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Green and Blue Infrastructure: An Opportunity for Resilient and Sustainable Cities?

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I. INTRODUCTION

The number of people living in cities has increased rapidly in the last decades due to a rapid population growth and, most importantly, increasing rates of urbanisation. The ongoing climate change brings along phenomena that may have an impact primarily on city inhabitants in the future. These may include for example water deficiency, (flash) floods, heat waves or drought. It is therefore necessary that cities react to these new conditions and use adaptive measures to help their inhabitants to adapt to climate change. Potential adaptive measures include nature-based measures that use green and blue infrastructure as an alternative to grey infrastructure to improve the life in cities.

Green and blue infrastructure thus may be an important means to fulfil the objectives of Resilient and Sustainable Cities. As for climate change adaptation measures, green and blue infrastructure refers, e.g., to greenery in public spaces, green roofs and facades, measures for rainwater absorption, retention reservoirs, measures to slow down water runoff, etc. These measures have a positive effect on people's life in cities and their health due to ecosystem services, which may assume various forms. In addition to primary benefits consisting of direct contribution to adaptation to climate change (flood risk reduction, temperature and microclimate control, water retention in (urban) landscape), these measures bring numerous co-benefits contributing to the populations' well being (e.g., energy savings, water purification, property value increase, support to biological diversity).

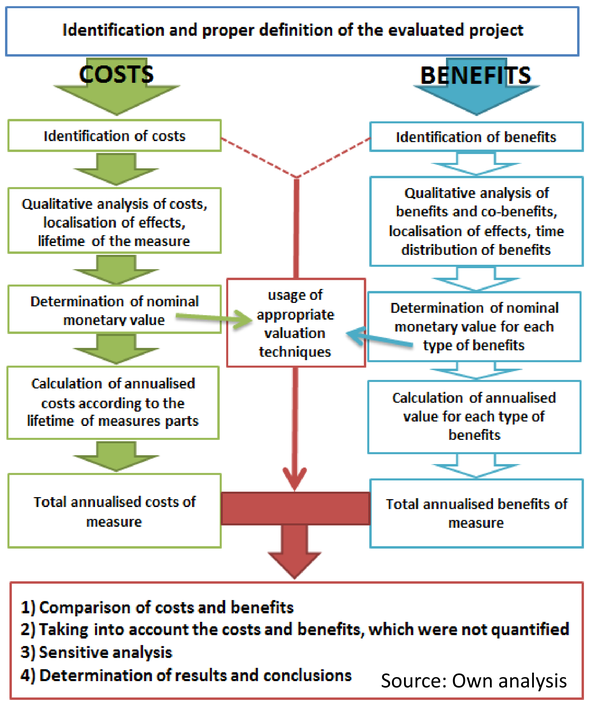
II. METHODOLOGY

Assessment of society-wide benefits and costs of the implementation of a specific measure is based on economic cost-benefit analysis (CBA) method and on annualization of costs and benefits, derived from the concept of real value of money and the opportunity to invest funds elsewhere.

The costs are set according to project budgets and estimated operating costs. The benefits are monetised based on bio-physical indicators such as volume of intercepted water, which saves the costs for transporting rainwater and its potential treatment in a wastewater treatment plant in the case of combined sewerage.

III. INTRODUCTION OF CASE STUDIES

Services provided and benefits are assessed on two different examples in the Czech Republic: (i) the construction of a green roof in Prague-Jinonice; (ii) the permeable pavement surfaces constructed for parking lots in Plzen-Struncovy sady.



Source: Own analysis

Green roof in Prague

Photo: Pavel Dostal © 2015

- Family house, finished in 2014
- Extensive green roof with a mild slope and substrate thickness of 8 cm
- Combination of modern architecture, smart buildings concept and green infrastructure in the form of green roof
- Roof area of 125 m^2
- Average rainfall in Prague 460 mm

Parking lot with permeable surface Pilsen

Photo: Eva Brejchová © 2015

- 33 parking spaces , finished in 2012
- Part of a sports centre Relax park
- Unilateral slope of a roadway with draining water into in-depth infiltration dry well made of gravel brash in the surrounding terrain
- Concrete semi-vegetative blocks
- Area of 934m^2
- Average rainfall in Pilsen 533 mm

IV. BENEFIT ASSESSSMENT

The identification of benefits is based on the ecosystem services approach. Besides ecosystem services divided into 4 groups (supporting, provisioning, regulating and cultural services), other benefits other benefits such as biodiversity (habitat creation), energy savings or increasing lifetime of the buildings are also taken into account. The following table shows qualitative assessment of the befits. The benefits valuated in monetary units are marked with a dollar symbol. Monetary value of green roof benefits is listed below.

	Reducing water volume at WWTP	Lowering risk of flooding	Supplying surface water and groundwater	Improving water quality	Regulation of micro-climate / city's heat island	Noise reduction	Energy savings	Air quality improvement	CO2 reduction	Erosion reduction	Real estate value	Recreational benefits	Increase in aesthetic value	Biomass production	Crop production (urban agriculture)	Habitat creation	Increasing lifespan / construction costs reduction
Green roof	$					$	$	$	$	U							$
Parking lot with permeable surface	$						U	U	U		U	U	U	U	U		$

Legend: Full provision | Limited provision | U Not provided | $ Benefits valuated in monetary units

Quantitative valuation – Green roof		Annualised monetary value	
Provided services/benefits	**Value/Description**	PURE SOCIAL BENEFITS (CZK)	PURE PRIVATE BENEFITS (CZK)
Rainwater runoff control	annual infiltration of 34,500 l	1,139	
Reduced noise in the building	reduction by 6 dB		1,338
Extended insulation lifetime	double lifetime (extended approximatly about 30 years)		1,746
Energy saving	annual 8.5 kWh per m^2 of the green roof area		4,686
Reduced emissions of NO_2 in the air	16 kg/hectare	65	
Reduced emissions of SO_2 in the air	4 kg/hectare		
Reduced emissions of O_3 in the air	30 kg/hectare		
Reduced emissions of PM_x in the air	8 kg/hectare		
Reduced emissions of CO_2	700 kg/hectare	6	
Cost savings for ordinary roofing	-		2,095
Total social benefits		**11,527**	

There is no adequate input information for monetary appraisal of the recreational and aesthetic benefits, including the determination of the impact on property prices and benefits from increased species diversity. Similarly, the benefits from the permeable surface were evaluated.

V. RESULT

The comparison of costs and benefits of both types of the measures shows that the total social benefits exceed the costs of the measure implementation and operating costs. From a purely economic point of view, the implementation of an extensive green roof and building of a parking lot with permeable surface make sense. The monetary value of the benefits excludes the cultural ecosystem services (benefits associated with recreation and aesthetics) and the positive impact of the green roof on biodiversity; the total benefits would be greater then.

C B	Yearly (annualised) costs (EUR)	Yearly (annualised) benefits (EUR)	Benefits-costs ratio
Green roof	291	430	1.5
Parking lot with permeable surface	729	1,754	2.4

VI. CONCLUSION

Adaptation to climate change is a major future challenge for cities, to which they will have to respond as the climate change phenomena progress. Besides purely technical adaptation measures to climate change, cities have a possibility to apply so called nature based (or ecosystem-based) adaptation measures, which are based on the use of green and blue infrastructure. In addition to the direct benefits to the process of adapting to climate change in cities, these measures bring numerous other co-benefits for both property owners and the entire society. The results of the qualitative and quantitative analysis show that the implementations of both the green roof in the specific case of a single-family house and the parking lot with permeable surface bring net social benefits.

Based on the calculation of social and private benefits and costs of implementation of green roofs (on an example of a standard newly built single-family house), we have proven that this measure can be implemented by the private sector without any major obstacles (or subsidy requirements). Thus, green roofs are an adaptation measure that actually invites local inhabitants to participate in solving the new challenges faced by cities.

B 4.3

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