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Concept, Design and Energy Performance of a Net Zero-Energy Building in Mediterranean Climate

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Abstract

The paper shows boundary conditions, conceptions, design criteria and expected energy performance of a new net zero-energy building, designed for a typical Mediterranean climate and presently under construction in a middle-size city of South Italy. The single-storey building is the final outcome of an Italian project – SMARTCASE – promoted under the umbrella of the European Regional Development Fund. The building has been designed for being a best practice of a new way of living, by reducing - as much as possible - energy needs, energy demand of active energy systems and by converting the entire request by means of on-site renewables. Starting from the architectural concept, and thus shape, geometry and organization of the functions, as well as by considering the thermo-physical peculiarities of the thermal envelope – built in coated X-lam in order to allow both thermal resistance and thermal capacity - the conception phase has interested many professionals. Analogously, all active energy systems, and thus the heating, ventilating and air-conditioning devices, equipment for domestic hot water, artificial lighting and plugged powers are the top of the technology. In addition, a great effort has been dedicated to monitoring and controls. Moreover, the solar energy systems, the air-cooled heat pumps, the geothermal boreholes allow to close to zero the energy balance.

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Keywords: energy efficiency; sustainable development; NZEB design; Mediterranean climate; numerical simulation.

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1. Impacts of Constructions on Urban Heat Islands. Target of Net Zero-Energy Buildings.

The building sector is one of the cause of UHI phenomenon and, moreover, its livability is negatively influenced by the UHIs. Indeed, urban construction materials have different thermal (heat capacity and thermal conductivity) and radiative (reflectivity and emissivity) peculiarities compared to surrounding rural areas, and this causes that more of the sun's energy is absorbed and stored in urban districts compared to rural surfaces. In addition, the height of buildings and the way in which they are arranged affect the rate of night cooling of the environment. On the other hand, hottest days and heat waves increase the overall energy consumption for cooling. The increase of energy efficiency of buildings can play a key role in reducing UHI effect as well as in reducing the energy demand for cooling. A key element of the EPBD Recast [1], in order to achieve long-term efficiency objectives, is the introduction of the standard of nearly zero-energy building (NZEB). How much energy the building can consume, which renewable energy sources are allowed and how close to the building the energy has to be generated are topics still under discussion among the Member States [2]. In the available scientific literature, different approaches have been adopted to define net or nearly zero-energy building concepts [3]. The most important issues are: the metric of the balance, the balancing period, the type of energy uses included in the balance, the accepted renewable energy supply options, the connection to the energy infrastructure, the requirements for energy efficiency, the indoor microclimate. All these points have been largely reviewed by Torcellini *et al.* [4]. In summary, the NZEB target can be approached by taking into account:

a) passive design of the building envelope for the reduction of the heating and cooling loads [5-7];
b) innovative high-efficient technological systems [8, 9] and renewables, necessary for achieving a zero or positive balance [10].

Passive design strategies can help to reach the first requisite to achieve the Zero-Energy Building category: be a very low energy building as underlined by Rodriguez-Ubinas *et al.* [11]. Globally, the National Institute of Standard and Technology [12] has recognized ten general principles, then used for the design of the Net Zero-Energy Residential Test Facility, a laboratory in the form of a typical residence for a family of four persons that has been constructed in a Campus in Gaithersburg. Some papers describe the implementation of NZEB concept in different climatic conditions. Cost optimal and most energy efficient fenestration design solutions were identified by Pikas *et al*. [13] for the cold Estonian climate. Berggren *et al*. [14] have summarized the overall design ideas for an office building, by evaluating whether it can reach the zero-energy definition according to the Swedish standard.

However, according to the aim of the proposed research, some interesting papers referring to Mediterranean countries (or warm/hot climates) will be summarized in the following lines. Through simulation results, Deng *et al.* [15] have shown that the electricity generation of PV can allow to meet the ZEB definition in Shanghai and Madrid. The design solution in Shanghai involves the adoption of an air-cooled hybrid heat pump (8 kW) which uses solar energy to assist the electricity driven vapour compression air conditioning device. Also 64 m^2 PV are designed. In Madrid, thermal mass, sun shadings and evaporative cooling are adopted. A ventilation tower supplies, passively, part of the ventilation and cooling needs by evaporative cooling, by using the wind as driving force. Moreover, mechanical ventilation with heat recovery and indirect evaporative cooling systems are used to reduce heat losses in winter and provide additional cooling in summer. Active cooling and heating are supplied through a radiant floor, connected to a reversible heat pump powered by photovoltaic (12.5 kW_p). Calculation results shows that primary energy payback times of ZEB are 10.1 years in Madrid and 17.9 years in Shanghai, with significant CO_2 equivalent savings, during 50 years of building lifetime. Oliveira Panão *et al.* [16] have discussed how low should be the energy required by a NZEB, in the context of Lisbon. For selected houses, built after 1990, by applying the cost-optimal solutions of thermal insulation and glazing type and considering energy efficiency improved systems, this study concludes that housing energy loads are 'low':

- for the indicative range of 70 kWh/(m^2 year), by summing energy demands for the space heating, cooling and domestic hot water;
- 100–110 kWh/(m^2 year) for all energy uses.

Eshraghi *et al.* [17] have found that it is theoretically possible to achieve zero-energy home for a typical family of four members in Tehran. The authors applied Trombe walls as passive strategy, a combination of 12 m^2 flat-plate and 9 m^2 of evacuated collectors and photovoltaic panels to guarantee thermal comfort, hot water and electricity needs. LEDs and fiber optics are used as lighting system. The annual electricity generation is almost 11,543 kWh while the annual electricity consumption from lighting, appliances, controllers and HVAC system is 4,105 kWh. Also for