A Legal Approach to Fostering Green Infrastructure for Improved Water and Energy Efficiency

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Abstract

Over the last 30 years, numerous protocols, agreements, and conventions were signed to ensure that environmental protection related to climate change, pollutants, biodiversity, soil erosion, and water quality, among others, is part of the agenda, and the language of ecology has been introduced into political discourse and public policies. However, this does not appear to have been sufficient and there remains a need for national and international instruments that respect all future citizens.

Buildings account for around 40% of EU energy consumption and 36% of greenhouse gas emissions. Ways of reducing the energy consumed by buildings have already been developed, in addition to methods to improve water management. One such approach is the so-called ecosystem service-based approach for green infrastructure, with nature-based solutions that involve much more than bringing nature to cities. Green roofs retain water in times of heavy rain, especially in "waterproof cities", mitigate the heat island effect and contribute to thermal efficiency of buildings. and air quality, with a significant effect in public health.

Current construction standards do not lay down strict environmentally friendly solutions. Laws and regulations have yet to become goal-oriented, holistic, and interdisciplinary. How could (r)evolution in the law help green infrastructures to thrive?

Keywords

Green roofs · Climate change · Energy efficiency · Sustainability · Urban law · SDGs 11 and 13

1 Introduction

When faced with extreme, unpredictable climate change-related situations, society's apparent lack of awareness and the insufficient technical preparation of political and administrative agents are barriers to implementing preventive measures and solutions to mitigate the intensity and harmfulness of environmental events. Any reflection on this matter must therefore consider two major spheres of action. A first focus must be on how to address current situations affecting biodiversity and human health, resulting from the global rise in temperature, shortages of drinking water (and lack of access to water) and pollution in general,

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among others. Simultaneously, it is essential to reflect on how to prevent any worsening of the current situation to avoid reaching the point of no return, and the inevitable desperate poverty and waves of migration that would ensue. It is no longer simply current sustainability that is sought, but rather future sustainability. Solutions must be found to increase society's resilience to the environmental unpredictability we are already experiencing, and work must be done to slow down its intensity and progress.

From a legal perspective, the issue of sustainable development is usually perceived through the legal rules governing economic activities and the functioning of the market, in addition to direct actions on the natural environment, and the range of existing legal instruments extends from the regional and national to the international and global.

The last three decades of legal environmental protection against climate change, pollutants, biodiversity in general, soil erosion and water quality have mainly been centred on the environmental issues *per se* rather than on their integration with other strategic planning frameworks, such as urban planning and urbanisation. However, urbanisation does, indeed, lead to (micro)climatic changes (Freitag et al. 2018; Paul et al. 2018; Şimşek and Ödül 2019; Din Dar et al. 2021). While it may not be immediately evident, buildings play a significant role in impacting the ecosystem. Governments and international organisations have so far failed to give the urban dimension the attention it warrants, when designing legal rules and restrictions. And yet, nature-based solutions combining biotechnology have existed for some time now, and are key in addressing climate, water, and energy problems, such as floods and droughts, and can also promote climate control. Efforts should be made to incorporate these solutions into urban law, first as incentives, and then as mandatory requirements within urban planning and construction, so as to promote more resilient urban ecosystems.

Blue-Green Infrastructures (BGI) are a key instrument in increasing resilience to adverse environmental and climatic conditions and can contribute to reducing the intensity of these conditions in the future. These structures offer direct and indirect benefits and equate to effective action by society. One area where they can be particularly useful is urban planning, specifically building construction. BGI have been described as a "network of interconnected wetlands, basins, and natural spaces, forming an essential means for coping with extreme weather conditions/floods" (Jeong et al. 2016; Din Dar et al. 2021). They include several technological solutions such as rain gardens, bio-swales, bio-retention cells, permeable pavements, green walls, and green roofs. These solutions have been gaining importance due to the "increasing evidence of [their] social, environmental, and health benefits" (Benedict and MacMahon 2006; Din Dar et al. 2021), which have long been recognised. BGI fall within the category of Nature-Based Solutions (NBS), which the United Nations Organization regards as a tool to accomplish several of the Sustainable Development Goals (SDG): "good health and well-being (SDG 3), clean water and sanitation (SDG 6), sustainable cities and communities (SDG 11), climate action (SDG 13), (...), and protection, restoration and promotion of sustainable use of terrestrial ecosystems (SDG 15)" (Cohen-Shacham et al. 2019, pp. 20, 22; Calheiros et al. 2022, p. 2).

We have chosen green roofs to demonstrate a simple urban solution within everyone's reach that can play a part in the fight against climate change. The next section provides a more technical description of this solution.

2 BGI and Green Roofs in the Urban Context

The term "green roofs" refers to green infrastructures established on the top of buildings the impact of which is much more than simply bringing nature into cities (European Environment Agency 2020; Abass et al. 2020; Devon County Council 2020; Pearlmutter et al. 2020, p. 1).

A green roof is an engineered multilayer structure that seeks to mimic nature. Underneath the visible top layer of vegetation there is, generally, a substrate that supports plant growth, a drainage layer for collecting water, and membranes that separate and interconnect the various layers. Green roofs retain water in times of heavy rain, especially in waterproof cities, and can serve as basins for storing water to be used in buildings for a range of purposes. They also mitigate the so-called heat island effect (whereby cities are warmer than their rural surroundings) and contribute to the thermal efficiency of buildings—at the same time helping to reduce energy consumption and combat energy poverty—as well as producing benefits in air quality. The health and social dimension of implementing such structures in cities goes far beyond all measurable outcomes.

A range of technical guidelines have emerged in recent years for best practice in green roof design and implementation, also incorporating location-specific features. These guidelines are an excellent starting point for disseminating this tool. By way of example, we may highlight the German FLL guidelines (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau 2008) and the Portuguese Technical Guide for Green Roofs (2020).[1] The design of the infrastructure should take into account the local climate conditions, which influence the choice of plants, and the local availability of materials, including substrates for plant growth and material for water retention. The assembly of the plants and materials drives the system's performance, which is measured by the target outcomes, such as improvement of water quality and stormwater management (Monteiro et al. 2015, 2017a, b).

3 BGI and Urban Law: A Perfect Match?

3.1 Positive Impacts of BGI and Green Roofs

Like many technological solutions, green roof infrastructures have both positive and less positive impacts.

Some of the positive impacts described in the literature include:

(i) Reduction of water quantity in situations of intense or diluvian rainfall. Storm water retention is usually the first benefit mentioned (Getter et al. 2007, p. 226; Carter and Fowler 2008, p. 151). This benefit can be very relevant for cities' sewer systems, preventing overflows;

(ii) Improvement of water quality through biological and mechanical purification processes, with the elimination of heavy metals, suspended pollutant particles or other pollutants from the air and from the water itself, implying benefits to the water cycle (Liberalesso et al. 2020). Some studies indicate a positive effect of reducing acid rain levels, with a positive impact on the control and combat of air pollution.[2] Despite a lack of data regarding CO_2 capture, it must be stressed that, overall, green roofs make an important contribution to fighting air pollution (American Rivers et al. 2012, p. 32);

(iii) Temperature control of public and private built spaces. Urban areas are known to be warmer than non-urban areas due to the lack of vegetation cover and due to human activity, and growing demand for housing is yet another source of stress in this regard (Mittermüller et al. 2021, p. 40). Green roofs can capture heat during the day and release it at night, contributing to a smaller temperature range. Depending on the structure, there may be benefits for public spaces, such as shade on roadways or vegetation cover on buildings by means of the evapotranspiration process (Koc et al. 2018; Mittermüller et al. 2021).[3] Temperature variations are not generally beneficial to

[1] Guia Técnico de coberturas verdes. 2020 ANCV.

[2] Referring to a study from 2007, American Rivers et al. (2012, p. 29, 44).

[3] Din Dar et al. (2021); Mittermüller et al. (2021, p. 49) (referring to the relationship between tall buildings and narrow streets as a factor to "increase daytime thermal comfort by providing shaded walkways". However, it has the drawback of being less thermal friendly in cold weather); American Rivers et al. (2012, p. 18).

human health (American Rivers et al. 2012, p. 16; Mittermüller et al. 2021, p. 49). Some studies have demonstrated a decrease in the impact of these, specifically a decrease in heat-related deaths, when urban planning incorporates BGI solutions (Din Dar et al. 2021);

(iv) Possible generation of micro-climates in cities which may contribute effectively to balancing temperatures (Din Dar et al. 2021);

(v) Climate control through reduction of the temperature range, leading to less energy being spent on climate control technology both to heat and to cool buildings (American Rivers et al. 2012; Din Dar et al. 2021).

In addition to the above, BGI in general provide other benefits that may not be easily measurable, either because their effects are more long-term, or due to the location or the difficulty in aggregating comparable data. Some of these benefits relate to (i) improvements in urban spaces, enabling the recovery of fauna and flora; (ii) decreases in noise pollution through the use of BGI on pavements (Liberalesso et al. 2020); (iii) mandatory green structures in urban planning, such as gardens and green corridors; (iv) recreational spaces to play sports or to socialise, which contribute to social engagement and improve mental health; (v) investment in the sustainability of buildings and cities as a tool for organising space and territory, enhancing real estate development and the value of cities (Liberalesso et al. 2020; Calheiros et al. 2022, p. 236); (vii) increases in green employment (American Rivers et al. 2012); and (vii) improvements in sanitary conditions in cities and the consequent decrease in the demand for health care.

Nevertheless, there are also some difficulties associated with the use of BGI. Firstly, it is not always easy to accurately determine the actual benefits and advantages of these structures given the diversity of the structures themselves, their location, and the type of vegetation used.[4] When considering location, whether the BGI is in a public space or in a private building will be relevant; and, in the case of a building, its height and construction materials need to be considered. For both scenarios, the constancy/inconstancy of the location's climate conditions is decisive for the choice of the structure. Although there are some studies on this subject, it is clear that more are needed and that these should be more in-depth (Din Dar et al. 2021). The difficulties mentioned above highlight the need to incorporate BGI into public policies and into the actions of administrative bodies and entities. In addition, since these structures are not yet in widespread use, there is a need to explain their costs, in some cases because they will affect individuals, and in others because they will affect the public budget. It is essential that an effective policy is developed to communicate the life cycle cost gains that these structures bring to people's daily lives (Din Dar et al. 2021). Normally, these benefits are neither "internalized by the building owner" (Carter and Fowler 2008, p. 152) nor by the public bodies who regulate such issues. Although some additional costs are involved, there are lifetime gains (for the individual and for the community), even if these structures require higher maintenance and the buildings themselves need to support a heavier load. This is one of the conclusions in the report *Banking on Green*: "green roofs may be more expensive than traditional counterparts but provide life-cycle efficiencies that make them less expensive over time" (American Rivers et al. 2012, p. 15). An effective communication policy will also help raise awareness of the importance of multidisciplinary solutions in solving global challenges. There is still some scepticism regarding this kind of solutions, not only due to their cost, but also due to the absence of accurate data on their benefits. Use of these instruments by public entities could, thus, help increase confidence in them. However, it is necessary to address social differences among citizens, which may hinder some individuals' access to this kind of solutions.

[4] Identifying such difficulties, (Mittermüller et al. 2021, p. 42).

4 Worldwide Solutions

Across the globe, various solutions have been adopted to foster the implementation of green roof technologies,[5] such as:

(a) Development of public policies to raise awareness of the importance of greenery in urban areas. Examples include Sydney (Green Roofs and Walls Policy); London (Living Roofs and Walls); Eindhoven; Hamburg (Green Roofs Strategy); Berlin (the city began implementing green roofs in 1988, imposing requirements for implementation); Karlsruhe (the first policies were adopted in 1982); Stuttgart (since 1980); Munich; Zurich (since 1991, all flat roofs which are not used as terraces must be turned into green roofs when building new housing developments, or renovating older ones[6]); Linz (considered a pioneer city, with green roofs being officially introduced in the city's development plans in 1985);[7] Copenhagen (the city has adopted a mandatory green roof policy as part of its bid to become the first Carbon Neutral Capital); Atlanta; Cincinnati (Green Roof Loan Program); Chicago (Green Permit Program); Toronto (the first city in North America to have a green roofs policy); Bogota (Agreement 418 of 2009); Portland (Ecoroof Floor Area Ratio - FAR); Seattle.

(b) Financial incentives for the construction of green roofs (direct and indirect incentives, subsidies, etc., sometimes related to mandatory maintenance of the spaces for a period of time):[8]

   (i) In Europe: Portugal with the Environmental Fund programme for sustainable buildings;[9] Barcelona; Lille (subsidy per m^2); Aalst; Courtrai; Kuurne; Oostende; Eeklo; Ghent; Bornem; Mechelen; Antwerp; Turnhout; Leuven; Eindhoven; Breda; Tilburg; Den Bosch; Capelle aan den Ijssel; Rotterdam; Delft; Leidschendam-Voorburg; Den Haag; Leiden; Nieuwegein; Utrecht; Amstelveen (the subsidy varies according to the extent of coverage); Amsterdam; Soest; Harderwijk; Apeldoorn; Almelo; Bocholt; Nijmegen; Dusseldorf ("Climate-friendly living in Dusseldorf"); Cologne; Munster (the incentive is a reduction in rain tax); Hengelo; Hamburg; Brémen; Hoorn; Leeuwarden; Smallingerland; Groningen; Oranienburg; Berlin (Energy Efficient Refurbishment program); Giessen; Frankfurt; Mannheim; Karlsruhe (fee reduction); Stuttgart (fee reduction); Munich (fee reduction); Linz; Graz; Vienna; Brno; Prague; Lausanne; Venice (infrastructure cost reduction); Heemskerk; mandatory maintenance for 15 years (Merelbeke and Wijnegem); mandatory maintenance for 10 years (Hamme; Sint-Niklaas; Herentals; Dessel; Stuttgart; Prague).

   (ii) In Asia: Singapore building subsidies (e.g. Skyrise Greenery Incentive Scheme—SGIS); Shenzhen (Urban Greening Uplifting Work Plan); Shanghai (The Shanghai government is providing its own subsidies to promote different specific features of green buildings related to energy saving[10]); Chongqing (there are two types of incentives—public construction and private construction premiums that are

[5] For comparison and details regarding the specific policies, Policy map: https://www.greenroofs.pt/pt/mapa-politicas. The references in Liberalesso et al. (2020) also contain links to many of the cities mentioned in this chapter.

[6] https://www.greenroofs.pt/pt/politica/zurique.

[7] https://www.greenroofs.pt/pt/politica/linz.

[8] The tax reduction regarding property or stormwater fee discount, applied by municipalities, is considered to be a benefit of promoting green infrastructures (Liberalesso et al. 2020).

[9] https://www.fundoambiental.pt/ficheiros/regulamento-edificios-sustentaveis-pdf.

[10] https://www.greenroofs.pt/pt/politica/shanghai.

processed after one year of installation and maintenance); Nagoya (the city has a system of financial incentives and a certification system for green facilities that, under certain conditions, counts towards housing loans—Nagoya City Private Facility Greening Support Program | The System of Greening Area | NICE GREEN Nagoya); Seoul (the city offers an indirect financial incentive due to the high cost of land acquisition);[11] Beijing (incentives are offered for developers).

(iii) In the Americas: Nashville (Green Roof Rebate | Nashville Stormwater Management Incentives); Austin (Green Roof Density Bonus); Cincinnati (fee reduction - Cincinnati Stormwater Management Credit); Milwaukee (Regional Green Roof Initiative—MMSD Green Infrastructure Partnership Program); Indianapolis; Washington DC (River Smart Rooftops Green Roof Rebate Program; River Smart Rewards and Clean Rivers IAC Incentive Programs); Montgomery (Rain Scapes Rewards Rebate Program); Baltimore (fee rebate—Baltimore Blue Roof Incentive); Philadelphia (Green Roof Tax Credit); New York (Green Roof Tax Abatement); Syracuse (Green Improvement Fund (GIF)); Toronto (Eco-Roof Incentive Program); Bloomington (Unified Development Ordinance); Minneapolis (storm tax rebate); Devens, MA (Financial incentives for LEED projects); Palo Alto (Palo Alto Green Roof Incentive); Mexico City (Plan Verde de la Ciudad de México); Goiania (Complementary Law no. 235/2012); Salvador (Sustainable Certification Program "IPTU VERDE"); Santos (tax incentives—Complementary Law no. 913/2015); Guarulhos (Law no. 6793/2010); Buenos Aires.

(c) Mandatory requirements; financial incentive programmes often include % coverage requirements:

(i) In Europe: municipal regulations in Portugal (Barreiro,[12] Sintra, Espinho,[13] Valongo,[14] Maia[15]); Paris (since 2015 it has been mandatory for new buildings in commercial areas to have green roofs or solar panels); Amsterdam; Hanover (Guidelines for Green Roofing in Urban Development Plans); Stuttgart (requirement that all flat roofs (up to 12° slope) should include green roofs[16]); Basel (all flat roofs should apply green roofs); Zurich (minimum roofing requirements); Prague (Technical Guide for Design, Installation and Maintenance of green roofs in the Czech Republic); Bolzano (Italian guide for the construction of green roofs and strategies for education and information on the subject, *Procedura R.I.E. (Riduzione dell'Impatto Edilizio)*); Turin—*Articolo 21* (green cover obligation when 20% of the land cannot be allocated to green areas); Malmo ("Ecological building", which requires a minimum of green spaces in buildings constructed on land sold by the city and developed by private developers[17]).

(ii) In Asia: Singapore (buildings constructed after 2010 must have green cover); Guangzhou (green cover technical specifications requiring the installation of green roofs including an indication of the type of vegetation);

[11] http://www.winklerpartners.com/wp-content/uploads/2013/05/SSRN-id2242630.pdf.

[12] Regulation No. 712/2019.

[13] Article 46 Building Regime.

[14] Article 92-A of the Municipal Master Plan of Valongo.

[15] Article 29-A "Coefficients of impermeability" of Chapter IV, Section I of Urbanization and Building.

[16] https://www.greenroofs.pt/pt/politica/estugarda.

[17] https://www.greenroofs.pt/pt/politica/malmo.

Hangzhou; Tokyo (The Tokyo Nature Conservation Ordinance (2001) requires private buildings over 1000 m^2 and public buildings over 250 m^2 to have at least 20% green cover (2015 data) and fines are issued for non-compliance); Seoul.

(iii) In the Americas: Toronto (Green Roof By-law); Los Angeles (Green Building Program); San Francisco (Better Roofs Ordinance); São Paulo (Environmental Quota Law, which is a new urban and environmental instrument to be used when issuing urban licences for new constructions and renovations—Decree no. 55.994/2015 and Decree no. 57.565/2016); Blumenau (Complementary Law no. 1174/2018); Porto Alegre (Complementary Law no. 734, of 24 January 2014); Cordoba (Ordinance (2016) establishing the mandatory installation of vegetated roofs in critical areas with respect to air pollution levels and the effect of heat islands[18]); Recife (Law no. 18.112/2015).

5 Urban Law Contributions

While urban planning law is obviously closely connected with land use planning, its relationship with the environment is also a strong one. Many urban law scholars have already acknowledged that there is a public policy dimension to sustainability within urban planning and building, which is presumed to be "one of the most relevant challenges of the 21st century" (Correia and Correia 2021, p. 27), given that increasing population density has created problems of social management and overloading of infrastructures related to environmental issues (Calheiros et al. 2022). The Portuguese Constitution has long been sensitive to this issue, emphasising, in Article 66(2), the connection between the two areas in what is commonly referred to as the urban environment or urban ecology (Correia and Correia 2021, p. 77). At the next level of legislation, the Portuguese Environment Framework Law (EFL) enshrines the principles of sustainable development linked to responsibility to current and future generations, management of water resources, protection of ecosystems, energy sustainability, and safeguarding of biodiversity.[19] The EFL sets out sectorial policies aimed at promoting sustainable development, thus guaranteeing the transversal nature of the public policies included in it. This crossover of public policies led the legislator to include provisions on air quality management in relation to buildings, preservation of water resources and mitigation of floods and droughts, halting of biodiversity loss, climate change, and waste-related issues. This Law also acknowledges the transversal nature of planning instruments (Art. 13) and highlights the importance of environmental performance instruments, such as stimulating demand for eco-design products, eco-efficiency, and services with increasingly reduced environmental impacts (Art. 20). Alongside the EFL, Article 2(b) of the Portuguese Public Policy Framework Law on Land Use, Land Planning and Urban Planning also highlights sustainable development as one of the major objectives in the fight against climate change, through the promotion of natural spaces in cities, leading to energy, environmental and transport sustainability (Correia and Correia 2021, p. 28). This evolution within Urban Planning Law has been further driven by the New Green Deal[20] and the corresponding internal regulation for Portugal's Circular Economy Action Plan. In addition, the influence of European Union Law in these matters is not new: one only needs to consider the importance of environmental impact assessments, strategic environmental assessments and the ecological network (Natura Network), regarding

[18] https://www.greenroofs.pt/pt/politica/cordoba.

[19] Article 3 (a) and (b) of the EFL.

[20] New Green Deal - COM(2019) 640 final, 11.12.2019: the role of cities in combating climate change (point 2.1.1); transport policy (point 2.1.5); enhancing biodiversity in urban spaces (point 2.1.6).

both directives transposed into Portuguese law and CJEU case law (Correia and Correia 2021, p. 63). National law reflects these influences in the field of planning.

Several areas of overlap can be found, beginning with some planning instruments primarily based on environmental needs. This is the case of sectorial programmes intended to implement certain policies in their specific area, namely “risk prevention, environment, water resources, nature conservation and biodiversity” (Article 39(2) of the Legal Regime for Territorial Management Instruments). The legal rules governing the various planning instruments establish urban plans that are binding on private persons, particularly with regard to the organisation of cities and construction. Decisions arising from sectorial plans must be taken into consideration, with the possibility of both plans and administrative acts being deemed unlawful. There are also other legal constraints, which F. Alves Correia and J. Alves Correia describe as “legal land use regimes” (Correia and Correia 2021, p. 154), that can be of great use in the implementation of BGI, namely the National Ecological Reserve and the National Agricultural Reserve. By imposing public utility restrictions, they limit the discretionary planning powers of municipalities regarding the content of Municipal Master Plans (MMP), requiring the municipalities to include measures associated with public policies on water protection, climate change, temperature control, energy use, and “flood risk management plans”.[21]

Two important areas in Urban Planning that help to produce maximum benefits regarding temperature control of urban spaces and buildings are urban space planning and building construction requirements (Liberalesso et al. 2020). Calheiros et al. (2022) identify green roofs as having “a long history”, but also stress that these have yet to become widespread and replicated in cities in line with that broadly set out in policy and strategic planning. According to Niki Frantzeskaki, a multidisciplinary approach must be adopted if nature-based solutions, including green roofs, are to be successful. Thus, she lists seven lessons drawn from her research: NBS must be “aesthetically appealing for citizens to appreciate and protect them”; they “create new green urban commons”; experiments with NBS “require and build trust between the city and its citizens both for the aim of the experiment and for the experimenting process itself”; “Different fora for co-creating nature-based solutions are needed that include and learn from urban social innovation”; NBS “require a collaborative governance approach. They are often initiated by local governments and require multiple actors to be designed, implemented and linked to urban life”; “An inclusive narrative of mission for nature-based solutions can bridge knowledge and agendas across different departments of the city” and this can help tackle departmental disputes; NBS must be designed so that “lessons for their effectiveness can be easily harvested”, thus making it easier to replicate them in other locations (Frantzeskaki 2019). Urban planning can contribute to a city’s sustainability via the inclusion of “urban greenery” (Patra et al. 2018, p. 82; Calheiros et al. 2022, p. 237) Studies on BGI have shown that various considerations may be relevant when designing urban planning solutions. For example, whether a particular street is wide or narrow will be a factor when weighing up the pros and cons of constructing tall buildings to combat temperature increases in cities. At the same time, landscape architects have an important role to play in determining the type of vegetation in different scenarios. Since space is limited, it may be necessary to opt for high-rise building solutions due, for instance, to demographic pressure in cities. In such cases, it is important to analyse whether planting deciduous trees is feasible or whether more appropriate infrastructures, such as green façades and green roofs, should be chosen (Mittermüller et al. 2021, p. 50). The best solutions are no longer dictated by aesthetic considerations, but rather by the quality of green spaces, whether these be gardens, green facades or green roofs (Kyttä et al. 2013, p. 43; Klemm et al. 2015, p. 87; Mittermüller et al. 2021, p. 51).

Green roof infrastructures are particularly suitable for urban areas where there is insufficient

[21] Correia and Correia (2021, p. 155). See Council of Ministers Resolution no. 51/2016, of 20 September.

space to build gardens or plant trees at street level. Technically, this kind of structure is incorporated in the "roof membrane" to "support plant communities which are tolerant to the extreme weather conditions found on rooftops" (Carter and Fowler 2008). Not all green roofs are the same, their structure being dependent on the structure of the building itself: intensive green roofs are suitable for commercial buildings and parking lots because of their weight; extensive green roofs, on the other hand, since they have a "much thinner profile which limits plant diversity", are more appropriate for less robust pre-existing buildings (Carter and Fowler 2008, p. 152).

In terms of the law, it is possible that the green roof solution, which has already been adopted in several cities in Portugal and across the world, will become a solution that is recommended for inclusion in architectural projects.[22] Indeed, given the pressure to address climate change, such solutions may even become mandatory (Liberalesso et al. 2020). A requirement to have green roofs could become part of each municipality's MMP, adjusted to align with specific land occupation decisions. For instance, with regard to building requirements, Article 46 of the Espinho MMP (1st September 2016) lays down several parameters related to vegetation. [23] The Plan also includes restrictions of an environmental nature, among others, such as changes in vegetation cover, and the Town Council is able to block the demolition of any built edifice, as well as the cutting or felling of certain trees and other vegetation. These restrictions are protected by a provision that allows a private person's plan to be rejected if it fails to comply with them. In Sintra, on the matter of energy efficiency, Article 49 of the Urbanisation Regulation provides for the use of green roofs, among other instruments (Diário da República 2017). Similar incentives exist in the laws of other European countries. A case in point is the Czech Republic, which has had a central national incentive programme since 2017, and has defined green roof construction requirements for those wishing to access these incentives.[24]

Decisions on the adoption of green roofs must consider, among others, the type of use of a particular area (residential or commercial), the configuration of the land, the biodiversity of the municipality, and other legal and mandatory requirements arising from other planning instruments.[25] Mandatory use of green roof infrastructures will need to be fully explained, and it may also be necessary to provide incentives, such as financial support for the disadvantaged and tax breaks to convince the wealthier sections of society. In Portugal, for instance, in Barreiro, the Municipal Regulation regarding financial support for investment—Regulation no. 712/2019—contains a provision favouring green roofs (Article 7 (b) and (c)). The MMP for the municipality of Valongo also contains a provision that grants financial support for the use of these structures.[26] In addition, financial support is also available from some central administrative bodies. For example, in September 2020, the Ministry of the Environment published its Regulations on the Award of Incentives—Support Programme for More Sustainable Buildings (Diário da República 2020). Regarding thermal insulation upgrades, the regulation seeks to support interventions "that promote the incorporation of biomaterials, recycled materials, nature-based solutions, green façades and roofs and bioclimatic architecture solutions in existing urban buildings or units thereof" (Diário da República 2020). Similar financial tools can be found in other European cities. Barcelona is one example (Associação Nacional de Coberturas Verdes Barcelona 2021), and in Berlin the

[22] Calheiros et al. (2022, p. 237) highlight the important role that the enactment of law could play in the green roof implementation.

[23] https://portal.cm-espinho.pt/fotos/categorias_informacao_ficheiros/1.1_rpdme_publicacao_em_dr_172014729359afc5ae454fd.pdf, accessed 21 October 2021.

[24] https://livingroofs.org/czech-buildings-finance-green-roofs/, accessed 21 October 2021.

[25] Reflecting upon these features, Venter et al. (2021).

[26] Article 92.A MMP, introduced on 5 February 2018 (Diário da República 2018).

inclusion of green roofs appears as a condition for constructions occupying parcels of land above a certain area (Associação Nacional de Coberturas Verdes Barcelona 2021).

Another interesting tool, also already implemented in some cities, is sustainability certification. The Leadership in Energy and Environmental Design (LEED) certification is one of the most popular and is used, in North America, in Chicago, Devens, MA, Boston, Los Angeles, and Vancouver, for instance (Liberalesso et al. 2020).[27] Other examples are “Qualiverde” (Rio de Janeiro) and the Green Building Evaluation Label (GBEL), which is used in China (Liberalesso et al. 2020).

However, before engaging in campaigns to convince society, governments must work with municipalities, as the latter have the power to incorporate such requirements in their MMP. Skilled human resources capable of building the most appropriate BGI solutions for each municipality are also essential. A programme called “Living Roofs and Walls”, has been in operation in London since 2008, using a policy based on persuasion, initially motivated by biodiversity enhancement (Mayor of London 2008). As part of its efforts to control rainwater, Copenhagen has been increasing the use of green roofs since 2008, and in 2010 green roofs became mandatory for all new buildings with roof slopes of less than 30 degrees (NYU | LAW 2019). Outside Europe, Toronto was the first city in North America to enact a green roof bylaw and create financial incentives (TORONTO 2019). Meanwhile, the city of Los Angeles chose to implement a programme aimed at large commercial spaces and residential buildings. This public policy encourages the use of these solutions by attaching points to them that can be used when applying for building certification (Department of Regional Planning 2021).

6 Conclusion

Although the current urban planning laws do not yet contain mandatory rules based on environmentally sustainable options, the macro-legislative level is already aware of the importance of urban law to sustainable cities. Portuguese climate law (Law no. 98/2021, 31 December) guides the various social actors towards the reduction of greenhouse gases, carbon neutrality and energy efficiency. It calls upon all administrative bodies, including municipalities, to apply, within their jurisdictions, competences and legal instruments, public policy regarding climate change. Regarding municipalities, they can incorporate BGI solutions in their municipal urbanism regulations to achieve “the sustainable use…of urban spaces” (Art. 28) and the promotion of green space“, “with the aim of increasing green coverage and mitigating the heat island effect of urban cent”es” (Art. 57, no. 2). If regulatory solutions at municipal level are flexible, they will allow the adaptation of BGI solutions to specific areas. Despite initially being only incentives, they should gradually become mandatory if they are to be part of an integrated effort to foster nature-based solutions.

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