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VEGETATION AND THERMAL COMFORT IN TEMPERATE AREAS: PROPOSAL OF AN INTEGRATED METHODOLOGY FOR URBAN AND BUILDING RETROFIT

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ABSTRACT

The paper points out the main outcomes of a doctoral research carried out at the Department of Architecture of the University of Palermo, aimed at investigating the issues of environmental, social and economic sustainability related to the recovery of the existing building stock with focus on social housing. In particular, starting from the analysis carried out on a real case of the city of Palermo, through the use of specific simulation tools, the research provides a new methodology for the design and the assessment of the effectiveness of plants and Building-Integrated Vegetation systems used as a cost-effective solutions for urban and building retrofit, contributing to new knowledge and understanding of the impacts of vegetation in temperate areas for the increase of cities energy efficiency and users' thermal comfort.

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1. Introduzione

The last decade has been characterized by a growing concern on a number of environmental, social and economical issues that made the sustainable development the main challenge of our society and one of our times most deeply embedded governments commitment.

The increase of temperatures registered in the last twenty years and the unavoidable consequences due to the exacerbation of the greenhouse effect have pushed the scientific community to demonstrate that such changes cannot only be attributed to the natural evolution of the planet[2]. The progressive intensification of extensive farming and agriculture and the related action of deforestation to convert woods in cultivated fields and grazing lands and the rampant increase of greenhouse gases emission caused by transports, industries and building construction, have demonstrated that men became the main responsible of the Earth's global warming. Together with the issues related to the use of fossil fuels, the growth of damaging effects on men health, policies for the provision of non-renewable sources and the continuous threats of energy crisis, became the background of an era where founding alternatives of environmental development is not only desirable but also necessary.

To aggravate this scenario, the global economic crisis has spread throughout a wide range of countries and regions of the Western world, including Italy and in particular the southern regions, causing unprecedented financial and social upheavals. Many of the surveys and studies show that poverty has grown visibly and point out an alarming increase in the number of persons requesting food assistance, clothing and a place to sleep (Perlo Cohen, 2011).

On the other hand, developing countries such as Brazil, China and India are experiencing a huge economical growth while establishing governments' commitments for the definition of policies aimed at a balanced social and environmental growth in an attempt to adhere the global development standards.

Following up the environmental, social and financial changes that occurred in the last decades, our cities became the mirror of the massive transformations that societies have undergone. As stated by Donzelot (2006), «...In half century, the city moved from the register of the solution to that of problems...», summarizing two essential nodes that characterized the evolution of urban areas, both in the so called developed and developing countries. Cities «...seem today exposed to contradictions...» (Fedeli, 2010): although they were (and are in the

[2] Since its formation our planet went through continuous phases of climate changes more or less rapid and cyclic. The periodical fluctuations of temperatures and rainfalls are natural consequences of this variability. Most of parameters that influence the climate (solar activity, atmospheric characteristics, internal or external planet factors) are in a slow yet continuous variation and, consequently, our climate is never static. Nevertheless, measurements effectuated in the last years, show the hottest temperatures ever registered since global measurements of Earth surfaces are available (1850) and the Intergovernmental Panel on Climate Change (IPCC), declared that the probability that the increase of temperature derives only from natural phenomena is extremely low (less than 5%).

case of developing countries) built up as expression of stability and stabilization, they often disclose an increasing social polarization and fragmentation and a great inattention for some basic rights such as housing, mobility, work and health.

Urban areas, because of the diffuse cementification and use of asphalt surfaces which flatly prevail on green areas, of motor vehicles emissions, industrial plants and heating and cooling systems of buildings, have on average higher temperatures (between 0.5 and 3 °C) than the rural areas nearby, generating the phenomenon known as "heat island effect". Beside the thermal discomfort issue, cities and towns, for all these reasons, experience increasing signs of environmental stress, notably in the form of poor air quality and excessive noise. With respect to air quality, ground-level ozone and fine particulate matter are the main pollutants in terms of their health effects. High concentrations of ozone in the troposphere, typical for the summer months, lead to an increase in the frequency of respiratory symptoms, and the World Health Organisation (WHO) attributes several thousand hospital admissions and premature deaths each year to this pollution (De Ridder, 2004).

At the same time, a large amount of social and anthropological studies is nowadays focused into causal explanations and new ways of understanding the synergies of decline and growth of our cities and the contemporary urban and social dynamics that originated from the financial global crises of Europe and USA and the economic boom of the developing countries. In this scenario, hence, urban planning and architecture design are striving to reinvent the role of the cities, meant as physical and social spaces, in a perspective of long-term sustainability.

The issue of Social Housing, in particular, turns out to be completely embedded in all these aspects. The theme of housing, in fact, in the field of the local welfare became a significative example of the necessity to address emerging global goals of sustainability, in all its meanings.

The European Union, as the world's second largest producer of social housing, following China, in the field of integrated measures for sustainable urban development, has declared in several occasion and through different action tools its commitment in made social housing a policy to support economic and urban growth and to mitigate housing bubbles in the private sector and the devastating effects these have on social and macro-economic balances. Moreover, as stated by the European Economic and Social Committee (2012) "Social housing has to deal with the new climate situation and the need to improve the energy efficiency of its existing stock and new supply".

Current national and international rules on the energy regulation of the built environment and the mitigation of the urban microclimate are strongly reiterating the necessity of effective interventions for the rehabilitation of the existing buildings, which require pondered consideration in terms of environmental, social and economic sustainability. In this sense, the enhancement of Social Housing performance is not related exclusively to the need to improve

energy efficiency and foster renewable energy but also to tackle exclusion of marginalised communities from access to housing and to affordable and high-quality social services. The aspects of energy and environmental sustainability, in fact, are strategic for social housing, at a global scale, because it implies a significative reduction of costs of buildings management and hence the possibility, for low-income households, to live in affordable conditions. For new construction buildings this can be relatively easy to achieve but the main challenge, in terms of design, efficiency and resources, is today represented by the retrofit of the large existing building stocks, which is expected to occupy the larger area of the construction sector in the next years representing a chance of awakening from the crisis[3].

What originates from all these considerations is that the concept of Social Housing today cannot be simply reduced to the construction aspect since the complexity of functions that it addresses to fulfill makes it «... a programme [...] which is becoming increasingly similar to an urban project...» (Rabaiotti, 2010). Researches and experiences of building transformation have demonstrated the need for a "plural" action, able to combine multiple and different requests coming from sites and stakeholders. This implies also an increasing necessity to intervene through harmonic inter-scale actions which can move from the urban planning to the architectural design. Actually, the term "urban retrofit", which refers to the renovation of micro-urban/district scale, has been recently introduced among the scientific community to be distinguished from the "building retrofit" which indicates the upgrading of the buildings performance.

In the context of current worldwide practices, two different approaches can be individuated: "deep retrofit", which entails substantial transformation of the building (envelope performance improvement, systems upgrading, volumetric addictions, etc), and "light retrofit" which consists in more detailed and implemented actions used strategically according to different priority and lower energy standards (Losasso, 2012). And if in some cases these two way of actions reflect different strategies approaches which are however held by planned, assisted and clear environmental policies (see the case of Germany and UK), sometimes they simply highlights difficulties of economic and financial nature.

On that topic, another aspect that should not be disregarded is the importance of energy investment policies that have started to spread out worldwide for the implementation of Social Housing in order to assure the economic feasibility of interventions and promote local employment and regional economic development. The issue of "urban living" is in fact moving from "heavy" and centralized welfare policies to "light" local practices with public provision often coexisting with a growing private sector, mainly consisting of specialised nonprofit or limited-profit bodies.

[3] It was estimated that in Europe new constructions add only around 1% to the total building stock on yearly basis and that in Italy, e. g., for the next 30 years about 70% of all actions in the field of the building industry will be refurbishment of the existing stock.

Starting from these considerations, the thesis investigates on possible strategies for the recovery of the existing Social Housing complexes, able to incorporate and combine the main aspects of sustainability, with focus on the environmental issues and the improvement of thermal comfort. In this sense, the use of vegetation is examined as a possible solution for the urban and the building retrofit in order to improve the environmental conditions -while providing other indirect benefits- of communities situated in temperate areas, where surveys on sustainable systems to cool cities are acquiring significant weight.

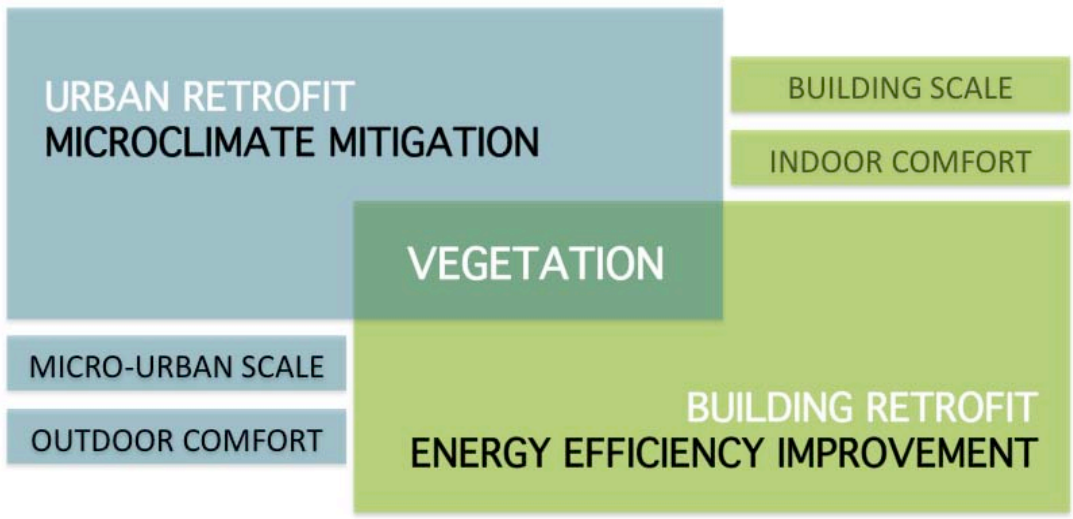

Figure 1 - Scheme showing the use of vegetation as a strategy of retrofit (Drawing of the Author)

The research has been carried out through a dual investigation conducted for Italy (in particular South regions) and the South-East region of Brazil[4]. The choice of moving through this parallelism arises from two main considerations. The two regions present similar geo-climatic characteristics which partially constituted the reason of the backward position of the two countries in the international panorama of sustainability applied to the construction sector. The undoubted difficulties registered in the last decade in transposing and adapting knowledge related to building energy efficiency, from cold-weather countries -such as USA or North Europe- are still reflected in a uncompleted and sometimes chaotic normative frameworks and in the slowness of application of innovative technique for existing buildings energy retrofit.

[4] The research has been conducted at the Department of Architecture of the University of Palermo (under the supervision of Prof. Rossella Corrao) although the candidate spent part of the doctoral programme as guest Ph.D. student in other institutions abroad. Specifically, in 2011 part of the research was developed with the support of Labaut - the Laboratory of Environment and Energy of the Faculty of Architecture at the University of São Paulo, in Brazil (under the supervision of Prof. Denise Duarte) and in 2012 with the collaboration of the Strategic Research Centre on Zero Energy Buildings of Aalborg University, in Denmark (under the supervision of Prof. Per Heiselberg).

Secondly, both countries are experiencing different but substantial social and economic transformations which are having significant repercussions on the reconsideration of the theme of housing and the necessity to promote human capital, urban innovation and strategic development planning, although maintaining a realistic vision on the economic feasibility of possible interventions.

In the light of this, the research aims at evaluating which role “light” urban and design retrofit interventions, that consider green space and Building-Integrated Vegetation (green roofs and vertical gardens) have in alleviating the adverse effects of urbanisation and enhance households life quality, focusing on the environment but also accounting for socio-economic aspects. After all, several researches that have been carried out in the last decades have demonstrated that effective ways of mitigating heat islands exist, and that, fortunately, these methods are fairly simple and inexpensive to implement. In particular, there is an increasing interest and potential for studying the effect of vegetation on microclimate. In fact, vegetation plays a unique role in global climate change studies, regulating the energy, water and gas exchanges between the earth-atmosphere interface (Akbari, 1992; among others). Plants can improve the urban environment from both macro and micro perspectives. At the macro-level, large green areas benefit their surroundings. At the micro-level vegetation, strategically placed around the buildings as well as green roofs and living walls, can significantly improve the energy efficiency of the built environment. In a comprehensive consideration, vegetation is recognised to provide several benefits in relation to environmental, social and economic sustainability.

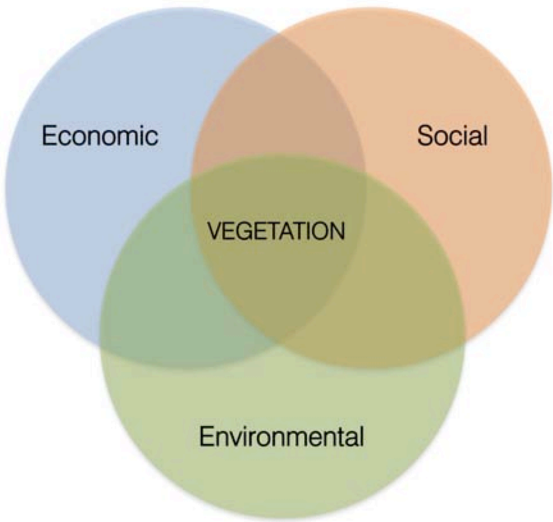

Figure 2 - Mutual relationship between economic, social and environmental sustainability related to the use of vegetation in urban areas (drawing of the Author)

Nevertheless, from an environmental point of view, although indoor comfort and building energy performance simulations, through the use of proper software tools, have been

acquiring increasing importance in the last years -thanks to sophisticated building energy assessments-, they still tend to be disjointed from the elements that characterized the surrounding environment, such as the presence of vegetation, types of soil and the albedo values of buildings surfaces, which actually have a significant influence on the environmental conditions of building interior. This is also demonstrated by the fact that, at present, researches on methods for measuring the impact of trees and building-integrated vegetation on microclimate and on thermal comfort are still limited.
However, considering the increasing interest emerging about this field of research, it is expected that over time methodologies and guide lines will emerge out, in relation to different climate conditions.
In this sense, the research aims at suggesting one methodology of this kind, in this way contributing to new knowledge and providing understanding of the environmental, social and economical impacts of vegetation in temperate areas and in particular in the Mediterranean basin.

2. Proposal of an integrated methodology for the assessment of benefits provided by vegetation on users' thermal comfort during district and building retrofit interventions

By means of numerical simulations performed with ENVI-met[5] and EnergyPlus[6] a new methodology has been applied to a case study individuated in the social housing complex Medaglie d'Oro of the city of Palermo, in order to assess to what extent vegetation, combined with other minor retrofit strategies, can affect the outdoor comfort of the district and, as a consequence, the users' comfort inside the buildings.
In particular, different scenarios of renovation through the integration of several vegetal species are analysed in order to verify the enhancement the outdoor and the indoor users' comfort.
The Medaglie d'Oro complex is located in a south-west peripheral area of the city that went through a progressive urbanization process starting from the '70s. The residential complex, designed in 1972 by B. Colajanni, is constituted by two rows of three seven-storey apartment blocks, facing each other, and a three-storey building situated between them, occupying a total area of around 29,500 m^2.

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[5] ENVI-met is a three-dimensional non-hydrostatic model for the simulation of surface-plant-air interactions not only for but especially inside urban environments. It is designed for microscale with a typical horizontal resolution from 0.5 to 10 m and a typical time frame of 24 to 48 hours with a time step of 10 sec at maximum. This resolution allows to analyse small-scale interactions between individual buildings, surfaces and plants.

[6] EnergyPlus is an energy analysis and thermal load simulation program based on a user's description of a building from the perspective of the building's physical make-up and associated mechanical and other systems


Figure 3 - Aerial photo of the Medaglie d’Oro complex

Despite its dimension and configuration, the complex is lacking of open spaces for residents’ leisure and social activities -conversely foreseen in the original layout-, due to the almost exclusive utilization of the area for the vehicular access and park. For this reason the site presents an extended use of asphalt (66.66%) and of concrete pavement (28.06%), while scarce spaces are assigned for vegetation (5.28%). The buildings are characterised by a reinforced concrete frame structure, visible from the outside, and external wall made by (from outside to inside) 13 cm pumice blocks separated from internal 8 cm perforate bricks by a 6 cm air cavity and finished with different thickness plaster layers on both sides.

The apartment blocks present considerable alterations of their original configuration as proved by the closure of many loggias and the addition of several air conditioning units hung to the buildings façades. These interventions demonstrate the inadequacy of the apartments to satisfy the contemporary users' needs related to the necessity of increased minimum living spaces and indoor comfort levels.

Figure 4 - Current state of buildings

The provided methodology has been applied according to the following steps:

- **Stage 1** - Analysis of the current state of the area both at micro-urban and building scale, including the analysis of local weather data.
- **Stage 2** - Meso-level simulation of an urban area of 470x740 m, enclosing the Medaglie d'Oro complex, in order to provide boundary conditions for the microclimate simulation within the residential area to be examined, in the absence of local measurements.
- **Stage 3** - Simulation of an area of 110x375 m corresponding to the Medaglie d'Oro complex, starting from the microclimate data acquired through the simulation at stage 2, in order to evaluate the effects of vegetation on the near-buildings meteorology. So, in addition to the current situation, four different "greening scenarios" were simulated, considering progressive addiction of vegetation with different LAI - Leaf Area Index values.

In particular the following retrofit scenarios were considered:

Scenario 1 - Additional vegetation: dense grass and 2m high hedges around the buildings;

Scenario 2 - Additional vegetation: dense grass, 2m high hedges around five buildings, few 10m high trees (medium dense crowns) in the central area and 15m high trees (medium dense crowns) around two buildings;

Scenario 3 - Additional vegetation: dense grass, 2m high hedges around five buildings, some 15m high trees in the central area (very dense crowns) and 15m high trees (medium dense crowns) around two buildings;

Scenario 4 - Additional vegetation: dense grass, 15m high trees (medium dense crowns) around all buildings and two compact stands of 15m high trees (very dense crowns) in the central areas.

- **Stage 4** - Simulation at the apartment scale in order to assess the indoor thermal comfort, starting from the microclimate data acquired through the simulation at stage 3, and proposal of some retrofit strategies at the building scale.

For each apartment (five in total) five different simulations were run (six for the top floor apartments) to assess to what extent the progressive use of vegetation -from the renovation of the outdoor environment to the application of living walls and green roof- combined with the substitution of the current windows and glazed doors, influences the indoor temperatures and tenants' comfort. Hence, the following scenarios were considered:

1. Current state;
2. Outside vegetation (as resulted from the previous stage);
3. Outside vegetation + Substitution of windows (low-e glazing);
4. Outside vegetation + Substitution of windows (silver low-e glazing);
5. Outside vegetation + Silver low-e glazing + Living walls;
6. Outside vegetation + Silver low-e glazing + Living walls + Green roof (only for the top floor apartment).

The urban simulations were performed with the software ENVI-met while the energy analysis and thermal load simulation at the apartment scale were run with the program EnergyPlus.

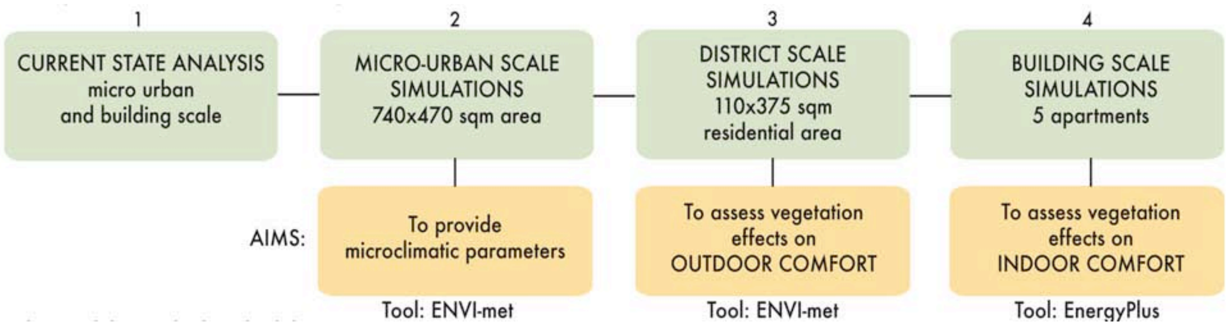

Figure 5 - Scheme of the used methodology

3. Results and conclusions

ENVI-met data generated in the first stage of simulations conducted on the social housing complex Medaglie d'Oro, in Palermo, demonstrate how effective the adoption of vegetation can be for the control of the outdoor comfort levels during the design and the renovation process of micro urban areas. In fact the results of the measurements gave important information about the microclimatic differences among the five scenarios analysed (current situation and four "greening scenarios") related to the social housing complex Medaglie d'Oro and prove that the cooling effect of the area is higher in correspondence of the internal common area of the complex where vegetation is denser. The values registered in this phase of simulation show that, during the hottest days of the year, reductions of temperature up to 3°C can be achieved in the external spaces, which implies the improvement of the outdoor thermal comfort and, consequently, better conditions to promote the community social life.

The environmental advantages of greening are not, however, restricted to improving urban microclimate and social relationships. In fact, starting from generated meteorology data of the first stage, the analyses held at the building and apartment scale with EnergyPlus demonstrate that the effect of shading, radiant interactions and evapotranspiration during hot days, have even a greater impact inside the apartments, with temperature decreasing up to 3.10°C. This implies higher level of indoor comfort and significant consequences on the energy consumptions needed for cooling as well as on the investments needed for the energy improvement of the buildings.

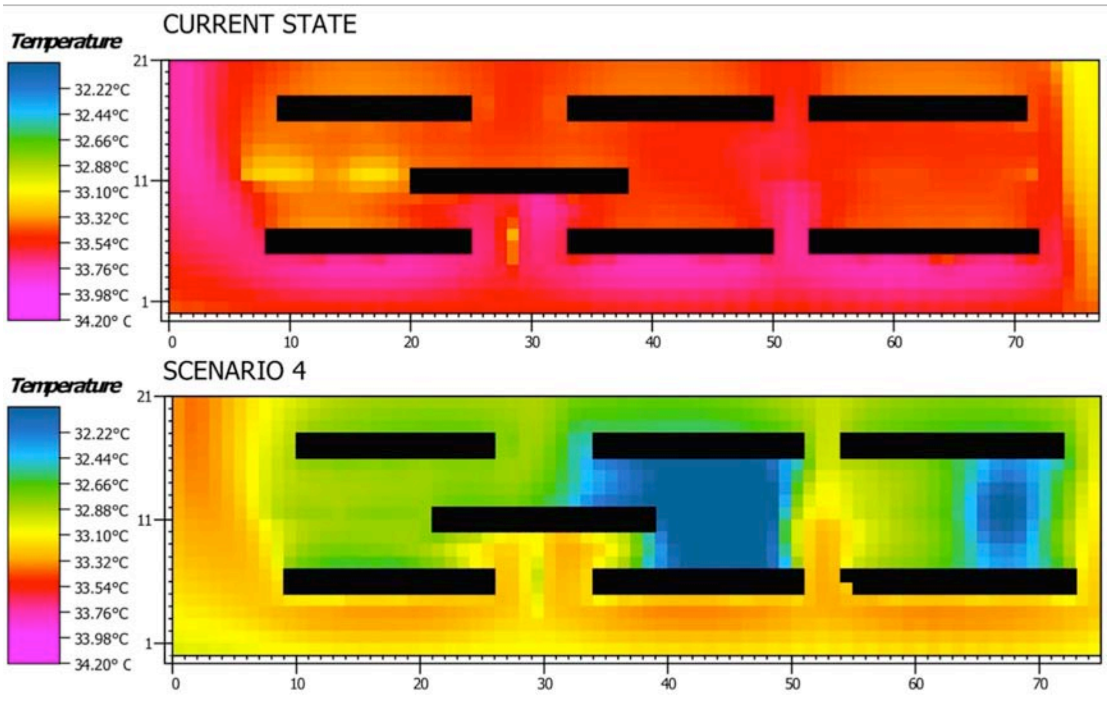

Figure 6 - Thermal map describing ENVI-met outputs

The last simulations, eventually, demonstrate that the use of building-integrated vegetation can provide further amelioration of the indoor comfort. In fact, through the integration of living walls and green roofs and the substitution of windows, a decrease of temperature up to 4.17°C was achieved.

Figure 7 - Thermal map referred to four apartments before (top) and after (bottom) retrofitting

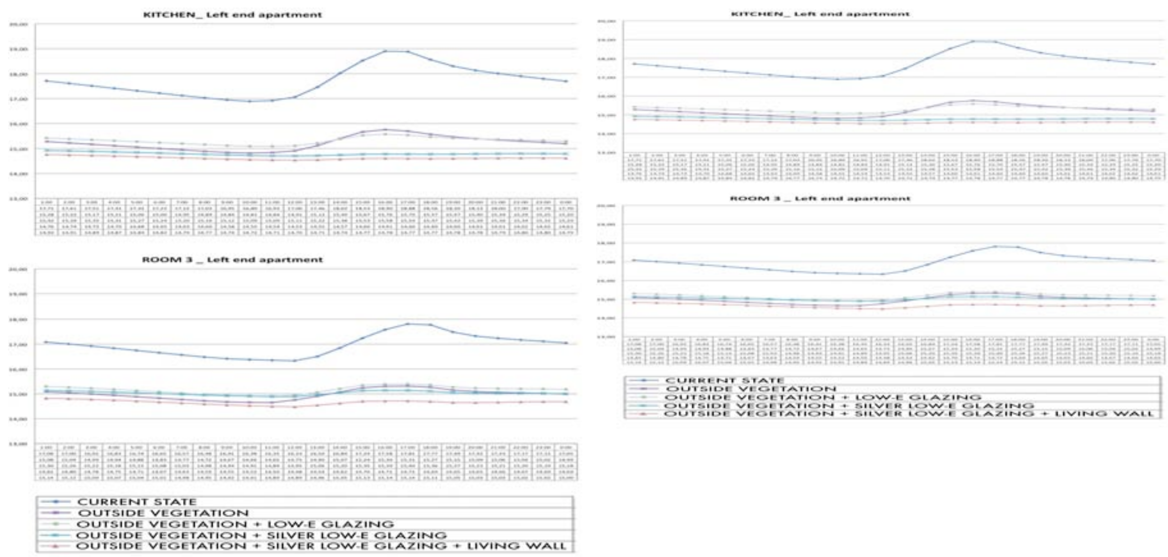

Figure 8 - Temperature trends before and after retrofittting

These results demonstrate the validity of the research starting assumption, according to which vegetation can be applied as a cost-effective solution for urban and building retrofit in order to improve the environmental conditions of communities situated in temperate areas.
According to the obtained results, this study can represent a starting point for the definition and validation of the proposed methodology as a tool for the assessment and design at the urban and building scale.
Management process of growth of urban areas and improvement of quality of life are indeed some of the key objectives of planners and administrations. In this regard, the methodology described and proposed in this work, may support local authorities and professionals into the research and the adoption of best retrofit practices for the improvement of the environmental quality outside and inside the buildings stocks, by providing assistance to the decision making process.
Although the scheme was assessed for the city of Palermo, it is expected that it will also contribute to knowledge applicable to other temperate regions and that it can assist in the definition of urban and building retrofit interventions and policies.
The hypotheses advanced not only take into account the environmental but also the economic aspects. The reduced investment capacity of the municipalities, the tendency of moving from "heavy" and centralized welfare policies to "light" local practices have recently led to the emergence of new actors and of new metropolitan governance, focused not only on institutional structures, but also in the presence of private agents, through sustainable partnerships. Public-private partnerships can therefore play a critical role in the application of such methodology, considering that it foresees the realization of punctual interventions whose costs could be divided by different stakeholders.

Figure 9 - Rendered image of the Medaglie d'Oro complex after retrofitting

Figure 10 - Rendered images of the Medaglie d'Oro complex after retrofitting

References

Akbari H., Davis S., Dorsano S., Huang J., Winnett S. (eds.) (1992), *Cooling our communities: a guidebook on tree planting and light-colored surfacing*, Wash. D.C., U.S. EPA.

Akbari H., Kurn D., Bretz S., Hanford J. (1997), Peak power and cooling energy savings of shade trees, *Energy and Buildings*, 25: 139-148.

Ascione P., Bellomo M. (2012), *Retrofit per la residenza. Tecnologie per la riqualificazione del patrimonio edilizio in Campania*, Napoli, CLEAN.

Banham R. (1984), Architecture of the Well-Tempered Environment, University of Chicago Press.

Bit E. (2005), *Il Nuovo Verde Verticale. Tecnologie progetti linee guida*, Wolters Kluwer Italia.

BPIE - Buildings Performance Institute Europe, *Principles for nearly zero-energy buildings. Paving the way for effective implementation of policy requirements*, 2011, http://www.bpie.eu (accessed December 2013).

BPIE- Buildings Performance Institute Europe (2011), *Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings*, http://www.bpie.eu (accessed December 2013).

Brown G. Z., DeKay M. (2013), *Sun, Wind, and Light: Architectural Design Strategies*, Wiley.

De Ridder K. (2004), *Benefits of Urban Green Space (BUGS)*. Research Summary.

de Dear R., Brager G. S. (1988), Developing an adaptive model of thermal comfort and preference, *ASHRAE Transaction*, 104(1a).

Donzelot J. (2006), *Quand la ville se défait, Quelle politique pour la crise de banlieues*, Paris, Editions du Seuil.

EESC - European Economic and Social Committee (2012), *Issues with defining social housing as a service of general economic interest*.

EPA - United States Environmental Protection Agency (2008), *Reducing Urban Heat Islands: Compendium of Strategies*, http://www.epa.gov (accessed December 2013).

Fahmy M., Sharples S., Eltrapolsi A. (2009), Dual Stage Simulations to study the microclimatic effects of trees on thermal comfort in a residential building, Cairo, Egypt, *Proceedings of the Eleventh International IBPSA Conference*, Glasgow, Scotland July 27-30.

Fedeli V. (2010), Città, laboratori di coesione sociale? Welfare locale e questione urbana, *Il Progetto Sostenibile*, 25: 12-17.

Feller M. M. (2011), *Quantifying evapotranspiration in green infrastructure: a green case study, Master Thesis*, Villanova University.

Fieldson R. (2004), Architecture & Environmentalism: Movements & Theory in Practice, *FORUM E-journal*, Vol. 6, Issue 1, http://research.ncl.ac.uk/forum/v6i1/fieldson.pdf (accessed December 2013).

Giordano L. (2007), *Mediterranean Vegetation Monitoring by Remotely Sensed Data: LAI retrieval and vegetation trend analysis within two forested areas in southern Italy*, PhD Thesis, Universita' degli Studi di Cagliari.

Green K. W. (1979), Passive Cooling: Designing Natural Solutions for Summer Cooling Loads, *Research and Design: The Quarterly of the AlA Research Corporation*, Vol. 11, N. 3.

Grosso M. (2011), *Il raffrescamento passivo degli edifici in zone a clima temperato*, Rimini, Maggioli Editore.

GRHC - Green Roofs for Healthy Cities North America (2008), *Introduction to Green Walls Technology, Benefits & Design*, September 2008.

Gupta A., Hall M. R., Hopfe C. J., Rezgui Y. (2011), Building Inegrated Vegetation as an energy conservation measure applied to non-domestic building typologu in the UK, *Proceedings of Building Simulation 2011: 12th Conference of International Building Performance Simulation Association*, Sydney, 14-16 November.

Hawkes D. (1980), Building Shape and Energy Use, in Hawkes, D. and Owers, J. (eds), *The Architecture of Energy*, London, Longmans, 1980.

Hawkes D., J. McDonald, et al. (2002), *The Selective Environment*, Spon Press.

Hawkes D., Willey H. (1977), User response in the environmental control system, *Transactions of the Martin Centre for Architectural and Urban Studies*, 2.

Heisler G.M. (1986), Energy savings with trees, *Journal of Arboriculture*, 12: 113-124.

Heisler G.M. (1986), Effects of individual trees on the solar radiation climate of small buildings, *Urban Ecology*, 9: 337-359.

Heisler G.M. (1989), Effects of trees on wind and solar radiation in residential neighborhoods, *Final report on site design and microclimate research*, ANL N. 058719, Argonne National Laboratory, Argonne, IL.

Huang J., Akbari H., Taha H. (1990), *The wind-shielding and shading effects of trees on residential heating and cooling requirements*. ASHRAE Winter Meeting. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.

Kurn D., Bretz S., Huang B, Akbari H. (1994), *The Potential for Reducing Urban Air Temperatures and Energy Consumption through Vegetative Cooling, ACEEE Summer Study on Energy Efficiency in Buildings*, American Council for an Energy Efficient Economy. Pacific Grove, CA.

Lien J., Ahmed N.A. (2011), Wind Driven Ventilation for Enhanced Indoor Air Quality, in Mazzeo, N. A.(ed.), *Chemistry, Emission Control, Radioactive Pollution and Indoor Air Quality*, InTech.

Losasso M. (2012), Presentazioni, in Russo Ermolli S., D'Ambrosio V., *The Building Retrofit Challenge. Programmazione e gestione in Europa*, Firenze, Alinea Editrice.

Margani G. (2010), L'edificio passivo nel clima mediterraneo, *Costruire in laterizio*, 141: 46-49.

Olgyay V., Olgyay A. (1963), *Design With Climate: Bioclimatic Approach to Architectural Regionalism*, Princeton University Press.

Oke T. R. (1982), The energetic basis of the urban heat island, *Quarterly Journal of the Royal Meteorological Society*, 108.

Oke T. R. (1988), The urban energy balance, *Progress in Physical Geography*, 12: 471-508.

Oosterlee J.A. (2013), *Green walls and building energy consumption: building energy simulation*, Eindhoven University of Technology.

Perlo Cohen M. (2011), *Cities in Times of Crisis: The Response of Local. Governments in Light of the Global Economic Crisis: the role of the formation of human capital, urban innovation and strategic planning*, Working paper, Institute of Urban and Regional Development, University of California-Berkeley.

Petralli M., Prokopp A., Marobito M., Bartolini G., Torrigiani T., Orlandini S. (2006), Ruolo delle aree verdi nella mitigazione dell'isola di calore urbana: uno studio nella città di Firenze, *Rivista Italiana di Agrometeorologia*.

Rabaiotti G. (2010), L'edilizia sociale: un servizio come e per chi, *Il Progetto Sostenibile*, 25: 18-23.

Ranade A. (2013), *Building Integrated Vegetation. Mitigating Urban Environmental Challenges with Building Material Technologies*, http://cityminded.org (accessed September 2013).

RUROS - Rediscovering the Urban Realm and Open Spaces (2006), *Designing Open Spaces in the Urban Environment: A Bioclimatic Approach*, CRES (Centre of Renewable Energy Sources), edited by Nikolopoulou M., Atene.

Voogt J. A. (2004), Urban Heat Islands: Hotter Cities, *Actionbioscience*, November 2004, http://www.actionbioscience.org (accessed December 2013)

Yoshino M. (1975), *Climate in a Small Area: An Introduction to Local Meteorology*, University of Tokyo Press.