URBAN RECREATION: ENERGY EFFICIENT RETROFIT FOR CARBON ZERO AND SOCIO-ORIENTED URBAN ENVIRONMENTS

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ABSTRACT

Appropriate strategies to reduce energy consumption, increase Renewable Energy Sources (RES) penetration within local urban ecosystems are the higher priorities towards low carbon cities. In this context urban canyons (UCs) -conceived and investigated as a whole consisting of the buildings blocks and the related open areas- represent the core of the search for new intersections between energy issues and urban dwellers. In fact, morphological and spatial geometry of UCs, thermal properties of surface coatings and green surfaces have a strong potential on the energy performance and cooling demand reduction in urban settings.
Furthermore, the urban buildings should be also investigated to understand the potential of mutual intersections between passive components, Energy Efficient (EE) techniques and RES.
Finally, efficient schemes for zero-energy requirements, energy construction quality, technological flexibility also need to fit with different users' needs and expectation, taking into account the different economic and social possibilities, within the large building stock throughout European cities. Existing buildings in urban environments represent the biggest challenge both in carbon terms –because of the large amount of existing stock- and for the social impact they may generate on the relationship between human behaviour and urban sites.
The URBAN RECREATION project – funded within the frame EU 7th Framework Programme for Research (Marie Curie-IEF Intra-European Fellowships -IEF-) aims at achieving an effective research action exploring the socio-technical mechanisms that can promote the concrete synergies between economic constraints, users expectations, EE systems and production, in renewed forms of urban expression. In other words, URBAN RECREATION aims at demonstrating the techno-economical and social feasibility of zero energy-zero emission retrofit in existing UCs. To reach this aim the research will:
- Develop a model which spatially depicts the energy of a selected urban area as a contribution to the mapping of the city energy consumption. The principles of the model -based on the city discretization into homogeneous districts characterised by several UC types- will be therefore applicable to other districts and cities.
- Study and evaluate the energy demand/potential of the UCs by designing –in different steps of actions- retrofitted scenarios to achieve carbon neutral UCs. The study will evaluate different solutions to diffusely integrate available technologies within UCs. Therefore Energy demand in the UCs and Energy saving potential of UCs by passive and RES will be fully investigated; Zero Energy-Zero onsite emissions in the UCs, where additional energy savings production by synergies between passive and active systems will be addressed.
- Study and evaluate existing constraints (technical, economic and social constraints) and the way to overcome conflicts/barriers to the designed scenarios' penetration into real UCs. To overcome these barriers and design a framework to achieve the development of low carbon scenarios and zero energy neighbourhoods, the research

project will also develop further activities (social, technical and economic incentives/actions) to fill the knowledge gap among low carbon techniques and their adoption at social and community city level.

KEYWORDS

nZEBs – nearly Zero Energy Buildings, Energy retrofitting, RES - Renewable Energy Sources, Urban Canyons, Socio-oriented Design

1 INTRODUCTION

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

Urban growth has reached such a peak, that bypasses, reversals, or new ways of development are needed (EU Report, 2010)[1]. 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. 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 by Ferrante (1997) 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[2]). 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 et al, 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. 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

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[1] Some significant and alarming figures: 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, Brussels, 2010). The average temperature on the Earth's surface has suffered an increase of +0.6% and is estimated to reach 1.5% by 2030. The progressive increase of global warming will specifically raise urban temperatures and heat island effect. 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.

[2] Measures performed during the POLIS Research Studies by the CIENE in Athens, Prof. Santamouris. Plants have a strong effect on climate: trees and green spaces can help cool our cities (Santamouris, 2001) (Buttstädt et al, 2010) and save energy (Yamashita, 1996). Trees also help mitigate the greenhouse effect, filter pollutants, mask noise and prevent erosion (Ferrante and Mihalakakou, 2001). 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 to 57 percent. According to this study, the direct effects of shading account for only 10 to 35 % of the total cooling energy savings.

flows and air circulation (Santamouris et al, 1999), (Ricciardelli et al, 2006) as well as air stratification within UCs. It is clear that 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, 2010). The comparative research carried out by the Host Institution demonstrated that the use of cool coloured materials (Synnefa et al, 2007) and thermo-chromic building coatings can contribute to energy savings in buildings, providing a thermally comfortable indoor environment and improved urban microclimatic conditions (Karlessi et al, 2009). It is therefore evident that UCs have to be conceived and investigated as a whole consisting of the **buildings blocks** and the related **open area** along the street/square.

Thus, morphological and spatial geometry of UCs, 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 (UCs) may be assumed as the central spatial core of climatic conditions in residential urban areas**. This special context 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

Over the last decades, energy oriented innovations in building technology have emerged in many areas of the building construction sector[3] (Brown and Vergragt, 2008), till the latest experiences aiming at setting to zero the carbon emission of new developments and even of a whole City[4]: a pilot city plan to set to zero the carbon emissions of Copenhagen has been developed[5]. The increasing interest in nearly Zero Energy Buildings (nZEBs), recent European and national Directives on Energy Performance of Buildings (EPB)[6], easier accessible Best Available Techniques (BATs) and Renewable Energy Sources (RES), all seem to point to further exploitation of BAT and better penetration of RES into new building construction.

The majority of these recent case studies refer to newly conceived buildings and large development plan.

Furthermore, in spite of growing investments in RES technology (Bürer and Wüstenhagen, 2009), feed-in tariffs and, in general, the policy incentives (Bulkeley, 2010), additional investments are needed to reduce carbon emissions and fossil fuel consumption[7]. "Needless to say, this is particularly challenging in a context of global economic slowdown such as the one the world is currently experiencing" (Masini et al, 2010).

Thus, the challenge now is to **widen technical ZEB knowledge** in **existing built environments**: we need to shift our technical understanding on EE from new developments

[3] Green buildings now belongs 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).

[4] A first zero waste-zero carbon emission City is to be constructed in Abu Dhabi, Masdar City, designed by N. Foster. Despite its location (the oil rich and hot part of the world) the development is designed as a huge, positive energy building, resulting in a self-sustaining, car-free city.

[5] The climate Plan (City of Copenhagen, 2009) demonstrates how to make Copenhagen the world's first carbon neutral capital by 2025 by means of using biomass in power stations, erecting windmill parks, increasing reliance on geothermal power and renovating the district heating network.

[6] 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. See also Task 40/Towards Zero Energy Solar Buildings, IEA SHC /ECBCS Project, Annex 52.

[7] The treaty issued by several NGOs calls for a doubling of market investments by 2012 and quadrupling by 2020 to attain the proposed carbon emission reduction targets (Meyer et al, 2009). As reported by Guy (2006), according to the United Nations Environmental Programme (UNEP) there is still an "*urgent need for the incorporation of EE issues to be included in urban planning and construction*".

and buildings to existing buildings, within UCs of active cities, since the large amount of existing stock represents the wider potential in carbon terms. In this context, recent studies and design proposals on building energy retrofitting (Ferrante et al, 2011) has proved that huge energy saving may be achieved in winter by adding different coatings to existing buildings. In particular, the combination of new building coatings like sunspaces or buffer zones (as shown in fig. 1) and RES, drastically reduce the energy performance indexes of the buildings **up to the target of nZEB**. These studies, performed during the winter season so far, need to be further investigated in order to quantify the **cooling** demand **reduction** of the proposed scenarios during hot **summer** conditions.

*Fig. 1(a, b, c, d). Energy retrofitting by new envelopes design in a reference building of Bologna. a) initial scenario; b,c) new scenario; d) different energy performance indexes (kWh/m^2*y) as a function of different retrofitting options (from left (grey) =initial state; to right (green) = final scenario)*

Thus, the context of buildings in urban areas should be further investigated, to understand the potential of mutual intersections between passive components, Energy Efficient (EE) techniques and RES. In fact, the study of the potential synergies between passive and active systems have not been fully explored; nonetheless it is particular important, since the use of EE systems and RES should provide additional energy saving deriving from passive-active interactions[8]. This represents a key added value to be gained from **closer collaborations** among **researchers**, existing business investors and **industrial partners** in the field of **RES**.
To achieve a proper **nZEB**, it is therefore crucial: i) to investigate the **cooling** demand reduction during hot **summer** conditions of retrofitted buildings; ii) to promote further investigation on synergy between passive and active energy technologies within existing urban environments, thus implementing research exchanges with economic business sectors in the common effort to activate smart and low carbon UCs.

1.3 Low Carbon Communities and Grass-root initiatives in the urban environment

Despite excellent studies and pilot zero-energy cities, an increasing societal need for human recognition in depersonalized urban environment is emerging. Furthermore, as a result of the functional or “Ford” city of the 20th century, in the open areas and along the city streets, the urban space was devalued by destroying the “transparency” of the facades on street level either by the infill of garages or by closing all doors and windows on ground level (Fig. 2).

[8] For example, the potential of PV systems in cooling, shading, increasing air stratification and vertical air extraction from UCs may produce additional energy savings, disregarded so far; wind micro-turbines may behave in interesting ways in urban environment: for example, the roof effect (Mithraratne, 2009) -which refers to wind colliding with a pitched roof- may accelerate the air movement thus improving the performance of a micro-turbine on the roof; furthermore, a micro-wind generator may help to extract air from buildings and urban environments.

Fig. 2 (a,b,c,d,e). Different urban canyons in the European cities. From the left to right: a)Vienna; b,c) Bologna; d,e) Athens.

Redesigning energy technologies in the urban areas is certainly a major scientific challenge. However, succeeding in this endeavour requires more than getting the engineering right (Webler and Tuler Seth, 2010). Thus, energy efficiency in urban settings is more than a technical problem. Recent studies have suggested that more focus should be placed on the social aspects at community level and that energy users should be engaged in their role of citizens. In fact, developing more sustainable consumption and production systems depend upon consumers' willingness to engage in "greener" and more collective behaviours (Peattie, 2010). In this frame, local urban communities have inimitable advantages in providing infrastructure for more sustainable consumption environment; in fact, different types of low-carbon communities as a context to reduce carbon intensity are emerging at different scales (Heiskanen, 2010). Existing literature (Mulugetta et al, 2010; Guy, 2006) stresses the need for a clear transfer from a technical/economically based urban theory to a human based and **socio-technical urban vision** to achieve a greener behaviour in urban environment. In this perspective, it is worth mentioning that timid attempts in the sustainable "re-design" of urban places by local-based communities are arising in the spatial sphere of the urban street environments (Fig. 3).

Fig. 3. Occupying small parking areas, the Urban Community Centotrecento Street in Bologna has encouraged small practices of self-organization among the inhabitants for a more sustainable management of space, equipment and resources.

Notably, some of Europe's leading innovation Nations have included **user-driven** or user-centred innovation as a way of providing innovative products and services that correspond better to user needs and therefore are more competitive. User-driven innovation (EU, 2009) is closely associated with design, and involves tools and methodologies developed and used by designers[9]. Practises of (re-)design of existing buildings by engaging final users are also occurring in different contexts of EU and worldwide (fig. 4).

Fig. 4 (a,b,c,d,e). User-centred design by participative process with the inhabitants in new (from left, a,b) and existing buildings (right, c,d,e).

In brief, there is a special need for efficient schemes where **zero-energy requirements, energy construction quality, technological flexibility can fit with different users' needs and expectation**, taking into account the different economic and social possibilities, within the large building stock throughout European cities. Existing buildings in urban environments represent the biggest challenge both in carbon terms –because of the large amount of existing stock- and for the social impact they may generate on the relationship between human behaviour and urban sites. Finally, we argue **UCs** (streets and connected residential buildings) are the **core of the search for new intersections** between urban dwellers and energy related issues. An effective research action should explore the socio-technical mechanisms that can

[9] EU (Commission of) Communities, 2009,"Design as a driver of user-centred innovation", Brussels, 7.4.2009, SEC(2009)501.

promote the concrete synergies between economic constraints, users expectations, EE systems and production, in renewed forms of urban self-expression.

2 CRITICAL ISSUES IN THE URBAN ENVIRONMENT

There is thus a lack of comprehensive information on the possible intersections between the BAT's options and a concrete inclusive approach to users needs. This is because close collaboration between physicians, engineers, architects, energy companies, stakeholders and urban dwellers, amongst others, is missing, which is probably why progress in this area is still limited to date. From the complexity of the state of the art in urban environment a series of missing issues arises. To sum up, there is an increasing need for:

- Further exploration of UCs' geometry for achieving better understanding of current energy demand within the different residential areas of the city. This further exploration should be observed and quantified not only with reference to the building blocks and urban textures considered as the "solid" part of the city, but also to the open streets environments, thus considering **the buildings and the related open spaces (**the UCs) as the "core" of energy investigation and the consequent global effects emerging from the cumulative effects of all the buildings and open areas in the canyons of the city;
- Energy retrofitting actions in existing building stocks within localized ground-based urban environment;
- Research studies able to bridge the knowledge gaps on the potential of both passive and active technologies by RES –solar, PV, Aeolian- and their mutual intersections in the thermal balance of UCs;
- Small scale and distributed RES penetration in local urban environments;
- Bottom-up processes aimed at including urban dwellers in low-carbon transition pathways within UCs[10].

Thus new connections between citizens, business investors and energy related issues should be investigated within localized UCs.

3 RESEARCH HYPOTHESIS

The energy of residential urban areas can be represented and estimated spatially according to a sequence of different UC types, considered as the basic urban units which characterize a whole city (as an example, see Fig. 5 -a,b,c-). Furthermore, the proposed research focuses on UCs, considering the buildings and the related open areas as a whole and the snowballing effects of all the buildings and open areas in the UCs: this holistic vision of urban energy demand can better drive urban planning decision and bottom-up, grass-root initiatives towards the adoption of alternative residential configurations/redevelopment of existing urban areas.

Fig.5 (a,b,c). a) Left: an example of discretized areas at the large urban scale within the Athens Central Area; b, c) Right part of the figure: aerial view (above) and zenith view (below) of the urban section (A) within an homogeneous district/area.

[10] "In the search of bridging the gaps between EE technology and society, we need to explore the potential links and intersections between technologies and urban dwellers in particular contexts of use, advocating the development of low-carbon and socio-oriented experiments in the urban environments" (Guy, 2006).

Thus, the assumptions of the URBAN RECREATION are the following:

i) in order to evaluate the energy demand and potential of an urban environment it is possible to develop a whole discretized city model based on different urban units (Whitehand, 2009), corresponding to the **building blocks and the related street/open area as a whole entity** (hereafter UCs);

ii) in these units retrofitting actions towards low carbon UCs have to be hypothesised and validated exploring both passive physical components (green and EE techniques for surfaces and coating materials) and energy micro-generating technologies by RES – solar, PhotoVoltaic (PV), Aeolian- etc.;

iii) the social and the economical feasibility of these actions in localized urban environments can more easily lead to bottom-up actions and drive towards a carbon neutral future (aim of the research).

4 ZERO ENERGY AND ZERO EMISSION URBAN AREAS

The goal of the URBAN RECREATION proposal is to demonstrate the feasibility of **Zero Energy and zero CO_2 emission Retrofitting** (**ZER**) throughout a whole city area. To reach this aim the research studies will:

i) - Develop a model which spatially depicts the energy of residential urban areas as a contribution to the mapping of total energy consumption in the built environment. This model will be based on the discretization of the city into different homogeneous districts, which would enable the model to be used for different case studies. Discretization of the city is a very important objective, especially considering the possible intersections with existing plan at Municipal/Regional level. The average Energy Consumption (EC) currently available in existing regulation tools will be combined with the large amount of available data (Santamouris et al, 2007) and referred to the batch of the buildings and the open areas, thus considering the UCs as the basic units for investigation of both energy and social issues in the urban environment.

ii) - Study and evaluate the energy demand/potential of the UCs; this will be achieved by designing –in different steps of actions- retrofitted scenarios in order to achieve zero energy, socially inclusive solutions by means of an inter-disciplinary research approach. The study will develop, perform and evaluate different possible solutions to achieve a sustainable and spatially localized distribution of energy, by means of technologies to be diffusely integrated in the urban buildings and canyons;

iii) - Promote further actions to contribute to fill the knowledge gap existing among low carbon passive techniques and the adoption of these technological solutions at social and community city level.

In order to investigate the validity of these hypotheses, the overall aim of URBAN RECREATION has been sub-divided into the following objectives:

4.1 Urban discretized model

Determine the instrumental values and the spatial format of the model of energy in the urban environment as a part of a broader analysis on energy consumption. In this objective we will develop a city model based on the different types of existing UCs geometry; a consistent part of the major Athens area will be mapped and 3 significant areas will be selected for further investigation.

4.2 Energy balance in the urban canyons (UCs)

Evaluate the initial energy balance of the urban environment. Estimate the thermal energy performance and the energy demand in 3 representative urban units within the major Athens area, to determine the value of the energy supply of at the initial state.

4.3 Energy saving potential of UCs

Determine the energy saving potential of the urban units. This will be achieved by designing: i) alternative urban scenarios by means of technological building components/materials and volumes aimed at reducing the building heating and cooling loads; ii) alternative urban scenarios integrating renewable energy sources in the urban building envelope and outdoor urban sets as well. These objectives will also be connected with business economic actors, industrial associations and SMEs.

4.4 Zero Energy and Zero onsite emissions in the urban areas

Determine the final scenario to achieve zero energy and zero CO_2 emission within UCs in winter and summer conditions. The final scenario will take into account the mutual effects arising from passive and active systems within UCs. This objective is particularly important, because of possible connection/integration of the study with industrial associations, SMEs: in fact, the possible synergies between EE passive and active systems (i.e. PV panels or micro-Aeolian systems and their potential in cooling, shading, increasing air stratification and vertical air extraction) may produce significant additional energy savings and interesting added value both to RES penetration into the market; creative ideas arisen during this phase can produce the further improvement of existing products, by turning existing building and RES components into renewed or new products.

4.5 Overcoming existing constraints

Study and evaluate existing constraints and the way to overcome conflicts/barriers to the designed scenarios' penetration into real UCs. This objective is addressed to analyse and overcome the existing technical, economic and social constraints and design a framework to achieve the development of low carbon scenarios and zero energy neighbourhoods.

4.6 Outreach initiatives

Promote community of practices, dissemination and workshops about successful retrofitting actions within real urban environments.

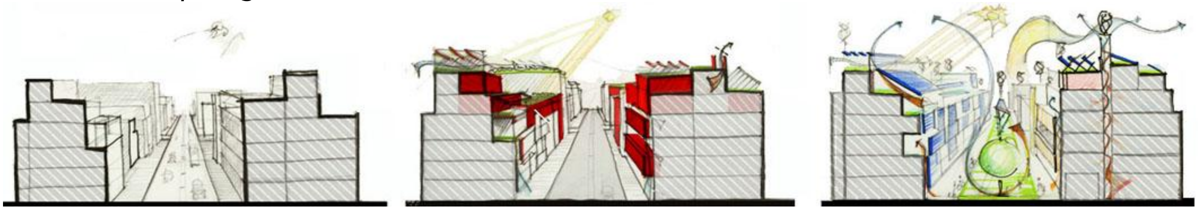

Fig. 5 (a, b, c) Different scenarios in the UCs. a) The initial scenario; b) Technological building components/materials (change of facades' surfaces, additional envelopes, additional spaces and volumes) in a first alternative UC; c) Interactions, synergies and possible additional energy saving within a complete UC scenario integrating passive and active systems (RES -PV and micro-Aeolian) in the urban building envelopes and outdoor urban sets.

5 CONCLUSIONS

Although no conclusions can be drawn (the project is just started), being a multidisciplinary and multi-scalar proposal, URBAN RECREATION may open new horizons and opportunities for research in the frame of possible intersections between social urban studies and economics, physics, technology, design disregarded until now. To sum up, the proposal will:

√ Explore –as widely as possible- social, spatial and technical relations among urban forms, EE techniques in a neighbourhood development strategy as a part of the broader larger city scale;

√ Demonstrate the high competitiveness of small scale energy saving and production within different urban areas;

√ Study the mutual effects between passive systems to reduce heating and cooling loads and RES as PV and Micro-Aeolian disregarded until now; the research use of technological components such as photovoltaic panels or micro-Aeolian systems should be further investigated in order to understand additional energy saving deriving from mutual interaction among passive and active techniques;

√ Study the actions/strategies to raise social awareness and citizens' consciousness of environment friendly tools and energy production/consumption in urban open spaces; the study will explore the actions to test social/technical feasibility in relation to alternative urban scenarios.

Therefore we foresee at least two/three research areas for possible spin off research topics, with regards to ERA competitiveness and long-term synergies: i) the social and urban sphere; ii) the industrial research implementation and design; iii) intersections between the two fields of interest.

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