A hectare of vertical forest (Bosco Verticale) in the centre of Milan. © Boeri Studio

A Great Climate Thanks to Vertical Forest

Apartment Build in Milan: Shrubs on Balcony Support Technology in Building

Klaus W. König

Designing building services according to what plants need. This is what is done in the greenhouses of every botanical garden. The plants are on the inside, protected by the building. But using the opportunities provided by the plant world first and considering the building services as a nice addition second has now been accomplished with as yet unprecedented consistency, at least with regard to skyscrapers. Here the plants are on the outside protecting the building and its residents – even up on the 20th floor. We're talking about two residential buildings one 80, the other 112 metres high and the greenery covering the buildings' facades makes up an area equivalent to a hectare of forest. This vertical forest (Bosco Verticale) is supplied with process water.

Air-conditioning is only used in this ambitious project in the summer if the shade caused by the trees and evaporative cooling capacity of the plants on the facade is not sufficient. Forestation here consists of 480 large and medium-sized trees, 250 small trees, 5,000 shrubs and 11,000 ground covers and hanging plants.

Background and preparation

The idea behind Bosco Verticale comes from Stefano Boeri. As an architect he looks for ways and means of realising urban development in an ecological and sustainable fashion. As a professor at universities in Milan, Genoa and Venice, he teaches how construction should and can be an interplay of human beings, animals and plants. In 2006-2008, the planning team, Boeri Studio, developed the design and technology that is used today in the project with the fine-sounding name of Porta Nuova Isola. It's located in an inner-city area, north of Milan's centre. Up until 60 years ago, this was the site of several large industrial plants with direct rail access to Porta

Garibaldi station. Following its restoration, a metro line was taken through the area, which, together with a new road concept, further improves access, both to the city and to the outskirts of the culturally and economically strong metropolis, which Milan, as capital of the Lombardy Region, has always been.

The 65-million euro project, Porta Nuova Isola, is now in the construction phase, which was scheduled to start in 2008 and finish by 2013. While the final floors are still being built, the trees have already "moved in" to their tubs on the lower floors. Dr. Laura Gatti and Emanuela Borio are responsible for selecting the plants. For years, these two specialists have examined trees and shrubs for their suitability for the particular requirements of this experiment. Wind pressure and wind suction, temperature and humidity, the supply of water and nutrients as well as how the roots would hold (in plant tubs which contain their typically light substrate) are the critical issues. To be on the safe side and for reasons of building liability insurance, wind-tunnel tests were carried out on original construction components at a university in Florida, USA. Fully mature, the trees will later reach heights of up to 9 metres. Although the height of the substrate in the plant tubs is only 1 metre, the length is variable; therefore the biggest trees can grow in 4-5 m^3 of this specially designed substrate. As a safety measure, each tree will have two or three attachment points, depending on its expected height, connecting it to a vertical cable, which is fixed to the balcony above. This prevents the tree from bending excessively, but still gives it the flexibility to move in the wind. "Another precautionary measure has involved growing the trees in a special nursery", Laura Gatti says, "to ensure that right from the start they grow according to the special conditions they will be exposed to when they are planted on the facade".

The content of the tubs does not become the property and responsibility of the residents upon purchase of an apartment. This is part of the "climate system facade" and will therefore be tended by a special horticultural team in compliance with a maintenance agreement. The team will be lowered down in a basket from above, similar to window cleaners, by a crane that moves along the ridge of the roof.

Process water concept and geothermal energy

All the plant tubs are connected to an automatic watering system. This is designed to be supplied with processed grey water from the apartments. The process water system is, in turn, supplied with groundwater. In the course of examinations of the building site grounds it was discovered that groundwater is available at a depth of about 20 m, which was formerly used by the factories that were located on this site. Since the industrial era came to an end a few decades ago here, it has been discovered on the one hand that the quality of groundwater reservoirs is deteriorating and, on the other, that the water level is steadily rising. This has motivated the city council to recommend the use of treated groundwater in building techniques. And they offer removal thereof at the lowest, legally permitted fees.

Several wells were drilled at the Porta Nuova Isola site. The water is treated and pumped into the process-water network, which subsequently supplies the water to the plant tubs on the outer walls of the apartment blocks. It is additionally treated by heat exchangers, making use of the geothermal properties of the groundwater for heating and cooling systems. As this is available all year round, the heat that is gained can also be used for the provision of hot water, which is also required throughout the year. A total of 4 heat pumps are installed in an underground technology

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Vertical section of the residential tower Porta Nuova Isola with its vertical forest (Bosco Verticale) in the centre of Milan. © Boeri Studio

Two residential towers, 80 and 112 m high under construction in February 2013. Large trees and shrubs have already been planted on the lower floors. Bushes and ground-cover plants will also be planted. © König

One of the heat exchangers in the underground technology centre. Geothermal energy from groundwater is used to provide warm water. © König

The lower floors of one of the two residential towers. Porta Nuova Isola, with their vertical forest (Bosco Verticale), February 2013. © König

Plant tub as balcony balustrade on the 14th floor before being planted. © König

One of the 4 pumps in the underground technology centre. Geothermal energy from groundwater is used to provide warm water. © König

Plant tub as balcony balustrade on the 14th floor, connected to automatic water system supplied by process water from the treated groundwater. © König

centre next to the heat exchangers. Ring pipe systems supply the two towers and a further three lower houses in the area with warm water, hot water, drinking water, etc. A separate transfer station underneath each of the buildings takes care of further distribution.

Excess groundwater is conveyed back into the earth via soakaways once the heat has been removed; in the winter a little cooler than when it was removed and in summer a little warmer, as the building's climate technology gives off its waste heat to the soakaway water. All in all, less groundwater is returned than is removed. The difference comes from the watering of the facade plants where evaporation is utilised for cooling purposes slightly raising air humidity levels in the surrounding area. "We carefully calculated the yearly water consumption for each tower, façade and floor. It's equal to the annual consumption of around 60 people," Laura Gatti explains. "We assume that the plants will need to be watered from March to October, but we could even continue watering during the winter if the weather is particularly warm, which sometimes happens. The system does not use potable water; the water comes from the watertable and has been used for heating/air-conditioning before."

Air-conditioning and certification of the building

The shade provided by the leafy trees in the summer months and the respective evaporative cooling is taken into account on a flat-rate basis when measuring the cooling performance inside rooms. The engineer has not provided specific data. However, the plan is to use data gathered during the initial few years in order to adjust the technology retrospectively. An evaluation of water consumption with regard to groundwater and drinking water will also be conducted; the respective water metres are said to have been installed. The project developer, Hines, is putting forward the project for certification in accordance with LEED (Leadership in Energy and Environmental Design) and hopes to receive a Gold award. "Two points for using groundwater for watering the grounds are already guaranteed," says the relevant LEED advisor, Mattia Mariani, and adds: "The water-saving fixtures in bathrooms and kitchens have also been taken into consideration. And points have also been gained for grassing the property in order to avoid urban heating." Just how many points can be awarded for the hectare of forest in front of the building's facade as a means to provide shade cannot be ascertained from the certification lists. Compari-

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The tree as a natural form of air conditioning

Every plant and tree transpires, thus acting as a natural type of air conditioning. Aloys Bernatzky, old master of German dendrology, described the functional value of a 100-year-old free-standing beech when exposed to the best ecological conditions in his book "Baumchirurgie und Baumpflege" in 1978. This 25 m high tree with a crown spanning 14 m, a crown volume of 2,700 m³ and an inner-cellular leaf area of 160,000 m² absorbs 2,352 g of CO_2 and 960 g of water every hour. It evaporates 10 m³ of water every year at a thermal energy consumption of a total of 8 x 106 kcal. At 1 cubic metre that corresponds to 8 x 105 or 800,000 kcal per year. In physics, the energy required to evaporate a cubic metre of water is given as 680 kWh. This figure refers to evaporation at 30 °C. At 100 °C it is only 630 kWh.

Project data: Bosco Verticale / Porta Nuova Isola	
Location	Milan /Italia, between Via de Castillia and Via Confalonieri
Total area of Porta Nuova Isola site	40,000 m²
Tower D	height 80 m, 18 storeys, 40 apartments
Tower E	height 112 m, 26 storeys, 73 apartments
Plant tub area on facades of the towers D and E	10,000 m²
Construction phase	2008–2013
Costs	€ 65 million
Architectural design	Boeristudio (Stefano Boeri, Gianandrea Barreca, Giovanni La Varra)
Landscape consultants	Emanuela Borio, Laura Gatti
Building contractor, general contractor and project developer	Hines Italia
Leed consultant, MEP design	Deerns Italia
Structural design	Arup Italia
Precipitation in Milan	980 mm
Process water from ground water, required daily for watering (seasonal)	max. 19–21 m³
Tower D annual (March – October)	min. 1855 / med. 1778 / max. 1975 m³
Tower E annual (March – October)	min. 3490 / med. 3343 / max. 3708 m³

Plant tub as balcony balustrade on the 14th floor being planted in February 2013. Shrubs and groundcover plants will also be planted. © König

sons have been looked for with awnings and then improvised.

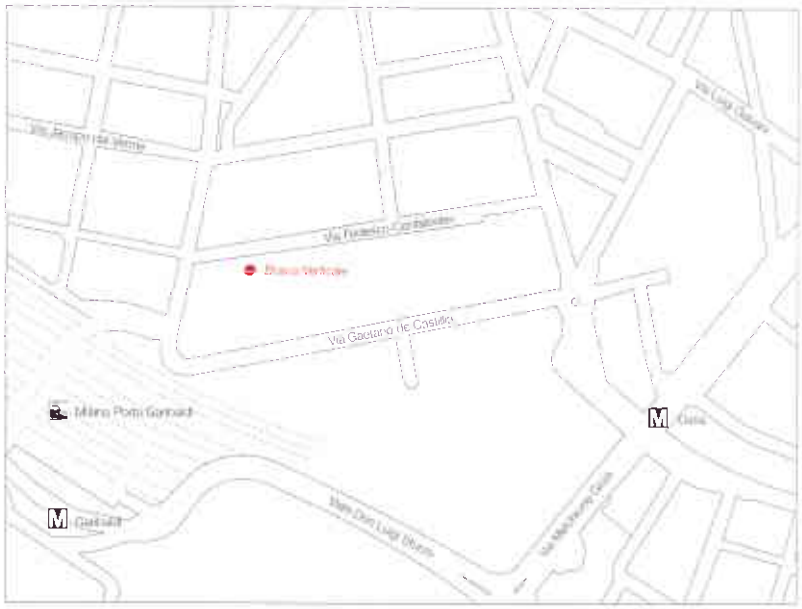
Outlook

In order to avoid conflicts of interest, Stefano Boeri has had himself released from his duties at the University Politechnico di Milano since he took over the appointment of mayor of Milan for culture, design and fashion in June 2011. His planning office, Stefano Boeri Architetti, has not recruited any new assignments since then. It can be expected of such a consistent and pragmatic visionary that his belief of the necessity to transform the town into an ecologically healthy organism and its architecture into works of art that enable energy and space to be saved will be carried forward in local politics.

Milan as a "playground" for this purpose is perfect as in the not all too distant future EXPO 2015 will be held here, with the motto: Feeding the planets; energy for life.

Together with partners and students, the Stefano Boeri Architetti office has been developing feasible models to gradually transform Milan's sealed and petrified cityscape into an organic Milan for years. Recommissioning of the 26 closed-down agricultural enterprises (agriculture and horticulture) alone could trigger the change, supported by the international trend towards urban farming, i.e. self-supply of city dwellers with garden

The lower floors of one of the two residential towers, Porta Nuova Isola, with their vertical forest (Bosco Verticale), May 2013. © Mann



Site diagram showing the Bosco Verticale Project, the new residential district Porta Nuova Isola in the northern part of the city of Milan. © Lukas König

The trees are grown in a special nursery to ensure that they grow according to the special conditions they will be exposed to when they are planted on the façade. © Laura Gatti

products by greening court yards, roofs and facades. Maybe EXPO 2015 will not only see the vertical forest of the Bosco Verticale residential towers on the Porta Nuova Isola site, but also further utopias of a "metropolis with biodiversity". This abstract-seeming term is the subtitle of the book "biomilano" bound in a suitably green cover. The respective models can be found illustrated in its over 150 pages. Author: Stefano Boeri, published 2011 by Corraini Edizioni, price € 26.00, ISBN 9 788875 703028.

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Evaporation mitigates the urban heat island effect

Non-permeable surfaces such as roofs, facades and roads impair the microclimate by disturbing the radiation and energy balance of areas. In city centres solar radiation is turned into perceptible heat and long-wave radiation instead of evaporating into water, causing the urban heat island effect. That is why buildings need to be cooled more in the summer. When conventionally generated electricity is used, in terms of the entire process in which energy is converted more heat is produced than cold, which intensifies the problem of global warming. One measure that can be taken to avoid this is to plant greenery on buildings, with the aim of providing shade and cooling through evaporation. This saves energy in air conditioning systems for buildings, improves the microclimate, binds dust and insulates noise.

Evaporation, a fascinating, globally-effective phenomenon, keeps our weather on the move. Your need for warmth is supplied worldwide by heat from the sun, which also causes humidity. This cools down the surrounding area. Vice versa, when humid air meets cooler layers in the atmosphere, clouds of very fine, condensed water are created. In turn, when this process continues, the clouds turn into rain and the bound-up energy is re-released. In this manner water and heat are continually transported from one place to another all around the globe. We also experience the change of the aggregate state from liquid to gas in our own bodies when we sweat. The heat required for evaporation is provided in this case by the environment and also by our bodies. Evaporation brings about the cool-down we need.