Journal of Civil Engineering and Architecture 10 (2016) 661-666
doi: 10.17265/1934-7359/2016.06.004

Is Greening the Building Envelope a Sustainable Design Practice?

Katia Perini and Fausto Novi

DSA (Dipartimento di Scienze per l'Architettura), Università degli Studi di Genova, Genoa 16123, Italy

Abstract: Nowadays, the number of products and also of architectural projects, qualified as "sustainable", is ever more growing. Following this trend, architectural design may exploit the use of (eco) materials and components to promote a project as sustainable even without considering its impact on the environment; This can be defined as architectural greenwash. This paper considers the case of green envelopes with the aim to evaluate if these can be defined as sustainable design practice. Green envelopes provide environmental advantages together with the suggestion to a green aesthetics par excellence. In fact, the integration of vegetation in urban fabric plays an important role in improving ecological and environmental conditions of (and in) cities, although systems can have a high environmental burden. This paper aims to answer the question: Is greening the building envelope a sustainable design practice? To do so, the paper provides a literature review which includes the main research developed regarding environmental burden, benefits and LCA (life cycle assessment) calculations of green envelopes.

Key words: Greenwash, green architecture, environmental sustainability.

1. Introduction

Data shows that architecture plays an important role in the field of sustainability. In fact, the building sector has one of the greatest impacts on the environment; Buildings consume a significant amount of energy over their life cycle and generate 40%~50% of the total output of greenhouse gases [1]. The majority of the world's population today lives in urban areas [2] and is responsible for 70% of global carbon emissions and nearly 70% of energy consumption—an increasing trend for both [3] with land converted to urban areas projected to triple by 2030 [4]. Furthermore, environmental problems within cities have significant consequences for human health, citizens' quality of life, and urban economic performance [5]. However, according to Hamin and Gurran [6], a denser urban environment could reduce the emissions connected to transportation needs and building energy use, and consequently their impact on climate change.

Corresponding author: Katia Perini, Dr., research fields: architecture and sustainability.

The ever wider diffusion of ecological theories and the recognisability of environmental imbalances took to an increasing use and integration of innovative elements connected to sustainability [7]. Nowadays, the number of products and also of architectural projects, qualified as "sustainable", is increasing too. Following this trend, architectural design may exploit the use of (eco) materials and components to promote a project as sustainable even without considering its real impact on the environment [8, 9]. Therefore, speaking about architectural greenwash may be appropriate, where a greenwash vocabulary definition is: Greenwash. When a company hides the true effects of its products or actions on the environment, by making it seem as though the company is very concerned about the environment [10]. This paper aims at evaluating if contemporary sustainable design practices can be related to greenwash-effect. Some questions arise: How to measure environmental sustainability? At which scale (building component, architectural project, neighbourhood, city scale)? This paper, with the aim to answer these questions, provides a literature review with respect to the international state of the art, considering the case of green building envelopes (the really “green” one). Green envelopes, as it will be described, provide environmental advantages together with the suggestion to a green aesthetics par excellence. In fact, the integration of vegetation in urban fabric plays an important role in improving ecological and environmental conditions of (and in) cities, although, as it will be shown, systems can have a high environmental burden.

2. Method and Materials

For the evaluation of the potential sustainability of green building envelopes, a broad analysis on research papers[1] was conducted. This is a qualitative overview on the main research published internationally on green envelopes (from 2000 to 2014). This study considers the main environmental benefits and costs related to the installation of green envelopes, to verify if a wide replication of green envelopes can be a good opportunity to improve the urban environment conditions. The analysis conducted takes into account the main benefits at the city-neighbourhood scale and at building scale (of course also aesthetic benefits). A critical overview on researches regarding environmental costs of such technologies (i.e., LCA (life cycle assessment) allows evaluating if contemporary sustainable design practices can be related to greenwash-effect.

3. Results and Discussions

3.1 Vegetation in Urban Areas

When speaking about green envelopes and environmental sustainability the effects of vegetation in urban areas has to be mentioned, due to its potential effects on the environmental imbalances of (and in) dense cities.

High levels of pollution in the atmosphere and the limitless expansion of urban areas cause the UHI (urban heat island) phenomenon resulting in the dramatic two to five degree Celsius temperature differences between cities and their surrounding suburban and rural areas [11~13]. High levels of air pollutants in dense urban areas are also responsible for serious damage to human health. The UNEP (United Nations Environment Programme) links urban air pollution to up to one million premature deaths and one million pre-native deaths each year.[2] According to a study conducted by Hoek et al. [14], daily mortality is significantly associated with the concentration of all air pollutants and especially ozone, particulate air pollution, and the gaseous pollutants sulfur dioxide (SO_2) and nitrogen dioxide (NO_2).

Urban parks affect air quality as demonstrated by a study conducted in China by Yin et al. [15]. Climbing plants improve air quality by collecting fine dust particles [16]. Researches demonstrate that, along with reducing the sources of air pollution (i.e., transportation, industry, and domestic heating and air conditioning) [17, 18], vegetation can play an important role inside a city.

The effects of rainfall on vegetated land versus on the hard surfaces of built-up areas are very different. The vast majority of precipitation that falls on vegetation is absorbed by soil and eventually joins the water table. Some is also absorbed by plants and transpired back into the atmosphere. Water cannot be absorbed by hard surfaces such as asphalt and concrete, however, and it runs off through drainage systems into rivers [19]. About 75% of rainfall on towns and cities is lost directly as surface runoff as compared to around 5% on a forested area [20]. High rainfall in urban areas is rapidly reflected in river level peaks, with possible floodings a frequent consequence when river banks cannot cope with the influx [19].

Green roofs, as well as small green areas on the ground, can be effective in reducing the stormwater runoff of cities [21, 22], with a runoff reduction around 60% to 85%, depending on green roof type and vegetation type [20, 23]. Green roofs also

[1] Journal papers on sciencedirect.com.

[2] www.unep.org.

improve water quality, although some roofing materials may add chemicals or metal compounds to the runoff water [24].

Integrated urban design at the neighborhood scale, at least, is needed in the cases of widespread small interventions, to improve environmental conditions in (and of) dense cities.

3.2 Performances and Costs of Green Envelopes

There are several possible integration modalities of green elements in architecture. These can have a major or a minor influence on the project conception and on the formal and functional characteristics.

For every type of green roof substrate thickness (given by the plant species used), maintenance needed, system weight, obtainable microclimatic benefits, influence on architectural aesthetic, loadbearing structure, costs, and use are different [19, 25].

Intensive green roofs have a higher environmental (and economic) impact but also a higher contribution on the building performance (insulation, cooling) and have a major influence on the formal and functional characteristics, creating gardens at several heights [19] (Fig. 1). In general, the environmental impact is connected to the green roof type and to the material used. Bianchini and Hewage [24] suggest to explore materials (use/re-use of waste materials) that can replace the current use of polymers to enhance overall sustainability of green roofs, since green roof materials often use polymers for all the layers except as a growing medium.

Vertical greening systems could be made by simple climbing plants; Others provide the possibility to cultivate species naturally not suitable for growing on vertical surfaces, thanks to the disposition of pre-vegetated panels, defined as “living wall systems” [19, 26, 27]. These systems entail very different environmental burden, due to maintenance and initial costs, as it will be described.

Vertical greening systems provide a large range of benefits. At building scale, the benefits of green façades and living wall systems are mainly related to energy savings for heating and air-conditioning and durability of façades. Studies demonstrate that a vertical green layer can contribute to the building envelope performances by creating an extra stagnant air layer, which has an insulating effect [28], and reducing the energy demand for air-conditioning up to 40%~60% in Mediterranean climate [29, 30].

However, some vertical greening systems, like the living wall system shown in Fig. 2, can require high maintenance needs. Maybe 30% of plants need to be replaced every year, panels can have a life expectancy of 10 years, automated watering systems need maintenance and plants need up to 3 litre/day per square meter; Differently, a simple climbing plant (direct green façade, Fig. 3) has very low maintenance needs (pruning) and may not require a watering system [31].

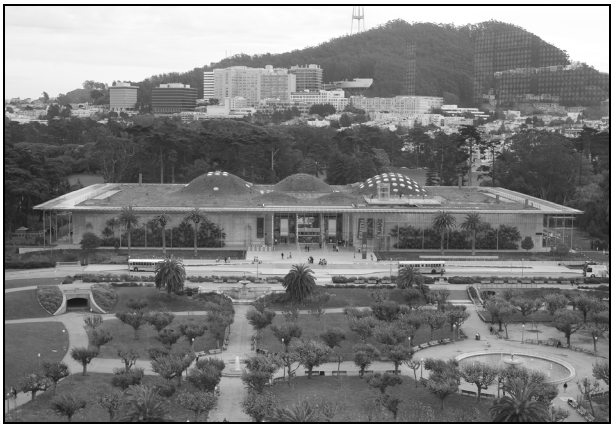

Fig. 1 California Academy of Sciences, San Francisco.

Fig. 2 The Driver, London.

Fig. 3 Via Vaina, Milan.

Another important aspect has to be mentioned: the perceptive qualities of green envelopes, which allow emphasizing the sustainability of a project. Repishti [32] writes about the use of plant elements in this "new kind of cosmetics" as a response to the growing rejection of the present image of the city.

3.3 Environmental Sustainability of Green Envelopes

The main benefits connected to a green building envelope regard environmental practices, economics, and social aspects, as the greenhouse gases output reduction, climate change adaptation, air quality and indoor and outdoor comfort conditions improvement, urban wildlife (biodiversity), human health, etc. These benefits concern several fields, which are all related and operated on a scale range; Some only work if a large surface in the same area is greened and their benefits are only apparent at a neighbourhood or city scale, others operate directly on the building scale [11, 19].

Some of these benefits, especially the ones related to the macro (urban) scale, are usually not taken into account for the evaluation of the environmental impact. This happens mainly because there is a lack of data or a state of incompatibility or simply because the benefits are unquantifiable with the tools usually used for life cycle analysis. Among the benefits related to the larger scale and the urban environment air quality improvement, carbon reduction, habitat creation and urban heat island mitigation can be hardly quantified due to the impossibility to estimate their effect connected to a single green façade or roof [33].

Kosareo and Ries [23] performed a comparative environmental life cycle assessment to compare environmental benefits and costs of a green roof for a 1,115 m^2 retail store in Pittsburgh, US. The conclusion was that although initial costs were high, the energy and cost savings made over the building lifetime made the green roof an environmentally preferable choice.

Studies indicate that the key properties of green roofs, that give them an environmental edge over other roof types in cost-benefit terms, are their potential energy use reduction through summer cooling and the extension of the life of the roof membrane, besides the aesthetic value [19, 23]. The increase of roof life regards the protection from heat exposure, which reduces the durability of some construction materials, such as bituminous systems [19].

A study conducted by Ottelé et al. [31] regarding a life cycle analysis of four greening systems shows the environmental burden profile in relation to the energy savings for air conditioning and heating. This life cycle analysis proves that direct greening systems have a very small influence on the total environmental burden. Thus this type of greening, without any additional material involved, can be considered a sustainable choice. For other cases analysed, the material choice plays an important role: A living wall system can be either a sustainable option or a system with a very high environmental burden, a climbing plant supported by a mesh can have a low environmental impact if made of plastic or wood or a very high impact if made of stainless steel.

Feng and Hewage [34] evaluate the lifecycle sustainability of the same systems analysed by Ottelé et al. [31], by comparing air pollution and energy consumption in the material production, construction, maintenance, and disposal stages, with air purification and energy savings in the operation phase. Their results demonstrate that the felt layer system (similar to the one shown in Fig. 2) is not environmentally sustainable in air cleaning and energy saving compared to the other systems analysed. The environmental performance of living walls is influenced by the types of materials and plants chosen for the systems, as well as the external factors, such as climate and building type. The LCA indicates the need of environmental friendly materials for sustainable living walls.

4. Conclusions

Although LCA can be an effective tool to evaluate and quantify the environmental impact of greening systems in relation to their positive effect at building scale, since energy and environmental performances within the limits of an individual building are measurable and assessable, several effects cannot be taken into account.

However, understanding if an application, extended to a more or less large part of a city, can be suitable according to measurable variables (temperature, humidity, noise, air quality, etc.) can be difficult, due to the need of effective methods to be applied on a larger scale. Another difficulty lies in the reliability of the data collected, which depends on the duration of the measurements (a few years), which in turn depends on the state and type of vegetation, the frequency of renewals, the changes in the climate, etc.

Vegetation can be used to characterize the aesthetic of a building, with the aim of promoting its sustainability. Although quantifying the environmental impact of (greening) systems can be useful to measure environmental sustainability in relation to the micro-scale benefits. An evaluation of the benefits related to the neighborhood/city scale is needed too to verify if greening the building envelope can be a sustainable practice or if it should be related to greenwash effect.

References

[1] Ardente, F., Beccali, M., Cellura, M., and Mistretta, M. 2008. "Building Energy Performance: A LCA Case Study of Kenaf-Fibres Insulation Board." *Energy and Build.* 40 (1): 1-10.

[2] Luederitz, C., Lang, D. J., and Von Wehrden, H. 2013. "A Systematic Review of Guiding Principles for Sustainable Urban Neighborhood Development." *Landsc. and Urban Plan.* 118: 40-52.

[3] International Energy Agency. 2008. *World Energy Outlook 2008.* Paris: International Energy Agency.

[4] United Nations. 2012. *World Urbanization Prospects. The 2011 Revision.* New York: Department of Economic and Social Affairs, Population Division.

[5] Commission of the European Communities. 2005. "EUR-Lex—52005DC0718—EN." Commission of the European Communities. Accessed January 23, 2014. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0718:FIN:EN:HTML.

[6] Hamin, E. M., and Gurran, N. 2009. "Urban Form and Climate Change: Balancing Adaptation and Mitigation in the U.S. and Australia." *Habitat Int.* 33 (3): 238-45.

[7] Perini, K. 2012. "Vegetation, Architecture and Sustainability." In *Proceedings of the EAAE/ARCC International Conference on Architectural Research,* 480-3.

[8] Perini, K., and Porcile, G. L., eds. 2014. *Architettura & Energia*. Vol. 1. Genova: Genova University Press. (in Italian)

[9] Nicolin, P. 2008. "Biopolitics and Architecture." *Lotus 135. Green Metaphor* 135 (October): 124-9.

[10] Longman. 2009. *Longman Dictionary of Contemporary English*. Harlow: Pearson Longman.

[11] Taha, H. 1997. "Urban Climates and Heat Islands: Albedo, Evapotranspiration, and Anthropogenic Heat." *Energy Build.* 25 (2): 99-103.

[12] Arnfield, A. J., Herbert, J. M., and Johnson, G. 1999. "Urban Canyon Heat Source and Sink Strength Variations: A Simulation-Based Sensitivity Study." Presented at the 1999 Congress of Biometeorology and International Conference on Urban Climate, Sydney, Australia.

[13] Santamouris, M., Papanikolaou, N., Livada, I., Koronakis, I., Georgakis, C., and Argiriou, A., et al. 2001. "On the Impact of Urban Climate on the Energy Consumption of Buildings." *Sol. Energy* 70 (3): 201-16.

[14] Hoek, G., Brunekreef, B., Verhoeff, A., Van Wijnen, J., and Fischer, P. 2000. "Daily Mortality and Air Pollution in The Netherlands." *J. Air Waste Manag. Assoc.* 50 (8): 1380-9.

[15] Yin, S., Shen, Z., Zhou, P., Zou, X., Che, S., and Wang, W. 2011. "Quantifying Air Pollution Attenuation within Urban Parks: An Experimental Approach in Shanghai,

China." *Environ. Pollut.* 159 (8-9): 2155-63.

[16] Ottelé, M., Van Bohemen, H. D., and Fraaij, A. L. A. 2010. "Quantifying the Deposition of Particulate Matter on Climber Vegetation on Living Walls." *Ecol. Eng.* 36 (2): 154-62.

[17] Colvile, R. N., Hutchinson, E. J., Mindell, J. S., and Warren, R. F. 2001. "The Transport Sector as a Source of Air Pollution." *Atmos. Environ.* 35 (9): 1537-65.

[18] Legambiente. 2012. *Mal'aria di Città 2012: L'inquinamento Atmosferico e Acustico nelle Città Italiane.* Report of Legambiente. (in Italian)

[19] Dunnett, N., and Kingsbury, N. 2008. *Planting Green Roofs and Living Walls*. Portland: Timber Press.

[20] Scholz-Barth, K. 2001. "Green Roofs: Stormwater Management From the Top Down." *Environ. Des. Constr. Feature.* Accessed December 23, 2015. http://www.greenroofs.com/pdfs/archives-katrin.pdf.

[21] Carson, T. B., Marasco, D. E., Culligan, P. J., and McGillis, W. R. 2013. "Hydrological Performance of Extensive Green Roofs in New York City: Observations and Multi-year Modeling of Three Full-Scale Systems." *Environ. Res. Lett.* 8 (2): 24-36.

[22] Palla, A., Gnecco, I., and Lanza, L. G. 2009. "Unsaturated 2D Modelling of Subsurface Water Flow in the Coarse-Grained Porous Matrix of a Green Roof." *J. Hydrol.* 379 (1-2): 193-204.

[23] Kosareo, L., and Ries, R. 2007. "Comparative Environmental Life Cycle Assessment of Green Roofs." *Build. Environ.* 42 (7): 2606-13.

[24] Bianchini, F., and Hewage, K. 2012. "Probabilistic Social Cost-Benefit Analysis for Green Roofs: A Lifecycle Approach." *Build. Environ.* 58: 152-62.

[25] Perini, K. 2013. *Progettare il Verde in Città: Una Strategia per L'Architettura Sostenibile*. Milano: F. Angeli. (in Italian)

[26] Corrado, M. 2010. *Il Verde Verticale*. Napoli: Sistemi Editoriali. (in Italian)

[27] Köhler, M. 2008. "Green Facades—A View Back and Some Visions." *Urban Ecosyst.* 11 (4): 423-36.

[28] Perini, K., Ottelé, M., Fraaij, A. L. A., Haas, E. M., and Raiteri, R. 2011. "Vertical Greening Systems and the Effect on Air Flow and Temperature on the Building Envelope." *Build. Environ.* 46 (11): 2287-94.

[29] Alexandri, E., and Jones, P. 2008. "Temperature Decreases in an Urban Canyon due to Green Walls and Green Roofs in Diverse Climates." *Build. Environ.* 43 (4): 480-93.

[30] Mazzali, U., Peron, F., and Scarpa, M. 2012. "Thermo-Physical Performances of Living Walls via Field Measurements and Numerical Analysis." *Eco Architecture* 4: 251-9.

[31] Ottelé, M., Perini, K., Fraaij, A. L. A., Haas, E. M., and Raiteri, R. 2011. "Comparative Life Cycle Analysis for Green Façades and Living Wall Systems." *Energy Build.* 43 (12): 3419-29.

[32] Repishti, F. 2008. "Green Architecture. Beyond the Metaphor." *Lotus 135. Green Metaphor* 135 (October): 34-41.

[33] Perini, K., and Rosasco, P. 2013. "Cost-Benefit Analysis for Green Façades and Living Wall Systems." *Build. Environ.* 70: 110-21.

[34] Feng, H., and Hewage, K. 2014. "Lifecycle Assessment of Living Walls: Air Purification and Energy Performance." *J. Clean. Prod.* 69: 91-9.