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ScienceDirect

Energy Procedia 111 (2017) 205 – 214

Energy Procedia

8th International Conference on Sustainability in Energy and Buildings, SEB-16, 11-13 September 2016, Turin, ITALY

A design strategy to reach nZEB standards integrating energy efficiency measures and passive energy use

[a], Fausto Barbolini[a], Paolo Cappellacci[b], Luca Guardigli[a]*

[a]University of Bologna, viale Risorgimento, 2, Bologna, 40136, Italy
[b]GIA, The Whitehouse, Belvedere Road, London, SE1 8, UK

Abstract

In this paper a design strategy is presented to integrate energy efficiency measures and passive energy use, in order to meet near Zero Energy Buildings requirements in European temperate climates. In particular, a hybrid system for the integration of natural and mechanical ventilation at different times of the year is proposed. ZEBs and nZEBs usually employ mechanical ventilation systems to provide air changes and energy saving. This common solution is in contrast with the principles of natural ventilation and adaptive comfort. It is well known that natural ventilation can significantly reduce the energy demand during the summer.
The case study is represented by a social housing complex located in the periphery of Modena (Italy), dating back to 1980. The project consists in the deep energy renovation of some buildings of this complex to accomplish nZEB standards. The proposal envisages two different modes of operation for the buildings, one for the cold season and one the warm season. For the cold season, a mechanical ventilation system with earth tubes and heat recovery has been designed, together with airtightness, solar greenhouses and high thermal mass and insulation. For the warm season the design allows a free-running use: open trickle ventilators applied to windows which provide background ventilation, mass and insulation mitigate the heat loads, vertical ventilation shafts support natural ventilation and free night cooling. The ventilation shafts are designed with aerodynamic principles to provide each apartment with additional (and maximised) differences of pressure due to the stack effect. The ventilation shafts have an important role for the free cooling. The renovated buildings are also equipped with active systems to compensate the remaining energy demand: a Combined Heating Power System (CHP), PV panels and solar thermal collectors.
The indoor comfort conditions in the warm season are evaluated according to the ASHRAE 55 adaptive model for free-running buildings. The internal comfort in the warm season is verified with a multizone dynamic simulation and a CFD analysis. The results of the study confirm that in the warm season acceptable indoor comfort conditions can be achieved in a free running nZEB.

Peer-review under responsibility of KES International.

Keywords: Near Zero Energy Buildings; integrated design; hybrid ventilation systems, ventilation shafts.

* Corresponding author. Tel.: +39-051-2093179; fax: +39-051-2093156.
E-mail address: luca.guardigli@unibo.it

Peer-review under responsibility of KES International.
doi:10.1016/j.egypro.2017.03.022

1. Introduction

In general terms a Zero Energy Building (ZEB), or Net-Zero Energy Building (NZEB), uses all cost-effective measures to reduce energy usage through energy efficiency and includes renewable energy systems that produce enough energy to meet remaining energy needs during [1]. The wording “Net” emphasizes the energy exchange between the grid connected building and the energy infrastructure [2]. In fact, most zero net energy buildings get part of their energy from the grid and return the same amount during the year, when their production of renewable energy is higher than the demand. Conversely, according to the EU Directive of 2010 (EPBD), a near Zero Energy Building (nZEB) still requires a small amount of energy on a yearly basis [3].

In the last years many definitions of NZEBs were given, depending on how and where this renewable energy is produced [4]. The same acronym is often used for the similar concept of zero emissions buildings, which is slightly different. Regardless these definitions, the efficiency required to achieve zero or near-zero energy goals leads essentially to two different actions: reducing energy demand by means of energy efficiency measures and passive energy use, and generating energy from renewable sources. There are many design strategies to increase energy efficiency, including airtightness to avoid infiltration and mechanical ventilation systems with heat recovery to provide air conditioning and indoor air quality (IAQ). The designed energy balance of a ZEB can however be invalidated with an improper use of technologies by occupants, such as opening windows, changing the operative temperature or not providing the right maintenance of systems [5]. Natural ventilation systems generally contrast with the principle of mechanical control of indoor environment [6, 7].

The mechanical control of thermal comfort, much emphasized in *ZEBs*, aims to reduce the interaction of users with the outdoor environment and this contrasts with the principles of psychological comfort. Besides, monitoring of ultra-low energy buildings in Italy has revealed that occupants rarely use mechanical systems properly and the energy consumption often exceeds the expected results. Thermal comfort is defined as that condition of mind which expresses satisfaction with the thermal environment [8] and depends on physiological and psychological aspects. The former have been widely investigated by Fanger and other scholars, the latter seem to be neglected, at least in the current design. Psychological aspects of comfort involve the interaction of occupants with the environment and vary with latitude, cultural and social factors. Adaptive thermal models, essentially valid for free running buildings, are based on the assumption by Humphreys and Nicol: ‘*if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort*’. These models are entirely focused on psychological aspects and allow wider tolerances of indoor thermal comfort conditions than the physiological-only ones [9].

The goal of this paper is to propose a design strategy to integrate natural and mechanical ventilation systems in a nZEB at different times of the year, overcoming airtightness related problems and thermal comfort ones. Energy balances are estimated according to current Italian standards; the concept of near Zero Energy Building is then referred to the global Energy Performance Index (Ep_{gl}) [Kwh/m^2y], as defined by the recent Decreti Interministeriali (June 2015). The Index takes into account the annual renewable demand of primary energy for space heating, water heating, cooling, lighting and equipment, in relation to the usable surface of the building, and should be near zero. By the beginning of 2021 all new Italian buildings must be nZEBs.

2. Design strategies

The design strategies are applied to the deep renovation of a social housing complex in the city of Modena, dating from 1980 (Figure 1a). The costs of this operation are not discussed in this paper. However, there are different ways of accomplishing the renovation, in relation to the amount of original structure that is going to be kept in place. The new buildings have approximately the same shape and volume of the old ones, except for new sunspaces and tilted roofs to host Photovoltaic panels. The existing buildings are located in a typical temperate climate: winter is not very cold, with temperatures rarely under 0°C; summer can be slightly hot, with the average of daily temperatures in the warmest months around 30°C. Wind speed is generally low at all times of the year, with values around 1,5 m/s, except for some gust at 5-8 m/s. The site of the building has 2258 Degree Days. The project (Figure 1b) seeks to follow a cost control strategy, taking into account three main objectives:

- Energy Saving through Building Design