Green Walls for Urban Climate Mitigation

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Abstract

Throughout the last years, vertical green walls are increasing their existence in modern buildings, providing numerous benefits to the buildings and to the surrounding area.

Milano citizens are becoming increasingly sensitive to environmental issues. The excessive soil consumption and the improper exploitation of renewable resources such as water and air, have brought and daily bring microclimatic imbalances that make the metropolitan citizens more and more careful and respectful for the environment in which they live.

The urban designer, in fulfilling his role, finds himself with a demand that varies according to the information of the mass media, promoters of healthy living, which involves paying attention to what we introduce into our organisms. This theme is becoming more and more relevant in cities like Milan, where the rhythms of life are marked by productivity, at the service of a city that represents the Italian business district. Today's citizen claims the quality of the reduced free time that remains between the daily commitments and, suffocated by rhythms and pollution, want to breathe fresh air and live in a healthy environment.

Always more often public administrations are promoting the reconstitution of the city through the use of urban greenery which is fundamental for making people live and feel good, but often - especially in urban centers - there is no land available for the planting as all horizontal surfaces remained covered by asphalt or houses. However, there are many vertical surfaces that can be redeveloped and converted into green filters for the pollutants absorption and restoration of the native microclimate.

Some experiments are being done in the metropolitan territory, but nowadays the maintenance of the green walls is still too high and, by performing a pro and cons evaluation, usually the owner doesn't find convenient to choose this wall type.

Even if the technology has not been still suitably developed and spread, the creative beauty potential and efficacy of the filtering walls in air cleaning, especially in big cities, has not to be underestimated and set aside. The significance of the mitigation capabilities at urban scale could reveal magnificent potential that has not yet been investigated. The main examples constructed in Milan will be shown at the present condition.

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| *Landscape*
| *Art Garden Museum*
| *Artist's Gardens*
| *Art-Park-Museum*

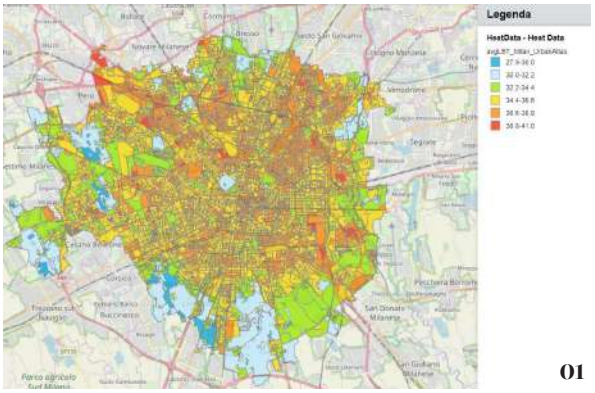
Introduction

Environmental sustainability is increasingly focal in the social, economic and therefore political debate. What urges the debate at the global level is, above all,fig the malaise perceived by the human being in the industrialized environment due to the disconnection that has arisen with nature. The inseparable pair "man-nature" is in fact the most authentic and essential that exists since the existence of our planet. The man of the anthropized context incurs daily in the alienation due to the separation from the environment that is natural to him, and consequently he is forced by the structure of our society to live far from the dialogue with himself. There is a link between man and Creation that every culture recognizes as its own because it is inherent in man, it is when productive activity becomes destructive and not very important for the environment, the balance is lost. Many are the initiatives of young people and others who undertake activities to restore natural ecosystems, such as associations

that undertake to collect plastic in the sea to save marine fauna or programs to safeguard endangered species. The need to curb the destructive impact deriving from the selfish attitudes of economic activity and to restore the original ecosystemic conditions is increasingly felt by all. The bodies in charge of safeguarding the wildlife and natural heritage are involved not only in making agreements with trade associations and studying solutions with the governing bodies of the territory, but also reiterating them by correcting long-term planning actions to combat the phenomenon of Earth pollution in an effective way.

The urban situation, although it may seem positive in the external eyes as it is more prosperous in economic terms, is very bad in terms of quality of life, resulting in the fact that the harm we do with our productive activities is actually done to ourselves as it pours out about us.

In the city of Milan the air is unbearable in winter due to pollutants produced by transport and build-ings, in summer the heat island effect contributes to further increasing the urban temperature, leading to an increase in energy consumption and consequently of polluting emissions: it seems being like a dog chasing its own tail. But how to get out of it?



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01
Daytime Surface Temperature Hotspots | Source: Municipality of Milan website - June 2019

The only way to get out of the portrayed vicious circle is to mitigate the effect of urban heat island through the development of a network of urban green spaces (Szkordilisz, 2014).

There are shared projects in all over the World to which the city of Milan is participating, like "Reinventing Cities" which is an international call to launch a resilient and zero emission urban regeneration, initiated by the C40 Cities Climate Leadership Group and made possible thanks to the contribution of Climate KIC and ofo, to which other 14 World cities decided to take part. Urban conversion into green city is the objective also for Rem Koolhaas project which aims to transform two railway stations in Milan into parks.

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Rem Koolhaas project rendering: conversion of Farini railway station in Milan | Source: url: https://milano.corriere.it/19_aprile_12/progetto-farini-san-cristoforo-oasi-verdi-ponti-l- idroscalo-bis-11327d0e-5cdf-11e9-a667-fe16632539a8.shtml?refresh_ce-cp)

Although the conversion of the cemented and asphalted surfaces is easier in the peripheral areas of the city of Milan, it is more complex to be done in the vicinity of the historic center and in the center itself. The urban morphology of the center, which has very ancient origins - it is a city that has seen the passage of both Roman civilization and Medieval period - is sometimes also characterized by narrow streets with only one lane. The forestation results difficult into this context. The absence of

greenery brings with it therefore also the failure in cleaning the polluted air as it can be operated by the plants through the photosynthetic process.

Stefano Boeri, a landscape architect who sent a strong signal in the world of designers with his "Bosco Verticale" located in the new redeveloped area of Milan Porta Nuova, sketched his imaginary "Forest City" in his last book, with the concept of bringing the city back to its natural origin, as the effective solution to counteract pollution and mitigating climate change until its minimization and complete reduction.

03
A vertical forest
Source: Stefano Boeri, 2015

The high population density has led us to develop our polluting buildings in height, but the "dead" vertical surfaces of the building envelope can be converted into green living and breathing surfaces, making the buildings work as living organisms that interacts with the surrounding environment, cooperating for the well-being of the city's ecosystem.

Some microclimate studies reports that the adoption of vegetation on façades protects the wall from direct radiation, which translates in multiple positive effects since the special climate created by plants is due mainly to evapotranspiration, absorption and reflection of solar radiation, modified wind move-ment, and CO2 assimilation.

All mentioned changes create the so called Oasis-effect in the urban green spaces, which is most important from energetic and microclimatic point of view.

According to the simulations done with ENVI-met, the measured values of wind speed and direction, Mean Radiant Temperature and Relative Humidity, show that with the plantation of green façade there are only slight changes in relative humidity values. Green façades mitigate the temperature of the wall shaded and Mean Radiant Temperature decrease too (Tzortzi-Georgi, Sophocleous, 2018).

Even thought, it has to be noted that, from a design point of view green walls (vertical greening):

1. Should be chosen according to climate, budge and architectural design;
2. They need regular maintenance for watering, nutrient substance and pruning, but it can be minimized;
3. They are beneficial because of sound reduction, aesthetic enhancement, external insulation and energy efficiency;
4. Plant species should be chosen according environment and natural supporting systems

Green walls can be applied for mitigating the effect of urban heat island, increasing biodiversity and ecological value. Vertical gardens have several advantages, besides of their positive energetic effects they have aesthetic value too, so they can also act as attractive media-façade as well, so they are used also with the aim of aesthetics improvements of the building by creating a "drawing" or pattern on the façade.

Also in outdoors exists a filtering capability has been intercepted since the plants act on the PMx absorption and on the uptake of CO2, NO2, and sulfur dioxide (SO2). Fine dust particles adhere to the plant surfaces, therefore plants are a perfect anchor for airborne particles at different heights (Ottele´ et al., 2010).

Another very important parameter is the foliage density. According to the sink capacity of leaves, which depends on their macro- and micromorphology, the PMx

collecting capacity of plants changes; leaves with different micromorphology (i.e., thick cuticle, cuticular waxes, hairs, etc.) are proven to be effective in collecting PM2.5 (smaller than 2.5 μm) (Perini et al., 2017; Roccotiello et al., 2016), among the most dangerous pollutants for human health (Powe and Willis, 2004).

Specific leaf characteristics like morphology, leaf area index, porosity and/or leaf area density, can increase the deposition and dispersion of PMx, improving significantly the air quality. With respect to all the benefits resulting from the studies conducted by institutions on the topic, and interviewing the main sector operators such as urban designers and contractors, this paper analyzes the microclimate improvement potential of green walls through their adoption in the urban centers and their applicability, considering problems related to their use and maintenance, thei psychological, environmental and social benefits they bring due to their relation with living in a healthy and sustainable environment, implying economic re-evaluation of the building stock.

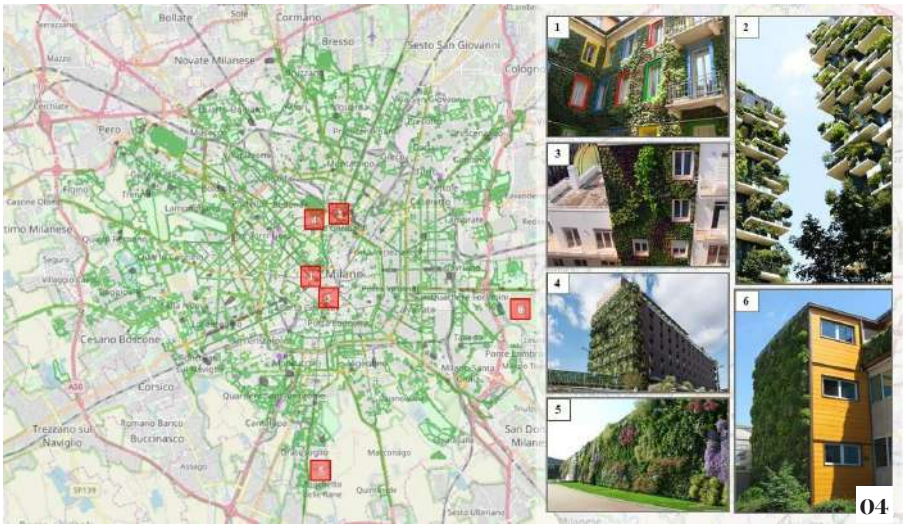
Methodology

According to Szkordilisz (2014), plant Green Façade improves the urban microclimate since is very fruitful from energetic and microclimatic point of view since they fight effectively the negative effects of the urban heat island as the ENVI-met simulation proved. Adopting Green Facades in the city of Milan then might improve the microclimate by:

- Wind speed increase due to the increase of roughness of the façade surface, which conse-quently improves urban cross ventilation;
- Relative Humidity decrease of 1-2% approximatively, which is relevant for internal air com-fort obtainment;
- Mean Radiant Temperature decrease up to 8-9°C thanks to the combination between increase of wind speed and decrease of Relative Humidity above mentioned, but also to the impact of shading.

The positive effects are considerable for both summer and winter period since the façade acts like a building second skin decreasing the probability of heat and cool transfer phenomena in the medium – i.e. the layers of the envelope. In fact, considering a gap between greening and the building envelope around 5-7 cm, the air speed in between is not such high to cause Temperature decrease, and behaves as an insulator by one side, by the other hand as a moisture subtractor.

To date, no surveys with suitable instruments have been carried out in the city of Milan to understand the impact that vertical facades can have by varying the microclimatic and pollution parameters, but will be the object of study of the next researches that will be carried out for the metropolitan city after the mapping of where the green systems have been installed, as follows.



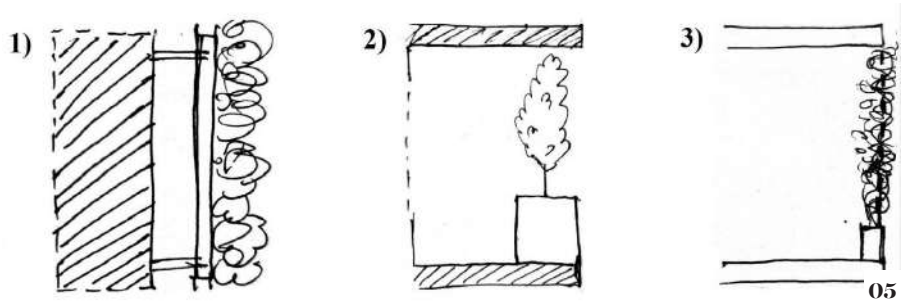
04
Green Heritage Milano map
Case studies images source: 1) 5) 6) Arch. Roberta Peverelli; 2) rb Plant Bruzzone Consorzio website; 3) Sandrini Green Architecture website; 4) AG&P Greenscape" (source: after Municipality of Milan website – 2019)

The examples nowadays present in Milan are respectively:

- 1) Caveau Cafe & Crudites - Largo Cairoli, 1 – Milano
- 2) Bosco Veticale – Milano Garibaldi
- 3) Beltrade Palace – Piazza Santa Maria Beltrade – Milano
- 4) Hotel VIU Milan – Via Aristide Fioravanti, 6 – Milano
- 5) Fiordaliso Shopping Center – Via Eugenio Curiel, 25 – Rozzano (MI)
- 6) Monza Cardiology Center – Via Carlo Parea, 4 – Milano

As it can be seen from the map of the cases mentioned above, the highest concentration of vertical green wall installations in Milan is present above all around the urban center where, comparing with the map of the Daytime Surface Temperature Hotspots, it is possible to detect that such applications are actually installed in the most critical points of the city in terms of the heat island effect created in the summer periods. The choice of adopting vertical facades in the center has additionally the function of transmitting to the citizen a message of care for the environment. Especially companies increasingly care about the image that potential customers have, especially if they operate in fields with large environmental impact. It can be observed therefore that the installation of a vertical green facade, having creative geometries and/or patterns or not, can also have an impact on corporate branding. This justifies why today in Milan the main investors of vertical green facades are once again the private individuals who are "anxious" to communicate to potential buyers that their productive activity is environmentally sustainable, and to create a healthy and productive environment for workers, even facing sometimes considerable maintenance costs (Szkordilisz, 2014) which depend on the poor technological development of the system.

Actually, the green facades installed in Milan and shown in figure 4 can be summarized in 3 typologies as in figure 5.



05
Arte Sella: Rotazione, 2011 (Paul Feichter). Val di Sella, Borgo Valsugana, Italy (credits: M. Borsotti, 2014).

To be more precise as it can be seen on the figure 5:

- 1) Panel system, where the panel might host the plants in holes or pockets; this is the case of the case studies 1, 3, 5 and 6. The advantage of this technology is the possibility of creating different patterns by using different pollution absorbing plants, which can facilitate the adoption by private companies.
- 2) Planting with trees on the façade: a classic example is the Vertical Forest (Bosco Verticale – case study 2). Although very suggestive and unique, it presents various complications for
- the installation, the choice of trees that can't grow beyond the available height, and also the maintenance or replacement of the green is very complex (a crane is installed on the roof to pull up the trees that should be eventually replaced).
- 3) Climbing plant on wires (case study 4): the advantage of this technology is that the wires lead the climbing path for the plants so that they can grow regularly and reduce maintenance frequency. A periodic maintenance is done to limit growth and avoid the "bush effect" on the façade – i.e. to maintain a neat appearance on the façade. The type of plant brings less problems by means of load bearing in case of replacement needs, unlike the type n ° 2.

By a technological and sustainable point of view, below on the table 1 reporting

the compared result with respect to some of the most important aspects that a green façade should exploit.

	Installation		Maintainance		Irrigation water management	Pattern creation possibility	Specific pollution absorbing plants placement	Support type
	feasibility	cost	feasibility	cost				
Case 1	3	13233					3s	ubstructure in non-corrosive material
Case 2	1	11321					2f	ull length vase placed on the balcony slab
Case 3	2	12221					1f	ull length vase placed on the balcony slab

Scores:

1	*low*
2	*medium*
3	*high*

06

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compared result with respect to some of the most important aspects a green façade

By a certification point of view – which is mostly important for private companies which want to invest in green facades to re-brend the company and show their sensitivity to environmental issues – a LEED table with credits category potentially obtainable through the use of a green façade is shown on table 2.

Sustainable Sites	Credit 3: Integrated Pest Management, Erosion Control and Landscape Management Plan (1 point)	~
	Credit 5: Site Development: Protect or Restore Open Habitat (1 point)	+
	Credit 6: Stormwater Quantity Control (1 point)	•
	Credit 7.1: Heat Island Reduction: Non-Roof (1 point)	•
	Credit 8: Light Pollution Reduction (1 point)	~
Water Efficiency	Credit 3: Water Efficient Landscaping (1–5 points)	+
Energy & Atmosphere	Credit 1: Optimize Energy Efficiency Performance (1–18 points)	+
Materials & Resources	Credit 3: Sustainable Purchasing: Facility Alterations and Additions (1 point)	~
Indoor E nvironmental Quality	Credit 1.4: IAQ Best Management Practices: Reduce Particulates in Air Distribution (1 point)	+
	Credit 2.1: Occupant Comfort: Occupant Survey (1 point)	+
	Credit 3.6: Green Cleaning: Indoor Integrated Pest Management (1 point)	~
Innovation in Operations	Credit 1: Innovation in Operations (1– 4 points)	+

07

07
LEED table with credits category potentially obtainable through the use of a green façade, source: Weinmaster, 2009

• *Qualifies for LEED® credit*
\+ *Positively effects LEED® qualification*
~ *No negative effect on LEED® credit*
Used courtesy of greenovergrey.com.

Despite the fact that the use of vertical green facades is still not very feasible today for public and private residential buildings use destination, the Vertical Forest has made a great contribution both in terms of communication of a new architectural thought, and as an environmental impact that this intervention had on the redevelopment and conversion of an entire district at urban level.

According to the urban designer of some of the facades mentioned and shown on the map above, the urban redevelopment passes through the transformation of gray into green and is what is called Greenscape. Through the design works done it has been observed in the practice of urban planning and redevelopment, in the city of Milan there is no land due to excessive overbuilding and, even where there are plantings, the stratigraphies containing soil layers are very small. Despite this it is possible to convert even spaces without land such as the inner courtyards of buildings in internal gardens. In the case of the external parts of buildings, an excellent solution is the conversion of gray facades into green ones.

The landscape designer confirms that green in general, and especially green facades, need maintenance and if not properly designed, they risk of being neglected and to become an element that contributes to make the city ugly. For this purpose, the urban designer points out that, in order to be able to convert gray into green, both the involvement of private individuals and the public is of fundamental importance so that everyone can collaborate for the correct management of the green.

In fact, it has been emphasized by both landscape designer and contractor on the topic of fertilization and irrigation that it is important during the design phase to take extremely care to water resources needed for the greenery in order to properly used and manage them. According to the contractor this also concerns the maintenance of the green façade from a technological point of view, and therefore its relative ordinary and extraordinary maintenance, above the initial façade price.

Discussion and Conclusion

It is underlined both by the urban designer and the contractor the difficulty that still exists in the diffusion of the use of this system, as also mentioned by Szkodlisz (2014), due to the high maintenance costs of the façade that derives from a lacking development of the technology and its related integrated design; in fact, according to the contractor, design problem occur when the client intends to apply the vertical green facade on an existing building as this implies that subordinate systems such as substructure and irrigation must be adapted to an existing envelope technology, and that therefore it is necessary to adapt to an old technology, which was not designed to accommodate additional loads or installations, to a new one.

The obstacles to the spread of green facades resulting from a precarious technological development of the system, confirmed both by the urban designer and the contractor, are certainly an obstacle to be overcome with the help of public and private stakeholders, companies or institutions and research centers , in order to arrive at a solution that allows the effective conversion of energy-intensive and polluting buildings into homes, offices and industries capable of having almost no impact on the environment and which contribute to cleaning the air, restoring the microclimate and biodiversity.

Furthermore, the vertical facades can be also as an artistic version on several walls to the level of an enduring ecological art creation of the modern images as have been done by Roberto Burle Marx in Brazil who was one of the pioneers of vertical artistic gardens (Tzortzi-Georgi, Vissilia, 2016). Exept the aesthetic value vertical green walls have while green walls have an additional of environmental, social, and economical benefits (Tzortzi-Georgi, Sophocleous, 2018) while they are an innovative way to improve the biodiversity in the cities as also Weinmaster (2009) mentioned. The green walls can be used as an alternative solution for indoor and outdoor walls and an extensive research can be done in the high-rise buildings (Tzortzi-Georgi, Sophocleous, 2018) and in the the “blind walls” into the cities concerning the method and the plant materials.

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