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NATURE-BASED SOLUTIONS AND BIOPHILIC DESIGN
Eco-systemic approaches to regeneration

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ABSTRACT
From the perspective of ecological transition, environmental design has assumed a central role in political strategies and design thinking on urban regeneration and energy and technological upgrading. The improvement of the environmental performance of cities and buildings tends toward two major results: higher quality of life and places according to socio-economic and aesthetic-cultural criteria; a balanced relationship between the built environment and the natural environment, with the related energy and ecosystem benefits. The contribution reflects the trans-scalar character of environmental regeneration and redevelopment processes in the broad spectrum of solutions suggested by the biophilic approach. Nature-based solutions are discussed as a means to pursue the improvement of the physical, social and environmental quality of the urban and built environment.

KEYWORDS
nature-based solutions, biophilic design, eco-system services, urban and technological regeneration, quality of life

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The worsening environmental and climate crises have radically changed attitudes on the sustainable regeneration of cities, oriented towards a trans-scalar, holistic and metabolic approach to redefining the balance between the natural and anthropic spheres. The widespread concept of 'urban landscape' denotes the need to identify the ecosystem of elements (artificial and natural) that populate it, and the dynamics of co-existence, production and transformation. Humankind and their environment are experiencing the point of greatest tension due to the intensive exploitation of the planet's resources and the need to adapt to increasingly adverse conditions. Cities represent the outcome, synthesising contradictions at all scales: local and global, physical and social, anthropic and natural, and becoming the terrain of complex challenges, well portrayed by the Sustainable Development Goals and strategies for ecological transition (UN, 2015; European Commission, 2019, 2020) of which the health, energy and geopolitical crisis have accelerated the pace.

These dramatic circumstances have rekindled the theme of economic, social and environmental well-being by associating it with two existential paradigms often left out of the narrative: the quality of public space, both urban and residential, and the relationship with nature. From a post-pandemic perspective – as well as in that of the 2030 Agenda (UN, 2015) – it will be crucial to make cities and human settlements more inclusive and sustainable, including in terms of social and climate justice, by reducing emissions, increasing the absorption capacity of pollutants in the urban environment and supporting ecosystem services through the introduction of Nature-based Solutions – NbS (Cataldi et alii, 2010).

The energy crisis has increased the race to improve the energy efficiency of buildings, which had already begun in recent years in Italy as well, thanks to the introduction of tax incentives known as Bonus and Super Bonus. These measures, adopted mainly on the building envelope and air conditioning systems, reduce dependence on gas consumption and non-renewable sources for heating and cooling buildings through better thermal insulation. This can be achieved through a holistic approach using biophilic design and NbS. The ongoing ecological transition process involves a broad spectrum of sustainable, political, social and design behaviours, which brings out an ecosystem perspective on air quality, and climate change mitigation, in which health and urban ecology are closely connected. These concerns, in line with the most recent urban sustainability strategies and practices – from the 2030 Agenda (UN, 2015) to the New European Green Deal for 2050 (European Commission, 2019) – are reflected in actions and design approaches aimed at improving the well-being and quality of life of communities also through nature-based solutions and technologies.

Goals and methodology | The contribution is part of a broader post-doctoral research project on Sustainable Building financed by the Region of Calabria (FESR FSE Funds 2014-2020) for the development of an innovative and sustainable system aimed at assessing the environmental quality and containment of energy consumption in residen-

tial buildings. The methodological premise is to identify interpretative models, regeneration strategies and sustainable recovery technologies for trans-scalar interventions in residential neighbourhoods, through interventions in public space – including mobility – and buildings. The contribution discusses possible design approaches and technological solutions capable of supporting local environmental and cultural ecosystem services and the environmental quality of cities in general. The first part will discuss the new design needs that emerged in the current socio-economic and cultural conditions. The second part will examine design approaches to ecosystem regeneration according to NbS, their typologies and applications for improving urban and territorial resilience (Mussinelli et alii, 2018). The third part investigates the technological applications of such solutions – green technologies and biophilic approach – in urban regeneration and building rehabilitation. The interventions are classified according to a taxonomy constructed from the action generated – addition, subtraction, replacement, thickening, integration – and the possible applications (Fig. 1).

A taxonomic matrix (Fig. 2) is built according to references and case studies to understand the design expressions given by the combination of technological choices and performance requirements on an aesthetic and formal level. Reference is made to Sergio Los's (2013) reflection on the 'epistemological turn' of sustainable architecture and the 'implications of sustainable design in architectural theory'. An attempt is therefore made to select cases in which 'instrumental acting' and 'communicative acting' of the project activities in synergy accompany the cultural evolution of man in the conscious process of transformation and adaptation of the environment through technology. In the current era, which Los would have described as an inter-somatic, ante litteram vision of the Anthropocene, the environment has been overwhelmed by the transformations of man and technology. On the contrary, we are witnessing a renewed awareness, both social and design-oriented, oriented towards the naturalisation of the existing through hybrid, heterogeneous, fluid city forms, mixed and multi-programmatic, multi-dimensional, multi-functional urban landscapes (Gausa, 2022).

The contribution discusses some of the possible strategies of urban regeneration and sustainable recovery, practices and solutions, oriented to improve environmental comfort, and suggests energy alternatives and new symbolic and cultural relations (Los, 2013) through projects and meta-projects of a techno-performative nature (Gausa, 2022). The field of sustainable design considers the city as an urban ecosystem, characterised by infrastructures and high population density, and including green and blue environmental infrastructures of pristine nature – forests, oases and protected parks – and man-made nature – cultivated areas, parks, gardens, courtyards, green roofs, trees (FIU et alii, 2020). Hybrid forms are not excluded, where natural elements meet urban and peri-urban areas in wetlands, rivers, canals, streams, lakes, ponds, and urban forests. In this sense, the contribution reflects the project's ability to support Ecosystem Services in terms of climate and atmospheric regulation, resource regulation and supply, biodiversity, and recreational services aimed at the leisure and aes-

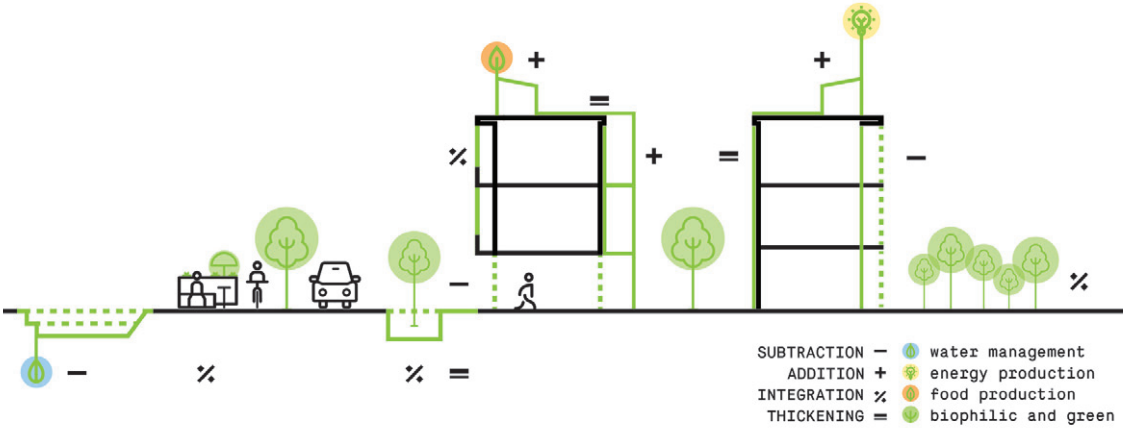


Fig. 1 | Diagram of design actions (credit: L. Errante, 2022).

Fig. 2 | Taxonomic matrix of reference case studies (credit: L. Errante, 2022).

thetic value of places (MEA, 2005). Regulatory Services and Cultural Ecosystem Services represent the most important categories for the sustainability of an urban ecosystem in terms of environmental and social quality (FIU et alii, 2020).

With this in mind, the contribution discusses approaches to urban regeneration and rehabilitation of the existing that can support and enhance the benefits provided by ES in terms of sustainability, healthiness and liveability of the urban and built environment.

Biophilic design and nature-based solutions | The issue of environmental quality and sustainable transformation in contemporary cities defines the project – urban, architectural, technological – in terms of complexity, transversality, adaptability, multiscalarity, multi-functionality, and hybridisation. Some authors suggest an image of an open, flexible, alternative urban environment, capable of adapting to its inhabitants (Sennet and Sendra, 2022) and to the natural ecosystem in which it is into, recognising the degree of disorder and unpredictability of the transformative processes that characterise both society and the urban landscape. The sustainable project is based on the relationship between the natural, urban and built spheres, and it is interesting to observe the renewed centrality of the envelope, the surface, the cover layer, the land use, and

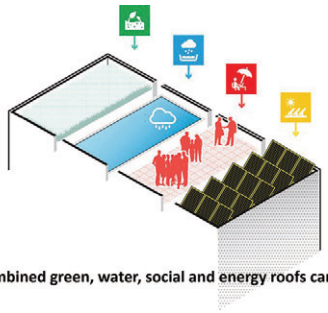
the skin as an interface between the natural and the artificial, with an estimable value from an ecological and economic point of view (Cataldi et alii, 2010).

Sustainable design should participate in urban naturalising but it is also important to manage the skills and the knowledge required for green design, to design cross-cutting and complex solutions at the appropriate scale (Kabisch et alii, 2016). Reflecting on sustainable urban regeneration and building redevelopment processes, the contribution focuses on viable solutions to the design of public space and the building envelope, examining approaches that respond to different socio-cultural and technical-performance requirements.

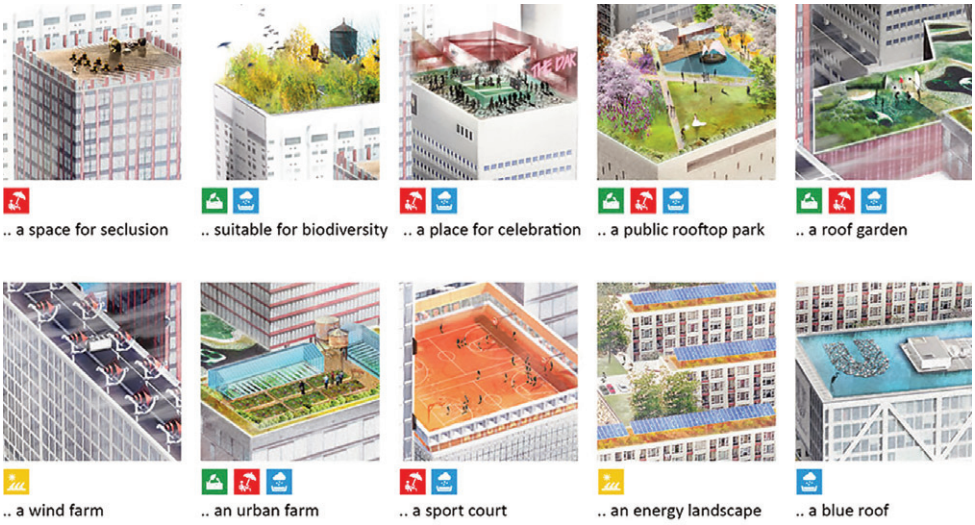
The evolution of the know-how on environmental design, bioclimatic and regionalist architecture (Los, 2013) shifts from the house-local climate paradigm to the built-natural environment paradigm, with similar assumptions. The key element is the rationalisation and maximisation of resources to mediate between the performance requirements that guarantee comfort and wellbeing for individuals and the conditions posed by the context, both from a climatic and morphological point of view, formulating appropriate design solutions and technical-constructive expedients. Today, due to the worsening climatic emergency, these technological solutions related to the natural elements are not just appropriate, but complementary and compatible, through positive and functional use of natural resources for a better environmental performance of the built environment and rebalancing the relationship between city, society and nature.

The integration of Nature-based Solutions (NbS) into technology and process choices is pursued with these assumptions oriented towards trans-scalarity, adaptability and biophilic design. The aim is to reintroduce nature into human experience, through aesthetic, material and graphic (Figg. 3-5), organic or artificial characteristics, recognising its benefits also in terms of the physical and mental health of individuals

Figg. 3-5 | Passeig de Sant Joan, project by Lola Domenech (credits: A. Goula, 2012).



Figg. 6, 7 | Rotterdam Rooftop Strategy (credits: De Urbanisten.nl, 2021).



(McDonald and Beatly, 2021). According to the European Commission (2021), NbS embody a socio-ecological innovation, already foreshadowed by Horizon 2020, considered effective in terms of economy, resilience and biodiversity through systemic, locally adapted and resource-efficient interventions and ecosystem services.

Eggermont et alii (2015) propose three types of NbS, differentiated by level of intervention. The first, is oriented to Nature Climate Solutions and includes the protection and conservation of endangered ecosystems to preserve biodiversity. The second involves the definition of functional management models aimed at the agricultural landscape. The third, more intrusive, implies new artificial ecosystems using green technologies at the urban scale. This classification defines the aim of the contribution to discuss the limitations associated with climate warming mitigation strategies in the urban and built environment through the use of NbS. For the naturalisation of the urban and built environment, reference is made to transformation actions of the public space and the building envelope that are useful to favour evapotranspiration, shading,

reduction of the heat island effect and urban flooding. Technological solutions acting through addition, subtraction, integration and thickening of horizontal and vertical surfaces are analysed.

Design and technological opportunities | NbS provide a concrete response aimed at increasing the resilience of the built environment by supporting urban and cultural ecosystem services (Morabito, 2021), an opportunity for technological advancement and social innovation oriented towards the achievement of transversal and multi-scalar solutions (European Commission, 2021). The debate on the deployment of NbS focuses on their actual technological maturity and integration with traditional technologies, as opposed to their total replacement (Osaka, Bellamy and Castree, 2021). Research has examined NbS as suited for the built environment (Fig. 2) and its greater ecological convenience for the regeneration of existing neighbourhoods and buildings instead of the new construction of 'green cities' (Scalisi and Ness, 2022).

The green roof is among the best known NbS, capable of performing multiple actions for the building and its occupants, including thermal insulation and potentially increasing biodiversity and food self-production, with benefits in terms of energy savings, improved microclimate and reduced heat island effect. At the core of the Rotter-

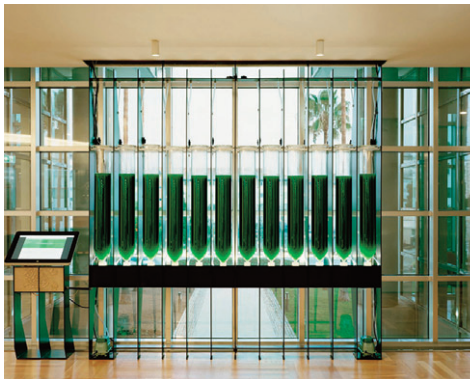


Fig. 8 | Bio Intelligent Quotient (BIQ) House, Hamburg, opened in April 2013 (credit: Colt International, Arup Deutschland, SSC GmbH).

Fig. 9 | Application of PhotoSynthetica technology, developed by ecoLogicStudio for air filtration through the use of spirulina algae on the facade of the Nestle factory in Lisbon (credit: ecoLogicStudio).

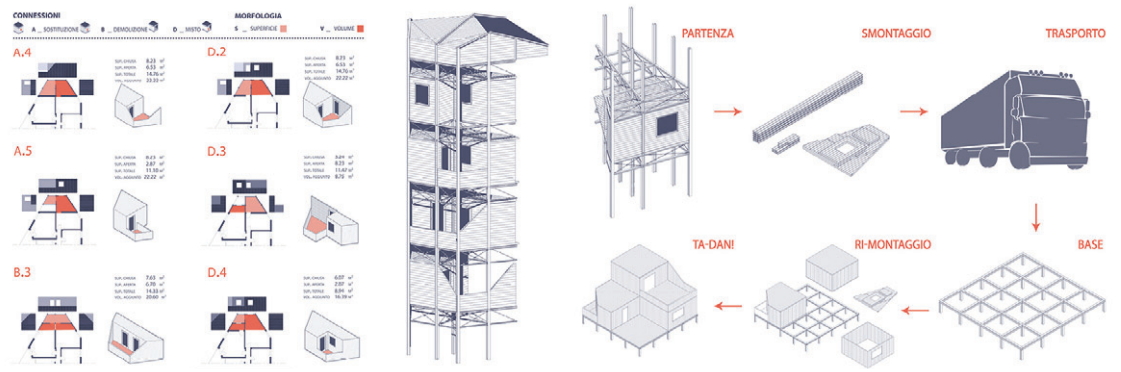


Fig. 10 | Functional additions in bio X-Lam on the façade of an existing residential building (credit: A. Quattrone, 2020).

Fig. 11 | Thailand, Thammasat University Rice Terrace Rooftop (credit: Citypopup.net, Landprocess).

dam Roofscape – Programme for Multifunctional Roofs strategy is the encouragement of various sustainable rooftop functions (Figg. 6, 7): green areas, water drainage and energy production systems, social and mobility, new housing and building management facilities. The integrated approach involves the combination of several functions placed according to the needs of the area and a monitoring programme of the intervention in terms of adaptation and mitigation (Gemeente Rotterdam, 2019). The programme is an emblematic case of the political ability to converge climate, social and design objectives through the collaboration between public authorities, in this case, the Munici-

Fig. 12 | Watersquare in Rotterdam by De Urbanisten (credit: De Urbanisten).

Fig. 13 | Watersquare in Rotterdam by De Urbanisten (credit: L. Errante, 2018).

pality of Rotterdam, and architectural signatures such as MVRDV and De Urbanisten, in charge of the design of access and plan of the Roof Landscape, respectively.

The green roof is a widely assimilated NbS from a technological and conceptual point of view and, for this reason, is also more easily implemented in terms of cost-benefit. Even with similar performance and micro-climate requirements, a study by the Politecnico di Milano reveals a substantial difference in construction and maintenance costs, which is higher for the installation of green walls (Morello, Mahmoud and Colaninno, 2020). On the other hand, there are numerous green roof alternatives for the direct and indirect thickening of the vertical surface of buildings, using light containment structures or cladding elements that provide for the housing of soil for

Figg. 14, 15 | Watersquare in Rotterdam by De Urbanisten (credits: L. Errante, 2018).

cultivation. The NEST (Natural Eco-System Tiles) system, one of the winners of the New European Bauhaus Prize 2021, is a technological solution aimed at improving the building's environmental conditions and thermal and acoustic insulation performance through an element made of local clay and designed for vegetation and nesting (Scalisi and Ness, 2022). The application of NbS to the building envelope is not limited to the vertical forestation paradigm, although it does support urban biodiversity. Innovation in this regard is the use of algae for CO_2 absorption (Scalisi and Ness, 2022) and the production of biofuel and organic fertiliser. This assumption supports the eco-LogicStudio's design research, experimentation, and realisation of the bioreacting façade, a shading system with algae in saline suspension that absorbs CO_2 and pro-

duces biogas with an annual increase of 4,500 kWh per year added to the 32MW of solar thermal energy available for the building (Fig. 8). Similarly, the design of a greenhouse as an air treatment systems with appropriate plant species or algae, to ensure the thermoregulation and filtration of air. This nature-based technology is scalable from the building to the environmental unit (Fig. 9). These NbS, integrated into buffer zones between the building and the environment, maximise its environmental and thermal insulation performance, collaborating in the eco-compatibility of building technology choices. Experimentation in this sense has been conducted for the design of functional additions through dry-built structures in bio X-Lam, according to the circular principles of design for disassembly, as part of the meta-design research for the sustainable recovery of the 'INA CASA Sbarre Inferiori' district in Reggio Calabria (Errante and De Capua, 2021; Fig. 10).

Alongside punctual solutions, urban NbS at the scale of public space is equally capable of enhancing ecosystem services and urban green infrastructure, with benefits on a social and recreational level, as well as climatic and environmental. From boulevards to the banks of watercourses running through the urban fabric, green and blue corridors can be imagined that can dispose of and slow urban flooding and, through vegetation and organic material, filter pollutants in water and air (Morello, Mahmoud and Colaninno, 2020). Can be noted that there is a benefit in shading, reducing the heat island effect and capturing particulate matter at the deposition level for the use of urban forestation, including linear trees, or permeable and semi-permeable pavements with plant inserts, which do not necessarily have a positive impact on ecosystem services.

This is due to two critical issues. On the one hand, the interaction between the planted species and the infrastructures below the road level is an obstacle that can be overcome through technological green and driveway solutions or with the aid of more complex solutions, in terms of functional stratification, such as the Cupolex Radici system. On the other hand, the selection of plant species must be oriented to guarantee both respect and an increase in biodiversity, as well as possible inconveniences for the health of individuals such as allergies and respiratory disorders. Another aspect that is not secondary is related to the shading projected by tree foliage onto buildings. For example, it will be appropriate to plant deciduous trees to the south, so that the sun's rays permeate during the winter and screen them in the summer months.

Such considerations can guide the correct design of parks and gardens to produce benefits at different scales, from the city to the indoors, also favouring activities of self-production and self-sufficiency in energy and food (Fig. 11), cohesion, a sense of belonging and regeneration of social commons. Examples include productive gardens planted with fruit trees or 'bee gardens' with flower varieties that promote pollination as a fundamental ecosystem services. Within the public space, street furniture can also be conceived, designed and selected as NbS. Shade zones, pergolas and green roofs, urban seating providing housing for vegetation, and the provision of cool urban oases with controlled ventilation and temperature.

An interesting configuration of public space is the water square, a water square built at lower heights than the street, generally accessible by stairs and steps, capable of containing large volumes of rainwater and regulating its runoff in a controlled manner. The case of Bonthemplein in Rotterdam (Figg. 12-15) is an international reference in this sense, with impacts on the environmental quality of urban space and liveability. The urban resilience strategy is enriched in formal and aesthetic values by treating surfaces and articulating diversified spaces for sports and recreational activities. The system of squares, arranged to respond to the principle of communicating vessels, is also the result of a participatory process mediated by the designers themselves (Errante, 2020).

Conclusions, limits and future developments | Today, the ecosystem approach to urban regeneration and building rehabilitation appears fundamental to providing alternative, credible and sustainable responses to energy efficiency, health and safety in the built environment. The NbS presented here does not represent an exhaustive picture of the panorama of environmental design, but the efforts made by policy, design and technology toward the integration of nature as a building material, mitigation and production tool and biochemical processes capable of constituting energy alternatives. The evolution of technology also accompanies designì towards a progressive but partial mixing of languages and communication codes related to sustainable architecture. Green technologies, the expression of performance and functional requirements are now understood, promoted and defended by politics and society.

In the face of numerous design and technological opportunities capable of rethinking the transformation of the urban and built environment as and through NbS, several authors (Scalisi and Ness, 2022; Osaka, Bellamy and Castree, 2021) still highlight some criticalities, especially in terms of process rather than design. On the one hand, the difficulty of modifying the erosive dynamics of urban expansion, which NbS alone cannot be able to compensate for. On the other hand, NbS may be economically costly compared to other technological solutions considered more ‘mature’, less unpredictable and more easily monitored in the short and long term. In the absence of proper cost-benefit assessments or quantifiable data, the adoption of NbS could potentially prove detrimental to the ecosystem balance and the health of individuals. In this sense, in addition to academic research efforts to formulate possible indicators of the effectiveness of NbS in combating climate change (Kabisch et alii, 2016; Sowińska-Świerkosz and García, 2021), the European Commission (2021) provides practical and theoretical support and evaluation tools for different dimensions of intervention (strategic, spatial planning, soft engineering, technological performance).

These efforts, supporting the formulation of nature-based policies, plans and projects, do not overcome the skills gap found on the theoretical and practical level, which slows down the concrete implementation of NbS and the related socio-economic and technical-performance impact study in the long run (European Commission, 2021). The dissemination of models for assessing and monitoring the impact of pro-

jects adopting NbS may also highlight the benefits of hybrid, natural and man-made, digital and cyber solutions with high environmental performance, with particular reference to clean and accessible energy production technologies. The sustainable exploitation of natural resources provided by the context through biophilic design and the use of NbS contribute to an ideal of a green, clean, healthy, productive, self-sufficient and resilient city, an ambitious goal that moves in the increasingly dramatic perspective of combating the environmental crisis and promoting climate justice.

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