

## **NATURE-BASED SOLUTIONS FOR CLIMATE RESILIENT BUILDINGS AND CITIES**

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### **ABSTRACT**

The paper addresses the topic of nature-based solutions applied in the architectural and urban design. These ideas are analyzed in the context of the opportunities they create for the humanity in terms of the sustainable growth and environmental protection. Nature-based solutions are inherently taken from nature. The first part of the paper presents their tremendous potential to be energy and resource-efficient, and resilient to change. In the second part of the research particular concepts driven from nature (copied from nature or inspired by nature) proposed for the buildings and cities are described and evaluated. The author discusses their functional usefulness, spatial appropriateness, adaptation to local conditions, end-user comfort, environmental benefits and the possibility of duplication. Nature-based solutions applied in urban planning can make cities more climate resilient and contribute to ecosystems restoration. The paper describes how sustainable urbanization can stimulate economic growth, make cities more attractive and enhance well-being of the inhabitants. It is also explained how particular buildings can benefit from the concepts driven from nature e.g. by increasing their energy efficiency and performance in terms of raw material consumption. In purpose to properly response to the climate challenge, humanity has to establish a new kind of partnership with nature. Using nature-based solutions should be considered as an important part of this approach. The concepts presented in this paper show some of the most promising options, such as integration of living systems with built systems and innovative combinations of soft and hard engineering. In conclusion some of the most promising nature-based solutions for climate resilient buildings and cities are indicated.

**Keywords:** *climate, ecosystem, building, resiliency, sustainability*

### **INTRODUCTION**

Nature-based solutions applied in the architectural and urban design are analysed in the context of the opportunities they create for the humanity in terms of the sustainable growth and environmental protection. Nature-based solutions are inherently taken from nature. The first part of the paper presents their “tremendous potential to be energy and resource-efficient and resilient to change” [1]. In the second part of the research particular concepts driven from nature (copied from nature or inspired by nature) and proposed for the buildings and cities are described and evaluated. The author discusses their functional usefulness, spatial appropriateness, adaptation to local conditions, end-user comfort, environmental benefits and the possibility of duplication. That leads to the selection of the most promising nature-based solutions for climate resilient buildings and cities.



## **OPPORTUNITIES CREATED BY NATURE-BASED SOLUTIONS**

Nature-based solutions applied in urban planning can make cities more climate resilient and contribute to ecosystems restoration. Sustainable urbanisation can also stimulate economic growth, make cities more attractive and enhance well-being of the inhabitants. Particular buildings can benefit from the concepts driven from nature e.g. by increasing their energy efficiency and performance in terms of raw material consumption. Nature-based approach should be perceived as the basis of the maintenance, restoration, and sustainable use of ecosystems, which is a first step for the climate change mitigation [2]. In this light, among the most promising opportunities created by nature-based solutions we can distinguish:

- Restoration of degraded city ecosystems (including water, soil and green areas)
- Enhancing biodiversity in cities, creating green and sustainable spaces
- Natural cooling and ventilation within the city
- Creating energy networks based on RES
- Increasing carbon sequestration
- Improving risk management and resilience, e.g. in coastal areas.

In the building scale nature-based solutions may contribute to:

- Increased energy and resource efficiency
- Innovative thermoregulation
- Resilient response to change
- Improved user comfort and well-being.

## **ACTIONS INSPIRED BY NATURE FOR CLIMATE RESILIENT CITIES**

In this part of the paper some nature-based solutions are analyzed in terms of their adequacy for the actions aimed towards climate resilient cities. The important role of nature-based urban regeneration is emphasized with particular stress on blue and green areas. It is also shown how natural cooling and ventilation can improve the quality of life in the cities. Finally the author explains the concept of ecosystem restoration and conservation inspired by nature.

## **URBAN ECOSYSTEM REGENERATION INSPIRED BY NATURE**

While a lot of actions have been undertaken for the cultural heritage conservation in cities, very few are oriented towards tackling challenges arising from biodiversity loss, climate change, more frequent natural disasters and rapid urbanisation [1]. At the same time nature-based solutions applied in the city scale can bring about considerable benefits for the local climate, biodiversity and water management. An interesting example of bioclimatic urban design in combination with urban ecosystem regeneration and climate action can be observed in ParcBIT, near Palma de Mallorca, Spain. ParcBIT project, developed in 1994-1999 by

## Section GREEN DESIGN AND SUSTAINABLE ARCHITECTURE

Richard Rogers & Partners (currently Rogers, Stirk, Harbour + Partners) and inaugurated in 2002, was supported by Ministry of Economic Development for the Balearics Region and partially financed by the European Union Thermie Programme. The proposal addressed the issue of regeneration of the dry and neglected northern suburb of Palma de Mallorca. The concept was based on the ecosystem healing with the increased biodiversity level that prevents soil erosion.

Nature-based solutions developed for ParcBIT were based on the series of biological and climatic analysis. One of the most important aspects was to provide the necessary amount of water for the new estate and surrounding agricultural areas (50 hectares altogether). Research model allowed to calculate the water demand for the summer season, when the precipitation level is insufficient. On the basis of this calculations the network of water reservoirs and weirs was designed to collect water from the winter rainfall and use it in the summer. The new development complements the landscape, local ecosystem and circulation patterns [3]. Buildings are located on the terraces, among the trees (Fig. 1). Ventilation corridors and shadowing elements are combined with the pedestrian communication system. The parking area located outside the estate contributes to better air quality as well as to the continuity of watercourses and small animals paths (Fig. 2).



*Fig.1 ParcBIT, Palma de Mallorca (from 2002), Richard Rogers and Partners. Buildings are located on the terraces, among the trees. Phot. B. Widera, 2013.*



*Fig. 2.*

Sustainable community uses renewable energy sources and applies elements of circular economy model. ParcBIT is self-sufficient in terms of water and food supply. Electricity is produced from the photovoltaic panels located outside the estate, while thermal comfort in the buildings is provided by the central heating and cooling system (CHCP). The edifice complex is equipped with the collection and recycling system which includes also water treatment and recovery unit. ParcBIT houses residential buildings, offices, business centres, commercial, service and educational facilities (school and kindergarten). Some of the most valuable aspects of this project are related to its positive influence on the local climate resulting from advanced technology used for the benefit of the environment and the users.

### **NATURE-BASED CONCEPTS FOR ECOSYSTEMS RESTORATION: GREEN AREAS, SOIL AND WATER CONSERVATION**

Remarkable cases of nature-based solutions are the ones that use the same technologies that can be found in nature. Many of them are related to the conservation of green areas, soil and water. These are phytoremediation, soaking, aerating and others. Some natural methods, e.g. evapotranspiration, may be used for carbon sequestration and thus contribute to preventing climate change.



*Fig. 3.*

The water aeration technique was successfully applied in Sparman (Kamenz, Germany). This former granite quarry was filled with water in 1970s but the water was muddy, with very low biodiversity level. In the first decade of the 21st century actions for ecosystem restoration were undertaken. They involved innovative concept of water conservation. A hose connected to compressor (which normally serves for filling diving cylinders) delivers air to the depth of 60 meters, which results with water aeration. Constant water movement prevents rotting processes at the bottom. That contributes to cleaner and warmer water inhabited by many plants and fish (e.g. huge sturgeons and pikes). The quarry is used as an attractive spot for scuba diving, which is an interesting option for revitalization of post-mining areas (Fig. 3). Local dive center developed environmentally safe infrastructure for divers and visitors, such as tank filling station, safe access to water, underwater platforms for exercises and bathymetric maps of the reservoir. Using any kind of cosmetics and chemical products is strictly prohibited. Multiple information boards help the guests to understand the ecosystem demands and challenges. This action helps to promote ecotourism and support local communities as new jobs and business opportunities are created (e.g. accommodation, restaurants, shops, etc.) [4]. However, the biggest advantage of this nature-based concept is its positive influence on ecosystem restoration, including green areas, soil and water

conservation. Similar methods can be duplicated to restore degraded water areas in cities and adapt them for well-being and sport activities.



*Fig. 4.*

## **NATURAL COOLING AND VENTILATION OF URBAN AREAS**

The most natural and effective way to provide cooling and ventilation in urban areas is to fill them with greenery. Trees, creepers, green roofs and walls offer shading, keep good humidity balance, absorb noise and dust, absorb CO<sub>2</sub> and produce oxygen. The concept of properly designed green corridors and wind passages that distribute fresh air throughout the urban tissue allows for natural ventilation. The successful application of natural cooling methods in the contemporary city could be observed in Miami (Florida, USA). With its hot and humid climate Miami suffers from overheating of urban areas. Especially in the summer months it is crucial to provide free access to outdoor zones with comfortable temperature range. Pérez Art Museum in Miami by Herzog & de Meuron (2013) with the green installation by Patrick Blanc is a spectacular example of the edifice dedicated to art, that created a high quality public space with natural shading and ventilation in its surroundings (Fig. 4).



*Fig.5 Pérez Art Museum, Miami (2013) Herzog & de Meuron, P. Blanc.  
Recreation area. Phot. B. Widera 2017.*

The elevated platform on which the three-story building is located and the extended canopy create a shaded veranda which brings the park into the museum [5]. French botanist, Patrick Blanc, in cooperation with local landscape architects and horticulturists, designed impressive columns and tubes hanging from the openwork ceiling planted with lush vegetation. The vertical gardens with tropical plants enfold the museum. The perforated canopy allows daylight penetration into the building.

The Pérez Art Museum and the green area around it are located on the waterfront. Landscape design encourages pleasant walking and outdoor recreation for families and tourists seeking for a moment of relax or open-air casual dining (Fig. 5). Various activities and events are regularly arranged. It is worth to note that the greenery was design to enrich existing ecosystem and create a home for birds, bees and small animals. The waterfront park was further extended with the establishment of Phillip and Patricia Frost Museum of Science (2017) by Grimshaw Architects in cooperation with Rodriguez & Quiroga Architects Chartered. Together with Watson Island Park, Miami Children's Museum and the Jungle Island, the complex consisting of parks, museums and waterfront allowed for cool breeze penetration towards Overtown. In the consequence it contributed to the improvement of the air quality as well as the thermal and visual comfort of the users. Environmental benefits should also be emphasised.

### **NATURE-BASED CONCEPTS APPLIED IN BUILDINGS**

Some innovative nature-based concepts for building design are briefly presented in this part. Examples include animal-based thermoregulation, thermal mass and water storage applied in the building scale [6].

## **THERMOREGULATION AND ENERGY EFFICIENCY**

Animal thermoregulation becomes more and more popular inspiration for nature-based building design. For example the fat stored in the camel's hump is a source of energy and water as a metabolism by-products. If the camel was evenly greasy, it would be difficult for him to transfer the heat surplus from the body to the environment (this process takes place mostly at night when the air is cooler). This observation can be used as a basis for building thermoregulation and energy efficiency. Some of the interesting cases involve passive night cooling combined with water storage. Radiant cooling solutions have been lately improved with more effective distribution of water or other cooling liquid. It is possible with the adequate control systems, such as BMS or Domotica. Promising results have been also achieved with the application of Passive Infrared Night Cooling (PINC) technology developed by ZAE Bayern in combination with phase change materials used for the heat storage and cooling [7].



*Fig.6 SolarLeaf, Hamburg (2013) bioreactive façade, Splitterwerk Architects, Arup. ©Colt/Arup/SCC.*

## **RESILIENT RESPONSE TO CHANGE**

Ability to provide adequate response to changing environmental conditions is one of the most amazing features of nature. Nature-based solutions for buildings discussed in this paper combine multiple functions and benefits to make the system more resilient: allow for maximum level of the user safety and comfort, preserve ecosystem health and biodiversity, reduce environmental pollution with carbon storage, etc. Advanced building skins can adapt to changing environmental conditions with properly designed gas and liquid exchange as well as various temperature and humidity control strategies. Façade materials containing titanium dioxide are able to eliminate pollutants from the air. Similar effect can be achieved with wall bio-filtration systems where properly selected green plants absorb toxins and improve air quality with higher oxygen partial pressure. Some innovative hybrid façade solutions combine photovoltaic energy with thermoregulation allowing for recovery of the part of solar energy which was not converted to

electricity. Other nature-based solutions demonstrate sustainable energy production, e.g. from organic photovoltaic cells or microalgae biofaçades [8] (Fig. 6).

## CONCLUSION

In purpose to properly response to the climate challenge humanity has to establish a new kind of partnership with nature. Using nature-based solutions should be considered as an important part of this approach. The concepts presented in this paper showed some of the most promising options, such as integration of living systems with built systems and innovative combinations of soft and hard engineering. Sustainable urbanization can stimulate economic growth, making cities more attractive and enhancing well-being of the inhabitants. Particular buildings can benefit from the concepts driven from nature e.g. by increasing their energy efficiency and performance in terms of raw material consumption. Other valid opportunities created by nature-based solutions are related to healing and restoration of degraded city ecosystems (including water, soil and green areas), enriching biodiversity in cities, creating green and sustainable spaces, providing natural cooling and ventilation within the city, creating energy networks based on RES, reducing pollution and environmental emissions with increased carbon sequestration, improving risk management and resilience, e.g. in coastal areas. The final conclusion of the paper is that nature-based solutions are often low-cost, logical and efficient and therefore should be considered in the first place in any kind of environmental and climate actions.

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