Journal of Environmental Management 254 (2020) 109743

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: http://www.elsevier.com/locate/jenvman

Research article

An environmental Life Cycle Assessment of Living Wall Systems

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ARTICLE INFO

Keywords:
Living Wall Systems
Life Cycle Assessment
Sustainability
Green walls

ABSTRACT

The Life-Cycle Assessment (LCA) is a standard approach for evaluating the environmental impacts of products and processes. This paper presents the LCA of Living Wall Systems (LWS), a new technology for greening the building envelope and improve sustainability. Impacts of manufacture, operation, and use of the systems selected, were evaluated through an LCA. LWS are closely related to several environmental benefits, including improved air quality, increased biodiversity, mitigation of heat island effects, and reduced energy consumption due to savings in indoor cooling and heating. Two prototypes have been selected, taking into account the modularity and the use of organic substrate as selection criteria. The systems evaluated were a plastic-based modular system and a felt-based modular system. The inventory data was gathered through the manufacturers. The LCA approach has been used to assess the impact of these solutions by focusing on the construction phase and its contribution to both the energy balance and the entire life cycle of a building. This approach has never been done before for LWS. The study found that out of the two systems through the manufacturing, construction, and maintenance stage of the LCA, the felt-based LWS has an impact on almost 100% of the impact categories analyzed, while plastic-based LWS has the lowest influence on the total environmental impact.

1. Introduction

Today, the European construction sector represents 40% of primary energy consumed from non-renewable resources, out of a total of 87% globally. In turn, the human ecological footprint has increased to 80% between 1960 and 2000 (Izrael et al., 2007). One of the most important challenges in construction is the use of raw materials, and the implications in terms of energy balance, consumption and the sustainability of the building during its useful life (Weißenberger et al., 2014). Thus, the reduction in energy consumption and its associated emissions is a main issue in architecture and engineering.

The duality of the life cycle concept and the construction sector can be summed up in concepts such as that of "low energy building" or "NZEB" (neat zero energy buildings), which aims to achieve the reduction of the impact on the environment during the building life cycle, the minimisation of the energy and resources consumption, as well as land use (Loga et al., 2017). An energy efficient building uses active and passive technologies to counteract transmission heat loss that affect energy consumption. The highest energy input in a building is found in the materials, known as embodied energy. Dixit et al. (2012) define the embodied energy like the energy sequestered in buildings and building materials during the entire life cycle. The construction sector has one of the most important environmental impacts on cities, and to face its consequences and reduce energy consumptions is necessary to promote solutions with an efficient performance during its entire lifecycle.

New technologies and building construction processes are being developed in order to improve the sustainability and efficiency of building envelops. Research has been carried out to develop new adaptable and intelligent facades that highlight their thermal behaviour and adaptability to different climatic contexts (Iommi, 2018), within these, the vegetable façades are particularly noteworthy.

Greening the building envelope provides benefits related to improved efficiency, a contribution to the immediate context through temperature regulation and reduced wind speed, as well as increased biodiversity in dense urban environments (Perini et al., 2011). Living wall systems (LWS) as part of vertical green solutions can improve the quality of urban living and reduce the global environmental impact caused by climate change (Dunnett and Kingsbury, 2008). The use of

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https://doi.org/10.1016/j.jenvman.2019.109743
Received 7 May 2019; Received in revised form 14 October 2019; Accepted 19 October 2019
Available online 6 November 2019
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Greening the building envelope with LWS taking into account the materials involved is a key step in selecting a solution that leads to an environmentally friendly performance. This study highlighted that the use of recycled materials, organic substrates, and low environmental impact materials are part of the sustainable strategies for the design of these systems. These should be considered as key strategies for the environment, sustainability, and low energy consumption of LWS, throughout their life cycles.

Acknowledgments

The authors want to thank to the project "LIFE Lugo + Biodinámico" Ref: LIFE14CCA/ES/000489, funded by the European Commission, for the support of this research.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jenvman.2019.109743.

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Glossary

Kg CO^2 eq: Climate change (CC)
Kg CFC-^{11} eq: Ozone depletion (OD)
Kg PM2.5 eq –: Particulate matter formation (PM)
CTUh –: Human tocixicity-no cancer effect (HTnoc)
CTUh –: Human toxicity-cancer effect (HTC)
Kg NMVOC eq –: Photochemical ozone formation (POF)
molc H+ eq –: Terrestrial acidification (TA)
molc N eq –: Terrestrial eutrophication (TE)
Kg P eq: Freshwater eutrophication (FE)
Kg N eq –: Marine eutrophication (ME)
CTUe –: Freshwater ecotoxicity (FEx)
Kg C deficit –: Land use (LU)
M^3 water eq –: Water resource depletion (WU)
Kg Sb eq –: Mineral and fossil resource depletion (MFRD)
LWS –: Living wall system
LCA –: Life cycle assessment
LCI –: Life cycle inventory