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GENOVA UNIVERSITY PRESS

International Conference on Urban Comfort and Environmental Quality URBAN-CEQ

28-29 September 2017 - University of Genoa, Italy

Edited by

Massimiliano Burlando, Maria Canepa, Adriano Magliocco, Katia Perini, Maria Pia Repetto

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DI GENOVA

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URBAN-CEQ
International Conference on Urban Comfort and Environmental Quality
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This volume contains the blind peer reviewed papers accepted for the International Conference on Urban Comfort and Environmental Quality held at University of Genoa, Italy, during 28-29 September 2017. The papers provide a current snapshot of leading research on urban comfort and environmental quality

Editor
GENOVA UNIVERSITY PRESS
Piazza della Nunziata, 6 16124 Genova
Tel. 010 20951558
Fax 010 20951552
e-mail: ce-press@liste.unige.it
http://gup.unige.it/

ISBN: 978-88-97752-91-2

Print on September 2017

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Environmental and energetic assessment of a vertical greening system installed in Genoa, Italy

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Abstract

Greening systems for the building envelope are often considered as an environmentally sound choice regardless of specific characteristics and context. Anyhow, every construction requires a specific contribution in terms of energy, materials, and resources; this results in pollution and generates an environmental burden. Thus, it is of paramount importance to evaluate the expected environmental score of a system. The objective of this study is to understand the environmental burden of a vertical greening system using the Life Cycle Assessment methodology. The results of monitoring activities of a real case study and an experimental elaboration of two scenarios allow assessing the real benefit generated by a greening system. Results show that the adoption of the greening system is a sustainable option, in terms of GHG and energy efficiency, highlighting the importance of LCA for measuring the environmental sustainability of construction components.

1 Introduction

Sustainability can be defined as the property of a material or product that indicates whether and in which measure the main requirements are met in a specific application respecting the three equally important pillars of the triple bottom line (Social pillar, Economy pillar, and Environment pillar). Air, water and soil impact on the living environment, on raw material and energy consumption, on waste generation, and on damage to the surrounding environment (Hendriks, 2002). Life cycle assessment (LCA) is a useful tool for measuring the environmental sustainability of a building component. LCA is a methodology regulated by the ISO 14040:2006 that gives the measure of the balance between environmental load and possible benefits, considering the environmental costs of production, transport, use, maintenance and disposal of all components. Ottelé et al. (2011) conducted the first life cycle assessment of four vertical green systems: a comparative assessment of the environmental impact, in relation to the energy savings obtainable for heating and air conditioning. The study is based on simulations and data obtained from other studies. With a similar approach, Feng and Hewage (2014) compare air pollution and energy consumption in the material production, construction, maintenance, and disposal stages, with air purification and energy savings in the operation phase. Both LCA conclude that the living wall system based on felt layers is not environmentally sustainable. According to Ottelé et al. (2011) the environmental burden highly depends on durability and material used.
The present research aims at assessing the environmental sustainability of a vertical greening system built in Genoa, Italy in 2014 in order to conduct an LCA study based on monitoring data (Perini et al., 2017).

2 Methodology

This study quantifies the environmental burden of a vertical greening system using the Life Cycle Assessment methodology. The Life Cycle Assessment (LCA) methodology, is used to understand the impact on the environment of various types of products and is regulated by ISO 14040.

The LCA structure is divided into four main phases:

- Definition of objectives and scope
- Inventory Analysis (LCI)
- Impact Assessment (LCIA)
- Interpretation.

The vertical greening system (VGS) under investigation is installed at the INPS headquarters in Sestri Ponente (called INPS Green façade pilot project). The life time frame of the vertical greening system under analysis is assumed to be 25-year. Bibliography shows studies presenting longer time frames, the choice here is therefore to be understood as a conservative one, thinking of the possible arise of different critical conditions after 25 years. The functional unit of the study is defined as: the environmental score for a VGS with a surface area of 129 m^2 with a lifetime of 25 years.

Figure 1 shows the system boundaries considered in the study. The cultivation of vegetation that has been inserted into the VGS is beyond the limits of study for lack of data and also the end of life with the disposal of the wall. The impact of these two parts of the life cycle is not considered to compromise the validity of the results.

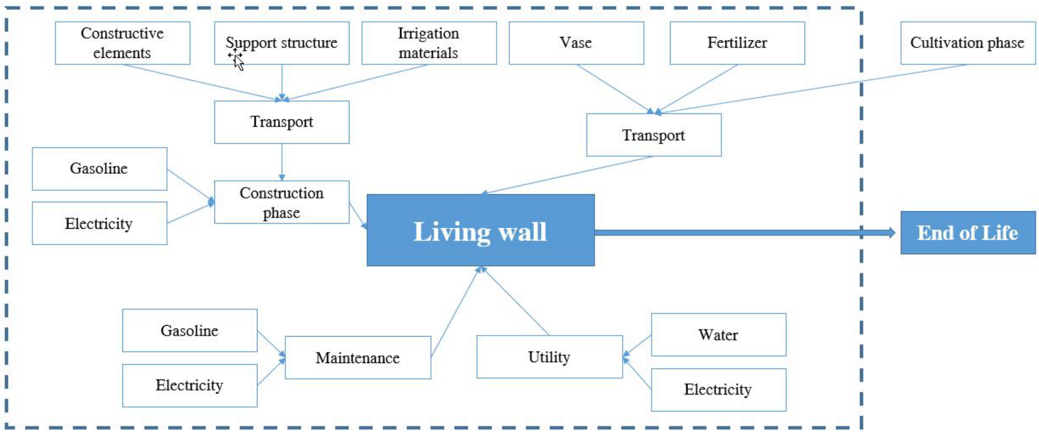

Figure 5. System boundaries of the system under investigation

The considered Impact assessment has been produced taking into account two impact categories:

- Glimmering gases, following the IPCC 2013 Global Warming Potential (GWP) method at 100 years
- Energy consumed throughout the life cycle with the Cumulative Energy Demand (CED) method

Vertical greening systems provide several benefits. In this preliminary study the improvement of thermal insulation of buildings was considered. This improvement is reached thanks to the green layer that avoids the direct radiation of the sun's rays on the wall, which does not heat up and does not radiate the heat inside. Perini et al. (2017) performed an experimental investigation to evaluate the cooling potential INPS Green Façade during summer. Based on the monitoring data, in this study the VGS is assumed to cool the air supplied to AC system, with an energy demand reduction of about 60%.

The improvement was then analysed by evaluating two scenarios:

- Scenario 1: Imaginary scenario where the wall has never been installed, therefore there have been no improvement of the wall and no impacts related to the construction of the vertical greening system
- Scenario 2: The real scenario in which the VGS have been build

These two scenarios were compared using the two impact methods presented earlier to evaluate the CO_2 Pay Back Time and Energy Pay Back Time. These indicators take into account only the energy and environmental balance and do not refer to any economic evaluation.

This was possible by comparing, thanks to parallel measurements, a green and an non-green situation.

3 Result and discussion

Table 1 shows the results of the analysis per m^2 of wall for 25 years of lifetime according to the two impact assessment method selected.

Table 8.Impacts calculated per 25years of life time.

Impact category	Result	Unit
IPCC 2013 100y	0,15	t CO_2 eq/m^2
CED	2957,89	MJ/m^2

In Figure 2, annual GHG emissions are presented for 25 years of useful life considered for the scenarios under investigation. According to Scenario 1, the scenario without the VGS (represented by the blue-colour in the image), the emissions considered are related to the only electricity used during the year. It can be noticed that for the Scenario 2, the one with the VGS (represented by the red colour in the image) the emissions for the first year are the highest, since all stages of construction and installation are considered. For the years following the first, the emissions for this scenario are constant, except for a non visible peak, which is too small to be appreciated in the figure, eight and sixteen year after the construction, in coincidence with the planned maintenance and replacement of the irrigation system, which has a useful life of about 8 years. Other impacts can be attributed to ordinary maintenance, electricity used for irrigation and fertilizer use. In addition to this, as with the other scenario, emissions from electricity consumption during the year are considered. However, the amount of electricity used is different, thanks to the energy efficiency improvements introduced by the construction of the vertical greening system.

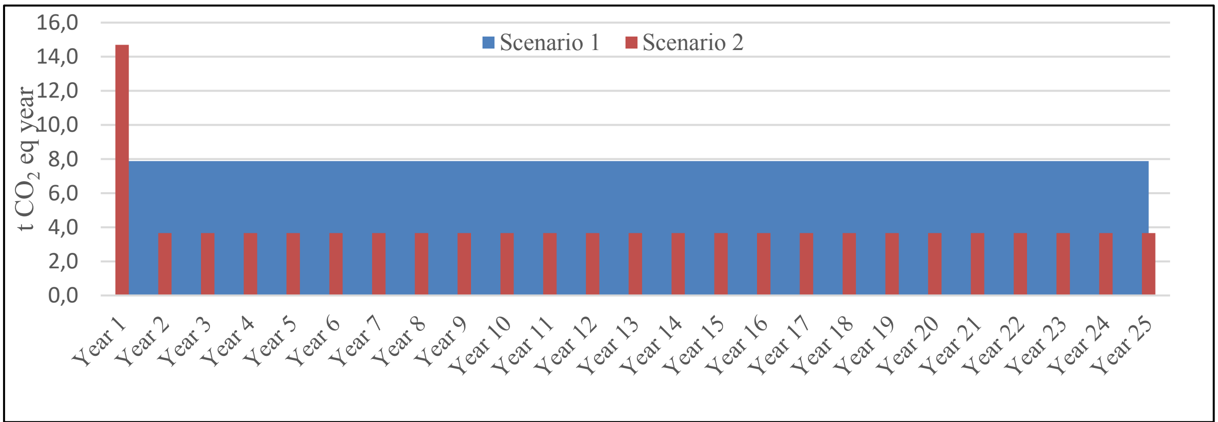

Figure 6. Comparison of GHG emissions over 25 years of useful life between the two scenario under investigation. Scenario 1 in blue, represents the case in which the vertical greening system does not exist. Scenario 2 in red, represents the case with the vertical greening system

An analysis has been carried out to determine when the environmental debt due to the construction of the green wall is repaid by a decrease of the emissions due to the energetic improvements and to understand whether these emission differences generates a positive environmental score for the Scenario 2. This analysis is called payback time and results in a very favourable result for the vertical greening system scenario. The environmental debt is repaid in about 3 years and take into account all the emissions along the 25 years of life cycle of both scenarios.

The same analysis has also been made with regard to energy impacts following the Cumulative Energy Demand methodology (CED). The results are comparable to the GHG emission analysis. Figure 3 shows the total energy consumption for both scenarios. Even in this case, the green building scenario presents a very high energy cost in the first year, due to the construction and the first phase of the vertical wall lifecycle. This, however, results in a very low energy consumption in the years following the first when compared with the scenario without a green wall.
A further analysis of the energy time payback. Again, the result obtained is excellent for the vertical greening system scenario, resulting in a payback time of just over 3 years and in an enormous amount of energy saved in the 25 years of time frame.

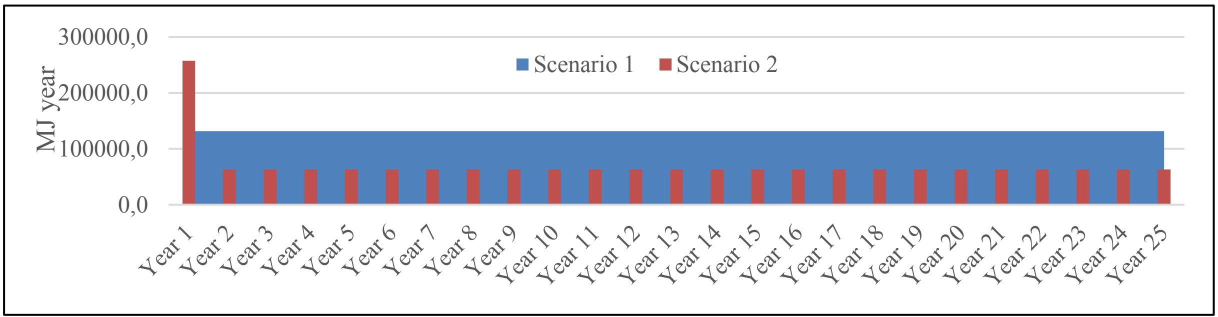

Figure 3. Comparison of CED over 25 years of useful life between the two scenario under investigation. Scenario 1 in blue, represents the case in which the vertical greening system does not exist. Scenario 2 in red, represents the case with the vertical greening system

4 Conclusion

This research has investigated the life cycle of a vertical greening system, comparing its GHG and energetic burdens using a LCA methodology. The analysis, based on data retrieved from real case study and field measurements, was conducted on two scenarios one with and one without VGS. The local energy and environmental advantages have been assessed in the previous sections, highlighting the possibility of reducing the building energy consumption, thanks to the greening system. At the level of global impacts, thanks to this analysis, it can be concluded that the adoption of the greening system is a sustainable option both with regard to the effects of GHG and the enhanced level of energy efficiency reached by the building after the VGS installation. The lack of data on cultivation and end-of-life is assumed to extend the payback time, but because we are abundantly within the life cycle of the green wall, they will not change the positive end result.

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Urban-CEQ international conference focuses on the evaluation of environmental quality of urban areas, considering a wide range of environmental problems, such as thermal comfort and air quality, and their effects on citizen life conditions and health. The event aims to be a meeting between specialists of fluid dynamics, designers and managers of urban areas in order to identify areas of frontier research, the sharing of useful targets for the improvement of urban environmental quality.

More than two thirds of European citizens live in cities, where many environmental problems are concentrated, such as lack of thermal comfort and poor air quality, which seems to be also responsible for life-threatening conditions. It is more and more necessary that the urban regeneration strategies are linked to objectives of environmental quality improvement.

ISBN: 978-88-97752-91-2