Blue-Green Infrastructures for Buildings and Liveable Cities

by Herbert Dreiseitl

A Turning Point

Blue and Green in nature are never static but in a state of constant flux. The dynamic of water and greenery is the environment's resilient language, its potential to create living systems and enhance evolution. Blue and Green in nature are the living landscape.

The ever-changing character and process of landscape have always been a challenge for the human desire for comfort and freedom. Our imaginations and desires to be more independent created architecture as we know it today. In today's urban fabrics, buildings of any function are mostly conceived as shelters. They define and separate an inner space from the outer environment. Here are the defined and controlled conditions of such urban rooms and there is the uncontrolled "wilderness" with its unforeseen and unpredictable surprises of instability like temperature extremes, wind and rain, and limited natural light. Even though we may not be fully aware of all the benefits for our civilizations that this strict separation of the inside and the outside brings along, we often call architecture the "third skin," in a metaphor suggesting that we experience it as the most exterior layer beyond our natural skin as the first and our clothes as the second layer.

Buildings have been getting more and more efficient in this separation of inner space from the exterior environment.
For the first time in history, and due to our very high standards of insulation, air control, integrated intelligent control systems, light regulation, etc., we can live in buildings in the urban fabric for weeks and months almost without any contact with the natural environment. Cities, like perfect machines and the supporting infrastructures, seem to make the natural environment a byproduct and dependency on nature a relic of the past.

Today, and probably even more so in the future, we can clearly see that this is not true. We are not independent but are instead embedded in and supported by our environment, in the many ways of which we are well aware. In light of this awareness of environmental damage and problems, it seems that today we are at a turning point. Missing vital aspects of interaction of the interior of buildings with the exterior environment is creating more and more challenges not only in physical terms but also in terms of the mental and cultural dimensions of society.

Buildings tell stories and create awareness. Basically any building receives water, air, comfort, energy, and virtual information from its outside. Consumers in buildings rely on natural resources that are coming from the outside, in the broadest sense. This also includes our daily food supply. We rely on minerals, nutrients, on good soil for agriculture, products from forests, oceans and so on, resources that often come from far away and that are transported into the urban fabric to feed each building and its inhabitants. Disposing of the remaining substance, including wastewater and sewage, is a challenge for which we have not yet found solutions that are not harmful for the environment.

Natural resources are the basis of our standard of living and the liveability of our cities. Even in the most sophisticated communities, especially children often have only a little knowledge about how food is produced, how e.g. tomatoes grow and where cheese comes from; they may see water and earth as something unaesthetic and dangerous that is better to watch on television than to touch with their own hands. Having encountered in my own practice and involvement with people many unreasonable fears and strange ideas about the environment, I think that such reactions show to what degree we have become alienated from the natural context in which we live. A lack of trust and confidence in values is often the reason for doubtful behavior, vandalism, and self-destruction, and constitutes a high risk for society.

How can new architecture bridge the division between outside and inside? How can we integrate green elements into buildings by creating win-win situations that produce better air, acoustics, biodiversity, and eventually liveability? How can we overcome the traditional separations in the building professions?

Blue-Green infrastructures is a concept in response to such questions. While it is becoming more and more important, it is not yet properly understood in its functions and values for the infrastructures of the city and its inhabitants: as a backbone for liveability and a dynamic repository for balancing and stabilizing life processes. To measure, count, and quantify the value of blue and green components in the urban context is a much more complex task than to do the same for the hard forms of engineered infrastructure, buildings, and real estate developments. As a first step, it is important to understand and design fluids like water and to learn how to imagine the processes of change related to green factors in design.

From Horizontal to Vertical

Why is it that parks and other green spaces are so often uninteresting and uninspiring, reduced to the role of placeholders for future developments or gaps in between buildings, fragmented and disconnected, so much unlike the seamless spaces of transition that would be needed for plants and animals to create a rich and diverse bio-habitat? Why are waterways, rivers, and streams often so unattractive and poorly treated in our cities today? For decades cities have been turning their backs on green corridors and especially on water bodies. The ensuing dilemma appears as flooding, erosion, and pollution. One major reason is that we have occupied much if not all of the spaces that previously belonged to the waterways, leaving only limited room for water after heavy storms and downpours. The rapid growth of urban sprawl in many parts of the world will continue to cover the earth's surface with asphalt and concrete, creating direct runoff effects that channel large amounts of water at the same time to the same place instead of slowing it down and holding it back to avoid such concentrations.

This state of affairs also has a significant effect on microclimates. The lack of Blue-Green infrastructures limits filtration and fails to hold back the microscopic wind-blown particles. The resulting increase in dust particles contributes to unhealthy living conditions. In city centers with fewer green spaces and water bodies, the concentration of dust particles is significantly higher; streets and buildings with greenery and trees have lower dust particle concentrations than those without. According to the WHO, 7.1 million people died as a result of air pollution in 2012.

As is well known from hot deserts, an absence of water incurs temperature extremes, with very high temperatures during daytime and a drop as low as below the freezing point at night. Similar microclimatic effects are observed in cities, where city center temperatures can easily deviate from those of the surrounding countryside by up to 10° C. Water and vegetation are the buffers that help to regulate temperature extremes.

Buildings and urban structures that are not flexible enough will not be able to cope with the dynamic forces of change, neither in the unpredictable rhythms of the environment nor in terms of socio-economic and political transformations. A comparison between structures in the natural environment and structures in the urban setting of most cities today reveals a significant difference: natural structures work with flexible spaces and resilient principles over time, using them as a potential for dynamic reactions and maintaining the balance in any event from a soft change to an unexpected disaster—including extreme climate conditions. It is all about processes over time, processes that have resources like integrated spaces, such as wetlands, available to function as buffers.

In our cities, we are confronted with even short-term changes between different needs at different times at one and the same place. Urban spaces can completely change in function throughout the day. For example, in India, a space that is used as a market in the morning can be used as a food court at noon, a bazaar in the afternoon, and an event space for a wedding in the evening. The urban planner Rahul Mehrotra calls this phenomenon "the kinetic city."

In this context, one can say that running out of space is one of the biggest challenges we are confronted with in most cities today. Growing populations that result in a growing demand for housing are in conflict with the different needs for infrastructures. In this ongoing conflict of priorities and ownership, all too often Blue-Green Infrastructures are the losers, for a large number of reasons. Therefore, it would be insufficient to limit Blue-Green Infrastructures to the remaining spots on the ground floors, so to speak, of cities. To keep cities healthy and to react to climate change with mitigation and resiliency, we have to explore other opportunities. One is to occupy the building itself.

Connecting Inside and Outside

For centuries, buildings have mostly been constructed with bricks, concrete, steel, and glass, and there has been no space for plants and water. Water, indeed, was seen as one of the biggest enemies; grass and moss were regarded as signs of deterioration. In this context we encounter historical examples of green roofs and breathing walls with willow bushes and trees.

In cities like Singapore, we now see a new trend in that innovative buildings contribute to urban Blue-Green Infrastructures. Buildings like the PARKROYAL on Pickering, the Tree House, or the Khoo Teck Puat Hospital are examples of a new generation of vertical green in the city. This includes the topic of water for irrigation, evaporation, and filtration and has many side effects for Blue-Green infrastructures in the urban environment.

Milestones, Experiments, and Change

Looking back to the development of Blue-Green Infrastructures, there are some pilot projects that have changed architecture and opened a new mindset.

Joachim Eble Architektur/Atelier Dreiseitl/Transsolar, Prisma, Nuremberg, Germany, ~~1991,~~ ~~interior~~ public areas.

Joachim Eble Architektur/Atelier Dreiseitl/Transsolar, Prisma, Nuremberg, Germany, 1991. Glass roofs. Artistic interpretation of water movement painted on glass.

The Prisma in Nuremberg, Germany, built in 1991, was a pioneer project with integrated vertical and horizontal green terraces, featuring a rainwater harvesting system that also functions as an air-conditioning, air filtration, and stormwater infiltration system. It is a mixed-use facility with 61 residential units, 32 offices, nine stores, a coffee house, and a kindergarten, developed for Karlsruher Life Insurance Company A.G. in a cooperation between Eble Architects in Tübingen, Atelier Dreiseitl in Überlingen, and Transsolar in Stuttgart. The urban ecology approach and technology employed at the time is still up-to-date today. Rooftop water is collected, cleansed, and sent through the building in two separate cycles. The first cycle irrigates the plants in the 15-m-high greenhouse, supporting an interesting waterscape of creeks and ponds. The other cycle pumps water between colorful, tall glass walls. Fresh air from the outside is filtered and conditioned by seven waterfalls with a height of 5 m each as part of an innovative rainwater management system. It features a process in which air enters the interior through open crevices and exits purified and cooled together with the waterfall into the greenhouse. The jet effect is not only an innovative technical solution but also an artfully designed environmental feature that encourages awareness of natural resources.

The combination of external rainwater harvesting and internal water usage results in a pleasant interior climate, as demonstrated by the air quality both in winter and summer and by the vitality of the plants. The sound of the waterfall creates a special and relaxing atmosphere in the greenhouse. In the infiltration system below the underground garage, remaining rainwater seeps into the ground under the building and refills the groundwater aquifer.

Visitors to Frankfurt can enjoy a grand view over the city from the Commerzbank Tower, completed in 1997 and for a long time Germany's tallest office building, designed by architects Foster + Partners and engineers Arup and Krebs & Kiefer. Designed as both a symbolic and functional green building, the Commerzbank Tower, although provided with active climate control systems, uses natural ventilation to reduce energy consumption, which has made the building one of the world's first ecological skyscraper. The most prominent innovation are three interior sky gardens that are situated in the east, south, and west of the tower, contributing additional green layers and offering ideal climatic conditions for the various plants they house. Sycamores, cypresses, and a redwood tree reach up to the 16-m-high glass ventilation flaps. Another feature are winter gardens on many different levels, which in the relatively

Bockemühl, Weller und Partner/Atelier Dreiseitl, Nikolaus Cusanus House, Stuttgart, Germany, 1992. Rainforest-like landscape with creeks and cascades in the roofed courtyard of the building.

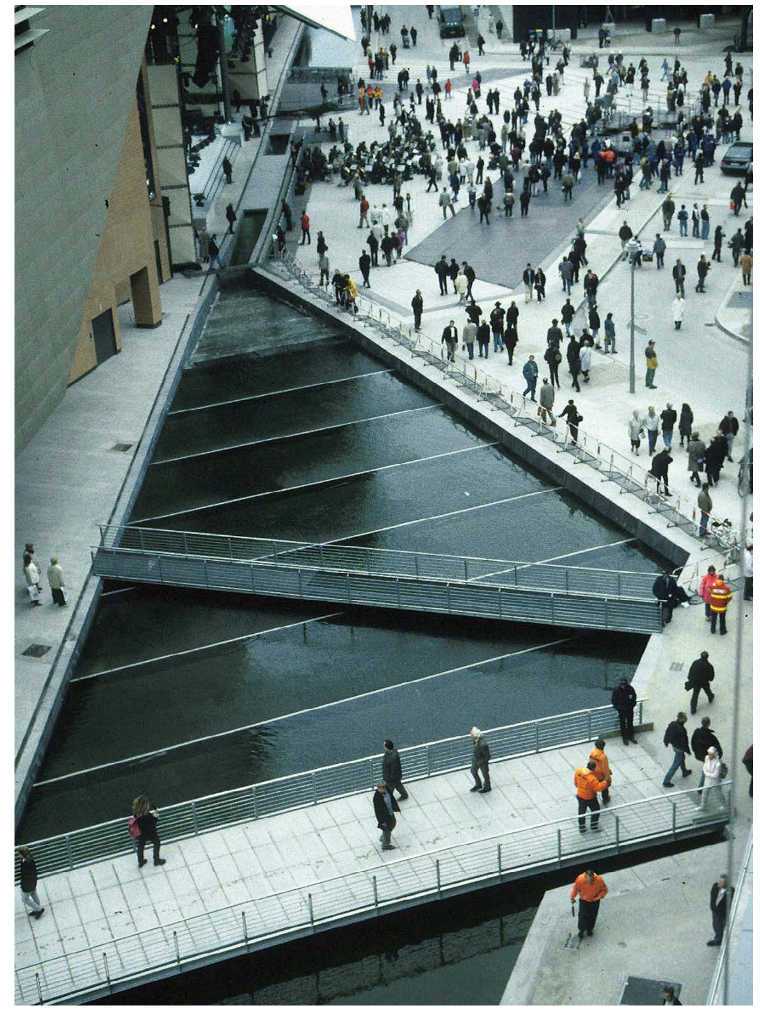
harsh climate of Frankfurt that is characterized by cold and dark winter days, provide spaces for the inhabitants to get fresh air and to socialize. The gardens also allow for vast amounts of natural light in the interior and provide pleasant views. Operable facade elements permit natural ventilation throughout the entire structure. Since 2008, the roof on the 57th floor has been home to a pair of rare and endangered peregrine falcons, tenderly cared for by the building's manager.

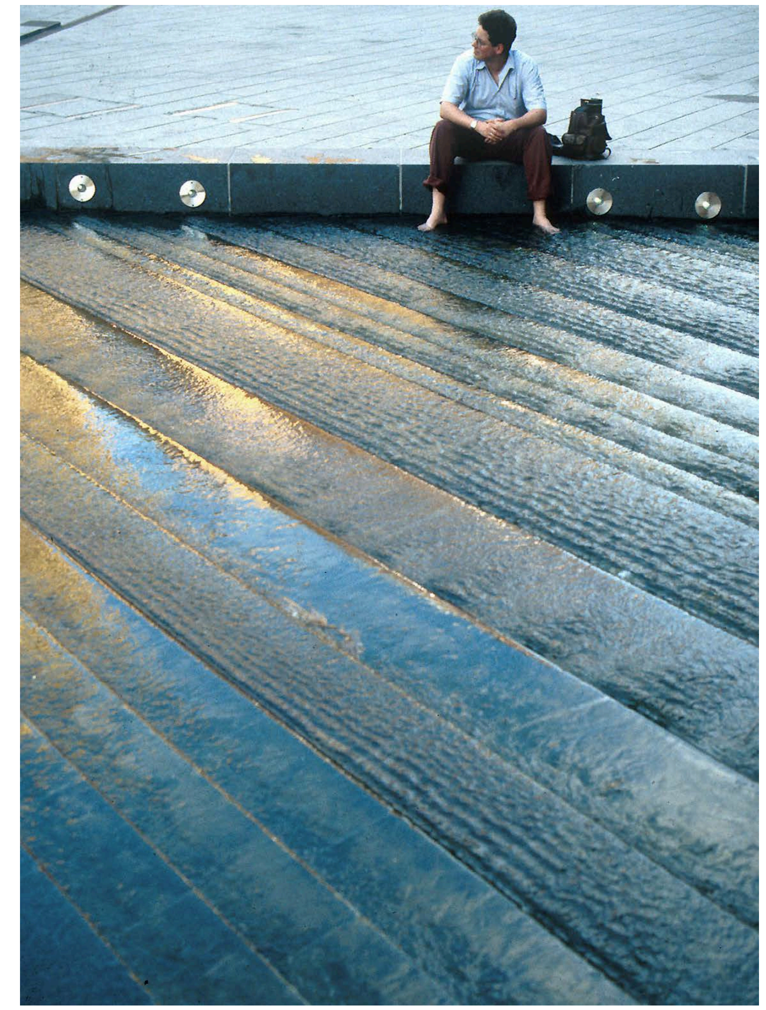
As one of the tallest buildings in Europe, the Commerzbank Tower brought ecological architecture out of its alternative niche and into the focus of some of the most ambitious architectural designs of the time. By opening up the previously mostly closed facades of tall buildings, the project proved that natural air and light can be brought into skyscrapers by way of stacked green spaces.

The Nikolaus Cusanus House in Stuttgart, Germany, a nursing and retirement home for 135 residents, responds to the desire to live close to nature in a central urban location. The generous 800 m² entrance hall provides plants, natural light, and water in a grand green space. No concrete or other hardscape seals the floor of this space. It is all natural earth, with air ventilation funnels embedded in it. A creek, fed by rainwater collected in cisterns, travels through the entrance hall. Water channels, or rills, are partly formed by local rocks found during construction, with meanders chiseled in or several rocks layered on top of each other. The tropical plants and natural stones make the courtyard a pleasant space on hot summer as well as on cold winter days. A small waterfall provides a calming sound, while a constant splashing and gurgling of water allows for private conversations. The adjacent platform-like floors reach out to the courtyard, making it, in an emphatic sense, the central space of the building.

In Berlin, Germany, in the heart of the city formerly divided into an eastern and western part, the teams of Renzo Piano, Christoph Kohlbecker, and Herbert Dreiseitl designed a sustainable city quarter in which water is used as a symbol of healing and to bring the two parts together again. The redevelopment of Potsdamer Platz with its urban water bodies employs sustainable stormwater management strategies in interactive water features and urban open space design. The large urban pond and watercourse use biologically cleansed stormwater collected from the surrounding buildings. The combination of green roofs, cisterns, cleansing biotopes, and watercourses used for natural drainage was the first urban waterscape at such a scale (1.2 ha). At the central Marlene-Dietrich-Platz, water forms

Renzo Piano Building Workshop/Kohlbecker Architekten & Ingenieure/Atelier Dreiseitl, Potsdamer Platz, Berlin, Germany, 2000. Dialogues between concrete and water. A large naturalized pond acts as cleansing biotope and retention basin.





Atelier Dreiseitl, Tianjin Cultural Park, China, ~~2012, rendering~~ and night view.

Atelier Dreiseitl, Strategic Flood Masterplan, Copenhagen, Denmark, 2013. Rendering of Gasværksvej street during normal rain. Rendering of Sankt Jørgens Sø with new park, of which the lower parts act as a retention basin during heavy rain events.

floating images that are shaped by flowing steps and cascades. Harvested rainwater is used to flush toilets and to irrigate the adjacent green spaces. Another innovative feature is a water cleansing system on the basis of natural filter substrates that function without any additional chemicals.

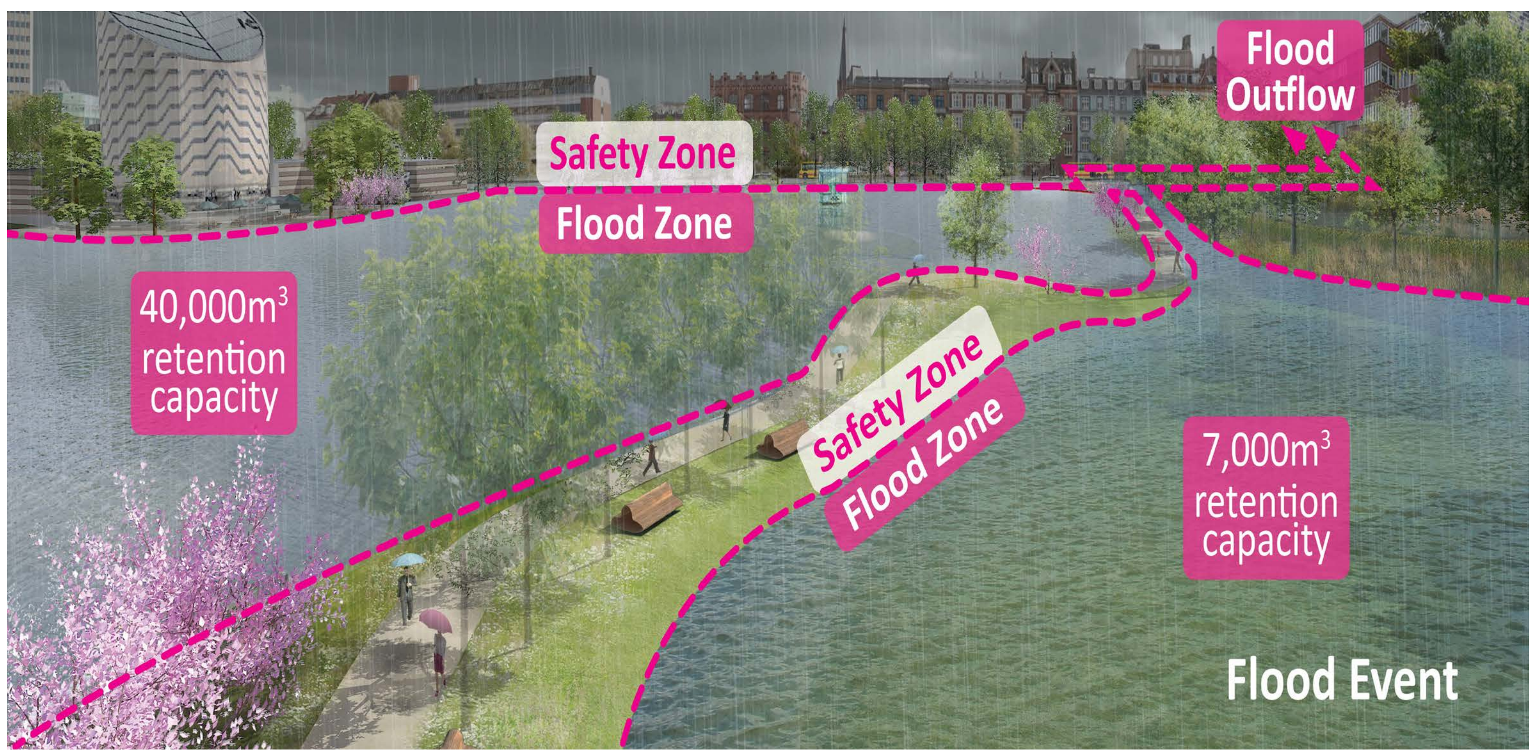
These innovative Blue-Green Infrastructures in the heart of a European capital created enormous interest and became a model for other parts of the world including the booming city developments in China. An example is the City of Tianjin, located half an hour by high-speed train southeast of Beijing and among China's top five cities. Situated close to the sea and endowed with a high groundwater table, Tianjin needs to prevent seawater from encroaching on inland areas. The design of a new cultural district, including a new opera house and a city hall, used the Berlin experience as a model for integrated Blue-Green Infrastructure. The urban pond system of 90 ha (222 acres) functions as a stormwater feature, a balancing water body that can process a once-in-a-decade storm event and buffer a once-in-a-century downpour. Avenues of trees and other plants shield the spectacular waterfront from cold Mongolian winds. The urban pond reduces temperature extremes, while its picturesque beauty sets the scene for Tianjin's outstanding cultural architecture.

A lesson learned from these examples is that sustainable solutions function best when they are networked on the scale of a large watershed, in an expansive urban context connected to a full range of other infrastructural systems, and when they are socio-culturally integrated. Many cities have lost almost all of their ecological structures and green corridors, including open waterways, productive landscapes, and park networks. By contrast, the most successful contemporary cities have managed to maintain and further develop their Blue-Green Infrastructures to their benefit. Among these is Copenhagen, Denmark. The Green Finger Plan of 1947, a strategy that was easy to understand and that in fact was implemented, has kept urban corridors free of construction. Today, Copenhagen is among the greenest cities, with the highest liveability and lifestyle rankings in the world.

Engineering and Beyond

Much research and development has gone into engineering in terms of mathematical models for hydraulics, flood risk analysis and settlement protection, energy efficiency, and other topics. Yet we still know very little about how an urban society can live

Atelier Dreiseitl, Strategic Flood Masterplan, Copenhagen, Denmark, 2013. Renderings of the new park at Sankt Jørgens Sø during fine weather and flooded during heavy rain.



Atelier Dreiseitl, Strategic Flood Masterplan, Copenhagen, Denmark, 2013. Sectional renderings of Sonderboulevard during fine weather and during a cloudburst event, where the landscaped area in the middle acts as retention basin.

in harmony with its natural environment. The Blue-Green resources are there, but what kind of water systems are adequate and will work effectively in the long term? What kind of infrastructure fits the scale of individual buildings with their specific functions and users?

In whatever scale we conceive of architecture, the Blue-Green Infrastructures are a driver of, and play a fundamental role in, connecting buildings to urban regions with their specific environments. Without proper management of water systems and green structures on a larger scale, there is no basis for the long-term sustainability of the implementation of small-scale solutions on the level of individual buildings. Having worked on urban landscape and water issues in many different regions and climate zones for more than three decades, it is my view that principles and guidelines can help but, as Blue-Green structures are alive and subjected as living systems to resilient change, solutions have to be individually adapted.

Obviously, climate zones with high levels of humidity, much rain, and warm temperatures have an advantage and work well for lush greenery. There is a higher risk that traditional engineering with water and greenery fails in projects and cities of arid regions. It would be unrealistic to expect the same intensive green in Abu Dhabi as in the Garden City of Singapore. Instead of planting non-local vegetation that requires enormous water and nutrient inputs, it would be preferable to use local plants with specific sensitivities and adapted characteristics. This would require an appreciation of the different aesthetics of desert plants with their subtle forms and colors. In the planning process for the new Zayed National Museum in Abu Dhabi, a project I pursued in collaboration with Foster + Partners, we succeeded in convincing our clients that local plants with minimal water consumption would fit best in terms of sustainability and enhance both the biophilic design and the unique local aesthetics.

A new language and awareness regarding Blue-Green issues is expected of engineering today. We can no longer divide projects into separate tracks of work and have to go beyond traditional working modes that are often characterized by disciplinary boundaries.

Blue-Green Technologies

Vertical structures using plants are becoming an important trend as a symbol for green architecture. In the last decade, many architects and engineers have discovered how to integrate plants to give buildings an environmentally friendly facade and character. Spectacular projects of artists and architects like Friedensreich Hundertwasser in Vienna, Austria, the Vertical Gardens by Patrick Blanc, early buildings by Ken Yeang, or examples like Arcadia by Chua Ka Seng & Partners and the PARKROYAL on Pickering by WOHA in Singapore have set new standards and encouraged others to follow suit.

The concept of buildings as being enclosed and encapsulated objects that are separated from the natural environment is being increasingly challenged. There is no doubt that this is a very positive development in architecture. But there are also critical sides of this trend that need to be addressed. Often a project looks good in the first few years but may have serious problems in terms of its functionality and maintenance later and sometimes fails completely in the long term. Plant structures are living systems and are very complex in their specific environmental needs, growth patterns, rhythms, and lifecycles. Already the creation of a successful horizontal landscape structure at ground level in the midst of building blocks and urban structures can be a challenge. Softscapes are in a process of permanent transformation. We have to think differently to grasp the natural conditions of plants and allow for their processes of change including growth, aging, and renewal. The challenge is even more complex when implementing green elements on more exposed vertical surfaces and in stacked positions.

As early as in the 1960s, the green roof movement in Germany, Switzerland, and Austria considerably increased our knowledge of these issues and set new standards. The current vertical green structures go beyond green roofs in their complexity. Today we know more about plant performance, substrates, and structures, but we still have to learn much more about sustainable integration, especially in terms of the water cycle.

Beyond differences in climate, every location differs in temperature, direct and indirect sun exposure, humidity and rain exposure, wind conditions, the orientation of buildings and facades, and surface materials. Together these factors create a microclimate that plants need to adapt to in order to remain healthy. Every cardinal direction, for example, has its own strong influence on diminishing or supporting plant growth. The same goes for the position on the building in terms of height. Some plants such as clamberers need structural support, others prefer to grow directly on vertical geotextiles rooted in planters, or like to hang over. Sometimes it is helpful to have different species

live in symbiosis in order to prevent invasive species from taking over.

Of prime importance is the preparation and selection of the substrate as well as the irrigation and drainage system. In contrast to natural ground soil, the substrate is per se limited in space. It has to support the plants in terms of appropriate humidity, nutrients condition, salt and pH value, all of which are critical for root development and symbiosis with microorganisms and fungi. All these factors keep the plants strong and healthy. Often, salt concentration increases over time and can become a problem. Therefore, water drainage is not only needed to avoid an excess of water but also to regulate the salt content in the substrate.

Nutrients are important as well, although many plants can survive with very little and in many cases natural rain is sufficient to water the plants. On the extended green roof systems of Berlin's Potsdamer Platz, we tested various substrates and finally decided not to use additional fertilizers. Fertilization may be useful in the beginning and for intensive greenery but is liable to create significant problems in water systems, as most nutrients cannot be completely absorbed by the root systems and end up in the water bodies. Nutrient-rich water will create algae growth and problematic eutrophic situations.

Automatic maintenance as well as periodic manual care are essential to keep the system vital and in good condition. Both horizontal and vertical green structures on buildings need particularly high levels of technical functionality in terms of design for maintenance.

Greenery needs water. Here is the dilemma we are facing today and will face even more in the future. If green structures demand substantial water supply from public systems under conditions of drought, plants might look green but we will create more water scarcity in times when we need every drop of water in our cities. The Blue factor needs to be combined with the Green infrastructures of the contemporary city.

The best Blue-Green urban infrastructure is a combination of decentralized and centralized systems. The reason is that water is often unevenly distributed by nature. While in natural landscapes this can be compensated for by water being retained in open lakes, swamps, rivers, streams, and in groundwater, the capacity of water storage in cities is limited, as water is drained as quickly as possible out of the city. The challenge lies not only in the technology but also in its implementation within the surrounding urban fabric.

Density as a Challenge and an Opportunity for Liveability

Blue-Green Infrastructures are most often located in the public realm and therefore at the forefront of public awareness. In vibrant cities, we can all see and experience how space is getting tighter and that there is a growing competition between functions, programs, and jobs. Better ways of sharing and multi-functional structures need to be developed. Increasing density is forcing us to come up with a better understanding and ways to better quantify the values that give even higher priority to Blue-Green systems. As many studies have shown, doing nothing is more expensive in the long run and will generate many problems for future generations. The issue is not only how to avoid floods but how to create healthier environments that provide better air quality, food security, and biodiversity. In this way, increasing density will help us focus on a more holistic and integrated approach to Blue-Green Infrastructures, with the aim of sharing spaces with different functions. This in turn necessitates that we overcome disciplinary boundaries and better integrate all design and planning processes.