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Benthemplein watersquare by De Urbanisten. Picture by the author.

PRACTICES

Environmental challenges and responsive public spaces: mitigation technologies against climate change and extreme climate events

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ABSTRACT

The concept of urbanity refers to urban life and the behaviors, values, and features — social, cultural, and aesthetic — acknowledged by the communities that live in the city and that today also have to confront the climate crisis. The contribution explores the impact of extreme weather phenomena — heat waves, heat island effect, water bombs — on the city and public spaces, analyzing adaptation strategies including Nature-Based Solutions (NBS). Such strategies are discussed according to their role in enhancing Ecosystem Services, improving the quality of the environment and the well-being of citizens. Such technologies, integrated into broader strategies and urban-scaled interventions, are central to strengthening cities' resilience, positively influencing perceptions of safety and environmental comfort contribute to a more sustainable and inclusive urban ecosystem.

KEYWORDS
Public Space; Environmental Crisis; Urban Resilience; Extreme Climatic Events; Nature-based Solutions.

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The worsening environmental and climate crisis and the chase to achieve sustainability goals have radically changed attitudes toward urban regeneration, oriented toward a trans-scalar, holistic, and metabolic approach to redefining the balance between the natural and anthropogenic spheres. This unprecedented perspective has also highlighted the fragility of urban systems and their ability to ensure — through spaces, services, and functions — a certain degree of well-being for the communities. The phenomena affecting the city today have a multidimensional scale characterized by a high degree of interrelation between the social, environmental, and economic spheres.

FIG. 1 Bosco Verticale, Via Gaetano de Castillia, Milan, Metropolitan City of Milan, Italy. Picture by Zach Rowlandson on Unsplash.

The very concept of urban landscape emphasizes the need to identify the ecosystem of elements (artificial and natural) that inhabit it and their dynamics of coexistence, formation, reproduction, and transformation. Today, humans and the environment are experiencing strong tensions due to the intensive exploitation of the planet's resources and the need to adapt to extreme and adverse climatic conditions and weather events. The latter are increasingly frequent and intense, leading to dramatic impacts and damages on infrastructure, cities, and populations. The contribution reflects, indeed, on the ability of design, new technologies, and urban transformation strategies to provide adequate tools for mitigation, safety, and security.

Based on these premises, the paper discusses how the negative impacts of the climate crisis and environmental challenges have repercussions

FIG. 2 Picture by Matt Palmer on Unsplash.

on the built environment, the infrastructures, the natural environment, the quality of urban life, and the perceived well-being of communities.

In particular, the paper examines the effects of three extreme climate events - Heat Island Effect, Heat Wave, and Water Bomb - which are among the most frequent and impactful. These also appear to be triggered by similar micro-climate conditions. Holistic, cross-cutting, and trans-scalar environmental mitigation strategies are then discussed, with their outcomes in communities' perceptions of their urban landscape. Thus, reference is also made to the ability of said strategies to produce a benefit in strengthening Ecosystem Services (Provision, Regulation, Support, and Cultural).

According to Sergio Los[1] Sustainable architecture and strategies have led to an 'epistemological turn' where 'instrumental acting' and 'communicative acting' synergy accompanies the cultural evolution of man in the conscious process of transformation and adaptation of the environment through technique. In the present times, which Los would have called inter-somatic — or Anthropocene — the environment has been overwhelmed by man-made transformations and technology.

The objective of the paper is to identify, among the many strategies for urban regeneration and sustainable recovery, practices and solutions that ensure adequate environmental comfort[2], appropriate energy alternatives[3], and symbolic relationships[4].

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1 Sergio Los, *Geografia dell'architettura. Progettazione bioclimatica e disegno architettonico* (Padova: Il Poligrafo, 2013).

2 Alessandro Rogora e Valentina Dessì (cur.), *Il comfort ambientale negli spazi aperti* (Monfalcone: Edicom, 2005).

3 Yona Friedman, *Alternatives énergétiques, plaidoyer pour une autosuffisance locale* (Paris: Dangles, 2011).

4 Los, *Geografia dell'architettura.*

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2. Human-nature balance in a broader perspective

Cities, their spaces, infrastructures, and human and non-human actors are the most complex products of society, the sum, the coexistence, and the interpenetration of multiple spheres in perilous balance. The social sphere and the goal of well-being are the reasons for technological and scientific progress. On the other hand, these are among the causes of the unsustainability of our lifestyles, social injustice, and inequality. Added to this complex discourse, the extreme climatic events and the negative impacts of the environmental crisis are changing how we experience cities. This happens in diverse contexts and ways, with different degrees of awareness of the population. For example, it can be observed how rising temperatures prevent people from experiencing open public spaces, preferring confined, air-conditioned places, or the inconveniences that many cities incur during brief but heavy rainfall. Today, the communities recognize that global environmental challenges have severe repercussions on our behavioral patterns and vice-versa. Our unsustainable consumption patterns, ranging from fossil-fuel energy to waste management and pollution, can worsen the side effects of the environmental crisis, first locally and then globally. Such awareness modifies the use and perception of our living spaces: dwellings, neighborhoods, public and private spaces[5].

The discussion of sustainability — physical, social, and environmental — finds a wide field of experimentation in the city, which always has different cultural and socioeconomic conditions that help determine the success or failure of urban transformation and regeneration strategies. The outcome of these strategies cannot be evaluated only in terms of the performance requirements and performance of technological solutions but also to bring a benefit to the entire urban ecosystem.

5 Alberto De Capua, and Lidia Errante, "INA-Casa a Reggio Calabria. Innovazioni socio-tecniche per il quartiere di Sbarre," in *Storie di quartieri pubblici. Progetti e sperimentazioni per valorizzare l'abitare*, a cura di Anna Delera ed Elisabetta Ginelli (Milano-Udine: Mimesis, 2022), 202–211.

FIG. 3 Rotterdam cityscape. Picture by the author.

According to the Fondazione Innovazione Urbana[6], urban ecosystems can be defined as those areas where the presence of grey, green, and blue infrastructures or with a high population density, also encompassing

6 Fondazione Innovazione Urbana, "Glossary: Nature-Based Solutions. Urban Agenda For The EU," (2021). https://www.fondazioneinnovazioneurbana.it/images/NBS/Urban_Agenda_for_the_EU_-__ENGLISH-4_1.pdf

urban and peri-urban areas, including parks, cemeteries, gardens, backyards, building lots, urban forests, individual tree specimens, green roofs, wetlands, rivers, canals, streams, lakes, and ponds. Those ecosystems provide benefits and services related to and directly benefiting urban areas.

The previous definition describes the urban and built environment as the presence of the many infrastructures humans use to enjoy that environment and, by extension, the flows of people, goods, and services that pass through them. Observing the city from an ecosystem perspective makes it possible to identify more or less extensive portions that are functionally independent as they are complex and diverse. It refers to the infrastructure of public space: it physically holds together the system of private and public, collective and individual mobility, and defines spaces for sociality, recreation, and commerce. Also, it regulates flows and behaviors in space through precise configurations that contribute, to different extents, to the quality of life of communities and the urban environment[7]. The urban environment can be considered a unicum composed of different sets of objects and subjects in dynamic balance whose relationships generate a performance requirement that sustainability strategies must consider.

A sustainable regeneration strategy has to secure, create, or reinforce the ecosystem services provided by such an urban environment, defined by the Millennium Ecosystem Assessment[8] as 'the multiple benefits from ecosystems to humankind' as life-support, provisioning, regulating, and cultural services. On the one hand, the first three refer specifically to environmental quality conditions of the ecosystem, natural or urban, referring to nutrient cycles, water accessibility, or biodiversity reproduction. On the other hand, Cultural Ecosystem Services (CES) represent those recreational opportunities and experiences enjoyable by natural elements. CESs represent, along with Regulatory Services, the most important categories for the sustainability of an urban ecosystem, as they provide benefitts in terms of environmental — microclimate and pollution reduction, water cycle, pollination — and social quality[9].

From this perspective, ESs ensure the conditions for the urban environment's sustainability and livability, with fallout on social, environmental, and economic dimensions. Urban regeneration processes, while opposing urban decay and land consumption, have not always been able to trigger sustainable development processes and long-term benefits.

From a broader perspective, the issue of sustainable development and the protection of Ecosystem Services is relevant to the quality of urban

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7 Alberto De Capua, and Lidia Errante, "Interpretare lo spazio pubblico come medium dell'abitare urbano | Interpreting Public Space as a Medium for Urban Liveability." *Agathón* 6 (2019): 148–161.

8 Millennium Ecosystem Assessment, *Ecosystems and Human Well-Being: A Report of the Millennium Ecosystem Assessment* (Washington: Island, 2005).

9 Fondazione Innovazione Urbana, "Glossary."

living and the perception of well-being. According to Santolini[10], a good provision of ESs increases the per capita wealth of natural capital, positively influencing its health and vulnerability. ESs, in this sense, can be correlated to natural commons, as these are of free use to the population but not yet quantified or properly esteemed for their economic value. On the contrary, it is observed that insurance policies are increasingly available to cover assets, buildings, and people against environmental hazards.

3. The impact of extreme climate events for cities and public spaces

Recently, the Mediterranean has experienced faster warming than the global average. Summer temperatures have increased, impacting water resources, agriculture, and human health. Heat waves have become more intense, endangering the safety of people, especially children, the elderly, and people with health problems[11]. On top of that, the increase in the intensity and frequency of rainfall and water bombs results in further aggravation of ecosystem conditions and severe damage to green and blue infrastructure.

The ESs erosion discourse is not limited to the ability of ecosystems to ease the impact of extreme climate events and mitigate them but also to the risk of triggering them and negatively impacting the social sphere of sustainability.

The contribution examines three extreme climate events that are the subject of the previously mentioned research: urban heat islands (UHIs), heat waves (HWs), and water bombs.

These three phenomena impact cities and the use of public spaces, including related urban services. They can be mitigated through specific adjustments and expedients involving micro-climate, urban morphology, the use of materials, and the multifactorial combination of some specific trigger conditions described below.

Urban Heat Island (UHI) occurs when the temperatures in urbanized areas are higher than in rural areas. During warmer seasons, this effect can lead to thermal discomfort, increased energy consumption, and aggravated pollution[12]. This phenomenon has a greater incidence and severity in highly urbanized settings, i.e., where the anthropogenic process of altering material surfaces results in extensive vegetation suppression, albedo variation, and general soil sealing. Specifically, the factors involved in the

10 Riccardo Santolini, "Servizi Ecosistemici e Sostenibilità," *Ecoscienza* 3 (2010): 20-23.

11 Riccardo Alberti, "Impatto dei cambiamenti climatici nel Mediterraneo," *INGV Ambiente*, 2023, https://ingvambiente.com/2023/07/04/il-cambiamento-climatico-nel-mediterraneo/.

12 Cátia Rodrigues de Almeida, Ana Cláudia Teodoro, and Artur Gonçalves, "Study of the Urban Heat Island (UHI) Using Remote Sensing Data/Techniques: A Systematic Review," *Environments* 8, no. 105 (2021).

FIG. 4 Urban landscape affected by heat and smog. Picture by Marek Piwnicki on Unsplash.

formation of the UHI are related to the ability of building materials to store heat; anthropogenic heat production and, in general, processes, systems, and infrastructure that contribute to the increase in average temperatures; the alteration and minimization of wind speed as a function of surface roughness; and the increased absorption of solar radiation by surfaces with lower albedo.

Factors that the UHI is capable of influencing include[13]:

- Local micro-climate;
- Local energy balance;
- Perceived thermal discomfort;
- Absorption of electromagnetic energy;
- Cooling of surfaces compared to planted surfaces;
- Increase in surface temperatures and reduction in relative humidity and latent heat;
- Intensification of sensible heat;
- The hydrogeological behavior of ecosystems;
- Public health.

The second phenomenon examined is the Heat Wave (HW), which is determined when very high temperatures are recorded for several consecutive days, with high humidity rates, high solar radiation, and scarce ventilation. It is defined considering the climatic conditions of a specific city or area, and no universal temperature threshold value can be identified to assess

13 ibid.

its magnitude. According to Kong et alii.[14], this phenomenon affects rural and urban areas equally severely with specific interactions with UHI.

Specifically, the causes of HW refer to:

- The reflectance and heat absorption properties of natural and artificial surfaces;
- The use of impermeable materials that reduce evapotranspiration and latent heat flux with alterations in urban atmospheric temperatures;
- Urban morphology in the vertical direction, which increases the canyon effect;
- CO2 emissions, which prolongs the effect over time.

FIG. 5 Urban flood. Picture by Mika Baumeister on Unsplash.

Briefly, HW occurs when there are very high temperatures for several consecutive days, with high humidity rates, high solar radiation, and the absence of ventilation. It is defined concerning the climatic conditions of a specific city or area, and no universal temperature-threshold value can be identified to assess its magnitude.

The last climate event examined is the water bomb. The most pertinent definition is Explosive Cyclogenesis, characterized by a rapid increase in the low-pressure area of an extratropical cyclone with strong winds and precipitation. The magnitude is classified according to latitude, which

14 ibid.

determines a specific threshold value for the effect of low pressure. The main impact of this phenomenon is connected to the absorption capacity of the soil. When the surfaces are impermeable or dry, flooding or sliding may occur involving the detachment of loose material such as mud and debris. The most frequent damage associated with this climatic event is flooding, which is severe in both rural and urban environments, often tragically associated with human loss.

Ths, climate change is not exclusively an environmental issue but has severe social, political, and economic equity implications. The impacts of extreme weather events, as a consequence of a much broader and worrying environmental imbalance, are increasingly severe on the most vulnerable communities, biodiversity, and the ability to produce food, generating a sense of uncertainty that affects the poorest segments of the population.

To address the effects of climate change, mitigation and adaptation strategies are essential. This includes reducing greenhouse gas emissions by adopting sustainable energy policies and promoting renewable energy. In addition, adaptation measures that improve water resource management, urban planning, coastal ecosystem protection, and climate-resilient agriculture[15] must be implemented.

However, these strategies have timeframes and modes of operation that require substantial effort and investment. While plans and projects are developed, often following bureaucratic processes that depend on the policy ideas of different national governments, several solutions are more targeted and applicable at the scale of public space through urban design.

4. Environmental strategies and challenges at the urban scale

The design opportunities related to the ecological transition and the regeneration of the built and urban environment, infrastructures, and spaces reconsider villages, cities, buildings, and homes according to environmental quality criteria. Among the others, the contribution acknowledges:

- The correct planning of the intervention, taking into account its impact on the social, economic, and environmental spheres;
- The circular process of execution and production of the work;
- The flexibility and transversality of ecological and social functions;
- The improvement of the environmental quality of the built environment and the quality of life of communities;
- The regeneration of social commons.

In this sense, villages and contemporary cities have the same need to reconstitute an adequate physical and social infrastructure, made up of

15 Riccardo, "Impatto dei cambiamenti climatici nel Mediterraneo."

FIG. 6 Detail of a green facade. Picture by Lili Banse on Unsplash.

a mobility network and aggregation spaces that can also be configured as environmental protection devices, off-grid energy production, containment of the heat island effect and absorption of harmful emissions. In particular, design and technological opportunities in the built environment can revolve around public space infrastructure and urban ecosystem services. For example:

- Extend the green areas, planting tree species to absorb harmful substances and emissions from urban mobility. Mitigation strategies for the effect of increased vegetation area include the application of green roofs and increased green spaces (urban and rural) such as parks and grasslands[16];
- Transforming boulevards into green corridors and increasing the vegetation cover help change the surface energy balance by increasing latent heat flux through evapotranspiration compared to sensible heat flux according to a given net radiation. That is, finding a reduction in surface and air temperatures and solar radiation transmitted to the subsurface near the vegetation surface;
- Increasing soil permeability through new areas of technological green areas able to interact positively with the sewerage network infrastructure;
- Integrate areas dedicated to the production of energy from renewable sources such as photovoltaic or kinetic surfaces, which can be used to supply public lighting or charging stations;
- In places affected by flooding from heavy rain, identify suitable spots for temporary water harvesting following the model of water squares;
- Redefine the hierarchy of urban mobility routes by providing

16 Jian Kong, *et al.*, "Urban Heat Island and Its Interaction with Heatwaves: A Review of Studies on Mesoscale," *Sustainability* 13, no. 10923 (2021).

adequate space for sustainable individual transport and related service infrastructure (such as e-bikes, e-scooters, etc.);

- Improving urban accessibility, with a focus on housing estates and public buildings and the definition of guided routes to essential services;
- Increasing albedo to reduce heat absorption by surfaces, i.e., to enhance the reflectance of urban surfaces and buildings preferring clearer or white surfaces and to reduce the energy consumption of buildings and cooling due to a general reduction in urban ambient temperature, heat accumulation in roofs, and anthropogenic heat in urban areas. These measures do not compensate for the effects of HW that can occur even in the presence of clouds that allow more solar radiation. The increase in albedo also partly reduces the air velocity and buoyancy effect.

Several strategies can be adopted to achieve the goals just described. In particular, working on the reintroduction of nature into the urban environment. Biophilic design reintroduces nature into the design process and human experiences, adding aesthetic, textural, and graphic features, both organic and artificial at the scale of the building, site, city, and region to accompany humans through their evolution and improve the physical and mental health of individuals[17]. Biophilic design is an approach that holds principles of good design at the building, site, city, and regional scale using the natural asset provided by the context in an environmentally sustainable way by:

- Protecting and enhancing the natural systems and green infrastructures from climatic events, ensuring the provision of essential services;
- Moderating air pollution and balancing microclimate through vegetation and providing cooling, evapotranspiration, shading, and reduction in urban flooding. Green rooftops alone may dramatically contribute to lower urban temperatures;
- Allow native biodiversity to adapt and shift as climate changes through an extensive and diverse network of parks and green spaces;
- Help cities to become more self-sufficient in times of resource scarcity;
- Encourage a healthier lifestyle, resulting in overall energy saving.

The biophilic approach can be described as an outdoor-oriented design at the neighborhood scale, with benefits reaching the regional since the individual level.

17 Robert McDonald, and Timothy Beatley, *Biophilic Cities for an Urban Century: Why Nature Is Essential for the Success of Cities* (Cham: Palgrave Pivot, 2021).

5. The pivotal role of public spaces

The system of urban public spaces — streets, squares, widenings, places of mobility, sociality, and exchange — is the first to be affected by the extreme weather events examined. Being outdoors, environmental discomfort is one of the causes of change in the behavioral patterns of people using public space. This phenomenon leads citizens to increase their awareness of the climatic and environmental crisis, making them progressively more interested and active in participation through bottom-up actions sponsored by activist groups, communities of residents, or interested groups who care about caring for places. For the same reasons, it is precisely on this plane that local government institutions, professionals, collectives, and communities meet the common need to trigger and experiment with innovative processes and designs for change. From a bottom-up point of view, during the pandemic, we have witnessed the intellectual rehabilitation of DIY and tactical urbanism, approaches that involve subtle and interesting technological implications. Bianchi[18] describes its outcomes in terms of design, highlighting the richness of forms and solutions of the broad movement from below devoted to the activation of co-creation processes for the transformation of places. The collective force expressed by these movements can be used as a key resource in adaptive regeneration strategies for the energy transition of cities. The communities can participate in the whole discussion on urban transformation by being directly or indirectly involved by local institutions.

The quality of urban life is closely related to the quality and diversity of public spaces, conceived as a system of elements within the city structure[19]. The fragmentation of public spaces affects the perception of well-being and urban livability, leading to greater social and physical marginalization of inhabitants. Public space, in its physical and social dimensions, represents a strategic infrastructure that connects and accommodates urban flows while regulating interactions between individuals and the urban environment[20].

In this perspective, a central role is played by the options that public space can offer. That is mixed opportunities according to different targets and needs of citizens, essential and optional functions relevant to daily life activities, a certain degree of accessibility considering a wide range of requirements, environmental and material comfort, and not less importantly, ethical and esthetical features and qualities that contribute to give meaning to that space.

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18 Riccardo Bianchi, *La dimensione attiva del progetto. Strategie di allestimento e re-design dello spazio pubblico* (Soveria Mannelli: Rubbettino, 2022).

19 Lidia Errante, "La qualità dell'abitare urbano nel processo di costruzione dello spazio pubblico," *Urbanistica Dossier* 15 (2018): 52-57.

20 ibid.

European and national energy transition policies emphasize the key role of urban public spaces and mobility, where several dynamics of transformation and social innovation have experimented with success.

A key element in the reading of public space is street furniture, which is not merely an accessory element but can contain several essential functions or trigger community engagement actions, educating on environmental issues in an engaging, playful, and interactive way.

An example of that is the TANDEM project, commissioned by the Ayuntamiento of Madrid and implemented by the NGO Creàtica with Enorme Studio, PEZestudio, and Todo por La Praxis[21], is worthy of interest. The Jardines del Arquitecto Ribera plaza is transformed into a laboratory for urban redevelopment and sustainable energy production, hosting three recreational and informative installations, each capable of producing up to 2KW/h from solar photovoltaics. The energy, accessible to residents for their daily needs, fuels the cultural activities planned in the square, promoting a playful use of technological design and integrating the energy transition with the self-building approach that Bianchi describe as "[...] a tool of socialized knowledge and practical awareness to realize projects with informal design, accessible to the whole community of citizens and able to activate dynamic processes of urban regeneration [...]"[22]. The goal to integrate environmental and energy performance into projects of physical and social quality does not exclude the adoption of eco or capable street furniture, suggesting greater integration with alternative and sustainable sources such as kinetic energy produced by footsteps. For instance, kinetic surfaces used in urban design as technological inserts in sidewalks, bike lanes, playgrounds, or transit locations produce 5 to 7 watts per step, which power an LED bulb for street lighting for 30 seconds. The energy is stored off-site with autonomous or grid-connected accumulators and batteries. While this solution is not inherently participatory, it is an equally interactive solution geared toward the gamification of the space thus created.

The design solutions above described represent viable possibilities that can animate public space by combining energy production with the playful use of furniture. On the other hand, these do not represent the solution to the issue of energy production definitively, as they have a punctual and, therefore, limited impact. Likewise, these are a good pretext for engaging the public and making them aware of the opportunities offered by new technologies in energy production from renewable and clean sources.

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21 Todo por la Praxis, "Tandem" (2017), https://todoporlapraxis.es/092-tandem/

22 Bianchi, *La dimensione attiva del progetto.*

6. Nature-based solutions in the design approach to sustainable urban regeneration

The Public Space-Public Life[23] approach aimed at urban design has evolved into the Soft City paradigm[24], oriented toward urban density, accessibility, and quality of public spaces in neighborhoods and housing estates. In this context, the idea of physical and relational proximity considers the neighborhood a minimal ecological unit, where accessibility is the result of a space-time-opportunity equation. Another example is the concept of the "15-minute city" in Italy well-argued by Ezio Manzini[25], and the experiment of Super-Illas of Barcelona (ES) that shows how urban regeneration needs a broader strategy that connects public spaces, mobility, and energy production as part of a more exhaustive concept of functional proximity.

On the other hand, NBSs work according to new design requirements such as safety, health, and eco-compatibility, adopting technologies suitable to the biophilic approach. Design approaches to ecosystem regeneration often adopt Nature-based Solutions (NBS) for improving urban and territorial resilience[26]. Even acknowledging their benefits, the applications are heterogeneous, requiring multi-scalar and multi-criteria methodological approaches to integrate NBSs into broader urban plans. According to Castellar et alii.[27], Nature-Based Solutions (NBS) have emerged to foster sustainable development and transversally addressing social, economic, and environmental urban challenges. At the same time, the authors also admit the difficulty of assessing their performance concerning ESs and urban challenges due to the heterogeneity of the technologies and the solutions applicable.

The recent literature on urban regeneration has seen rising attention on the neighborhood scale, using NBSs for building retrofitting and urban regeneration strategies oriented to an environmental and ecosystemic approach. Two different applications and scales can be distinguished: the building envelope and the public space. The integration of vegetation, vertical or horizontal, promotes evapotranspiration, shading, and reduction of the heat island effect and urban flooding. Green roofs alone can contribute significantly to urban temperature reduction. In this sense, Morabito[28] argues that NBSs can provide a concrete response aimed at increasing the resilience of the built environment by supporting urban

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23 Jan Gehl, and Birgitte Svarre, *How to Study Public Life: Methods in Urban Design* (Washington, Island, 2013).

24 David Sim, *Soft City: Building Density for Everyday Life* (Washington: Island, 2019).

25 Ezio Manzini, *Abitare la prossimità. Idee per la città dei 15 minuti* (Milano: Egea, 2021).

26 Elena Mussinelli *et al*. "Il ruolo delle Nature-Based Solutions nel progetto architettonico e urbano," *TECHNE* 15 (2018): 116-123.

27 Joana A. Castellar et al., "Nature-Based Solutions in the Urban Context: Terminology, Classification and Scoring for Urban Challenges and Ecosystem Services," *Science of the Total Environment* 779, no. 146237 (2021).

28 Roberto Morabito, "La transizione verso l'economia circolare in aree e comunità urbane: approccio ENEA," *TECHNE* 22 (2021): 28-34.

and cultural ecosystem services and providing an opportunity for technological advancement. Integrating nature into cities helps reduce UHI, improve air quality, and increase urban resilience[29], enhancing and supporting ecosystem services, serving as a tool for climate mitigation and adaptation, and serving as a space for recreation and social cohesion. By the intrinsic nature of public space, these sometimes take on the connotation of green or blue infrastructure, such as the banks of waterways that run through the urban fabric and that, with due differences, help to dispose of and slow down stormwater runoff through the presence of vegetation and organic material that filter its pollutants[30].

FIG. 7 Benthemplein watersquare by De Urbanisten. Picture by the author.

NBS has not to be conceived as high technology design: among the many, tree planting and green boulevards are the most common in urban design, providing microclimate mitigation benefits, capturing PM particles by acting directly at the deposition elevation, and improving soil permeability.

Public spaces or street furniture can be designed and used as NBS: shade zones, pergolas, green roofs, and urban seating can accommodate

29 Lidia Errante, "Nature-Based Solutions and Biophilic Design: Eco-systemic Approaches to Regeneration," in *On Sustainable Built Environment: Between Connections and Greenery*, edited by Francesca Scalisi et al. (Palermo: Palermo University Press, 2022): 118-131.

30 Eugenio Morello, Israa Mahmoud and Nicola Colaninno (eds.), *Catalogue of Nature-Based Solutions for Urban Regeneration. Energy & Urban Planning Workshop, School of Architecture Urban Planning Construction Engineering* (Milan: Politecnico di Milano, 2020).

FIG. 8 Benthemplein watersquare by De Urbanisten. Picture by the author.

vegetation and define green cool areas. On the other hand, the proper morphology of land elevations and height differences can represent an optimal solution to manage and control stormwater and urban floods. The case of Benthemplein (Rotterdam) is an international reference in this regard, with results of environmental quality of urban space and livability. The logic adopted for the water square is to have the square level at a lower elevation than the street, making it accessible by stairs and slopes. The systems of three main squares can contain large volumes of rainwater and regulate its runoff. The urban resilience strategy is formally and aesthetically enriched by the surface treatment and articulation of diversified spaces for sports and recreational and leisure 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[31].

The case of Benthemplein, although not recent, is still a very current example of a Nature-based Solution that integrates solutions inspired by natural processes to face the worsening of the environmental crisis and the consequent extreme climatic events like explosive cyclogenesis. In

31 Alberto De Capua, and Lidia Errante, "Technological design for the environmental transition of the city. Opportunities for innovation | Il design tecnologico per la transizione ambientale della città. Opportunità di innovazione," *TECHNE* 26 (2023): 78–85.

an urban context of soil consumption and sealing, managing rainwater is a concrete emergency, worsened by the progressive deterioration of green and blue infrastructures that naturally regulate water flows. On the other hand, hybrid solutions such as De Urbanisten's Benthemplein represent an opportunity to encourage social interaction and improve the quality of urban living by mitigating the risk of flooding. This combination of engineering, nature, and urban design at the scale of public space has highlighted a positive impact on the well-being of communities, acting on different temporal lengths: the unpredictable one of the extreme climatic event, which has a limited duration but potentially long-term effects, and that of the daily life of the communities, which find in Bonthemple residents in a space of sociality.

7. Future perspective of the research and conclusions

The future of research on climate mitigation strategies and urban regeneration focuses on integrating advanced technologies and ecosystem approaches to improve the sustainability of cities[32]. This goal can be achieved by conceiving new ways to design and live the urban environment: from the eco-districts to the use of green technologies in building redevelopment, there are unlimited and yet promising solutions for improving urban resilience and quality of life[33]. According to several authors, an ecological design should be:

- Planned according to its impact on the social, economic, and environmental spheres;
- Flexible according to scenario steps that take into account the worsening of extreme weather events and climate change phenomena;
- Able to reuse existing buildings and resources[34];
- Aim at circularity in the production, execution, and management stages[35].

In this sense, the response to environmental challenges cannot be limited to eco-technologies or assessing energy performances. It has to manage at the same time different matters such as the regulation of microclimate, the provision of shading and cooling areas, and, as a consequence, decreasing energy demand. The many solutions offered by technological advancement and eco-design, in general, all contribute to accelerating a process of ecological transition that involves a broad spectrum of

32 De Capua and Errante, "INA-Casa a Reggio Calabria."

33 ibid.

34 Tom Bergevoet, and Maarten von Tuijl, *The Flexible City: Sustainable Solutions for a Europe in Transition* (Rotterdam: NAI, 2016).

35 Lidia Errante, "Hybrid Communities and Resilient Places: Sustainability in a Post-Pandemic Perspective," in *Possible and Preferable Scenarios of a Sustainable Future: Towards 2030 and Beyond*, edited by Cesare Sposito (Palermo: Palermo University Press, 2021): 32-45.

sustainable behaviors, from the habits of everyday life, with significant impacts on the perception of a healthy and safe place[36].

This evolutionary process of technique and design culture mediates not only between man and nature, which is the premise of the investigation. Also, as Los expected, we are witnessing a progressive merging of languages and communication codes related to sustainable architecture. Green technologies are no longer just an expression of a performance requirement, managing to integrate different functions, increasingly understood, promoted, and defended by politics and society.

At a time in history characterized by social, cultural, geopolitical, economic, and climatic changes, urban transformation plays a driving role in investing and supporting such a necessary ecological transition.

From this perspective, there are three requirements o technological design:

Alternative: i.e., able to provide alternatives adaptable to different contexts and social dynamics, non-dogmatic to innovation and ecological transition processes potentially unsuitable for socio-economic contexts characterized by energy and economic poverty. That is, introducing behavioral patterns oriented to save energy and reduce consumption where it is not viable to submit structural or infrastructural transformations.

Proximity: using relational proximity and social innovation as key elements of urban ecological transition strategies from a local perspective, activating support networks, collaborative and shared management, and production models. Manzini[37] describes it as a diverse, relational, and hybrid proximity similar to the 15-Minute City model.

Disordered: according to Sendra and Sennet[38], an open and flexible urban form turns out to be more robust, allowing more creative use of technological tools. Overcoming the hyper-determination of both the visual forms of the city and its social functions (ibid.), the urban morphology can be adaptable and rearrangeable according to controlled chaos. Other than allowing new possibilities, combinations, and bottom-up expressions, this paradigm enhances the flexible form of the city and its capacity to respond with resilience to extreme climate events.

Open Source: capable of realizing, within function and design, a stratification of meaning by considering the urban context as a palimpsest, the result of shared choices and self-determination where actions and strategies can be replicated, disseminated, and repurposed[39].

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36 Errante, "Nature-Based Solutions and Biophilic Design."

37 Manzini, *Abitare la prossimità*.

38 Pablo Sendra, and Richard Sennett, *Designing Disorder. Experiments and Disruptions in the City* (London: Verso, 2020).

39 Carlo Ratti (a cura di), *Architettura Open Source. Verso una progettazione aperta* (Torino: Einaudi, 2014).

The innovation required from the technology is redeeming itself with nature through sustainable solutions to directly or indirectly guarantee well-being and environmental comfort for citizens. Foreseeing energy alternatives in technological design meet environmental, social, and economic sustainability requirements. The emergence of climate change determines new design needs that can only be addressed through an ecological approach that requires a deeper knowledge of the phenomena that occur in climate change and how they impact specific urban assets. Technologies and design solutions can be considered appropriate to solve local environmental contingencies if embedded in precise urban plans that consider the quality of ESs and the capability of territories and communities to adapt.

The approach must be mutual: on the one hand, monitoring climate data to simulate the intensity, frequency, and recurrence of extreme climatic events, considering their impact on the short and long run; on the other hand, understanding how urban morphologies, building materials, and canopies can worsen the effect of climate challenges to and how to use design to correct the micro-climatic aberrations of contemporary cities.

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