POLITECNICO DI TORINO
Repository ISTITUZIONALE

Nature-Based Solutions as a Strategy for Adaptation to Climate Change

Original
Nature-Based Solutions as a Strategy for Adaptation to Climate Change / Giordano, R. - In: New energies for the cities / Rogora A., Carli P.. - STAMPA. - [s.l] : UNA, Urban NarrAction Press, 2024. - ISBN 9788894454277. - pp. 207-225

Availability:
This version is available at: 11583/2996299 since: 2025-01-08T16:12:12Z

Publisher:
UNA, Urban NarrAction Press

Published
DOI:

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)

15 November 2026

NEW ENERGIES FOR THE CITIES

edited by

Alessandro Rogora and Paolo Carli



UNAPRESS 06
Urban NarrAction

Opera assoggettata a double peer review

Edito da: UNA, Urban NarrAction - Progetto editoriale in free press per la divulgazione e la diffusione di ricerche e buone pratiche [urbannarraction.net]

Comitato editoriale:
Matteo Clementi
Valentina Dessì
Maria Fianchini
Luciana Mastrolonardo

Comitato scientifico:
Stella Agostini, *Università degli studi di Milano*
Alessandra Battisti, *Università degli Studi di Roma- La Sapienza*
Paola Boarin, *University of Auckland*
Paolo Carli, *Politecnico di Milano*
Matteo Clementi, *Politecnico di Milano*
Valentina Dessì, *Politecnico di Milano*
Michele D'Ostuni, *Università di Bologna*
Maria Fianchini, *Politecnico di Milano*
Roberto Giordano, *Politecnico di Torino*
Tae Han Kim, *Sangmyung University, Seoul, South Korea*
Michele Lepore, *Università "G.D'Annunzio" Chieti-Pescara*
Luciana Mastrolonardo, *Università di Pescara*
Antonello Monsù Scolaro, *Università degli studi di Sassari*
Eugenio Morello, *Politecnico di Milano*
Marialena Nikolopoulou, *University of Kent*
Elisabetta Palumbo, *RWTH Aachen University*
Anna Pages Ramon, *Universitat Politècnica de Catalunya, Barcellona*
Donatella Radogna, *Università "G.D'Annunzio" Chieti-Pescara*
Rosa Romano, *Università degli studi di Firenze*
Antonella Trombadore, *Università degli studi di Firenze*
Antonella Violano, *Università della Campania- Luigi Vanvitelli*

NEW ENERGIES FOR THE CITIES

edited by
Alessandro Rogora, Paolo Carli

UNAPRESS 06
Urban NarrAction

Authors **VII**

Foreword. New energy for the city **XV**
Gianni Scudo

An Informal Glossary **XXV**
Paolo Carli

PART I - Urban Climate and Micro-Climate

Urban Physics Lecture Program for Architects **3**
Benoit Beckers

Pluvial flooding in compact neighbourhoods: digital analysis for climate-adaptive buildings and urban spaces **31**
Michele Morganti, Simona Mannucci and Ilaria Fiocchi

Energy Functioning of an Urban Settlement Through the Ages **53**
Qian Zhang

Water based solutions for cooling the cities: from city to building **87**
Valentina Dessì, Adrian M. Valek and M. Pereira Guimaraes

PART II - Evaluation and Modelling Systems, and Tools

Using Open-source GIS to support energy and carbon flows accounting in urban areas **113**
Matteo Clementi and Marco Migliore

TRACES: simulating the social acceptability of technical transformations and behaviours **143**
Alessandro Rogora

163

Green Infrastructure based on smart technology
Tae Han Kim

Pluvial flooding in compact neighbourhoods: digital analysis for climate-adaptive buildings and urban spaces **179**
Mónica Alexandra Muñoz Veloza, Lorenzo Savio and Stefano Bellintani

Nature-Based Solutions as a Strategy for Adaptation to Climate Change **207**
Roberto Giordano

To Have Urban Sustainability, Citizens Must Be Given a Nudge **227**
Paolo Carli

Editors and Authors

Alessandro Rogora, architect, Ph.D. in Architecture and Environmental Technology, is a full professor of Architecture Technology at the Department of Architecture and Urban Studies (DAStU) of the Politecnico di Milano. He has taught at the universities of Ferrara, Venice, Lugano, and numerous international institutions, including ETSAB-UPC in Barcelona. A specialist in sustainable design, he has participated in numerous national and international research projects and has published over 200 scientific contributions and numerous books on the relationship between architecture, construction, energy, and sustainability. He has also worked as a designer and energy consultant, contributing to the realization of lighting projects in Italy, a great passion of his research and work, and sustainable building projects, receiving various awards and recognitions in design competitions.
E-mail: alessandro.rogora@polimi.it

Paolo Carli is an architect and Ph.D. in Architecture Technology. He was/is a researcher at the Dipartimento di Architettura e Studi Urbani (DAStU) of the Politecnico di Milano. He focuses on urban and micro-urban environmental design, an area in which he has coordinated and participated in national and international research projects. His methodologies and strategies involve inclusion of people, co-design, and citizen participation in both design choices and actions for the construction and maintenance of shared spaces.
E-mail: paolo.carli@polimi.it

Benoit Beckers is an engineer, Ph.D. in Architecture, and full professor at the University of Pau (France). His most important publications concern computational geometry, and more particularly the partitions and projections of the sphere, which are the bases of geometric methods for radiative transfer simulation. Currently, he is working on their connection with the Finite Element Method in problems related to urban physics. At the same time, he is developing more personal research on the perception of waves, considering its influence on the history of architecture and the city. He is the author of monographs on the evolution of concert halls, perspective representation, color systems, and, in progress, the shape of cities, presented in the form of conferences and reports on his personal site, www.heliodon.net.
E-mail: benoit.beckers@univ-pau.fr

Stefano Bellintani, associate professor of Architectural Technology at the Dipartimento ABC - Real Estate Center of the Politecnico di Milano, is co-founder of the Italian Proptech Network (DABC, Politecnico di Milano) and a member of the board of Assofintech. He is also a Founding Partner of BRaVe m&t - Management and Technology, a spin-off of the Politecnico di MIlano, as well as the author of several national and international books and scientific publications.

Matteo Clementi, is associate professor of Building Technology and Environmental Design at Department DAStU of the Politecnico di Milano, he carries out research activities dealing with tools to support sustainable design on neighbourhood and urban scale and to support the development of local self-sufficiency scenarios at the territorial scale. He is particularly interested in the application of open source tools in order to support processes consistent

with the bioregional development and the circular economy.
E-mail: matteo.clementi@polimi.it

Valentina Dessì is an architect, Ph.D., and associate professor. She belongs to the Dipartimento DAStU of the Politecnico di Milano. She teaches Environmental Design and Architecture Technology and carries out research activities mainly oriented to the bioclimatic design of urban spaces and to the evaluation of the outdoor and indoor environmental comfort conditions. She is currently involved in international researches: (H2020-MSCA-ITN) on adaptation strategies to climate change, and in particular on the role of water as a strategy to reduce the urban heat island, and Bize_UrFarm on the potential of urban farm integration in the architecture. She publishes on books and scientific journals, and participates as a speaker at international conferences.
E-mail: valentina.dessì@polimi.it

Ilaria Fiocchi, architectural engineer, graduated cum laude with a thesis in Sustainable Building Design at Sapienza University of Rome with Honours Programme in 2023. Her interests are based on urban regeneration, hydraulic risk in urban spaces and building renovation. In 2022 she attended two international workshops on climate change. She worked as a Project Manager Assistant in an engineering company focused on infrastructures design. She is currently a Facility and Project Manager Specialist in an engineering consultancy company.

Roberto Giordano is a full professor in Environmental and Building Design at the Politecnico di Torino. His Ph.D. thesis at the Politecnico di Milano focused on methods for assessing the environmental sustainability of building products.

He participated in and directed research on designing and implementing Living Wall Systems. He co-founded a start-up enterprise at the Politecnico di Torino. Its objective was to implement a modular vegetated façade, for which a patent was filed. He lectures on Transition Energy - Low Carbon and Design for Climate Resilience courses at the Master of Science in Architecture for Sustainability at the Politecnico di Torino. He is the author of more than 100 publications.
E-mail: roberto.giordano@polito.it

Mariana Pereira Guimaraes, graduated from the University of São Paulo in Civil Engineering, obtained a degree in Public Health from the Harvard T.H. Chan School of Public Health, and a degree in Urban Planning from the Harvard Graduate School of Design. She is currently pursuing a Ph.D. at the Politecnico di Milano as part of the H2020-MSCA-ITN-EID SOLOCLIM research program, focusing on Solutions for Outdoor Climate Adaptation. The topic of her thesis is: 'The evaporative city: Guidelines on urban adaptation and regeneration using water.'

Taehan Kim has been working at Sangmyung University since 2009 and is currently a full professor. He conducts research on the development of climate change response technology and performance evaluation using green infrastructure. Additionally, he is involved in projects ordered by government agencies such as the Ministry of Environment, Ministry of Agriculture, Food and Rural Affairs, Korea Forest Service, and Small and Medium Business Administration. As a member of the government committee, he served on the Central Urban Planning Committee under the Ministry of Land, Infrastructure, and Transport. In terms of academic activities, he holds positions as the vice president of the Korean Institute of Landscape Architecture, the Korean Institute of Traditional Landscape Architecture, and the Society of People, Plant, and Environment.
E-Mail: taehankim@smu.ac.kr

Simona Mannucci Ph.D. in Architecture and Urban Planning at Sapienza University. She is a researcher at the Department of Civil, Building, and Environmental Engineering DICEA, at Sapienza. Her research interests include adaptive approaches to increase resilience in urban planning in case of climate-related uncertainties, specifically urban floods. She is also involved in a project to produce a database of building archetypes and investigate the role of Bio-based insulations for energy savings.

Michele Morganti, architectural engineer by education, PhD in Architecture, Energy and Environment, he is associate professor of Sustainable Building Design at Sapienza University of Rome. His research addresses the environmental performance of buildings, urban spaces, and cities, ranging from energy use to human well-being. Current studies focus on the relationship between urban climate change, microclimate, and building energy performance, with a particular interest in housing. He was the winner of *UPC Barcelona Tech's Special Doctoral Award* for his PhD thesis *Sustainable Density*, and of Politecnico di Milano's 2018 *Best Young Researcher Publication* for the book *Ambiente costruito mediterraneo: forma, densità, energia*.
E-Mail: michele.morganti@uniroma1.it

Marco Migliore is an architect, Ph.D in Technology and Design for the Built Environment, and research fellow at Departement of Architecture and Urban

Studies of the Politecnico di Milano. Author of national and international publications, he deals with issues relating to the circular economy in the construction sector, as well as the study of experimental structure for the cultivation in urban areas on impervious surfaces

Lorenzo Savio is an architect, Ph.D. in Innovation Technology for the Built Environment, and associate professor at the Dipartimento DAD of the Politecnico di Torino. He has been collaborating continuously since 2008 on numerous research activities related to the recovery of rural and twentieth-century architectural heritage, energy retrofitting and the use of renewable energy sources in buildings, low-impact materials for sustainable architecture, and physical and perceptual accessibility to the built environment.

Gianni Scudo, architect and former full professor of Architectural Technology at the Politecnico di Milano, he has been conducting research in the field of environmental design and the integration of renewable energy technologies at the building and micro-urban scale since the 1970s. He has served as President of the Degree Program in *Environmental Architecture* and Vice Dean of the *Faculty of Architettura e Società*, as well as a Visiting Professor at several European universities, including Barcelona, Lausanne, and Mendrisio. He was also the scientific director of the journal *Il Progetto Sostenibile*. He has published dozens of books, scientific articles, and popular articles in the field of bioclimatic and environmental design.

Adrian Moredia Valek, graduated in architecture from the Autonomous University of Guadalajara, obtained a Master's degree in Urban Management & Development from the Institute for Housing & Urban Development Studies at Erasmus University Rotterdam. He completed his Ph.D. at the Politecnico di Milano as part of the H2020-MSCA-ITN-EID SOLOCLIM research program, focusing on Solutions for Outdoor Climate Adaptation. The topic of his thesis is: 'Cooling Cities: Innovative Water-Based Cooling Systems in the Era of Urban Heat.'

Mónica Alexandra Muñoz Veloza is a Colombian research fellow at the Department of Architecture and Design (DAD) of the Politecnico di Torino, where she obtained her cum laude Ph.D. in "Architecture. History and Project" in 2022 and her Master's degree in "Architecture for Sustainable Design" in 2017. She is currently employed in the field of architectural technology and environmental design, conducting her research within the project "S[m2]art (Smart Metro Quadro) Guardando la città metro per metro."
E-mail: monica.munozveloza@polito.it

Qian Zhang is an architect and researcher specializing in microclimate-oriented architectural design. Currently pursuing a Ph.D. in Architectural, Urban, and Interior Design at the Polytechnic University of Milan, Qian has over 10 years of experience in architectural design schools and renowned companies. Qian's focus on pushing boundaries and exploring new approaches is reflected in his rich research achievements.
E-mail: qian.zhang@polimi.it

PART II

SYSTEMS AND TOOLS FOR ENVIRONMENTAL EVALUATION, AND MODELLING

Nature-Based Solutions as a Strategy for Adaptation to Climate Change

Roberto Giordano

Nature-based solutions (NBS) are 'solutions' for urban infrastructures that use greenery to address complex challenges related to the effects of climate change at the urban scale. From forests to Living Wall Systems (LWS), NBS integrate vegetation and urban materials.
In addition, within several frameworks, including urban planning and building detailing, NBS offers multiple environmental, social and economic benefits. With a focus on climate change adaptation, NBSs mitigate the urban heat island effect and improve stormwater management.
The chapter describes the results of a research study on the design and construction of an LWS. Some of its physical, technological and agronomic performances were monitored over about two years.
Based on the achievements, the chapter, finally, highlights some critical issues that must be addressed to promote and disseminate NBSs, particularly LWSs in the future.

The Nature-Based Solutions

A Nature-Based Solution can be defined as urban infrastructure based on greenery to simultaneously tackle sustainability challenges by maximising the benefits of nature (Sowińska-Świerkosz et al., 2022; European Commission, 2015; European Commission, 2022).

Nature-Based Solution encompasses many possibilities, ranging from urban and peri-urban forests to Living Wall Systems (to be understood as vertical enclosures or partitions that allow the rooting and growth of one or more plant species on its surface) (Dorst, H., 2019).

This means some Nature-Based Solutions are wholly and entirely made up of plant elements. In contrast, others require the integration of vegetation and materials, which, once fully integrated, make up a technology (i.e., a green roof solution). The materials perform several functions, such as filtration, control of root growth, drainage, and waterproofing. (Figure 1).

A Nature-Based Solution is used in several fields: i.e. urban planning, agriculture, water management, and infrastructure development.

The scientific literature provides an articulate picture of Nature-Based Solutions' features and properties.

First, Nature-Based solutions aim to provide many benefits concurrently, addressing multiple environmental, social and economic issues. For example, wetland renewal improves water quality and provides a habitat for wildlife and recreational opportunities for people (Sowińska-Świerkosz et al., 2022; Jessup, K. et al., 2021).



Figure 1. Examples of Nature-Based Solutions' integration in urban settlements. Author's source.

Besides, Nature-Based Solutions recognise the importance of local knowledge and empower communities to participate actively in decision-making processes. In other words, it emphasises community engagement and cooperation among several stakeholders (Adams et al., 2023; Wickenberg et al., 2022).

Finally, Nature-Based Solutions enhance the resilience of the natural and built environment to some climate change effects (Xi, 2022), as is also better described in the next paragraph.

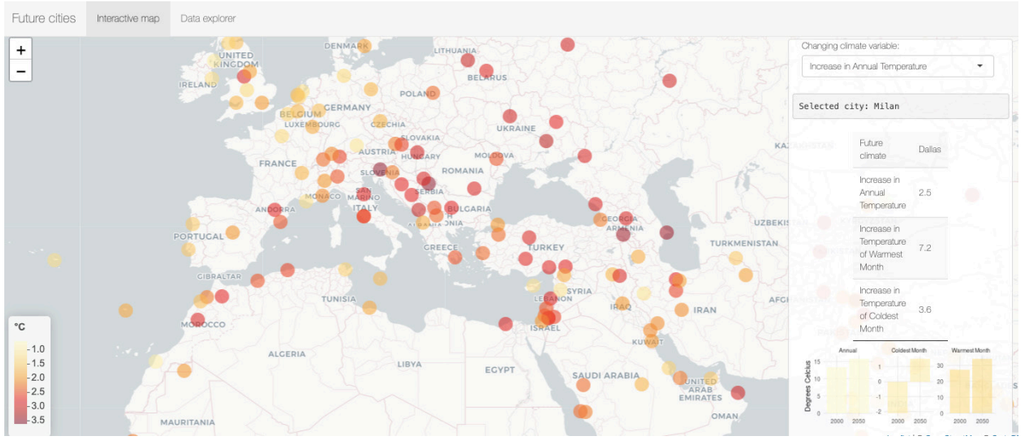
Figure 2. The City of Milan is changing in climate projection by 2050. The expected increase in temperature is about 7.2 °C more than in 2019. (source: https://hooge104.shinyapps.io/future_cities_app/)

Nature Based-Solutions as a strategy for climate change adaptation

Adapting cities to climate change means implementing a certain number of strategies to maintain a comfort and safety threshold in terms of temperature, rainfall, humidity, etc., that will no longer be the same in 20-30 years.

Looking at a City such as Milan in 2050 that will have a similar climate pattern to the City of Denver (Figure 2), there is no doubt that a gradual renovation of both outdoor and indoor environments will be necessary to maintain acceptable ecological and social standards (Bastin, 2019).

By reinventing or renovating the urban environment with Nature-Based Solutions, it is possible to turn cities and neighbourhoods into “urban ecosystems” that contribute



to climate change mitigation and adaptation. Nature-Based Solutions' role in climate change mitigation is mainly due to carbon sequestration. Particularly grasslands, wetlands, and forests (including urban forests) can capture and store atmospheric carbon dioxide through photosynthesis. Trees, in particular, are highly effective at carbon sequestration (FAO, 2016; FAO, 2020).

Nature-Based Solutions are a particularly effective climate adaptation strategy, as they can extend shaded surfaces and the evapotranspiration processes in the urban landscape. Simultaneously, they are suitable for reducing building enclosures' surface temperature and helping the rainwater drainage of collection systems. (FAO, 2016).

The effectiveness of Nature-Based Solutions (Figure 3) for climate change adaptation can be approached from several perspectives (IUCN, 2021). Particularly in the urban landscape, Nature-Based Solutions can be used for the following goals:

- **Urban resilience fostering.** By restoring, maintaining and planting forests, wetlands, and greenery, cities increase their ability to resist some climate-related events like heavy rains, floods, and droughts.
- **Urban Heat Island (UHI) mitigation.** Urban areas are particularly exposed to heat waves and increased temperatures due to the UHI effect (Xi, C. et al., 2022; Candelari E. et al., 2014). Nature-Based Solutions can mitigate the UHI by reducing the temperature locally and providing cooling benefits for citizens.
- **Rain Water management.** Nature-Based Solutions can contribute to effective rainwater management, regulating

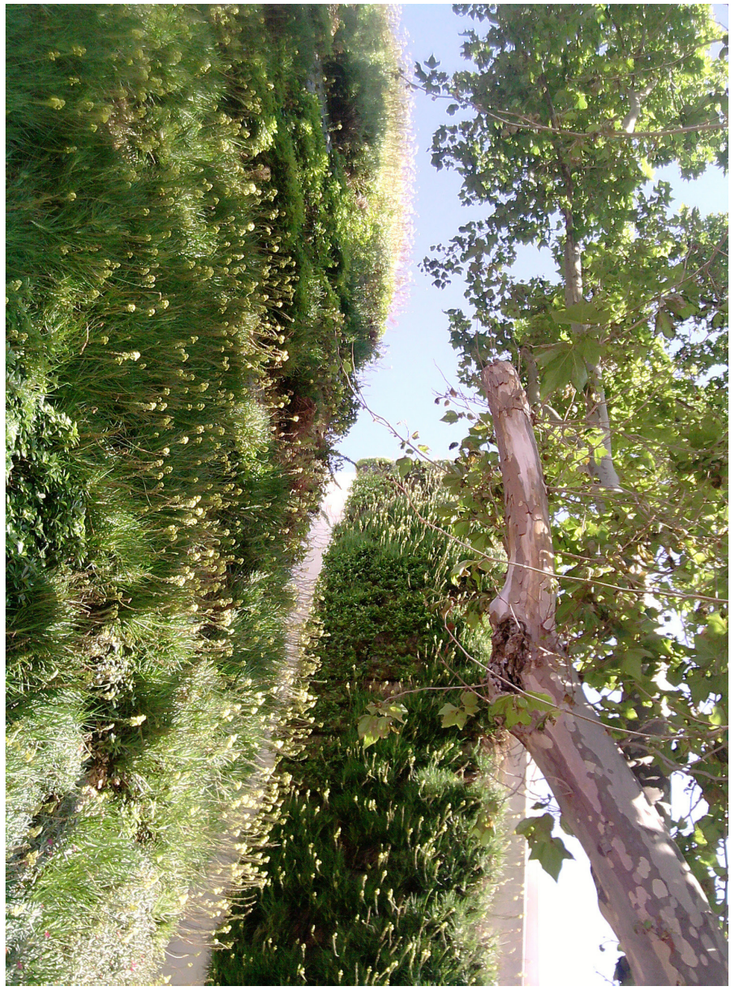


Figure 3. City of Valencia. Example of an integration of Nature-Based Solutions in the urban habitat.
Author's source.

water flows, filtering water, and reducing the risk of floods. They can also enhance water availability during dry periods and recharge groundwater reserves.

Table 1 summarises the significance of trees and greenery for climate change mitigation and adaptation in the urban landscape.

As shown in Table 1, vegetation - regardless of its design - is a compelling adaptation solution to climate change.

Table 1. Significance of urban forest type for climate change. Author's elaboration from the book Guidelines on Urban and peri-urban forestry.

Nature-Based Solutions	Significance on a scale of 1 to 5 (1 = very low significance; 5 = very high significance)	
	Climate change mitigation	Climate change adaptation
Peri-urban forest and woodlands	●●●●●	●●●●●
City parks and urban forest (> 0.5 ha)	●●●	●●●●●
Pocket parks and gardens with trees (< 0.5 ha)	●	●●●●
Trees on streets or in public squares	●●	●●●●
Other green spaces with trees and greenery (i.e. green roofs, green walls)	●●	●●●●

Living Wall Systems and climate change adaptation

The Technology and Environment research team of the Politecnico di Torino carried out some research projects in Nature-Based Solutions. One focuses on Living Wall Systems and some related environmental performances that were investigated and monitored.

Living Wall Systems is a specific vegetated façade solution for a building. The Living Wall Systems' features can be summarised as follows (Giordano et alt., 2017; Riley, 2017):

1. They generally include a modular or container system containing the plants and growing medium. Living Wall Systems are often fastened directly to walls and require a specific frame or vertical and horizontal mullions to support the plant and growing medium's weight.
2. They usually incorporate irrigation to water and provide plant nutrients.
3. They commonly have a higher planting density compared to green walls. The species are carefully planted, making dense vegetation on the wall.

GRE_EN_S (GREen ENvelope System) is the acronym of an EU-funded research project that was aimed at designing, prototyping and monitoring an advanced Living Wall System designed with modular container covered with vegetation, made of recycled and natural materials and characterised by a high-energy/environmental performance (Serra et al., 2018). Among other specific objectives, the research project aimed to assess the potential of the Living Wall System as an adaptation solution to climate change-related environmental effects, namely the UHI.

GRE_EN_S was divided into phases that dealt with the following tasks:

- the survey of existing Living Wall Systems solutions;
- the material sorting for the modular system (container) and the growing medium;
- the design and construction of prototypes;
- the assessment of technological, agronomic, and thermal and acoustic performance on a test cell and a sample building in Turin. (Figure 5).

Three Living Wall System prototypes were designed and built. The third and last prototype was a 50 by 50 cm module, about 6 cm thick (without vegetation). Each module had six pockets arranged in two lines to contain the plants. The module also had a few holes to allow the watering system to pass through. Once the prototype was verified to operate correctly on the test cell, the research team built around 90 modules, 80 of which were installed onto the sample building.

The sample building was aligned along the east-west axis, allowing it to have a south and a north façade. The absence of obstructions around the building permits, especially on the south façade total exposure to the sun in both the summer and winter seasons.



Figure 5. The GRE_EN_S sample building is located in Turin (I). Latitude: 45°04'13". The picture shows the building's surface temperature sensors.

Figure 5 shows a building divided into two independent portions. The first (left) is the Living Wall System developed within the GRE_EN_S project. The second (right) is an insulated wood-clad façade. Both facades have the same theoretical U-value. The two sample building portions were equipped with radiant heating panels with temperature sensors for the winter period.

The monitoring was carried out for 18 months (2013-2015), covering two summers and one winter season. It has been handled by an interdisciplinary team organised as follows:

- The building technology researchers have investigated the water needs during the summer months (L/m² per day of water) and have checked, through regular inspections, for possible failures of materials and components.
- The agronomists have analysed the leaf apparatus of the plant species selected for the sample building (Leaf Area Index - LAI).
- The energy department researchers have monitored the surface temperature of south and north-facing façades (T °C).

The monitoring reports the following findings. It was checked that the water requirement in the hottest period (June to September) is at most 2 L/m² per day. Such value is less than that of an extensive green roof in a Mediterranean climate, for which an average daily water requirement is ranged between 2.6 and 9.0 L/m² per day (Pirouz, 2021).
Although the Living Wall System cross-section is only a few centimetres, thus enabling a small growing medium, the plant species tested (Bergenia crassifolia, Heuchera and Lonicera nitida) did not show any stress, keeping the LAI comparable to an analogue species, planted in soil, under the same climate (Serra et al., 2018).

The measurements in the summer season were carried out in free-floating conditions.

Free-floating conditions helped assess the surface temperature of the sample building walls in the absence of summer air-conditioning services. The outdoor surface temperature was measured on the south and north façades (Living Wall System vs wood cladding).
Particularly the peak temperature difference between the Living Wall System (covered with Lonicera nitida) and the wood cladding wall was found to be 23°C on the average sunny summer day, i.e. the daily hourly average temperature (24h) calculated in July. Such temperature variation is mainly due to the vegetation's evapotranspiration processes. Relative temperature differences were also found with the other plant species tested.

Achievements

The research shows that a Living Wall System with a module thickness of only a few centimetres (6 cm) can be recognised as a suitable technology to improve the adaptation of buildings to the effects of climate change in cities. The Living Wall System reduces the wall surface temperature, thus mitigating the Urban Heat Island (UHI).
However, the Living Wall System's thickness of a few centimetres (excluding the plant part) has another strength. The extra thickness of a wall does not usually exceed 10 cm (counting the 6 cm of the Living Wall System and the air space between the vegetated side and the wall outer side where the irrigation system is installed); this means that the Living Wall System typology, designed and developed within the GRE_EN_S project, has undoubtedly some potential for installation on new buildings, but above all, it is suitable for being easily integrated on existing buildings.
Based on the findings over the 30 months the sample building was monitored, leaf growth was not reduced by the small amount of growing medium in the modules' pockets. The drip-irrigation system, where nutrients were diluted daily, provided a little vegetative suffering (observed on three modules of 80) and good pest resistance.

During the monitoring, leaks in the irrigation system occurred a pair of times (mainly due to some installation difficulties during the construction of the sample building). However, these leaks did not cause any particular inconvenience to Living Wall System's functions. This is due to the air gap, which keeps the plants and the module away from the wall part, the reverse assembling modules' construction techniques, thanks to the bayonet mount to the aluminium frames, and, mainly, the small amount of irrigation used to water the Living Wall System (an annual average of 1.2 L/day/m^2), which avoids any stagnation processes.

No studies on the drainage capacity of the Living Wall System (i.e., its ability to retain rainwater for a prolonged period) were conducted as part of the research. Later studies (Boano et al., 2019; Prodanovic, 2019) conducted on Living Wall Systems with similar features to those described in this chapter have, however, demonstrated the potential capacity of plants and growing medium to remove certain substances, in particular nitrogen, usually contained in grey water and rainwater.

These scientific findings highlight another Living Wall System benefit from being considered once again as a solution to improve the climate resilience of the urban habitat.
In many geographical regions, long-term droughts are frequent, followed by extreme weather events during which many millimetres of water are released onto the ground quickly (from 15 minutes to an hour).
The first flush rainwater usually is rich in pollutants. These leach onto impervious surfaces (e.g. roofs and streets) and are rapidly carried to the sewage system without filtration. In some streets and squares, which are more exposed to certain pollutants, such as nitrogen dioxide (NO_2), green roofs, green walls, and Living Wall Systems could be placed to exploit their filtration and dilution properties.
Milan, for instance, has an interactive map that monitors the air NO_2 concentration, showing 50 by 50-metre pixel images. The map highlights the most high-risk city areas (https://www.cittadiniperlaria.org/dati-inquinamento-milano/) where the Nature-Based Solutions integration programmes could be launched.

Conclusions

Nature-Based Solutions, as pointed out by the European Commission, FAO and scientific literature, are technologies able to provide systemic benefits in the urban habitat. The outcomes described in the GRE_EN_S research also highlight the role of Living Wall Systems as an adaptation solution to tackle climate change. At the same time, it is also worth highlighting the constraints of Nature-Based Solutions deployment, also reported in some of the mentioned papers. One in particular in these conclusions is appropriate to remark. Nature-Based Solutions are predominantly viewed by various stakeholders (citizens, planners, agronomists, politicians) as solutions intended to make the urban landscape more attractive perceptually. It is a correct aim but must be regarded as something other than the leading urban landscape design and construction standard.
Most cities worldwide have a non-negotiable and delayable need to "put into practice" the climate resilience targets in many domestic and international pledges, particularly the Paris Agreement.
It is necessary to make the stakeholders aware of the changing scenarios ahead and the potential of Nature-Based Solutions.
Widespread dissemination to inform stakeholders, including this book, is a chance to raise awareness. Let us hope it works.

Acknowledgements
I acknowledge the financial support provided by the POR-FESR fund.
Special thanks to Prof. Valentina Serra (Department of Energy, Politecnico di Torino) and Prof. Federica Larcher (Department of Agricultural, Forest and Food Sciences, University of Turin) for their cooperation in monitoring and testing the Living Wall System.
I also wish to thank the Department of Architecture and Design's research team, particularly Prof. Elena Montacchini and Prof. Silvia Tedesco. Their work has been crucial in designing, building, testing and implementing the Living Wall System.
Finally, thanks to the small and medium enterprises engaged in the material selection, manufacturing, and installation stage. Living Wall System would never have been realised without them.

References

Adams, C., Frantzeskaki, N., & Moglia, M. (2023). Mainstreaming nature-based solutions in cities: A systematic literature review and a proposal for facilitating urban transitions. Land Use Policy. https://doi.org/10.1016/j.landusepol.2023.106661

Bastin, J. F., Clark, E., Elliott, T., Hart, S., Hoogen, J. van den, Hordijk, I., Ma, H., Majumder, S., Manoli, G., Maschler, J., Mo, L., Routh, D., Yu, K., Zohner, C. M., & Crowther, T. W. (2019). Understanding climate change from a global analysis of city analogues. PLOS ONE, 14(7). https://doi.org/10.1371/journal.pone.0217592

Boano, F., Caruso, A., Costamagna, E., Ridolfi, L., Fiore, S., Demichelis, F., Galvão, A., Pisoeiro, J., Rizzo, A., & Masi, F. (2020). A review of nature-based solutions for greywater treatment: Applications, hydraulic design, and environmental benefits. Science of The Total Environment, 711. https://doi.org/10.1016/j.scitotenv.2019.134731

Candelari, E., Giordano, R., & Serra, V. (2014). Vertical Greening Systems and Urban Heat Island related aspects: outcomes of a research project. In Proceedings of the 3rd International Conference on Countermeasures to Urban Heat Island Proceeding (pp. 12). October 13-15, Venice.

Dorst, H., Van der Jagt, A., Raven, R., & Runhaar, H. (2019). Urban greening through nature-based solutions – Key characteristics of an emerging concept. Sustainable Cities and Society, 49. https://doi.org/10.1016/j.scs.2019.101620

European Commission, Directorate-General for Research and Innovation. (2022). The vital role of nature-based solutions in a nature-positive economy. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/307761

European Commission. (2015). Towards an EU Research and Innovation Policy Agenda for Nature-Based Solutions & Re-Naturing Cities. https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en

FAO. (2020). Global Forest Resources Assessment 2020 – Key findings. https://doi.org/10.4060/ca8753en

FAO. (2016). Guidelines on urban and peri-urban forestry, by F. Salbitano, S. Borelli, M. Conigliaro, & Y. Chen. FAO Forestry Paper No. 178. Rome: Food and Agriculture Organization of the United Nations.

Giordano, R., Montacchini, E., Tedesco, S., & Perone, A. (2017). Living Wall Systems: A Technical Standard Proposal. Energy Procedia, 111. https://doi.org/10.1016/j.egypro.2017.03.093

International Union for Conservation of Nature (IUCN). (2021). Nature-Based Solutions for disaster risk reduction. Available at: https://www.undrr.org/words-action-nature-based-solutions-disaster-risk-reduction

Jessup, K., Parker, S. S., Randall, J. M., Cohen, B. S., Roderick-Jones, R., Ganguly, J., & Sourial, R. (2021). Planting Stormwater Solutions: A methodology for siting nature-based solutions for pollution capture, habitat enhancement, and multiple health benefits. Urban Forestry & Urban Greening, 64. https://doi.org/10.1016/j.ufug.2021.127300

Pirouz, B., Palermo, S. A., & Turco, M. (2021). Improving the Efficiency of Green Roofs Using Atmospheric Water Harvesting Systems (An Innovative Design). Water, 13. https://doi.org/10.3390/w13040546

Prodanovic, V., McCarthy, D., Hatt, B., & Deletic, A. (2019). Designing green walls for greywater treatment: The role of plants and operational factors on nutrient removal. Ecological Engineering, 130. https://doi.org/10.1016/j.ecoleng.2019.02.019

Riley, B. (2017). The state of the art of living walls: Lessons learned. Building and Environment, 114. https://doi.org/10.1016/j.buildenv.2016.12.016

Serra, V., Bianco, L., Candelari, E., Giordano, R., Montacchini, E., Tedesco, S., Larcher, F., & Schiavi, A. (2018). A novel vertical greenery module system for building envelopes: the results and outcomes of a multidisciplinary research project. Energy and Buildings, 146. https://doi.org/10.1016/j.enbuild.2017.04.046

Sowińska-Świerkosz, B., & García, J. (2022). What are Nature-based solutions (NATURE-BASEDSOLUTIONS)? Setting core ideas for concept clarification. Nature-Based Solutions, 2. https://doi.org/10.1016/j.nbsj.2022.100009

Wickenberg, B., Kiss, B., McCormick, K., & Palgan, Y. V. (2022). Seeds of transformative learning: investigating past experiences from implementing Nature-Based Solutions. Frontiers in Sustainable Cities, 4. https://doi.org/10.3389/frsc.2022.835511

Xi, C., Ding, J., Wang, J., Feng, Z., & Cao, S. J. (2022). Nature-based solution of greenery configuration design by comprehensive benefit evaluation of microclimate environment and carbon sequestration. Energy and Buildings, 270. https://doi.org/10.1016/j.enbuild.2022.112264

Urban settlements are constantly increasing, and we are approaching a point where over half the human population will live in cities. This human concentration gives rise to complex problems, ranging from pollution to difficulties providing resources to sustain the inhabitants' lives. This situation results in low resilience of urban settlements to events that may affect the territory and the settled society. The complexity of consumption patterns and the flows of energy and matter in transit (inflows and outflows) require a profound rethinking compared to the past, as these flows differ in magnitude and complexity. This book, New Energies for the City, represents an initial attempt to reflect on the complexity and specificity of urban metabolism, as well as on potential solutions to address and transform the identified critical issues into possible elements for mitigating problems. New Energies for Cities explores the challenges and opportunities related to the transition towards more sustainable and resilient cities, with particular reference to Milan.



UNAPRESS 06
Urban NarrAction

urbannarraction.net

ISBN 9788894454277