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Energy retrofit to nearly zero and socio-oriented urban environments in the Mediterranean climate

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ABSTRACT

The paper aims at presenting alternative ways of investigating, planning and managing sustainable urban environments, by exploring the possibility to use energy retrofitting options as a socio-economical leverage towards nearly Zero Energy Buildings (nZEBs).

The connecting theme of the proposed research path is that the crises of energy supply and global warming need to be tackled with an interdisciplinary, both socio-technical and engineering approach.

In particular, the design study and the performed technical–economical evaluation demonstrate that energy efficiency in residential urban complex can be considered as an extraordinary opportunity to restore environmental, social and urban quality.

The techno-economical feasibility assessment, the proper identification of the types of intervention and their combination in possible scenarios must be investigated and estimated on a case-by-case basis, with an effective and interdisciplinary design approach integrating in a whole system the socio-technical aspects into the feasibility study of economical and architectural issues.

In this context, a renewed role of architects and planners is what is need for a real shift in the building practice. In fact, instead of trying to structure the informal through the architectural production based on authorship, architects should consider the users' perspective and their need as self-organised processes of negotiation. This strategy can help in engaging a real shift from the current practice towards a social sustainable process where inhabitants and designers work together to find effective and real solutions to social and technical questions.

The urban and technological strategies here presented suggest a multi-fold approach that could stimulate the process of energy renewal according to a socio-oriented use of architectural tools in urban environments.

1. State of the art and crucial issues in the Mediterranean cities

Cities and their surroundings areas consume the 80% of final energy in the European Union and more than two thirds of the population lives in urban areas (EU Commission, 2011). Urban growth has reached such a peak, that bypasses, reversals, or new ways of development are needed (EU Report, 2010b). Some significant and alarming figures are reported in literature. The world population has grown from 2 to 6 billion, and soon will reach 7 billion, while the percentage of human beings living in cities has increased from 3% in 1800 to 14% in 1900 and is estimated to rise from the current 50% to 75% in 2050. The figure for Europe is still higher: 83% of the population are expected to live in cities by 2050 (EU Report, 2010a).

Increasing urbanization and deficiencies in development control in the urban environment have important consequences on the thermal degradation of urban climate and the environmental efficiency of buildings (Santamouris, 2001, 2007, 2012).

The average temperature on the earth's surface has suffered an increase of +0.6% and is estimated to reach 1.5% by 2030. As a consequence of heat balance, air temperatures in densely built urban areas are higher than the temperatures of the surrounding rural zones (Santamouris, 2001; Yamashita, 1996). In fact, the progressive increase of global warming will specifically raise urban temperatures. After the Messina earthquake of 1908 (which caused about 83,000 deaths) the hot summer of 2003 with ~70,000 deaths, mostly in the cities, was the second heaviest natural disaster of the last 100 years in Europe.

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Other problems, such as building deterioration and unused/abandoned areas, are also concentrated in cities. Furthermore, Mediterranean cities are now faced with new and persistent problems of unemployment, poverty, social exclusion, (e)migration (Garniatia, Owena, Kruijsena, Ishadamyb, & Wibisonoc, 2013; Leschke, 2013).

In this context, "the objective of Energy Efficient (EE) and economically viable societies appears to be particularly challenging in a context of global economic slowdown such as the one the world is currently experiencing" (Masini & Menichetti, 2010). In fact, the severe reduction of energy consumption towards zero energy buildings and districts is especially crucial given harsh economic times.

1.1. The energy potential of green and passive techniques in the urban microclimate

As a consequence of heat balance, air temperatures in densely built urban areas are higher than the temperatures of the surrounding rural zones. The phenomenon, known as 'Heat Island' (HI), is due to many factors (Santamouris, 2001; Yamashita, 1996): the canyon geometry, the thermal properties of materials increasing storage of sensible heat in the fabric of the city, the anthropogenic heat, the urban greenhouse; all these factors contribute to increase urban HI effect.

Research studies on this subject refer usually to the 'urban HI intensity', which is the maximum temperature difference between the city and the surrounding area (Santamouris, 2001).

In this context the city of Athens represents a highly significant pilot study: data compiled by various sources (Ferrante, Mihalakakou, & Odolini, 1997; Giannopoulou et al., 2010; Santamouris, 2001, 2007, 2012) and surveys performed in Athens on the HI intensity – involving more than 30 urban stations – show that during hot summer seasons urban stations present temperatures that are significantly higher than the ones recorded in the comparable suburban stations (the gap varies from 5 to 15 °C). It is well known that trees and vegetation have a strong effect on climate since green spaces can help cool our cities (Buttstädt, Sachsen, Ketzler, Merbitz, & Schneider, 2010; Santamouris, 2001, 2007, 2012) and save energy (Yamashita, 1996). Trees also help mitigate the greenhouse effect, filter pollutants, mask noise and prevent erosion (Ferrante & Mihalakakou, 2001; Fintikakis et al., 2011). Results of computer simulations aimed at studying the combined effect of shading and evaporative transpiration of vegetation on the energy use of several typical one-storey buildings in US cities have showed that by adding one tree per house, the cooling energy savings varied from 12 to 24%, while adding three trees per house can reduce the cooling load between 17 and 57% (Akbari, 2002). According to this study, the direct effects of shading account for only 10–35% of the total cooling energy savings. As a consequence, the cooling load of reference buildings in city centre is about twice the value of equivalent buildings in rural areas.

Furthermore, previous research work developed within the frame of the research project POLIS in Athens (Ferrante, Santamouris, Koronaki, Mihalakakou, & Papanikolau, 1998) have showed some appropriate procedures to design the use of natural components – such as green roofs and pedestrian permeable surfaces – within Urban Canyons (UCs). The design of outdoor spaces – even if reduced to the envelope of the buildings because of existing urban constraints within thickly built urban areas – as well as the use of natural components have been regarded as key means to improve urban conditions in relation to both microclimate and reduction of pollutants. By 'making-up' the building's surfaces and elevation facades with green components or shading devices, four different scenarios have been proposed in four different UCs in Athens downtown (Fig. 1).

Experimental software research models have been used to quantify the positive effects of these selected passive techniques. Obtained results clearly indicated that outer surfaces' alternative design acts as prior microclimate modifier and deeply improves outdoor air climate and quality (up to 2/3 °C reduction in ambient temperature) (Santamouris, 2001).

Other significant physical factors in the thermal performance of urban environments are wind flows and air circulation (Ricciardelli & Polimeno, 2006; Santamouris, Papanikolau, Koronakis, Livada, & Asimakopoulos, 1999) as well as air stratification within UCs. In particular, the HI effect and the microclimatic conditions typical of UCs (Bitan, 1992) appear to be strongly influenced by thermal properties of the materials and components used in the buildings and on the streets (Buttstädt et al., 2010). Furthermore, comparative research studies (Synnefa, Santamouris, & Apostolakis, 2007) demonstrated that the use of cool coloured materials and thermo-chromic building coatings can contribute to energy savings in buildings, providing a thermally comfortable indoor environment and improved urban microclimatic conditions (Karlessi, Santamouris, Apostolakis, Synefa, & Livada, 2009).

It is therefore evident that urban areas in the Mediterranean climate have to be conceived, investigated and re-designed as a whole consisting of the buildings blocks and the related open area along the street/square (Ferrante & Cascella, 2011).

Thus, morphological and spatial geometry of urban areas, thermal properties of surface coatings and green surfaces have a strong potential on the energy performance and cooling demand reduction in urban settings. As a first conclusion note, we can state that microclimate in the urban canyons and urban areas may be assumed as the central core of climatic conditions in the city. The special context of urban environments needs to be further investigated by means of a more holistic approach able to integrate the potential of mutual intersections among the different physical components (green, surfaces, coating materials, new buildings envelopes) and their effects on urban climate in a comprehensive design tool.

1.2. Policy background and zero energy case studies

To respond to the growing urban environment energy demand, energy oriented innovations and practices, regulative instruments and incentives are emerging, such as the recent European and national Directives on Energy Performance of Buildings EPB on nearly Zero Energy Buildings (nZEBs), or the investments in Renewable Energy Sources (RES) technology like feed-in tariffs and policy incentives. In fact, in the frame of the legislative plane, recently the European Parliament (Directive 2010/31/EU on the EPB), amending the previous 2002 EPB Directive, has approved a recast, proposing that by 31 December 2020 all new buildings shall be nearly zero-energy consumption and will have to produce as much energy as they consume on-site (Task 40/Towards Zero Energy Solar Buildings, IEA SHC/ECBCS Project, Annex 52).

In particular, over the last decades, energy oriented innovations in building technology have emerged in many areas of the building construction sector (Brown & Vergragt, 2008; Dakwale, Ralegaonkar, & Mandavgane, 2011) till the latest experiences aiming at setting to zero the carbon emission of new developments and even of a whole City. Nowadays we may state that green buildings belong to the "history of architecture": the first prototype buildings and their attempts to achieve zero-heating in the form of solar houses date back to 1950s (Hernandez & Kenny, 2010).

Among the recent experiences is the well known urban village BedZED (Beddington Zero Emission Development), winner of the prestigious Energy Awards in Linz, Housing and Building category, Austria, 2002 (Marsh, 2002). A first zero waste-zero carbon emission City is to be constructed in Abu Dhabi, Masdar City, designed by