SARKA KONASOVA

Czech technical university in Prague, Czech Republic

COST-BENEFIT ANALYSIS OF GREEN ROOFS IN DENSELY BUILT-UP AREAS

Abstract:

This paper presents a cost-benefit analysis of vegetated roofs in urban areas based on an extensive literature review in multiply fields. Green roofs have been used as an environmentally friendly roofing structure for many centuries and considered as a sustainable product. Research shows that private benefits are usually high enough to justify the additional investment for a private decision maker. Although, when the public benefits are added to the private benefits, than in the most cases benefits outweigh additional costs of green roofs. The analysis is conducted to demonstrate the private and public costs and benefits of integrated vegetation into building envelopes. Most of the benefits are not directly measurable in economic term, thus their monetary value is estimated due to other studies.

Keywords:

built-up area; cost-benefit analysis; green roof

JEL Classification: Q51

COST-BENEFIT ANALYSIS OF GREEN ROOFS IN DENSELY BUILT-UP AREAS

SARKA KONASOVA

Abstract:

This paper presents a cost-benefit analysis of vegetated roofs in urban areas based on an extensive literature review in multiply fields. Green roofs have been used as an environmentally friendly roofing structure for many centuries and considered as a sustainable product. Research shows that private benefits are usually high enough to justify the additional investment for a private decision maker. Although, when the public benefits are added to the private benefits, than in the most cases benefits outweigh additional costs of green roofs. The analysis is conducted to demonstrate the private and public costs and benefits of integrated vegetation into building envelopes. Most of the benefits are not directly measurable in economic term, thus their monetary value is estimated due to other studies.

Keywords:

built-up area; cost-benefit analysis; green roof

JEL Classification: Q510

1 Introduction

The construction industry is responsible to please human development needs and desires. Unfortunately, the opposite side of this development is deterioration of the environment based on utilization of non-renewable materials. Buildings are responsible for approximately 40% of energy consumption and 36% of CO_2 emissions in the EU. Nowadays, more than 35% of EU's buildings are over 50 years old and almost 75% of building stock is energy inefficient [1]. Therefore, more renovation of existing buildings has the potential to lead to significant energy savings, reduction of emissions, and re-use and recycle of materials. One of the best options, how to achieve all these benefits is via integration of vegetation into building envelope, for example in form of green roofs.

Green roofs are roofs that are partially or completely covered by vegetation. Vegetated roofs are increasing features of cities' urban planning due to their multiple environment benefits. There are two main types of green roofs: extensive and intensive. Intensive roofs are often called roof gardens. They need a reasonable depth of soil and require permanent maintenance in comparison to thin layer of soil and use of less demanding plants of extensive green roofs.

This article aims to promote green roofs by converting their benefits into monetary terms. Cost-benefit analysis is a decision support tool for developers and home-owners. Developers can market their buildings with beneficial green technologies and the relatively higher investment can be at least partly justified with the benefits.

2 Method

Costs and benefits of green roofs differ depending on many characteristics such as: type of green roof, location of building, weather conditions, cost of materials, energy consumption, labour, discount rate, and inflation. The analysis is conducted for two main types of green roofs: extensive and intensive. Costs and benefits are divided in two categories: private and public. Private costs and benefits of green roofs are those that are achieved just by the property owner. Public costs and benefits are those achieved by society. Analysis will estimate and total up the equivalent money value of the benefits and costs of vegetated roofs to establish whether their installation is worth it.

3 Costs and benefits of green roofs

3.1 Private costs and benefits

In this section, each private costs and benefits of green roofs are shown. The findings are resulting from the literature.

Initial costs

The main barrier of green roofs is the additional costs compared to conventional roofs. The costs for green roofs vary significantly across the world. Bianchimi and Hewage [2] calculated the costs of extensive green roofs range from 90€/m^2 to 113 €/m^2. The costs of intensive green roofs were estimated around 127 €/m^2 - 440 €/m^2 [3].

Longevity

Liu and Baskaran [4] estimated in their study the life cycle of green roof is 40 years, while the life of conventional roofs is about 20 years. Due to information that green roof have a double lifespan than standard one (regular bitumen roof), the present value of the benefit of green roof is 23.6 €/m^2.

Energy cost savings for heating and cooling

Energy savings vary based mostly on location of building but also on thickness of soil and type of plants. Lee et al. [5] calculated that green roof can save 0.14 - 0.52 €/m2 in cooling energy and 0.17 €/m2 in heating energy (natural gas).

Noise reduction

Extensive green roofs may increase transmission loss up to 10 dB at low frequency and up to 20 dB at mid-range frequencies [15]. The cost of adding a plasterboard layer, a generally used tool to improve the noise insulation, is used to calculate sound insulation benefit of vegetated roofs. The total costs of plasterboard installation are around 25 €/m^2 in the Czech Republic (labour costs of 50% are included).

Storm water management

Vegetated roofs can reduce the demand of the sewer system on capacity by delaying water flows and reducing total runoff by retaining of storm water and releasing it to back to the atmosphere by evapotranspiration. The city of Portland charges a monthly fee of 70 €/1000m^2 for impervious surfaces to improve its storm water system [6]. Therefore, it could be saved 0.07 €/m^2 by installing permeable roofing material such as green roof.

Tax reduction

The effort of city of New York to enhance installation of green roofs brought financial benefit for owners of vegetated roofs by receiving a one year tax credit of 48$/m2 (39 €/m^2) [7].

Property value

Green roofs give the opportunity to utilize an unused space by creating a pleasant place to relax and enjoy the great outdoors. There is not direct literature to note a commercial or residential property value increase based on installation of green roofs. The total value of property depends on many factors. One of them is also natural landscapes and green place on the rooftop. The increase in the property value of the building with green roof was assessed to be around 1.2% with regard to study showing the increase of property value of 7.1%, if it is close to forest [8]. The study of Bianchini and Hewage [2] estimated that extensive green roof can increase property value from 105 €/m^2 to 140 €/m^2 and intensive green roof from 139 €/m^2 to 498 €/m^2.

Operation and maintenance cost

Operation and maintenance cost of green roofs are extremely important to ensure their positive impacts. The annual operation and maintenance costs of vegetative roofs were estimated between 0.5 €/m^2 to 11 €/m^2 [8].

3.2 Public costs and benefits

Green roofs help to provide additional green space with many environmental and social benefits in densely built-up areas.

Urban heat island effect

In urban environment, vegetation has been largely replaced by impervious surfaces such as concrete, asphalt that reflect less solar radiation. The built-up areas contribute to the urban heat island effect, when urban areas are significantly warmer than surrounding suburban and rural areas. Studies have found that the urban heat island effect can add between 1 °C to 6 °C to ambient air temperature [9]. Study of Zinzi and Agnoli [10] estimated that green roofs save 10%-14% of the electrical energy consumed in cooling residential buildings. By considering the price of electricity as 0.14 kWh [11], this analysis estimates that green roofs can reduce urban temperature, represented as benefit, 0.01 €/m^2 [2].

Air quality improvement

Studies have consistently shown how vegetation on green roofs traps air particles and gas pollution that contribute to air pollution. Tan and Sia [12] demonstrate in their study that levels of fine particles (PMx) and sulphur dioxide (SO2) decreased by 6% and 37% in the immediate surrounding air space after a green roofs were installed. A study conducted in Toronto shows the area of 109 ha of green roofs can remove around 8 tons of unspecified air pollutions per year [13]. Thereby, the improved air quality benefits of green roofs range around 0.02 €/m^2 [2] based on calculation of the carbon reduction tax.

Flood risk reduction

Green roofs can be applied almost to any rooftop given weight load capacity. The study conducted in Toronto [14] shows that green roofs have capacity to capture an average of 70% of rainfall over a given time, relieving sewer system and reducing risk of floods. The cost to the national economy of England and Wales, due to urban flooding, was calculated €350 million per year. However, flood risk depends on region, green roofs could save 0 €/m^2 to 0.02 €/m^2 [2].

Biodiversity

Vegetated roofs help increase local biodiversity and provide habitat for wild species within urban areas. Brenneisen [16] concluded in his study that low maintenance green roofs offer suitable habitat for animal and plant species that are able to adapt to urban conditions and are mobile enough to reach the habitats on the roofs. Increment of biodiversity is not a common investment, therefore, benefits of green roofs ranges from 0 €/m^2 to 0.01 €/m^2.

Aesthetics

Green roofs provide psychological and aesthetical benefits for people living in urban areas. The study of Hartig [17] demonstrates that event a short time exposure to green spaces has helpful effect on better mental state of people. However, vegetated roofs do not offer the same level of benefits as parks, still provide a space of relaxation inside built-up areas. The aesthetic benefit of extensive green roofs was estimated 5% (6.7 €/m^2) and intensive green roofs 8% (35 €/m^2) based on current demand of properties with integrated vegetation within building envelope.

4 Green roof cost-benefit assessment

Table 1 summarizes the private and public costs and benefits of implementation of green roofs. Benefits are dependent on a number of different factors such as location of building, height of building. The Table 1 shows two scenarios of extensive roofs and intensive roofs. The analysis shows that the private benefits are mostly high enough to cover the current level of the private costs of the most common available green roofs. Considering the membrane longevity or the increase of property value, these benefits may particularly justify the additional initial costs of green roofs. It is important to mention that every case is unique with regard to location in the city, type of building, or type of use.

Table 1: Private and public costs and benefits of green roofs

	Costs and benefits	Type	Time frame	Extensive green roofs			Intensive green roofs		
				Value (€/m²)		Function	Value (€/m²)		Function
				Low scenario	High scenario		Low scenario	High scenario	
Private	Initial costs	Cost	One time	90	113	Uniform	127	440	Uniform
	Longevity	Benefit	Every 20 years	23.6		Constant	23.6		Constant
	Energy cost savings								
	-cooling	Benefit	Annual	0.14	0.52	Uniform	0.14	0.52	Uniform
	-heating	Benefit	Annual	0.17		Constant	0.17		Constant
	Noise reduction	Benefit	One time	25		Uniform	25		Uniform
	Storm water management	Benefit	Annual	0	0.07	Uniform	0	0.07	Uniform
	Tax reduction	Benefit	Annual	0	48	Uniform	0	48	Uniform
	Property value	Benefit	One time	105	140	Uniform	139	498	Uniform
	Operation and maintenance	Cost	Annual	0.5	11	Uniform	0.5	11	Uniform
Public	Urban heat island effect	Benefit	Annual	0	0.01	Uniform	0	0.01	Uniform
	Air quality improvement	Benefit	Annual	0	0.02	Uniform	0	0.02	Uniform
	Flood risk reduction	Benefit	Annual	0	0.02	Uniform	0	0.02	Uniform
	Biodiversity	Benefit	One time	0	0.01	Uniform	0	0.01	Uniform
	Aesthetics	Benefit	One time	0	6.70	Uniform	0	35	Uniform

Source: Author

Higher implementation of green roofs would drive down the cost level of green roofs and increase the level of public benefits. Some benefits are expected to emerge only with high level of implementation rate.

5 Conclusion

The aim of this study was to demonstrate the costs and benefits of vegetative roofs. The type of green roof also plays an important role due to storm water management, biodiversity, and operation and maintenance costs. Many benefit do not have direct monetary value, therefore it is necessary to validate also their environmental and social benefits. Given a lack of research of green roofs for all regions, this analysis can be applied to any urban area.

The assessment of costs and benefits demonstrated that installation of green roofs would be a good investment with regards to public benefit. Currently, the private benefits are not high enough to justify a green roof installation, unless its installation increases a membrane longevity or a property value. This can be changed in the near future by supportive policies offering a new regulation and law toward to sustainability or real estate tax abatements. It is also essential to demonstrate advantages of public benefits of implemented vegetation into building envelope to developers or home-owners to understanding direct impact on increasing value of property and neighbourhood.

Acknowledgement details

This paper was supported by the CTU Student Grant Competition, grant no. (SGS18/017/OHK1/1T/11).

References

European Commission (2018) Buildings, Available from: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings, [accessed 10.04.18].

Bianchini, F. & Hewage, H. (2012) Probabilistic Social Cost-Benefit Analysis for Green Roofs: A Lifecycle Approach, Building and Environment, Elsevier, 58(58), 152–162.

Britain Tourism Board. Available from: http://www.visitbritain.com/en/Destinations-and-Maps/Countries/Britain.htm; 2012 [accessed 06.04.18].

Liu, K. & Baskaran, B. (2003) Thermal Performance of Green roofs through Field Elevation, Proceedings for the first North American green roof infrastructure conference, awards, and trade show, p. 1 – 10.

Lee, A., Sailor, D., Larson, T. & Ogle R. (2007) Developing a web-based tool for assessing green roofs, Greening Rooftops for Sustainable Communities, Minneapolis, April 29eMay 1. Green Roofs for Healthy Cities.

City of Portland (2008) OregonCost benefit evaluation of Ecoroofs, Available from: http://econw.com/reports/ECONorthwest_Cost-Benefit-Evaluation-of-Ecoroofs_2008.pdf; [accessed 10.04.18].

New York City, (2010) Available from: http://www.nyc.gov/html/dof/html/property /property_tax_reduc_individual.shtml#green [accessed 6.04.18].

Acks K. A (2005) Framework of cost-benefit analysis of green roofs: initial estimates, Available from: http://ccsr.columbia.edu/cig/greenroofs/green_roof_cost_benefit_analysis.pdf; [accessed 11.04.18].

EPA (2017) Heat Island Impacts, https://www.epa.gov/heat-islands/heat-island-impacts\ [accessed 6.04.18].

Zinzi, M. & Agnoli, S. (2012) Cool and green roofs. An energy and comfort comparison between passive cooling and mitigation urban heat island techniques for residential buildings in the Mediterranean region, Energy and Buildings, Elsevier, 66–76.

Electricity prices for households in the Czechia from 2010 to 2017, semi-annually (in euro cents per kilowatt-hour), https://www.statista.com/statistics/418073/electricity-prices-for-households-in-the-czech-republic/, [accessed 11.04.18].

Tan, P. & Sia, A. (2005) A Pilot Green Roof Research Project in Singapore. InProceedings of Third Annual Greening Rooftops for Sustainable Communities Conference,Awards Trade Show, Washington, DC, May 4–6.

Currie, B., A. & Bass, B. (2008) Estimate of Air Pollution Mitigation with Green Plantsand Green Roofs Using the UFORE Model, Urban Ecosystems, 11(4), 409–422.

Hill, J., Drake, J., Sleep, B. & Margolis, L. (2017) Influences of Four Extensive Green Roof Design Variables on Stormwater Hydrology, Journal of Hydrologic Engineering/Volume 22 Issue 8 - August 2017.

Connelly, M. & Hodgson, M. (2013) Experimental Investigation of the Sound Transmission of Vegetated Roofs, Applied Acoustics, 74(10), 1136–1143.

Breinneisen, S. (2006) Space for Urban Wildlife: Designing Green Roofs as Habitats in Switzerland, Urban Habitats vol. 4, pp. 27-36.

Hartig, T., Mang, M. & Evans, G. (1991) Restorative Effects of Natural Environment Experiences, Environment and Behavior, vol. 23, pp. 3-26.