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A review of green roof incentives as motivators for the expansion of green infrastructure in European cities

Key words: green roof, green infrastructure, incentives, benefits, European cities

Introduction

City development for residential, commercial and transportation purposes contributes to the disappearance of green areas. Only in Austria, 15–25 ha of land are sealed every day (Pendl, Hüfing, Muerth, Tributsch & Jäger-Katzmann, 2009). The urban sprawl tendency only enhances this phenomenon. The development of biologically active areas leads to the loss of recreation areas and potential habitats. The biodiversity of the given land decreases and the proportional share of specific elements in the water and heat balance become distorted. According to the World Health Organization (WHO), the minimum green areas should be 50 m^2 per urban agglomeration resident (Russo & Cirella, 2018). However, the reality is different. In many European cities, urban areas do not provide adequate space for green infrastructure. As a result, building green roofs, which are one of the green infrastructure solutions, is becoming increasingly perceived as an action with a beneficial influence on the urban environment. Apart from the possibility to recreate biologically active areas in cities (partly, e.g. 50% in Poland), numerous studies confirm the capacity of green roofs to retain rainwater and delay runoff, as well as to reduce the amount of pollutants in air, improve the microclimate and positively influence the urban heat island effect (Shafique, Kim & Rafiq, 2018; Burszta-Adamiak, Stańczyk & Łomotowski, 2019). Another factor that is increasingly appreciated in cities, is the fact that green roofs provide friendly, green leisure spaces and improve the aesthetical values of buildings (Sutton, 2014). Other argument that supports their construction is the possibility to reduce carbon footprint in cities (Ugai, 2016) and direct water footprint (Fialkiewicz et al., 2018). Green roofs can also be included in the "smart city"

policies adopted by numerous cities, where the aim is to improve service efficiency and urban quality of life by using new technology (Brudermann & Sangkakool, 2017; Shafique et al., 2018). The increased interest in these solutions also results from the fact that cities are willing to present themselves as regional, national or global centres of active adaptation to climate changes. This is reflected in the provisions of numerous strategic documents, climate change adaptation plans, in technical guidelines, as well as in legal regulations, including, among others, construction law and water management regulations.

The current state of knowledge confirms that measurable effects of the green roofs application in urban areas may be achieved first of all when large green areas located near one another are constructed. Due to that, the construction of green roofs in cities should not be limited to single investments scattered all over the town. The surface of roofs in urban areas account for approx. 40–50% of the total sealed areas in cities (Stovin, Vesuviano & Kasmin, 2012), so the potential for constructing green roofs is much higher than the current state of their realisation. One of the reasons of the limited number of green roof investments is the insufficient number of incentives for investors which might reduce the relatively high initial construction costs of such solutions and contribute to raising social awareness of the possibility to construct such roofs and the need to maintain them in good condition throughout their operation period.

So far, the practices of stimulating the development of green roofs have been recognised quite well through national and regional government policies, in several Asian and American cities (Chen, 2013; Olubunmi, Xia & Skitmore, 2016). A review of the green roof legislation, policies and tax incentives in North America can be found also at the website of the Environmental Protection Agency (EPA, 2019). As a result of the growing interest in the benefits of constructing green roofs in Europe, including in Poland, the need to introduce various kinds of incentives for the popularisation of green roofs in urban areas has been noticed in European cities as well. The main reasons for the realisation of investments with green roofs in European countries include the need to increase biologically active areas in towns, to reduce carbon emissions of cities, mitigate heat island effects and improve urban flood control.

The main aim of this paper is to review the European experiences (including Polish) in the area of implementing tools used to motivate public investors as well as individuals to construct green roofs. All information gathered and collated were used to identify the most popular initiatives for the construction of green roofs and to formulate recommendations for creating future incentive programmes addressed to various groups interested in constructing green roofs in urban areas.

Material and methods

The review of incentives aimed at the popularisation of constructing green roofs in European cities was based on information contained in research articles, technical reports, design guidelines, law regulations and case studies. The scope

of the analysis included both financial and non-financial incentives. Each of the incentives encourages the installation of green roofs on existing or new buildings. The analysis covered 52 cities located in 11 countries in Europe. The period of implementing the incentives were the years 1970–2017. All the analysed motivational tools are still used in the cities included in the review.

Results and discussion

The first initiatives aimed at supporting the construction of green roofs in European cities were introduced in Germany in the 1970s (Brudermann & Sangkakool, 2017). Since that time, considering the measurable benefits from their implementation that translated into a growing number of investments with green roofs, an increasing number of countries have become interested in green policies for sustainable urban development.

Local authorities, who decide whether to grant subsidies and to what activities and regulate the principles of eligibility for such donations, are important elements in promoting environmentally friendly solutions. The initiatives taken with the aim to increase the surface area of green roofs in cities are divided into financial or non-financial incentives (Tables 1 and 2). The first ones consist in granting financial support aimed at convincing the potential investors to construct a green roofs. This group of incentives includes subsidies or donations granted to reimburse part of the costs incurred on the realisation of the investment. This solution is common in Belgium, Germany, Switzerland and the Czech Republic. In some German *lands* and certain Dutch cities, local government policy combines the possibility to obtain subsidies with statutory obligation to construct a green roof during the construction of new buildings. This incentive involves various requirements that have to be met if a green roof is constructed (e.g. a flat roof or a specific roof inclination). Other financial solutions used in practice are tax allowances (e.g. real property tax allowance). This form of incentive was introduced in Wrocław (Poland) in 2015. Based on it, the usable areas of residential premises located in buildings, on which green roofs were constructed while the resolution was effective, were exempt from tax. The amount of tax allowance depends on the number of floors in the building, on which the green roof was constructed and the surface area of the green roof (the share of the green roof area in the total surface of the roof) (Resolution XV/268/15). In several cities (e.g. Düsseldorf, Hamburg), constructing a green roof results in decreased fees for discharging stormwater and snowmelt to the sewage system.

Another group of motivational tools are non-financial incentives. They include instruments that focus on gratification (gratifying incentives). Most of the society has a positive attitude towards investments that comply with green policy and receive various awards and green certificates for sustainable development. As a result, residents will be more willing to purchase such residential premises. Such incentives involve granting additional points during the green buildings certification process, i.e. the Building Environmental Assessment

Method (BEAM) which was established in Hong Kong in 1996 (BEAM Society, 2010) or the Leadership in Energy and Environmental Design (LEED) which is a certification rating system developed by the US Green Building Council (USGBC, 2009). During the certification, 1–2 points are awarded additionally for ensuring biodiversity on roof surfaces. This results in the necessity to construct green roofs taking into account various plant species and to design areas that will foster the development of small fauna.

One of the tools used to reduce the surface of sealed areas in towns is the enforcement of land usage intensity and the surface of biologically active areas. Due to that, non-financial incentives also include solutions that introduce the indicators taken into consideration in compensatory environmental activities. One of such factors is the Biotope Area Factor (BAF), developed in the 1990s in Berlin (Badach & Raszeja, 2019). The BAF factor enables to classify land surfaces depending on their ecological value, based on evapotranspiration capacity, permeability, possibility to store rain water, relationship to soil functioning and provision of habitat for plants and animals. The BAF factor is calculated as the quotient of biologically active area for the given area to the total surface area of the land plot, according to the set of assumptions. The obtained results constitute the basis for formulating target BAF factors for specific urban functions, which the developers are obliged to comply with at the stage of obtaining building permits for new investments. The higher the BAF factor, the more important is the given type of biologically active area in environmental compensation. For example, the weighting of surfaces with vegetation unconnected to soil below is 0.5; of green roofs is 0.7 and that of surfaces with vegetation connected to soil below is 1.0. The developers can thus use a wide range of options combining different areas with different types of surfaces for achieving the required standard. Such planning tools have different names throughout Europe, such as green space factor, green points system, the maximum density of built-up area or green-area-per-capita factor (Kruuse, 2011).

The non-financial incentives also include the so-called secondary motivational tools, i.e. those that are executed in the "background", alongside other forms of incentives. They are realised in all the analysed European cities. They consist in providing expert designer support as well as marketing and legal assistance at the stage of planning, designing and realisation of the investment. Such form of support not only allows the investor to save time, but, first of all, to minimise the risk of an erroneous project and to expedite formal procedures. Market demand-related incentives and educational incentives are equally important. Examples of such tools are those that are based on promoting the benefits of green roofs in terms of the pro-environmental actions of the investor (improved microclimate, reduced energy consumption in buildings, etc.) aimed at improving the quality of life of residents. Other types of promotional instruments are market demand-related incentives. These tools use the knowledge about the increased demand for buildings with greenery and the fact that buyers are willing to pay a higher price in comparison to traditional

TABLE 1. Financial incentives in selected cities (own studies based on Carter & Fowler, 2008; Claus & Rousseau, 2012; Boas Berg, Radziemska, Adamcová & Vaverková, 2017; Brudermann & Sangkakool, 2017)

COUNTRY; City	Type of financial support
AUSTRIA; Vienna	Subsidies – co-financing the construction of green roof: 8–25 EUR·m^{-2} (max. 2,200 EUR per project). Additionally, co-financing maintenance costs: 0.19 EUR·m^{-2} (Inspection twice a year, removal of growing trees, cutting grass).
BELGIUM; Flanders	Subsidies – co-financing the construction of green roof: 31 EUR·m^{-2}.
CZECH REPUBLIC	Subsidies – co-financing the construction of green roof: around 18 EUR·m^{-2}.
GERMANY; Darmstadt	Subsidies – co-financing the construction of green roof: up to 5,000 EUR.
GERMANY; Düsseldorf	50% reduction of the fees for rainwater and snowmelt discharge for a constructed green roof.
GERMANY; Esslingen, Stuttgart	Subsidies – co-financing the construction of green roof: 17.9 EUR·m^{-2}, max. up to 50% of the costs.
GERMANY; Hamburg	Real property tax allowance (up to 50%), provisions in the Hamburg Strategy on the realisation of the green smart city concept; the Ministry of Environment and Energy provides financial support needed for the construction of green roofs (a total of 3 million EUR by the end 2019), co-financing up to 60% of the costs of green roof construction, reduction of stormwater fees up to 50%. If the green roof is not connected to the sewage system, then stormwater fees are not charged.
GERMANY; Munich	Subsidies – co-financing the construction of green roof: 30 EUR·m^{-2}, reduced stormwater and snowmelt fees (buildings with green roofs of a height up to 10 cm and a pitch lower than 15° pay fees reduced by up to 70%).
NETHERLANDS; Alphen aan den Rijn, Almelo, Amsterdam, Amstelveen, Apeldoorn, Capelle aan den IJssel, Den Haag, Groningen, Den Bosch, Leeuwarden, Leiden, Nijmegen, Nieuwegein, Rotterdam, Soest, Utrecht, Tilburg, Zoeterwoude, Zwijndrech	Co-financing of the construction of green roof: 30 EUR·m^{-2}. The maximum amount requested is 2,500 EUR for individuals and 25,000 EUR for the construction of apartment buildings and businesses. The maximum subsidy is 50% of the total roof cost.
POLAND; Wrocław	Local legal regulations on the exemption of usable areas of residential premises from real property tax (up to 100%) as part of the project of intensification of the development of green areas in the city of Wrocław (2015–2021).
SWEDEN; Stockholm	Reduced stormwater fees (based on the annual amount of stormwater discharge per building).
SWITZERLAND; Basel, Zurich, Lucerne	Subsidies – co-financing the construction of green roof: 32 EUR·m^{-2}.

TABLE 2. Non-financial incentives in selected cities (own studies based on Carter & Fowler, 2008; Boas Berg, Radziemska, Adamcová & Vaverková, 2017; Brudermann & Sangkakool, 2017; Wolański, 2019)

COUNTRY; City	Type of non-financial support
CZECH REPUBLIC	The Ministry of Environment together with the State Environmental Fund of the Czech Republic announced a new continuous call in the New Green Savings Program (2017–2021).
DENMARK; Copenhagen	Green roofs are a part of the Wastewater Plan, the Climate Plan of the City of Copenhagen, some technical guidelines, e.g. the guidelines for sustainability in constructions and civil works and the city's Strategy for Biodiversity. Since 2010 green roofs are mandated in most new local plans. Legislation – green roofs are required for all newly constructed roofs with a pitch of less than 30°.
GREAT BRITAIN; London, Westminster, Camden, Islington, Hackney, Tower Hamlets, Southwark, Lambeth, Kensington, Chelsea	Provisions in the Climate Change Adaptation Strategy set requirements for green roofs in new buildings in London's Central Activities Zone policy area.
FRANCE	Legal regulations – since 2015 all new buildings in commercial zones must be partially covered by either green roofs or solar panels.
GERMANY; Berlin	Realisation of numerous programmes aimed at making the city greener, e.g. the Courtyard Greening Programme (1983–1996); Biofactor – Biotope Area Factor (BAF).
GERMANY; Essen	Legal regulations – each newly constructed or modernised building in the city centre should contain green areas.
GERMANY; Esslingen, Stuttgart	Legal regulations – all roofs of a pitch below 12° and all roofs of new buildings should be green.
GERMANY; Munich	Legal regulations – flat roofs of a surface area over 100 m^2 have to be green to designate the land area for other purposes.
SWEDEN; Malmö	Biofactor – Green Space Factor (GSF).
SWITZERLAND; Basel, Zurich, Bern, Lucerne	The requirement to construct green roofs on all newly constructed buildings with flat roofs; the requirement to select components to increase biodiversity.

buildings. In such event, developers treat green roofs as added value of their investment, which is an additional incentive for their potential customers.

Introducing incentives to popularise green roofs proves the need to perform actions aimed at increasing biologically active areas in cities and at increasing city resistance to climate changes by introducing nature based solutions. The conducted review of motivational solutions demonstrates that the most commonly used forms of incentives are direct subsidies for the construction of green roofs and legal regulations (Table 3). Practice shows that these are the solutions that achieve the best results. This is proven by Germany, which has a long tradition of using this type of incentives. The surface of green areas in Germany

increases by 13.5 million m^2 every year (Mentens, Raes & Hermy, 2006). This translates directly into the increase in studies conducted there to evaluate various aspects of the functionality and usefulness of constructing green roofs. One of the tangible effects of these experiences was the introduction of the Forschungsanstalt Landschaftsentwicklung Landschaftsbau (FLL) guidelines (FLL, 2002), which were first developed in 1997 and published in 2002 (the last update was introduced in 2018). Since then, most European countries have considered the FLL guidelines as the basis for constructing green roofs. Another example of a country, where initiatives supporting the development of green roofs are successfully implemented, is Denmark. There, the successful implementation of the adopted incentives also leads directly to the realisation of green roof. The requirements concerning the construction of green roofs included in the local spatial development plans enabled to construct 200,000 m^2 of green roofs in Copenhagen only in two years (2010–2011). The most diversified range of incentives exists in Germany (Table 3). This results from the fact that each of the German *lands* conducts a separate green policy in terms of the activities aimed at sustainable development of cities. Table 3 demonstrates that the form of incentives that is most often used in European cities is co-financing the construction of green roofs and local legal regulations that oblige investors to construct such roofs on newly constructed or modern-

TABLE 3. List of incentives used in specific countries

Country	Type of incentive					
	Co-financing of the construction of green roof	Co-financing of the maintenance of green roof	Legal requirement	Tax allowance	Reduced stormwater fees	Biofactor
Austria	+	+				
Belgium	+					
Czech Republic	+					
Denmark			+			
Great Britain			+			
France			+			
Germany	+		+	+	+	+
Netherlands	+					
Poland				+		
Sweden					+	+
Switzerland	+		+			

ised buildings in cities, subject to certain conditions.

The conducted analysis reveals that the type and number of the introduced incentives does not depend on the climate, in which green roofs may be developed. Semaan & Pearce (2016) proved that it does not depend on the country's economic health (gross domestic product – GDP), either. In fact, many factors exist that influence both the adoption of green innovations and the development of policies to promote that adoption, including other socio-economic factors. One of these factors is the attitude towards green solutions, which results from the social awareness of the benefits of constructing green roofs and the advisability of their use. This makes it extremely important to implement the aforementioned "background" incentives alongside other financial and non-financial incentives.

The analysed countries also include those, where the incentives were introduced only one or two years ago, and their measurable effects are not as spectacular as in Germany or Denmark. Unfortunately, in many European cities, green roofs are still treated as a relatively unimportant element of the urban environment (Brudermann & Sangkakool, 2017). This sceptical attitude of investors to constructing green roofs is usually linked to the lack of knowledge of the technology of their construction and of the environmental, social and economic benefits from their realisation. This phenomenon is enhanced by the occasional news about poorly constructed green roof (leaks, dampness, problems with maintaining the roof vegetation in good condition, etc.). Another limitation that affects the current state of introducing incentives may be insufficient information about the required administrative actions which are often excessively complex and prolong the procedure of obtaining a building permit. In the opinion of the authors, setting the incentives at a low return on investment level might be another factor that leads to poor interest in the proposed solutions. Such situation may be encountered when reduced stormwater or snowmelt fees are offered, or during the settlement of real property tax. If savings on fees are in the amount of several or over 10 PLN annually, the investment costs may be returned after 20–30 years, which is not an attractive offer for investors. In some of the cities there is a lack of strategy and vision by leaders, executives and administrators. This also translates into insufficient interest in the construction of green roofs. Incentives based on excessively strict requirements for the structure of the constructed green roof (e.g. minimum surface area or substrate thickness) to be eligible for co-financing or tax allowance may also make the offer less attractive for investors. Some cities complained about the public procurement procedures (the administratively easiest approach, selecting the cheapest offer, creates a lot of undesirable side effects and in the lack of integration each managing organization behaves differently). The monitoring systems to measure success are also usually weak. Therefore, maintaining green space is seen as another financial barrier. Many public and private clients see maintenance as an obstacle, ignoring the potential it holds. Hence, many cities called the attention to the difference between the creation vs maintenance of green spaces. Complaints usually

concentrated on the lack of funding for regular maintenance. All these barriers directly affect the degree of using the proposed incentives by investors.

Recommendations

Identifying the barriers that emerge during the practical implementation of the adopted incentives allowed us to pinpoint the weaknesses of the motivational system. In the opinion of the authors, this may be the basis for determining the directions of establishing future incentives for cities that will decide to introduce them. The awareness of the existing types of barriers may also encourage those cities that have already introduced green policies to modify them in order to improve the current state of use of the incentives. The motivational system should be modified on several levels. First of them is education. The satisfactory level of acceptance of the BAF factor in Berlin proves that this aspect has been taken into account. At the stage of creating the factor, groups of experts, representatives of the local community, the public administration, and environmental NGOs had the possibility to express their opinions on the weighting assigned to the given type of development (single-family, multi-family, etc.). Another major success of these consultations was the fact that BAF was taken into account in urban spatial development (i.e. in local spatial development plans). Another form of improving the awareness of the functioning of green roofs in cities is the realisation of demonstration projects, accessible to those who are interested in learning more about the technology. The educational programme for residents, investors, and city policy makers should be closely integrated with a municipal campaign aimed at the popularisation of green roofs. Such campaign may be conducted through various channels, including leaflets, press articles, posters, online promotion, etc. Another important aspect of a well-developed incentive should be its flexibility. At the stage of considering the BAF factors in the design, developers may choose from several different options of greenery or creating water-permeable surfaces. Thus, they may select such systems that will be the most beneficial for them, for future users of the area and for the environment. Another important feature of a motivational tool should be its simplicity. Both the structure of the proposed incentive (in terms of calculations) and the implementation procedure (administrative issues) should be simplified. An example of such incentive is determining the subsidy amount per each constructed square meter of the green roof, along with tax allowance or reduction in stormwater or snowmelt discharge fees. The experiences of European cities show that the best results, translated into the number of realised green roof investments, are achieved when the set amount of subsidies is reasonable, so that the investor can receive return on investment within several (max. 5–10) years. Incentives should be created in form of packages (several options at the same time), in connection with legal regulations. The aim of such strategy is to include the provisions on green roofs in legal regulations concerning construction, water management and spatial planning of green areas. Provisions in legal regulations should be introduced on

statutory or ordinance (national) level. In the existing system, regulations on incentives are limited to provisions in local laws (city development strategies, local spatial development plans, etc.), which fosters the development of green roofs in certain parts of the country (often limited to one city), while the issue is neglected in other parts.

Future financial incentives should not be limited only to co-financing the stage of construction of the green roof. As far as green infrastructure solutions are concerned, the stage of operation is extremely important, as it requires, when necessary, conducting maintenance works (fertilising, weeding and irrigation during long dry periods). Among the analysed cities, only Vienna (Austria) has foreseen subsidies on maintenance costs in the incentives. The maintenance costs are co-financed in the amount of approx. 0.19 EUR·m^{-2} and the scope of works cover inspection twice a year, removal of growing trees and cutting grass.

Conclusions

The degree of realisation of green roofs in cities that have introduced incentives, compared with cities where such motivational tools have not been implemented yet, allows us to conclude that the implementation of such incentives for various groups of stakeholders is currently an indispensable element of local policy. Nowadays, local governments possess tools that enable them to motivate residents and local entities to construct green roofs in municipal areas.

In spite of several barriers that hinder the development of green roofs in towns, growing interest in this type of solutions is expected. Due to that, it is necessary to develop motivational instruments for the construction of green roofs. Such tools should include mainly financial incentives and obligatory legal provisions. Additionally, promotion, social dialogue, good tactics (policies, strategies), and studies are required. Further challenges for today's cities include providing technical and administrative support in designing, constructing and maintaining green roofs. Only such multi-faceted approach will lead to the increase in the number of cities with well-developed green infrastructure on the map of our continent.

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Summary

A review of green roof incentives as motivators for the expansion of green infrastructure in European cities. Nowadays green roofs play a key role in alleviating the negative effects of urbanization. Despite investors awareness of the advantages of green roofs, there are still some barriers that hinder investments on a large scale. As a result a financial and non-financial incentives are implemented. The review presented in this paper allowed to identify the most popular initiatives and to formulate recommendations for creating incentive supporting implementation of green roofs in urban areas.

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