci. 28 52-59
- [5] Xian Li H, Gul M, Yu H, Awad H and Al-Hussein M 2016 *Energy Build*. **126** 353-364
- [6] Attia S 2018 Net Zero Energy Buildings (NZEB) Concepts, Frameworks and Roadmap for Project Analysis and Implementation Butterworth-Heinemann 273-302
- [7] Attia S, Eleftheriou P, FXeni F, Morlot R, Ménézo C, Kostopoulos V, Betsie M, Kalaitzogloue I, Pagliano L, Cellura M, Almeida M, Ferreira M, Baracu T, Badescu V and Hidalgo-Betanzosk J M 2017. *Energy Build.* 155 439-458.
- [8] Ascione F, Bianco N, De Masi R F, de Rossi F, Vanoli G P 2019 Solar Energy. 184 11-29.
- [9] ISO International Organization for Standardization, ISO 9869-1:2014 Thermal insulation, Building elements, in situ measurement of thermal resistance and thermal transmittance Heat flow meter method.
- [10] UNI Italian Unification Body, UNI EN 15251:2008 Criteri per la progettazione dell'ambiente interno e per la valutazione della prestazione energetica degli edifici, in relazione alla qualità dell'aria interna, all'ambiente termico, all'illuminazione e all'acustica. (in Italian)
- [11] UNI Italian Unification Body. UNI EN 12464-1:2011 Luce e illuminazione, illuminazione dei posti di lavoro, Parte 1: Posti di lavoro interni. (in Italian)