BUILT ENVIRONMENT DECARBONISATION
AN ECTP COMMITTEE

ECTP Built Environment Decarbonisation Committee

NBS Initiative Position Paper:

Embracing Nature-Based Solutions for Sustainable Development

List of acronyms

AI	Artificial Intelligence
EC	European Commission
ECTP	European Construction and sustainable built environment Technology Platform
EIB	European Investment Bank
EU	European Union
NBS	Nature-Based Solutions
NEB	New European Bauhaus
SDG	Sustainable Development Goals
TEN-N	Trans-European Nature Network
UN	United Nations

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Introduction

Background

ECTP, the European Construction Technology Platform, is an organization driving innovation and change through research, aimed at creating a better future for the Built Environment industry in Europe. Its main mission is to develop new R&D&I strategies to improve competitiveness, meet societal needs, and address environmental challenges through an Innovative Built Environment. Recognizing the importance of research in making strategic decisions today and future-proofing the industry for tomorrow, ECTP uses its strategic research agenda to identify challenges and lead the way to industry growth and sustainability. This includes informing and influencing Research and Innovation investment in Europe, facilitating collaboration, and mobilizing expertise within the Built Environment. The involvement of the BED Committee (Building Environment and Design Committee) within ECTP has further strengthened this initiative, addressing issues related to the built environment and design within European construction technology strategies.

Within this background, the process leading to the formation of the task group on "Embracing Nature-Based Solutions (NBS) for Sustainable Development", and the subsequent development of this position paper, followed a structured and collaborative approach. Beginning with the introduction of the initiative to BED members in June, it progressed through phases of engagement, coordination, and active participation. In September, activities commenced with a call for participants, followed by the establishment of roles and the initiation of work in October and November. This period saw the administration of a survey to gauge awareness of NBS, setting the stage for informed discussions. Coordinated by RINA Consulting, the task group attracted over 20 participants, predominantly affiliated with the ECTP Committee in the BED, B4L, and H&R groups, with a strong representation from academia and research organizations. The diversity of expertise and perspectives enriched the collaborative effort, ensuring thorough consideration of NBS-related issues. The process emphasized inclusivity, recognizing the value of contributions from all participants and fostering an environment conducive to knowledge exchange. Throughout the endeavor, the focus remained on delivering high-quality outcomes, leveraging collective expertise to produce a comprehensive and impactful position paper. This work highlights the collaborative approach driving sustainable development efforts within the Built Environment sector under the auspices of ECTP.

Context

The European Commission defines NBS as: *Nature-Based Solutions to societal challenges are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, districts, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. Nature-Based Solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services.*

In the global context, NBS have gained significant traction in recent years. 2022 was a turning point, with key intergovernmental agreements highlighting their importance. The fifth United Nations Environment Assembly adopted resolutions emphasizing NBS to achieve Sustainable Development Goals. At UNFCCC COP27, they were recognized for addressing climate change, leading to initiatives like ENACT. NBS are integral to the Kunming-Montreal Global Biodiversity Framework, aiming for harmony with nature by 2050. They were also featured in Ramsar Convention resolutions. Both IPBES and IPCC acknowledge their crucial role in tackling biodiversity and climate crises.

The same determination and ambition in research and innovation policy are also present in the EU, which aims to position itself as a leader in innovating with nature to achieve more sustainable and resilient societies.

New European Bauhaus and policy framework

Drawing inspiration from the historical Bauhaus movement (1919-1933) which sought to integrate artistic vision, architecture and technological-industrial innovation, the New European Bauhaus (NEB), was launched in 2020, as a part of the broader European Green Deal, with the overall objective of creating a more sustainable, inclusive and aesthetically pleasing future (Figure 1). The European Green Deal sets high ambitions around Europe's climate neutrality, sustainability, and inclusion. In this respect, it involves a broad package of policy initiatives and measures, such as the Climate law and the Renovation Wave (towards climate neutrality), the Biodiversity Strategy (towards restoring ecosystems), the Circular Economy Action plan (towards the sustainable use of resources). At the same time, the EU legislation is being updated to reflect the increased ambition of the "Fit for 55" package, with the Energy Performance of Buildings Directive (EPBD), the Renewable Energy Directive (RED), and the Energy Efficiency Directive (EED) being currently revised.

The New European Bauhaus, being an initiative driven by environmental and societal challenges, is the European Commission's creative and interdisciplinary approach that connects the European Green Deal to our living spaces and experiences.

The intention is to integrate these goals into various existing and upcoming policies and programs, in support of the "just transition" as described by the EU Green Deal and of the EU biodiversity strategy for 2030. Especially concerning the building sector, NEB is to be considered when defining relevant regulatory frameworks, as it can provide information in areas outside the scope of purely energy regulation. On the other hand, Nature-Based Solutions, when implemented by the NEB fundamental values ("Beautiful, Sustainable, Together") and the NEB working principles (co-creation, participation, governance), can perform as a multifunctional tool supporting ambitious policies that integrate environmental and socioeconomic goals.

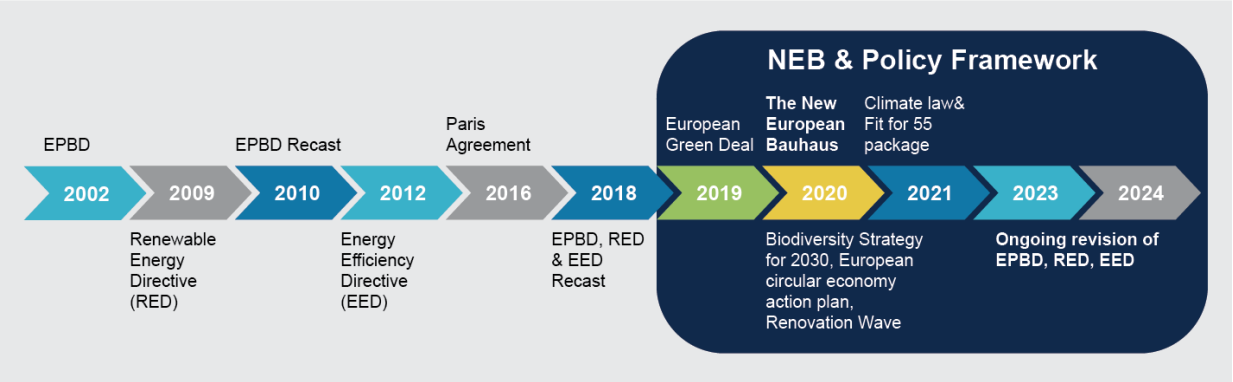

FIGURE 1 THEMATIC TIMELINE

Purpose of the Position Paper

Aligned with the European Green Deal priorities, the EU climate adaptation strategy, and the EU's climate ambitions for 2030 and 2050, as well as the EU biodiversity strategy for 2030, and drawing upon the foundational values of sustainability, inclusion, and aesthetics embedded within the New

European Bauhaus (NEB), our objective is to advocate for the increased utilization of Nature-Based Solutions (NBS). By doing so, we seek to bolster resilience and foster the sustainable, balanced, and inclusive development of urban, peri-urban, and rural areas. Our aspirations encompass a broader societal transformation toward a more sustainable, inclusive, and resilient society, wherein NBS play a key role. We envision NBS as integral components of our living spaces, enhancing our well-being, fostering social cohesion, and preserving our cultural heritage. Recognizing the multitude of benefits they offer, from microclimate regulation to addressing climate change, water management, job creation, tourism opportunities, urban regeneration, and promoting health and well-being, we advocate for the widespread adoption of NBS. We believe that communities stand to gain immensely from embracing this new societal vision, characterized by sustainability, resilience, health, well-being, and inclusion. Furthermore, we emphasize the urgent need for a standardized methodological framework to quantify the health benefits provided by NBS. Such a framework would facilitate strategic planning, decision-making, and policy development at all levels, thereby enabling informed and effective implementation of NBS initiatives.

How NBS embrace the UN Sustainable Development Goals

The 2030 Agenda for Sustainable Development (UN, 2015) defined 17 interlinked global objectives (the Sustainable Development Goals) and 169 targets. The Agenda aimed to balance the three dimensions of sustainable development (economic, social and environmental), based on the five pillars of People, Planet, Prosperity, Peace, and Partnerships. In overall, the Sustainable Development Goals (SDGs) were designed to be a blueprint for achieving a sustainable future for all, with specific indicators identified to quantify and measure the impact of the relevant implemented actions. Sustainability is in fact at the centre of the 2030 Agenda, as also highlighted by the attributed importance of sustainable management of natural resources along with the contribution of ecosystems to supporting economic activities and the well-being of local communities. At the same time, many of the SDGs and their associated targets embrace biodiversity and ecosystems.

In accordance with the 2030 Agenda global objectives, NBS "*contribute to sustainability, improve environmental quality and citizens' well-being, whilst simultaneously providing opportunities for economic development*" [1]. NBS, by harnessing the power and resilience of natural ecosystems, offer a multifaceted approach to address global challenges.

NBS tend to be associated with "conservation goals" such as SDG14 (Life below Water) and SDG15 (Life on Land). Nevertheless, when deemed through a wider context, not only do they align with the environmental objectives but also, they intertwine with socio-economic aspects, essential for holistic and sustainable development [2]: NBS and associated green investments can be linked to SDG1, towards tackling poverty, while supporting economic growth through the creation and promotion of green job opportunities (SDG8). Urban agriculture can be linked to SDG2, towards ensuring food security and improved nutrition. On the other hand, education based on NBS supports inclusion, endorses social cohesion, and reduces inequities (SDG10), but also promotes lifelong learning (SDG4). NBS can also be linked to objectives related to the sustainable management of water and sanitation (SDG6), ensuring sustainable energy (SDG7), adapting, and fighting climate change i.e. through urban green space planning (SDG13) while promoting responsible consumption and

1 European Commission, Directorate-General for Research and Innovation, (2021). Evaluating the impact of Nature-Based Solutions: a handbook for practitioners, Publications Office of the European Union. https://data.europa.eu/doi/10.2777/244577

2 JUSTNature H2020- Sonja Gantioler, et al. (2023). Conceptual and action framework on low carbon | high air quality Nature-Based Solutions (v.3.1). Zenodo. https://doi.org/10.5281/zenodo.7669322

production (SDG12) [3]. Green infrastructure in cities and districts can lead to a positive impact on the health and well-being of citizens (SDG3) [4] from a One Health approach. Equally important, NBS by fostering social cohesion and addressing social issues, are one of the main instruments to accomplish SDG11 (Sustainable Cities and Communities). In summary, the strategic integration of Nature-Based Solutions is indispensable for the successful realization of the SDGs, offering a pathway that is not only environmentally sound but also socially inclusive and economically viable.

Common challenges and future trends in built environment

The trend in European countries is fewer people per household. As a consequence, the living space per person increases (Figure 2 shows an example from Germany [5]: from 46,1 m^2 in 2011 to 47,4 m^2 in 2022). Additionally, the average size of apartment increases as well (from 91,1 m^2 in 2011 to 92,2 m^2 in 2022, Figure 2). Therefore, the need for affordable apartments in urban areas is still high, despite the fact that the number of apartments increases stronger compared to the population (6.7% more apartments and 8.0% more living space compared to 5.3% increase of population between 2011 and 2022, Figure 2). The number of older people in bigger houses or apartments increases, as they make up a larger proportion of society than in the past. They tend to stay due to the increase of rents for new apartments within the last years. Additionally, during the pandemic the trend for young families was to live in more rural areas around cities.

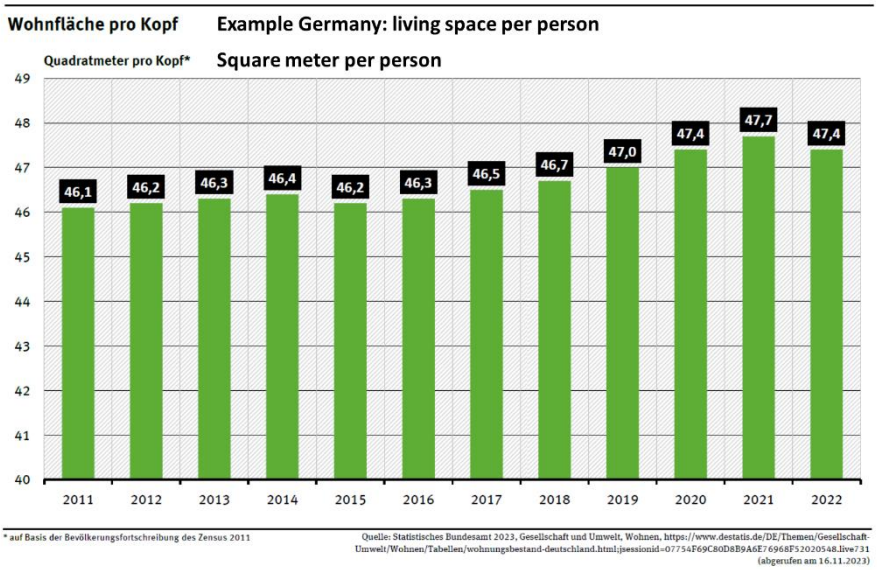

FIGURE 2 TREND OF LIVING SPACE PER PERSON IN GERMANY, FROM 2011 TO 2022

Most of the new apartments and houses were built on new areas which increased land use. New apartments and houses in rural areas need more space compared to more dense apartment buildings in cities and districts. This development poses a big challenge for natural and terrestrial ecosystems with respect to land-use, biodiversity and resilience.

New areas for buildings need also areas for services (schools and kindergartens, sports, etc.) and infrastructure provision (streets, public transport). NBS in combination with intelligent re-use and

3 ThinkNature H2020- Giorgos Somarakis, et al. (2019). Nature-Based Solutions Handbook. 10.26225/jerv-w202.

4 VARCITIES H2020, Emanuele Zilio et al. (2022). Report on multiple benefits expected from Visionary Solutions

5 Umweltbundesamt: https://www.umweltbundesamt.de/daten/private-haushalte-konsum/wohnen/wohnflaeche#zahl-der-wohnungen-gestiegen

densification of existing urban areas could help to decrease the land-use for new apartments and housing.

The ECTP Strategic Research & Innovation Agenda 2024-2030 from October 2030 [6] considers these challenges in its Objective 1: Resilient, adaptive, decarbonised and regenerative built environment. This objective sets priorities for moving towards generating positive impacts on the environment. Its fourth Research & Innovation priority goes beyond mitigating negative impacts on climate through the decarbonisation of the built environment; it covers other environmental aspects such as biodiversity, water, use of raw materials, and sets out R&I activities to exceed neutrality and generate positive impacts. Two of the three topics contribute to the challenge:

- *Frugal, simplified, robust and adaptable designs*: This topic includes the development and demonstration of effective and affordable solutions at local scale for water treatment/re-use and resource upcycling which properly consider the civil and industrial domains creating sustainable and circular approaches at district or city scale.
- *Renaturation and circularity at building and district scale for positive impact on the environment*: This topic will develop affordable, durable and safe NBS for green integration to the building envelope to contribute to solar gain control, water management, protection of biodiversity, etc., as well as decision-making and maintenance guidelines. As well as the exploration of solutions for CO2 storage in the built environment (such as carbonization of materials, use of NBS as green façades and roofs, food production, and micro-algae wastewater systems).

6 ECTP Strategic Research & Innovation Agenda 2024-2030. https://www.ectp.org/resources/publications

1 Defining Nature-Based Solutions

1.1 Main challenges addressed by NBS

NBS is a novel concept, with the term first used in the late 2000s. Initially focusing on ecosystem-based initiatives and complementing biodiversity conservation and environmental management strategies [7], the term was eventually pushed forward in the EU Research and Innovation Policy agenda with economic and social considerations introduced. The report of the H2020 Expert Group on "Nature-Based Solutions & Re-Naturing Cities" published in 2015, defined NBS as actions inspired by and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience [8]. The same report emphasized the significant potential of NBS to turn environmental, social and economic challenges into innovation opportunities. A year later, the International Union for Conservation of Nature (IUCN) described NBS as actions that protect, sustainably manage and restore natural or modified ecosystems, while simultaneously providing benefits for human wellbeing and biodiversity [9]. In 2022, the UN Environment Assembly formally adopted the definition of Nature-Based Solutions as "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity benefits."[10]NBS is therefore identified as an "umbrella term", encompassing many kinds of actions and levels of intervention in ecosystems with a significant potential to address environmental, social and economic dimensions of global challenges. In this context, the characterisation of NBS can be done based on the challenges addressed. For this, IUCN identifies the areas of i) Water security, ii) Food security, iii) Human health, iv) Disaster risk reduction and v) Climate change. The EC on the other hand, identifies NBS as critical for the following seven categories of challenges: i) Urban regeneration, ii) Well-being in urban areas, iii) Coastal resilience iv) Watershed management and ecosystem restoration, v) Sustainable use of matter and energy, vi) Insurance value of ecosystems and vii) Carbon sequestration. The concept of working with nature to address global challenges is also expressed by the principal goals of NBS, as those are described by the EU Research and Policy Innovation agenda, including Sustainable urbanisation, Restoration of degraded ecosystems, Adaptation & mitigation of climate change, and Risk management & resilience.

Fully aligned with the UN Sustainable Development Goals, NBS address challenges related to climate change mitigation, water management, land use and urban development, while at the same time they contribute to solving challenges spanning across social and economic domains. It is important to also mention the strong connection between NBS and cultural heritage when promoting sustainable growth of urban areas. All these contributions underscore the diversity of Nature-Based Solutions, encompassing various types and applications that can be implemented at multiple levels.

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7 Hilde Eggermont, et al. (2015). Nature-Based Solutions: New Influence for Environmental Management and Research in Europe. Gaia: Okologische Perspektiven in Natur-, Geistes- und Wirtschaftswissenschaften. 24. 243 - 248. 10.14512/gaia.24.4.9.

8 European Commission, Directorate-General for Research and Innovation (2015), Towards an EU research and innovation policy agenda for Nature-Based Solutions & re-naturing cities – Final report of the Horizon 2020 expert group on 'Nature-Based Solutions and re-naturing cities' – (full version), Publications Office https://data.europa.eu/doi/10.2777/479582

9 IUCN, Emmanuelle Cohen-Shacham et al. (2016), Nature-Based Solutions to Address Global Societal Challenges; Available online: https://portals.iucn.org/library/node/46191

10 United Nations Environment Assembly of the United Nations Environment Programme UNEP/EA.5/Res.5 (2022), available online: Information on reports and updates by the Technology and Economic Assessment Panel (unep.org)

1.2 Diversity of Nature-Based Solutions – different types and applications

In order to be effective Nature-Based Solutions need to be adopted at several levels. According to their different nature of intervention and especially with respect of which actors need to take the lead, Nature-Based Solutions can be classified into three main categories [11] (Figure 3): i) Strategies for urban planning, ii) Actions for management and monitoring, and iii) Objects (such as equipment and infrastructure). Examples for the different types of Nature-Based Solutions can be explored further on the Nature-Based Solutions Explorer [12].

FIGURE 3 INFOGRAPHIC OF NBS THREE MAIN CATEGORIES FROM WWW.NATURE4CITIES.COM

A successful implementation of NBS, therefore, requires the up-skilling and involvement of different types of actors: decision-makers, planners and implementors and providers of technologies and solutions that can be applied. Only if all these actors are motivated and prepared to act hand in hand, NBS will be able to unfold their benefits for nature, climate, and citizens, no matter what kind of challenges they are addressing nor if they are high or low tech and integrated at building, city, district level or beyond. Therefore, guidelines, policies, and research are needed to promote the enhancement and exploration of these solutions, involving all these stakeholders. Such frameworks

11 From infographic developped in the H2020 project Nature4Cities available on www.nature4cities.eu/nature-based-solutions

12 https://NBS-explorer.nature4cities-platform.eu/?hl=en

should facilitate collaboration, provide incentives for innovation, and ensure effective integration into planning processes at all levels.

2 Harnessing Nature-Based Solutions for Complex Challenges

2.1 Integrated approaches to NBS

Integrated approaches to NBS should be considered and utilized synergistically with other practices and policies, rather than as isolated interventions. This entails integrating NBS into urban development plans, water resource management strategies, climate change adaptation measures, and biodiversity conservation efforts. By adopting an integrated approach, the benefits of NBS are maximized, ensuring they are part of a comprehensive strategy to tackle multifaceted environmental and social challenges. Investing in NBS yields positive outcomes for both the environment and people, thereby contributing to building a safer and more sustainable future for all.

2.2 Adapting to Climate Change

In this framework, NBS act as catalysts and enhancers of climate change mitigation and adaptation measures across urban systems and infrastructures, provided that they prove a high degree of context specificity that responds to local social needs and to the requirements of the built environment. This role can be envisaged at three scales: at the building level, at the district level, and at the interface between urban and rural.

The integration at the building level and within other important infrastructures is a major driver of climate resilience: this includes *"engineered ecosystems such as bioswales and retention areas, constructed wetlands or green roofs, green walls on buildings and greening of other urban elements (e.g. playgrounds, parking areas, railway, etc.)"*[13]. NBS solutions for climate-resilient food systems in urban settings has also emerged as a promising experimentation ground for circularity and climate resilience in cities [14], contributing to food security (i.e. access to quality and healthy food for all in cities), to biodiversity and the provision of ecosystem services and resource efficiency [15].

It is precisely in the field of resource efficiency that NBS can play an effective role in cities, specifically concerning sustainable water management: the permeabilization of urban surfaces, sustainable urban drainage systems, rainwater harvesting solutions can all be fostered by the use of NBS such as green roofs, bioretention systems, 'rainforests' and hydrophyte systems [16].

Works of desigilation, accurate soil assessment, and proper naturalization turn out to be of paramount importance within an adaptive design approach that can redesign both at the district and urban/suburban scales of the landscape. The redesign of existing public space, including the many interstitial spaces found within contemporary urban contexts, becomes an opportunity to experiment with innovative NBS that can adapt to and counteract climate change. One example is "*self-*

13 Calliari, E., Castellari, S., Davis, M., Linnerooth-Bayer, J., Martin, J., Mysiak, J., ... & Zandersen, M. (2022). Building climate resilience through Nature-Based Solutions in Europe: A review of enabling knowledge, finance and governance frameworks. Climate Risk Management, 100450.

14 Canet-Martí, A., Pineda-Martos, R., Junge, R., Bohn, K., Paço, T. A., Delgado, C., ... & Baganz, G. F. (2021). Nature-Based Solutions for agriculture in circular cities: Challenges, gaps, and opportunities. Water, 13(18), 2565.

15 Artmann, M., & Sartison, K. (2018). The role of urban agriculture as a nature-based solution: A review for developing a systemic assessment framework. Sustainability, 10(6), 1937.

16 Oral, H. V., Carvalho, P., Gajewska, M., Ursino, N., Masi, F., Hullebusch, E. D. V., ... & Zimmermann, M. (2020). A review of Nature-Based Solutions for urban water management in European circular cities: a critical assessment based on case studies and literature. Blue-Green Systems, 2(1), 112-136.

establishing green area" which are still uncommon in urban contexts but can work on important indicators from an ecosystem perspective such as biodiversity enhancement.

Designing strategies that are able to identify different transformation scenarios in respective different urban contexts: starting from the suburbs, where usually the availability of permeable surfaces is greater, up to consolidated historic centers where pre-existing constraints and limitations can and should push research to an even greater level of innovation. Addressing the process with a systemic, integrated and organic approach that assesses the different fragilities existing in the urban context, starting with climatic ones, gives NBS solutions the key role of ecological connectors. Design elements that are customized and designed to respond to local criticalities, but at the same time are easily transferable and implementable to provide continuity to the urban ecological infrastructure.

When it comes to human health and quality of life, NBS solutions in the city effectively contribute to reducing temperature[17] and, consequently, Urban Heat Island (UHIs) and, if properly outfitted[18], provide people with safe places where to find refuge from the increasingly intensifying heatwaves. While the concept of climate shelter has become increasingly popular, the literature and experimentations have mostly focused on artificial spaces where a cooling system and the provision of water were the only necessary preconditions [19]. Integrating NBS in the design of climate shelters, especially addressing the needs of vulnerable targets such as children and elders [20], will achieve paramount importance as temperatures rise in cities.

These strategies present both a people-centric approach, which supports the right to green spaces and its accessibility for all, and a broader contribution to the provision of ecosystem services and the enhancement of the green infrastructure for the beyond-human ecosystem at the urban and peri-urban levels, allowing adaptation to Climate Change.

2.3 Making European Critical Infrastructure resilient to natural disasters

The applications and adaptations to Climate Change that benefit the entire community can also be utilized in relation to critical infrastructure. Critical infrastructure is an asset or system which is essential for the maintenance of vital societal functions. The damage to a critical infrastructure, its destruction or disruption by natural disasters, terrorism, criminal activity or malicious behaviour, may have a significant negative impact for the security of the EU and the well-being of its citizens. Looking at different categories of critical infrastructure, the following groups with a direct connection to NBS can be identified: i) Energy & Water Infrastructure, ii) Food production, iii) Transportation Infrastructure, iv) Information and Communication Technologies (ICT) Infrastructure, v) Governmental Buildings and buildings of special interest (Health, Legal order, Finance), vi) Chemical and nuclear industry. Of course, not all critical infrastructure is exposed in the same way, so the categorization of vulnerabilities and the risk exposure, as well as specific mitigation measures should be of high interest for national governments.

17 Alvarez I., Quesada-Ganuza L, Briz E., Garmendia L. (2021). Urban Heat Islands and Thermal Comfort: A Case Study of Zorrotzaurre Island in Bilbao. Sustainability 2021,13, 6106. https://doi.org/10.3390/su13116106

18 Azcarate I., Acero J.A., Garmendia L., Rojí E. (2021). Sustainable Cities and Society 72(2021)102996. https://doi.org/10.1016/j.scs.2021.102996

19 Amorim-Maia, A. T., Anguelovski, I., Connolly, J., & Chu, E. (2023). Seeking refuge? The potential of urban climate shelters to address intersecting vulnerabilities. Landscape and Urban Planning, 238, 104836.

20 Baró, F., Camacho, D. A., Perez del Pulgar, C., Ruiz-Mallén, I., & García-Serrano, P. (2022). Nature-Based Climate Solutions in European Schools: A Pioneering Co-designed Strategy Towards Urban Resilience. In Urban Resilience to the Climate Emergency: Unravelling the transformative potential of institutional and grassroots initiatives (pp. 125-146). Cham: Springer International Publishing.

Besides natural hazards such as earthquakes, storms, wildfire, flash floods, heat waves, pests and droughts, the short to long term effects of climate change are in spotlight of current adaptation and mitigation strategies in critical infrastructure. As an example, current forecasts calculate a 10-times larger cooling need for buildings in 2050 [21]. Heavy rain events and flash floods occur in higher density and shorter timeframes [22]. Due to the absence of functional water-soil-air bodies and sealed surfaces, the built environment and embedded infrastructure is exposed the most.

Nature-Based Solutions are of utmost importance when it comes to securing critical infrastructure from hazards and climate change related environmental damage. Due to their comprehensive benefits and services portfolio, NBS can be strategically deployed to protect critical infrastructure and buildings from multiple hazards and the short to long term effects of climate change.

Just as in the examples of critical infrastructures reported in Figure 4, green roofs and walls do not only enlarge the lifespan of the building and deliver their cooling effects to the neighbourhood, but they also prevent the building from overheating and minimize cooling, heating and energy needs. They can as well help buying time in terms of a power outage. A cooler building as well keeps drinking water in safe condition. NBS that manage flash floods, such as raingardens, storage roofs, retention ponds, permeable pavements, bioswales and other sponge city technologies prevent buildings and transportation infrastructure from flooding and secure ground water bodies condition, additionally securing fresh water supply. What is more, NBS in combination with agriculture help protecting crops and securing harvest and they as well contribute to soil erosion protection and drought resilience as well as pest control. Embracing NBS can significantly contribute to enhancing the resilience of European Critical Infrastructure to natural disasters.

FIGURE 4 EXAMPLES OF CRITICAL INFRASTRUCTURES AND NBS: THE FIGURE ON THE LEFT SHOWS THE PERCY MILITARY HOSPITAL IN CLAMART (FRANCE), WHILE THE FIGURE ON THE RIGHT SHOWS THE R&D CENTRE TELECOMMUNICATION NETWORKS PROVIDER IN BOULOGNE-BILLANCOURT (FRANCE)

2.4 Realizing health and economic benefits through NBS

When discussing critical assets and elements of the entire community, it's also essential to emphasize that Nature-Based Solutions can mitigate a variety of health risks. This is particularly the

21 https://home-affairs.ec.europa.eu/pages/page/critical-infrastructure_en

22 https://www.klimafonds.gv.at/press/studie-kuehlbedarf-von-gebaeuden-steigt-bis-2050-deutlich-an/

case for risks related to extreme heat. By exacerbating cardiovascular and respiratory diseases sustained high temperatures increase the risk of mortality and morbidity and provoke mental stress. In summer 2003 the heat wave all over Europe accounted for over 70.000 excess deaths [23].

However, NBS not only reduce risks, but also strongly promote physical and mental wellbeing in different dimensions. Studies show that the quantity of available green space as well as the proximity of it correlates to physical activity [24]. Outdoor exercise and gardening are proven to help prevent and manage diseases and maintain healthy body weight. Beyond that physical activity can improve mental health, quality of life and well-being. This is also true for viewing or experiencing natural environments as research showed a strong correspondence with lower perceived stress as well as healthier mean cortisol levels. Proximity and access to green infrastructure was further found to decrease the level of psychological distress and anxiety [25] and accelerate recovery from illness [26]. By forming or augmenting place-based partnerships between people and nature, NBS further favour social behaviour and interactions which are crucial for both well-being and physical health [27].

Despite the evidence that NBS have an important impact on public health and wellbeing there are only few studies translating the health benefits to a monetary value [28]. As the existing studies use different methodology, boundary conditions and scales (individual / communal) the calculated numbers cannot be compared. Furthermore, most of the work focused on green spaces and natural environments and didn't include more recent green infrastructure developments, such as green roofs and walls. The fact that that specific health benefits are not only age but also gender dependent and social and cultural values associated with NBS are shaped by socio-ecological, institutional, and political realities further complicates the calculation [29]. Undisputed is that especially individuals from low socioeconomic status (SES) populations benefit from mitigating climate change by strengthening green infrastructure due to the uneven distribution of resources in terms of private green space and energy for cooling [30]. A standardized methodological framework for calculating the health benefits provided by NBS is urgently needed to specify the return on investments. This would facilitate strategic planning, decision-making, and policy development at all levels.

Regarding the economic benefits achieved through NBS, the construction sector presents a significant opportunity, particularly with advancements in the application of biobased materials. Examples of these materials, ranging from hemp and wood to cork and date palm wood, offer various benefits at different processing levels, including insulating, load-bearing, plastering, and filling purposes [31]. Their advantages are multifaceted. Firstly, they contribute to the health and well-being of users by enhancing thermal comfort and promoting smarter, cost-effective energy use [32]. Moreover, research indicates their cost-effectiveness, particularly in insulation applications, while

23 https://doi.org/10.1016/j.crvi.2007.12.001

24 doi:10.1016/j.socscimed.2009.11.020

25 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4049158/

26 10.1016/j.explore.2012.12.002

27 10.1037/amp0000103

28 KPMG: Green, Healthy, and Productive: The Economics of Ecosystems & Biodiversity (TEEB NL): Green Space and Health, KPMG; 2012

29 https://doi.org/10.1016/j.cosust.2017.08.00

30 https://doi.org/10.1016/j.ufug.2015.09.003

31 Bourbia, S., Kazeoui, H., & Belarbi, R. (2023). A review on recent research on bio-based building materials and their applications. Materials for Renewable and Sustainable Energy, 1-23.

32 Yadav, M., & Agarwal, M. (2021). Biobased building materials for sustainable future: An overview. Materials Today: Proceedings, 43, 2895-2902.

studies on availability and market expansion suggest a reduction in import dependency of construction materials in Europe [33]. Ultimately, bio-based materials enable buildings to develop carbon-storing capabilities, yielding positive impacts across social, economic, and environmental dimensions [34]. Figure 5 represents a business case within the supply chain and construction industry. This data underscores the potential for Europe to reduce its dependency on materials from outside the continent, thereby enhancing materials independence. Moreover, the incorporation of bio-based materials offers the added benefit of long-term CO2 storage capability by sequestering carbon within the structural building components. These examples highlight well how realizing health and economic benefits through NBS is already a certainty.

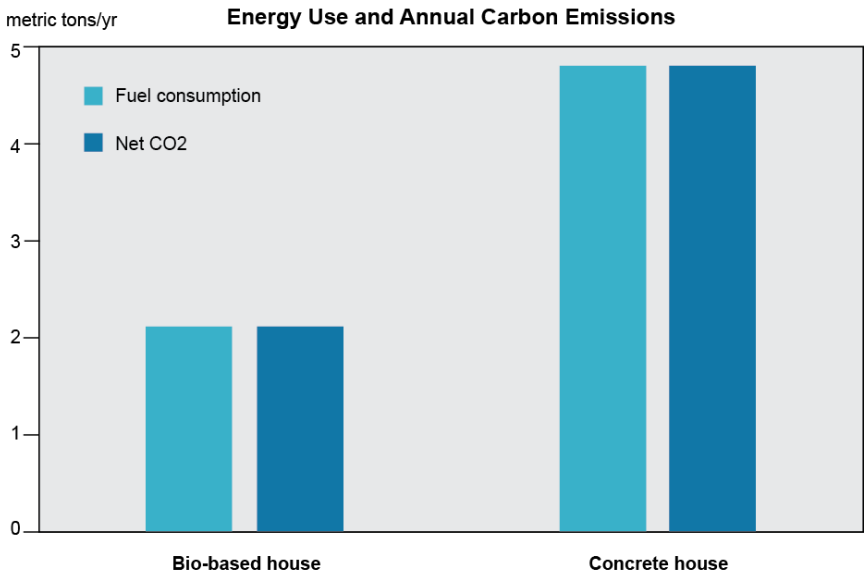

FIGURE 5 ANNUAL CARBON EMISSIONS FOR BIO-BASED AND CONCRETE HOUSE, RETRIEVED FROM BOURBIA ET AL. 2023 [27]

2.5 Fostering community engagement and stakeholder collaboration

As highlighted earlier in the paper, achieving successful implementation of NBS necessitates the engagement of diverse stakeholders: decision-makers, planners, implementers, and providers of relevant technologies and solutions. While there has been a notable paradigm shift towards collaborative urban planning in recent decades, it still requires concerted efforts from all parties involved to actively engage in the planning process. This entails active participation from local authorities, policymakers, researchers, practitioners, as well as local communities and citizens [35] [36]. The engagement of all actors becomes crucial for this transition to be successful. The shift towards new collaborative ways of working also affects how NBS initiatives are designed, implemented and

33 Schulte, M., Lewandowski, I., Pude, R., & Wagner, M. (2021). Comparative life cycle assessment of bio‐based insulation materials: Environmental and economic performances. GCB Bioenergy, 13(6), 979-998.

34 Pittau, F., Krause, F., Lumia, G., & Habert, G. (2018). Fast-growing bio-based materials as an opportunity for storing carbon in exterior walls. Building and Environment, 129, 117-129.

35 Healey, P. (1997a) Collaborative Planning: Shaping Places in Fragmented Societies. London: Macmillan.

36 Healey, P. (2003). Collaborative Planning in Perspective. Planning Theory, 2(2), 101-123. https://doi.org/10.1177/14730952030022002

assessed and situates citizens at the center as beneficiaries of NBS but also key actors in their success.

Engagement with local communities and stakeholders has been identified as crucial in delivering successful NBS [37] [38]. Fostering engagement could also bring additional benefits such as generating social acceptance regarding the implementation of NBS [39]; ensuring a fair distribution of NBS benefits [40]; generating understanding and trust in government [23] and enacting environmental advocacy [41]. Other reasons to actively involve stakeholders are to foster a sense of ownership, to better meet citizens' needs, to learn from one another using local knowledge and creating mutual understanding, which enhances the quality of the decision-making process [42].

There are different types of engagement approaches based on decades of research in the field of public participation, the Ladder of Citizen Participation by Arnstein [43] being one of the most renowned models. A more recent one, the Spectrum of Public Participation, developed by the International Association for Public Participation (IAP2), has been widely used by practitioners since the early 2000s. It consists of five levels of engagement: 'inform', 'consult', 'involve', 'collaborate' and 'empower', offering a spectrum from fully 'top-down' to entirely 'bottom-up' approaches. While empowerment is arguably the most equitable form of participation, the aim of engagement, the available capacities and resources and the local context of each NBS initiative, can help to determine which of the engagement approaches (or a combination of approaches) will be more effective in each individual case.

In most NBS initiatives there is a rich diversity of stakeholders involved, including people with different cultural backgrounds, people with disabilities, the elderly, the youth and those with little time to participate. Javaid and Habeeb [44] identify four main categories of participants: the *"Unsocial, Uninformed, Objectors and Unheard"*. This variety requires a mix of engagement techniques and styles including formal (e.g., citizen juries, surveys, planning workshops) and informal formats (e.g., nature walks, bike rides, site visits, presence at street fairs and festivals), creative techniques (e.g., child friendly engagement approaches, working with artists or participatory theatre for conflict resolution), hands-on activities (e.g., citizen science, community working bees, tree planting days) and, last but not least, online and hybrid approaches, which enrich the traditional offline ways and

37 van Ham C., Klimmek H (2017) 'Partnerships for Nature-Based Solutions in Urban Areas – Showcasing Successful Examples' In: Kabisch N., Korn H., Stadler J., Bonn A. (eds) Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Theory and Practice of Urban Sustainability Transitions.

38 Frantzeskaki, N (2019) 'Seven lessons for planning Nature-Based Solutions in cities', Environmental Science and Policy, vol.93, p.101-111.

39 Fisher, F (2004) 'Building Bridges Through Participatory Planning', United Nations Centre for Human Settlements UNCHS (Habitat).

40 Haase, D., Kabisch, S., Haase, A., Andersson, E., Banzhaf, E., Baró, F., Brenck, M., Fischer, L.K., Frantzeskaki, N., Kabisch, N., Krellenberg, K., Kremer, P., Kronenberg, J., Larondelle, N., Mathey, J., Pauleit, S., Ring, I., Rink, D., Schwarz, N., Wolff, M., 2017. Greening cities – To be socially inclusive? About the alleged paradox of society and ecology in cities. Habitat International 64, 41–48.. https://doi.org/10.1016/j.habitatint.2017.04.005

41 Van Herzele A, Collins K, Tyrväinen L, (2005) Involving People in Urban Forestry — A Discussion of Participatory Practices throughout Europe, In: Konijnendijk C., Nilsson K., Randrup T., Schipperijn J. (eds) Urban Forests and Trees. Springer, Berlin, Heidelberg.

42 RMIT University (2023). Urban Green-Up. Innovation Action Gran Agreement No. 730426. Deliverable D1.11 - Co-creation and co-development tools and procedures.

43 Arnstein, S.R. (1969). A Ladder of Citizen Participation. Journal of the American Planning Association, 35(4), 216-224.

44 Javaid, S & Habeeb, R (2018) Participatory Planning in Urban Green Spaces: A Step towards Environmental and Social Equity. Conference Paper: 6th National Seminar on Architecture for Masses on the theme of "Environmental Remediation & Rejuvenation", At Jamia Milia, New Delhi, India.

that proved crucial to keep the engagement alive during the challenging Covid-19 pandemic years [42] but should be used with caution due to their potentially exclusionary effects [45].

To sum up, advanced community and stakeholder engagement skills have proven to play a big role in the successful planning and implementation of NBS initiatives. Still, there are range of barriers blocking effective engagement processes such as the lack of close community collaboration [46] [47]; organizational cultures that preclude the involvement of communities in decision making and delivery processes [48] [49] and project teams lacking adequate skills and experiences in engagement [31] [50] [51]. There are other language-related barriers, normally associated with communities from diverse socio-economic and cultural backgrounds, that also obstruct engagement efforts [52].

Addressing those challenges and enabling community engagement, however, requires going beyond the identification of suitable target-specific approaches and the resolution of technical constraints. It calls for an open and transparent agreement on the terms of engagement from the start, so that the process benefits those that we seek to engage. valuating engagement could take different forms. Including the provision of technical assistance, trainings, resources, information that meet people's needs [53], direct monetary remuneration for the time and efforts that engagement entails, but also access to knowledge, networks and policy-making processes that enables the recognition of community needs and the removal of structural barriers that constrain the achievement of their goals [54]. For the desire and interest in continued engagement to be sustained, however, it should be based on an authentic effort to understand and meet the needs of those involved, on a model of shared power and responsibilities and on relations of respect, care and trust. Only this way will engagement enable the empowerment of those involved and will contribute to building the capacities for and culture of participation required to enable effective NBS implementation but also the shift to collaborative planning that holds the promise of making cities greener, more resilient and inclusive places for all.

45 Manderscheid, M., Fiala, V., Edwards, F., Freyer, B., Säumel, I. (2022) Let's Do It Online?! Challenges and Lessons for Inclusive Virtual Participation. Frontiers in Sustainable Food Systems 6: 732943

46 Kinzer, K. How can we help? An exploration of the public's role in overcoming barriers to urban sustainability plan implementation. Sustain. Cities Soc 39, 719–728 (2018).

47 Brink, E. & Wamsler, C. Collaborative Governance for Climate Change Adaptation: mapping citizen-municipality interactions. Environ. Policy Gov. 28, 82–97 (2018).

48 Kronenberg, J. Why not to green a city? Institutional barriers to preserving urban ecosystem services. Ecosyst. Serv. 12, 218–227 (2015).

49 Wamsler, C. Stakeholder involvement in strategic adaptation planning: transdisciplinarity and co-production at stake? Environ. Sci. Policy 75, 148–157 (2017).

50 Wamsler, C. From Risk Governance to City-Citizen Collaboration: capitalizing on individual adaptation to climate change. Environ. Policy Gov. 26, 184–204 (2016).

51 Croeser, T., Garrard, G. E., Thomas, F. M., Tran, T. D., Mell, I., Clement, S., Sánchez, R., Bekessy, S. Diagnosing delivery capabilities on a large international Nature-Based Solutions project. npj Urban Sustainability (2021) 1:32.

52 Okello, N., Beevers, L., Douven, W. & Leentvaar, J. (2009) The doing and un-doing of public participation during environmental impact assessments in Kenya, Impact Assessment and Project Appraisal, vol.27, no.3, pp.217-226.

53 Freudenberg N, Pastor M, Israel B. Strengthening community capacity to participate in making decisions to reduce disproportionate environmental exposures. Am J Public Health. 2011 Dec;101 Suppl 1(Suppl 1):S123-30. doi: 10.2105/AJPH.2011.300265. Epub 2011 Oct 20. PMID: 22021323; PMCID: PMC3222508.

54 Edwards, F. L., Manderscheid, M. & Parham, S. (2023) Terms of engagement: mobilising citizens in edible Nature-Based Solutions, In: Journal of urbanism Routledge.

3 Urban Perspectives on Nature-Based Solutions

Integrating Nature-Based Solutions into the built environment, particularly within Smart Cities, cities, and districts, promotes a harmonious coexistence between urban development and the environment. Examining issues and solutions from the urban perspective is both important and essential.

3.1 Smart City integration

When addressing the concept of embracing NBS for sustainable development, it is imperative to consider the exemplary manifestation of the built environment, which pertains to urban, cities, districts, and Smart Cities. Smart Cities leverage cutting-edge technologies to enhance efficiency, sustainability, and the overall well-being of urban inhabitants. However, the relentless urbanization associated with this concept often leads to ecological degradation and challenges related to climate change. Integrating NBS into the Smart City paradigm offers a harmonious approach to address these issues, fostering a balanced coexistence between urban development and the environment.

In order to be mainstreamed in the planning and design of cities, the benefits of NBS and the provision of ecosystem services should be matched with the possibilities offered by ICT, Artificial Intelligence (AI) and digital and technological solutions offered by the smart city framework and its operational advancement – for instance, through the mapping and gathering of data on tree canopy, shading capacity, the diversity of arboreal species, their contribution to UHI mitigation, their proximity to other urban infrastructures and to CO_2 absorption.

The Smart City concept, when coupled with NBS, provides an unprecedented opportunity to promote biodiversity within urban landscapes. Leveraging technologies that are able not only to provide a snapshot of the current situation, but also to provide real-time responses through AI and automation (for example through digital twin concepts) regarding the management, upkeep and enhancement of NBS in the city, together with simulation and visualizations able to forecast different scenarios for NBS development in critical urban areas.

According to the World Economic Forum, the integration of NBS into smart city planning can happen through a series of emerging data solutions and technological innovations which support the development and monitoring of NBS and “to transform them from a solution that is scientifically compelling and increasingly demanded, into one that is operational, scalable, cost-effective, transparent and trustworthy [55]. These include remote-sensing solutions that deliver estimates on carbon stocks and the relative changes due to growth and degradation; cost-efficient biomass inventories for monitoring, reporting and verification (MRV) systems; platforms allowing to reliably compare and confront data about the whole global ecosystem in terms of carbon sequestration and loss in different parts of the world.

In conclusion, the integration of NBS in the Smart City concept is imperative for fostering sustainable urban development. This synergistic approach not only addresses environmental challenges but also enhances resilience, biodiversity, and overall quality of life within urban environments. This concept should then broaden, recognizing the importance of greening not only urban areas but also local communities. To achieve this integration successfully, collaboration among urban planners, environmental scientists, and technology experts is crucial, emphasizing a holistic and interdisciplinary approach to Smart City development.

55 https://www.weforum.org/agenda/2022/12/nature-based-solutions-are-essential-for-tackling-the-climate-and-biodiversity-crises/

3.2 Green Infrastructures in the Built Environment

The concept of green infrastructure, as defined by the European Commission, encompasses strategically planned networks of natural and semi-natural areas aimed at delivering various ecosystem services while enhancing biodiversity. These services range from water purification to climate mitigation and adaptation, ultimately improving environmental quality and citizens' well-being [56]. Among the green infrastructures that are most applicable to the built environment are urban parks and green spaces, green roofs, and green corridors. The integration of strategies focused on green infrastructure, NBS and urban ecosystem services is consistent with an ecosystem-based approach to urban planning, which looks beyond an anthropocentric view of planning itself to embrace overall ecosystem resilience [57]. Within this framework, NBS represent the conceptual and factual connectors between the grey and social infrastructures of the city and the green infrastructure (Figure 6), being the 'units' that recompose the green infrastructure itself within the urban environment: these units are ecological connectors for biodiversity and pollination, for water collection and for de-sealing, and it is imperative to strengthen the presence of green infrastructure in areas which would otherwise experience scarcity in ecosystem services [58].

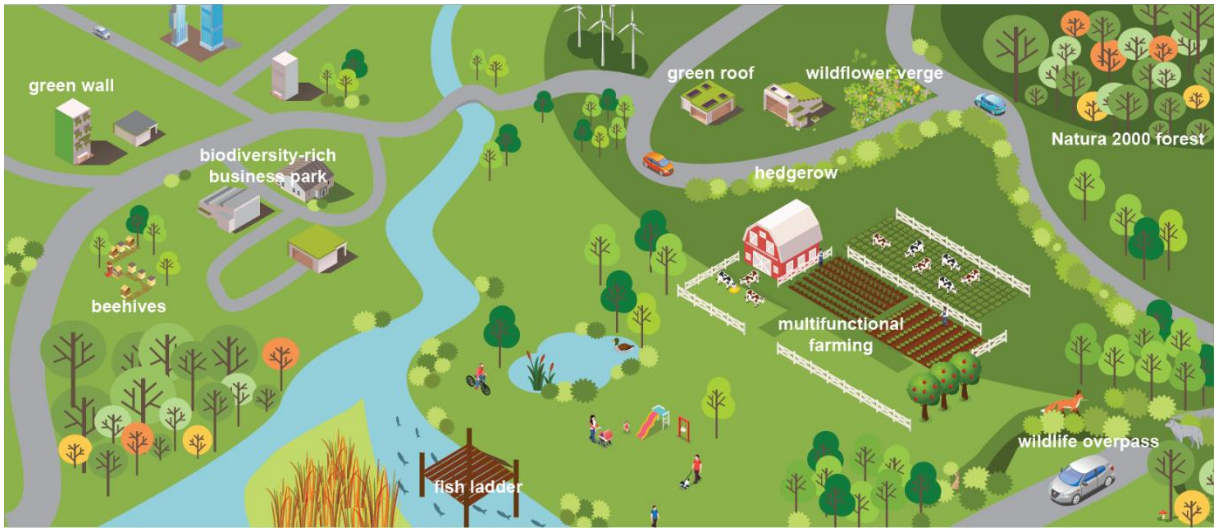

FIGURE 6 POTENTIAL COMPONENTS OF GREEN INFRASTRUCTURE: A NETWORK OF GREEN CORRIDORS AND ARCHITECTURAL INTERVENTIONS. CORE AREAS, PROTECTED AS NATURAL PARKS (NATURA 2000 FOREST), ARE COMPLEMENTED BY VARIOUS TYPES OF CORRIDORS: NATURAL (RIVERS), RESTORED (REEDBED), OR ARTIFICIAL (WILDLIFE OVERPASS). MULTI-FUNCTIONAL ZONES ARE ESSENTIAL FOR COMPATIBLE LAND USES TO SYNERGIZE, SUPPORTING DIVERSE LAND MANAGEMENT COMBINATIONS WITHIN THE SAME SPATIAL AREA. ADAPTED FROM "BUILDING A GREEN INFRASTRUCTURE FOR EUROPE" BY EUROPEAN COMMISSION [59]

NBS for stormwater management offer sustainable alternatives to traditional methods in the face of increasing urbanization and climate change impacts. These solutions leverage natural processes,

56 European Commission Available on the web: https://environment.ec.europa.eu/topics/nature-and-biodiversity/green-infrastructure_en Accessed 2024-01-26.

57 Wild, T. C., Henneberry, J., & Gill, L. (2017). Comprehending the multiple 'values' of green infrastructure–Valuing Nature-Based Solutions for urban water management from multiple perspectives. Environmental research, 158, 179-187.

58 Haase, D. (2021). Integrating Ecosystem Services, Green Infrastructure and Nature-Based Solutions—New Perspectives in Sustainable Urban Land Management: Combining Knowledge About Urban Nature for Action. Sustainable Land Management in a European Context: A Co-design Approach, 305-318.

59 Proverbio D. (2018) On the modeling of green corridors with Agent-Based simulations. Thesis. https://www.researchgate.net/figure/Potential-components-of-a-green-infrastructure-a-coordinated-network-of-green-corridors_fig2_337858374

including permeable surfaces, green roofs, and urban wetlands, to mitigate flooding and improve water quality (Figure 7).

Permeable surfaces reduce surface runoff by allowing water to infiltrate into the ground, while green roofs absorb and release rainwater through evaporation and transpiration. Urban wetlands act as natural sponges, slowing down stormwater and aiding in pollutant removal through biological processes.

The benefits of NBS include flood reduction, improved water quality, promotion of biodiversity, microclimate regulation, and enhanced aesthetic and recreational value in urban areas, improving mental and physical health. To optimize the impact of Green infrastructure implementation, understanding the positive and negative aspects of each considered species is crucial.

Moreover, increasing Ecosystem Services and Biodiversity in these systems also ensures a higher resilience of urban areas to Climate Change effects. Water Scarcity due to Climate Change and increased water demand implies new challenges for urban renaturalisation. In some areas of the planet with limited access to potable water during drought, decentralised treatment plants can be placed in green spaces or urban parks with NBS to provide safe reclaimed water for irrigation.

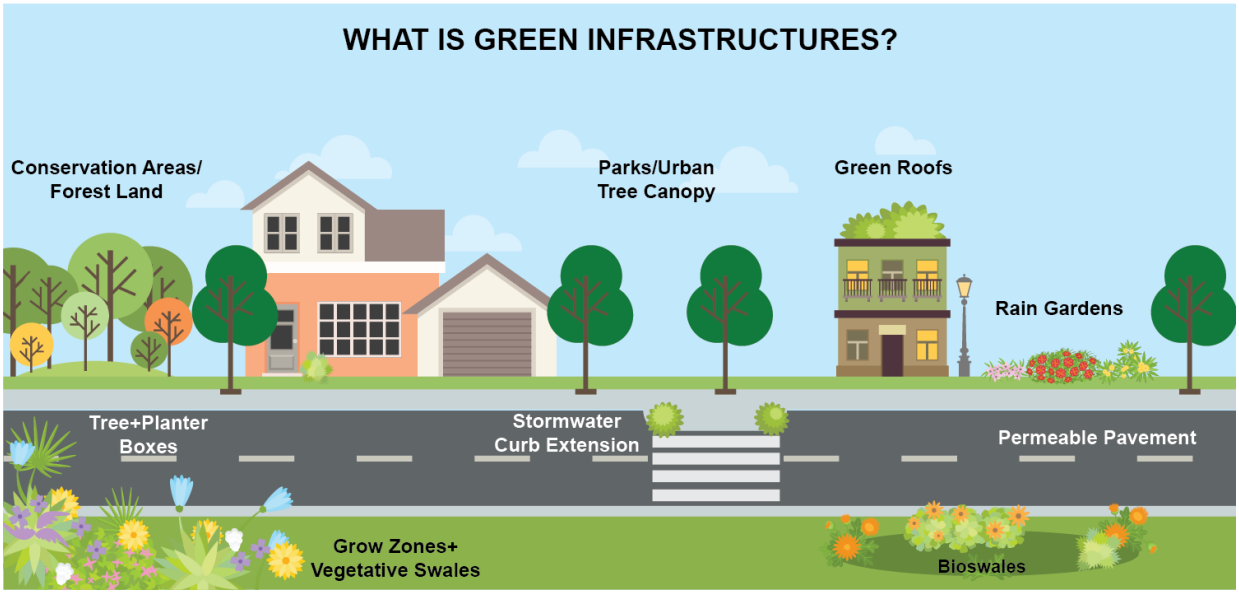

FIGURE 7 SKETCH OF URBAN GREEN INFRASTRUCTURES. ADAPTED FROM HTTPS://WWW.BREC.ORG/GREEN-INFRASTRUCTURE

3.3 Urban Parks and Green Spaces

Urban parks and green spaces play a crucial role in enhancing the quality of life in cities, providing various social, environmental, and health benefits. Recreation and leisure opportunities abound within these green havens, offering spaces for activities like walking, jogging, cycling, picnicking, and sports, fostering relaxation and social interaction, thereby contributing to community well-being. Furthermore, green spaces contribute to environmental sustainability by improving air quality, reducing urban heat island effects, and supporting biodiversity, thereby mitigating the impact of climate change through carbon sequestration and natural cooling mechanisms. Access to these areas has been linked to improved mental health, stress reduction, and overall well-being, while physical activities promote healthier lifestyles, aiding in the prevention and management of health issues. Moreover, parks serve as vital hubs for community building, hosting gatherings, events, and activities that foster social cohesion and a sense of belonging among diverse populations. Their aesthetic appeal enhances urban design, acting as landmarks that contribute to a city's identity and

attractiveness, thus increasing property values and attracting businesses and residents. Additionally, parks support urban biodiversity, offering ecosystem services like water filtration, soil retention, and pollination, while also serving as educational spaces that provide information about local flora and fauna, environmental conservation, and sustainable practices. Ensuring accessibility and inclusivity in park design and programming is essential for creating equitable and diverse urban environments that cater to all members of the community, regardless of age, ability, or socioeconomic status.

Cities around the world are recognizing the importance of integrating green spaces into urban planning to create more sustainable, liveable, and resilient communities. There are several EU funded projects such as Urban Green Up, UNaLab, REGREEN, UPSURGE that have developed replication schemes, decision support systems or Renaturing Urban Plans to implement urban parks and green spaces maximizing the positive effects of NBS.

Green infrastructure, including Urban Parks and Green Spaces, plays a significant role in reducing air pollution by effectively capturing dust particles, absorbing pollutants, and preventing dust transportation. Numerous studies have demonstrated the ability of plants to positively impact air quality by absorbing atmospheric pollutants [60]. This natural filtration process does not only help to improve the overall air quality within urban environments but also contributes to the health and well-being of city residents.

3.4 Green Roofs and Green Corridors

Green roofs are interesting as NBS to counteract several environmental and socio-economic problems associated with urban sprawl and climate change [61]. They are artificial ecosystems that can mitigate challenges such as urban heat islands as less heat is absorbed from the sun compared to a dark roof cover [62]. Literature studies, such as [60], quantify the benefits of green roofs. They can decrease the cooling load by up to 70%, lower indoor temperatures by as much as 15 °C, and notably enhance thermal comfort conditions. Additionally, akin to natural reservoirs, green roofs can retain rainwater, delay runoff and promote evapotranspiration. The feasibility of combining green roofs with rainwater harvesting systems to blue-green roof for saving potable water or stormwater management is highly dependent on local climatic conditions and the characteristics of the green roof system [63]. Studies show that well designed blue-green roofs ensure minimal trade-offs and a maximum in ecosystem services over time [64].

There are some important aspects to address to succeed in creating a long-lasting green roof that will maximise biodiversity, such as for example the depth of the substrate and the incorporation of native or drought-resistant flora [65]. There is also a need for access to irrigation water during periods with prolonged drought. This can be resolved by collection and storage of rainwater directly on the

60 Zhou et al., 2010

61 Calheiros, C. S., & Stefanakis, A. I. (2021). Green roofs towards circular and resilient cities. Circular Economy and Sustainability, 1(1), 395-411.

62 Susca, T., Zanghirella, F., Colasuonno, L., & Del Fatto, V. (2022). Effect of green wall installation on urban heat island and building energy use: A climate-informed systematic literature review. Renewable and Sustainable Energy Reviews, 159, 112100.

63 Mihalakakou, G., Souliotis, M., Papadaki, M., Menounou, P., Dimopoulos, P., Kolokotsa, D., Paravantis, J.A., Tsangrassoulis, A., Panaras, G., Giannakopoulos, E. and Papaefthimiou, S., 2023. Green roofs as a nature-based solution for improving urban sustainability: Progress and perspectives. Renewable and Sustainable Energy Reviews, 180, p.113306.

64 https://doi.org/10.1016/j.ecoleng.2021.106422

65 Wang, L., Wang, H., Wang, Y., Che, Y., Ge, Z., & Mao, L. (2022). The relationship between green roofs and urban biodiversity: A systematic review. Biodiversity and Conservation, 31(7), 1771-1796.

roof or in tanks in basements where it can be pumped to ensure the survival of plants [66]. Taking advantage of the existing space in the top of the buildings, the integration of green roofs will support the cities' transition towards circularity and resilience.

As shown in Figure 8, the ecosystem services which can be provided by green roofs are equally valid for green façades. Green façades reduce energy consumption for cooling and heating through natural insulation and shading and can significantly contribute to the remediation of air pollutants [67]. Like for green roofs the selection and health of the plants is crucial for the provision of ecosystem services and requires regular maintenance. Moreover, in view of climate change façade design concepts for minimizing run-off and mitigating the urban heat island effect by storage of rainwater and subsequent evaporation are currently being researched [68]. In addition to façades greened with higher plants, moss façades and façades greened with biofilms or lichens are being scientifically investigated [69]. Architects develop new concepts in which the buildings and the urban environment are scaffolds designed for hosting multispecies coexistence and collaboration [70].

66 Berg, A. B., Hurajová, E., Černý, M., & Winkler, J. (2022). Anthropogenic Ecosystem of Green Roofs from the Perspective Rainwater Management. Acta Scientiarum Polonorum Architectura, 21(1), 9-19.

67 DOI: 10.3233/SCS-230014

68 DOI: 10.1002/cend.20220000

69 https://doi.org/10.1016/j.jobe.2023.107201

70 Farinea, Chiara: Design for Companion Species: Developing Collaborative Multispecies Urban Environments. In: Schröder, J.; Sommariva, E.; Sposito, S. (Eds.): Creative Food Cycles - Book 1, 2020. S. 245-251. DOI: https://doi.org/10.15488/10118

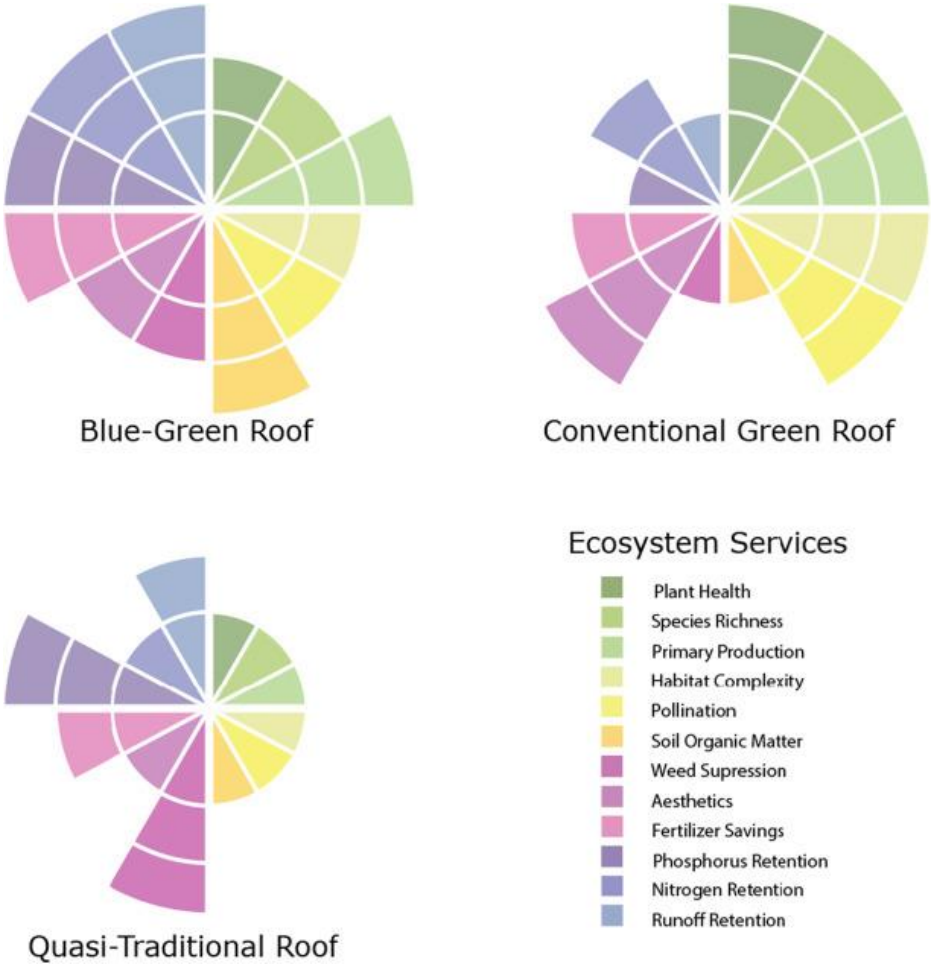

FIGURE 8 GREEN INFRASTRUCTURES AND ECOSYSTEM SERVICE [71]

Green corridors are landscape elements that prevent the negative effects of fragmentation of habitats. They consist of a network of different NBS, such as for example ecoducts, parks, protected green areas, water ways and domestic gardens. Strengthening such networks can support the biota in urban parks and wildlife refuges and the seasonal migrants that sometimes depend on urban habitats for their survival [72]. City planners in the municipalities need to be engaged in the topics of biodiversity to interconnect the ecosystems and biotopes. The areas will lead to mutual benefits for the urban inhabitants, such as heat island mitigation, air quality improvement through particle retention and lastly for recreation in beautiful green areas.

3.5 Economic Viability in urban settings

More than 55% of the world's population lives today in urban areas [73]. The urban environment covers an estimated area of approximately 222 000 km^2 in the European Union and the United Kingdom and continues to grow at a rate of approximately 3% per decade. As the urban population continues

71 taken from: https://doi.org/10.1016/j.ecoleng.2021.106422

72 Rudd, H., Vala, J., & Schaefer, V. (2002). Importance of backyard habitat in a comprehensive biodiversity conservation strategy: a connectivity analysis of urban green spaces. Restoration ecology, 10(2), 368-375.

73 World Bank based on data from the UN Population Division

to grow, the challenges of life in densely populated cities are intensifying as well. The most prominent, severe and complex environmental challenges impacting humans and ecosystems are represented by the urban heat island (UHI) [74], characterized by higher temperatures within the city, the air pollutions concentration, and the intense precipitation.

In this context the implementation of NBS has received increasing attention not only in research but especially on the political agenda. A growing body of evidence shows positive ecological outcomes of NBS, such as an increase of the green infrastructure[75] and their inherent potential to successfully adapt to changing environmental conditions. Within the European Union, the implementation of NBS across all landscapes is considered key to achieving the ecosystem restoration goals of the EU Biodiversity Strategy for 2030. NBS are also believed to be essential for achieving climate change mitigation goals in dense built environment.

NBS provide sustainable solutions that not only respond more effectively to climate change-related hazards than conventional grey solutions but also contribute to reducing their frequency and intensity. In addition, NBS have an important advantage in their potential to create new green jobs. Through participatory processes, local communities can become involved in the planning and implementation of NBS projects, which can lead to job creation and economic development. The long-term nature of many NBS interventions also brings longer job security for employees and can offer opportunities for direct monetizable economic benefits to municipalities.

A recent EIB report on investing in NBS categorises implemented NBS in Europe [76] in different ecosystems, showing a vast majority in the urban ecosystem, considering both urban regeneration (including changes in management) and development of new NBS, such as the implementation of green roofs, green façades, green corridors, and parks. According to the report, EU funds represent the most common investor in NBS. In the future, the demand for urban NBS can be expected to rise exponentially, and the additional investment in urban NBS is estimated at €136 000 per km^2 on average [77].

In general A small number of studies discuss the cost-effectiveness and the economic viability of NBS. While NBS serve multiple purposes, the quantification of social and economic aspects, including the distribution of costs and benefits across stakeholders, is still limited. Demonstrating the economic viability of NBS interventions is crucial to increase their uptake in urban areas, as well as to ensure public acceptance, which is key to the deployment of a long-term NBS strategy. Both scientific literature and practice have been contributing to this evidence with cases where NBS represent the most economically viable approach, showing their economic opportunity [78].

The costs and benefits of NBS need to be clear to stakeholders and potential investors. An important barrier to the mainstreaming of urban NBS is a lack of evidence on their performance, and communication of the value of their co-benefits [79].

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74 https://www.bes2ecure.net/home

75 Girardin C.A.J., Jenkins S., Seddon N., Allen M., Lewis S.L., Wheeler C.E., Griscom B.W., Malhi Y.

Nature-Based Solutions can help cool the planet - if we act now

76 State-of-play and way forward for public and private financial measures in Europe. European Investment Bank, 2023

77 Biodiversity financing and tracking. European commission

78 https://networknature.eu/casestudy/22882

79 Bockarjova M, Botzen WJW, Bulkeley HA, Toxopeus H. Estimating the social value of Nature-Based Solutions in European cities. Sci Rep. 2022 Nov 18;12(1):19833. doi: 10.1038/s41598-022-23983-3.

Beyond direct economic benefits, NBS address societal challenges and contribute to improving human wellbeing. A strong added value of NBS is the multiple co-benefits they provide in addition to the main societal challenge they are designed and implemented for. Nevertheless, the co-benefits associated with NBS are often difficult to monetize.

Scientific evidence of the multiple benefits of NBS is rapidly expanding, but the approach is still new. Unfamiliarity with measures, and uncertainty about the results, may hamper uptake at a wider scale. Socio-economic aspects and cost considerations are crucial due to their key roles in securing stakeholder buy-in and attracting private investments.

Practitioners and researchers, meanwhile, must step up efforts to monitor and evaluate the effectiveness of interventions, in particular of NBS, and apply the results to improve future decision-making.

The return on investment, the efficiency and effectiveness of the intervention, and equity in the distribution of benefits and costs are key determinants of success for an NBS. This criterion requires that sufficient consideration is given to the economic viability of the intervention, both at the design stage and through monitoring the implementation.

4 Rural Perspectives of Nature-Based Solutions

Integrating NBS into the rural environment, encompassing protected areas, coastal regions, and local ecosystems, fosters a balanced coexistence between development and the natural surroundings. Analyzing challenges and solutions from a rural perspective is both important and essential.

4.1 Protected areas

As integral components of both the built environment in a broad sense and rural areas in a narrower context, NBSare increasingly embraced within protected and coastal areas as well. Protected areas of the European Union are areas which need and/or receive special protection because of their environmental, cultural or historical value to the member states of the European Union. They include NATURA 2000 sites (areas protected under the EU Birds and Habitats Directives) - the backbone of the Trans-European Nature Network, complemented by nationally designated areas (e.g. national parks and nature reserve)[80] and other effective area-based conservation measures (OECMs).

According to the European Environment Agency, the EU biodiversity strategy for 2030 sets out a target of protecting at least 30% of EU land by 2030, while also ensuring that all protected areas are effectively managed. If the designation of protected areas continues at the rate seen in the past decade (1.7 percentage points increase since 2011), the target will not be met. Moreover, the designation of protected areas is not in itself a guarantee of biodiversity protection as their management is a decisive factor in achieving the conservation aims. And as emphasised in the EU biodiversity strategy, protected areas in the EU can no longer be managed as isolated units but need to be understood as part of a wider Trans-European Nature Network (TEN-N). This requires building an ecologically coherent network that ensures both spatial and functional connectivity within countries and across borders.

80 https://www.eea.europa.eu/data-and-maps/explore-interactive-maps/european-protected-areas-1

As stressed by IUCN (2022[81]), understanding how NBS and protected areas can work most effectively together is a critical part of the puzzle. However, the emphasis of NBS to date has been more on management and restoration than it has on protection policies and protected areas. If designed correctly, NBS and protected areas are in most cases fully compatible and mutually reinforced. Indeed, protected areas are ideal vehicles for that proportion of NBS that comes from natural ecosystems, thereby providing values like ecosystem adaptation, ecosystem-based mitigation and disaster risk reduction, and for natural infrastructure.

Such NBS are to be selected on a case-by-case basis and include restoring natural vegetation in watersheds, natural wetlands, peatlands and grasslands; natural regeneration of native vegetation, particularly trees, in forests; protecting and restoring coastal habitats (e.g. seagrass beds, mangroves, saltmarshes, coastal forests – see also in the next chapter). However, not every NBS fits into a protected area, for instance plantation of non-native trees or monocultures may sequester carbon but they will not support biodiversity. Bringing NBS into area-based conservation requires a detailed understanding of what such protected areas can and cannot do, with clear responsibilities. The question of trade-offs between overall ecosystem services and biodiversity values is also becoming increasingly important, while bad practices such as greenwashing need to be avoided. Challenges remain in capacity building and scaling up from individual projects to mainstream applications.

Another field of application of NBS in relation to protected areas that requires investigation is how NBS can contribute to improving the connectivity between Europe's natural land and seascapes by 2030 and the TEN-N. A resilient network of protected and conserved areas indeed requires ecological connections facilitating the movement of living organisms across those areas. NBS could be applied to reinforce or create green corridors and provide many other services such as carbon sequestration or recreational spaces for people.

4.2 Coastal areas

Conventional, concrete-based coastal defense structures are not able to adapt to and compensate for sea-level rise and need to be regularly maintained and reinforced. Such structures also tend to cause unwanted erosion in other locations[82]. NBS are an attractive alternative for coastal protection: they reduce the risk of coastal flooding by diminishing the height of storm surges, reduce wave intensity, and protect coasts from erosion, thereby stabilising shorelines. They are more climate-resilient and can grow with sea-level rise or, if necessary, can be easily adapted. They can also increase biodiversity and provide other ecosystem services such as cooling service, water purification, carbon sequestration, recreational spaces.

NBS for coastal management encompass a range of strategies aimed at enhancing resilience and sustainability while leveraging natural processes and ecosystems. These include enhancing manmade coastal structures with ecological features, such as living breakwaters, to restore ecosystems and provide *hybrid infrastructure*. Additionally, NBS involve enhancing, protecting, or restoring natural habitats like sand dunes, wetlands, saltmarshes, mangroves, seagrass beds, and oyster reefs (*green infrastructure*) (Figure 9, Figure 10). These measures not only offer flood or erosion benefits but also provide various ecosystem services, contributing to overall coastal

81 Dudley, N. et al., Nature-Based Solutions and protected and conserved areas, IUCN: International Union for Conservation of Nature. IUCN Japan Liaison Office, Institute for Global Environmental Strategies (IGES), US, Equilibrium Research, UK. Retrieved from https://www.iucn.org/resources/jointly-published/nature-based-solutions-and-protected-and-conserved-areas on 04 Jan 2024. CID: 20.500.12592/cwj09c.

82 www.recreate-net.eu

resilience and biodiversity conservation. By integrating these approaches, coastal communities can achieve effective and sustainable management of coastal areas while preserving and enhancing natural ecosystems.

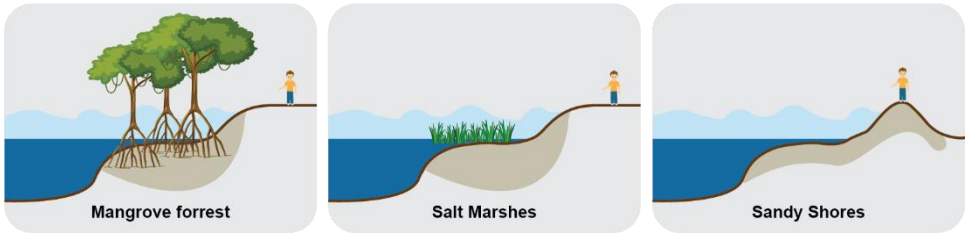

FIGURE 6 EXAMPLE OF GREEN SOLUTIONS FOR COASTAL MANAGEMENT, ADAPTED FROM WORLD BANK (2021)

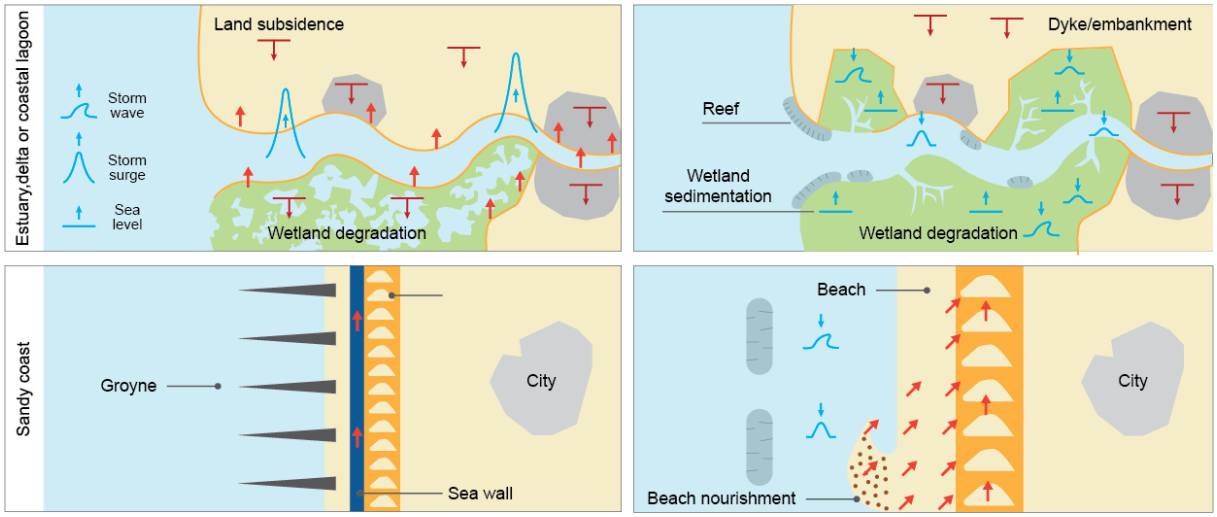

FIGURE 7 CONVENTIONAL VS. NATURE-BASED COASTAL DEFENCE MEASURES. BLUE ARROWS INDICATE CHANGES IN STORM WAVES, STORM SURGE, AND SEA LEVEL; RED ARROWS INDICATE THE NEED FOR MAINTENANCE AND HEIGHTENING OF DYKES, EMBANKMENTS, AND SEA WALLS WITH SEA-LEVEL RISE; BROWN ARROWS INDICATE LAND SUBSIDENCE. ADAPTED FROM TEMMERMAN ET AL., 2013[83]

The implementation of NBS in coastal and estuarine areas of Europe has shown a notable increase since the 1990s, particularly accelerating between 2005 and 2015 [84]. Case studies examined by researchers primarily focused on coastal adaptation to hydrometeorological hazards, with 54% situated in urban areas and 46% in rural or non-populated regions. Many of these case studies adopted hybrid solutions incorporating wetlands, with a notable concentration in the United Kingdom (UK) and the Netherlands. This preference is likely influenced by the Netherlands' historical challenges with flooding and the UK's well-established shoreline management plans and wetland compensation schemes. Notably, the implementation of coastal NBS in southern Europe significantly

83 Temmerman, S., Meire, P., Bouma, T.J., Herman, P., Ysebaert, T. and De Vriend H.J. (2013): Ecosystem-based coastal defence in the face of global change. Nature 504, 79–83.

84 Moraes RPL, Reguero BG, Mazarrasa I, Ricker M and Juanes JA (2022) Nature-Based Solutions in Coastal and Estuarine Areas of Europe. Front. Environ. Sci. 10:829526. doi: 10.3389/fenvs.2022.829526

lags behind other regions. The main challenge therefore consists in adapting and replicating successful cases and best practices, with a focus on Southern Europe.

The replication and scaling up of these cases should consider local settings and contexts, as the effectiveness of NBS is highly associated with the site conditions (e.g. water depth, hydrological system, sediment supply, tidal range, existing manmade structures, vegetation density, anthropic pressure such as use of the site for recreational or economic purposes). For instance, the Mediterranean coastal resilience can be improved thanks to the restoration of *Posidonia oceanica* seagrass meadows, a species which is endemic to the Mediterranean Sea[85] (Figure 11).

Given the significance of coastal areas, it is crucial to raise awareness about the benefits of these practices is also essential, as some of them could conflict with other types of coastal development or land use (such as restricting the use of the area in case of sand dunes) and hinder societal acceptance. Standardization and centralisation of information from successfully implemented projects would also be beneficial, to ensure the effective implementation and integration of NBS into coastal management strategies.

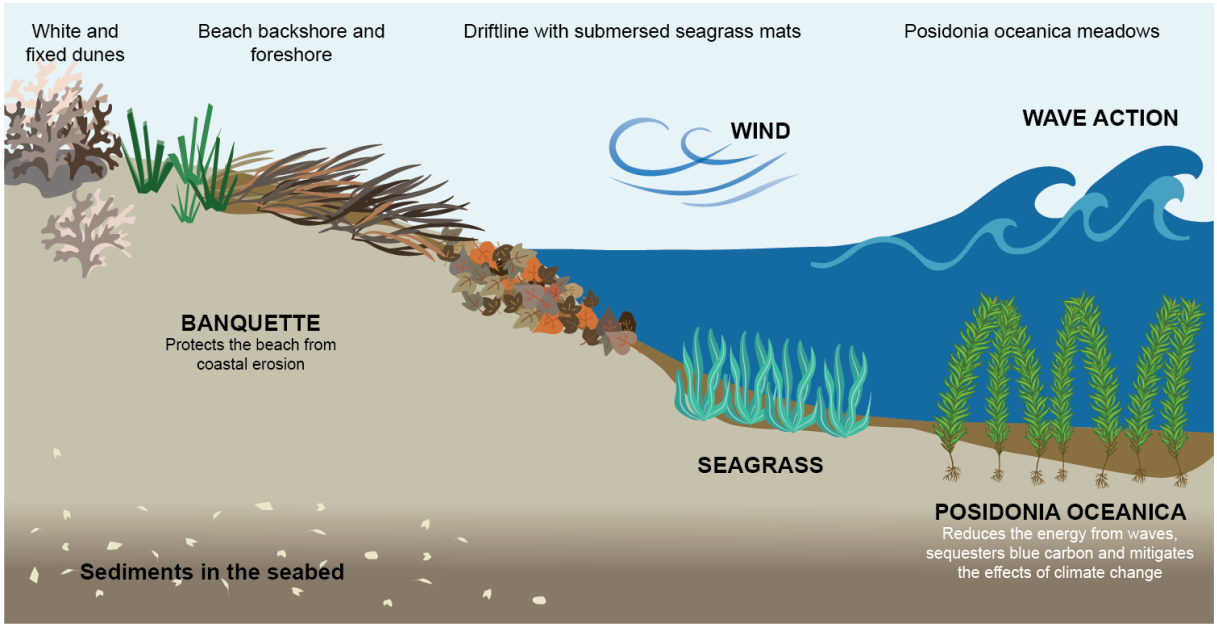

FIGURE 8 IMPROVEMENT OF MEDITERRANEAN COASTAL RESILIENCE THANKS TO SEAGRASS BEDS. ADAPTED FROM UICN(2022)[85]

4.3 Conservation and promotion of Local Ecosystems

Rural areas and their population entities are the interface between what is natural, wild, untamed and what is populated, productive and ordered by humans. This interface was well understood and maintained through our history, following the principles of nature (sustainability, circularity and efficiency) rural populations created a system capable of producing value, landscape and culture, while fencing the rest of the urban world from nature. This fencing and the industrialization have created in urban populations and economies a disconnection from these sustainability values, generating economies of scale and the challenges we face today as a society. These economic

85 UICN (2022) Enhancing Mediterranean coastal resilience with Posidonia oceanica and Nature-Based Solutions. Retreived from https://posbemed2.interreg-med.eu

values had been pushed in the rural areas, destroying and depopulating Local Ecosystems and increasing the multifactor current divide between urban and rural areas. NBS represents an opportunity to reverse this trend and apply and recover sustainable solutions to empower rural communities. In order to promote and foster resilient Local Ecosystems we should see these areas as a complex systems and act in these different key areas:

- Biodiversity Conservation and Preservation: NBS focus on preserving natural habitats, which is fundamental to maintaining biodiversity. This includes protecting wild areas, restoring degraded ecosystems, and creating ecological corridors that allow migration and genetic flow among species populations. In rural settings, we should apply any of these solutions in conjunction with local populations, promoting these projects as an opportunity for them and not as an imposition.
- Sustainable Natural Resource Management: Natural resource management is the essence of many rural population entities. We should entitle these communities to apply NBS (traditional and innovative) to be the guardians of their territory, assuring a long-term financial sustainability while preserving the health of their ecosystems. This includes techniques of responsible agroforestry, smart grazing or promotion of responsible agri-food products.
- Climate Change Resilience: A combination of the two last areas is how we can act on the natural and humanised ecosystems to resist climate change, not only to be neutral but to be on the forefront of climate change resistance. This includes works in the areas of climate neutrality (with food and energy self-sovereignty as fundamental strategies) but also using NBS as a guide to plan and act in the territories to resist climate change consequences. In many parts of Europe wildfires are going to become a great risk if we don't plan and act on the territories to mitigate their consequences.
- Local Culture and Traditions: Many NBS are based on traditional knowledge and practices, integrating local wisdom into natural resource management and local economy organisation. This not only reinforces the effectiveness of these solutions but also helps preserve local heritage, fostering social cohesion and belonging in rural communities and promoting community-led initiatives.
- Education and Community Empowerment: Traditional work practices in rural areas often played the role of transmitting local traditions and educating the new generations in social and ecosystemic values. With the disappearance of these traditional work practices, we should innovate and promote educational and community activities to promote these values and empower the local communities, so they can make sustainable decisions in their business and daily-life activities, as well as to identify local needs and potential impactful solutions.

Moreover, even though this is not the core topic of this section, the integration of emerging technologies into NBS adds a crucial dimension in the conservation and promotion of local ecosystems, especially in rural settings. The use of drones, remote sensors, and geographic information systems enhances the monitoring and mapping of ecosystems, while artificial intelligence and advanced data analysis offer valuable predictive/simulation insights. All this data should be presented to society making use of novel technologies to make it attractive but also trusted to maximise its impact. Moreover, mobile and digital technologies enhance community participation and education, and innovations in sustainable agrifood optimise natural resources. These technologies not only increase the effectiveness of NBS but also facilitate sustainable resource management and business and strengthen community resilience against environmental challenges. In summary, NBS in rural environments offer a holistic approach to the conservation and promotion of local ecosystems. By integrating environmental, social, and economic considerations, NBS can create resilient systems that benefit both nature and the communities dependent on it. We call this holistic approach retro-innovation, listening to the traditional and vernacular knowledge in conjunction with the technical and scientific ones to rethink the future socioeconomic models of the Local ecosystems.

4.4 Economic Viability in rural settings

NBS appear to be a promising means for increasing the sustainability in dense urban and rural spaces [86]. However, their application is often hampered due to economic reasons. In fact, while the benefits are well recognized the related economic values are not generally attributed. As a results benefits provided by the NBS are difficult to assess and compare with others cost/benefit solutions and are often not considered. This is due to the fact that green infrastructure like trees, green open spaces or other NBS solutions are not normally valuated with monetary terms being not goods directly traded into the monetary market [87].

In general, one of the key factors contributing to the effectiveness of nature-based solutions (NBS) is the lack of awareness about their capacity to deliver a range of co-benefits beyond just their risk-reducing effects. It's important to recognize that many of these co-benefits may take time to materialize, highlighting the need for long-term thinking and planning when implementing NBS. The creation of a specific market for NBS would increase the diffusion of good practices from the early design stage.

5 Policy Recommendations

Effectively addressing the theme of embracing NBS for sustainable development requires a multidimensional and comprehensive approach. Central to this approach lie policy recommendations, serving as the practical framework for translating theoretical concepts into action. Indeed, policies play a pivotal role in promoting the integration of NBS with innovative technologies, incentivizing private sector engagement, enhancing public awareness, and fostering data-driven approaches to address environmental challenges. Through a combination of financial incentives, regulations, and public-private partnerships, policies facilitate the development and deployment of technological decision-support systems, stimulate private sector investments, support public awareness campaigns and educational initiatives, and streamline access to environmental data and the adoption of data-driven technologies. This paper underscores the imperative of implementing these policies to enhance the built environment, considering both urban and rural perspectives.

5.1 Integrated digitally enabled and technological decision-support systems for the green transition of climate neutral cities

As previously discussed in this paper, adaptation to climate change presents a grand challenge that spans across multiple domains: the development of solutions for the resilience of human settlements to phenomena such as rising temperatures and increasingly frequent heatwaves, or to floods and drought, happens at the interplay of nature-based, technological and sociotechnical components. This has a twofold rationale: on the one hand, transformation at the systemic level and broader societal change can only happen if the interconnectedness of urban systems is acknowledged for; on the other, the EU Green Deal has advocated *"that no one is left behind"* [88], thus putting to the fore the imperative to make the twin digital and green transitions inclusive for all [89].

86 https://www.phusicos.eu/

87 https://www.naturvation.eu/home.html

88 https://ec.europa.eu/commission/presscorner/detail/en/AC_23_3426

89 https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/twin-green-digital-transition-how-sustainable-digital-technologies-could-enable-carbon-neutral-eu-2022-06-29_en

The axes on which policies and strategies should move to ensure the incorporation of NBS in urban design and urban governance can be summarised in promoting a critical reading of territories through data-driven approaches; designing the whole value chain of regenerated green-grey infrastructures in the cities and districts, including their future maintenance, to ensure their viability; include social justice in the planning of the integrated infrastructure through concepts such as proximity, accessibility and right to green spaces and, ultimately, developing and using digital technologies that are able to communicate processes and results, include citizens in the co-creation of urban transformation, support the visualization of AI-based scenarios and simulations for the urban green transition. They are broken down as follows.

Defining an integrated approach that can unite NBS with social innovation technologies and processes promoting a systemic and organic vision of the ecological infrastructure of a reference context. This means activating a particularly accurate reading of the territory that does not focus solely and exclusively on the implementation of public works, but is able to produce data, information and generative design elements that can guide the intervention itself.

When imagining an urban transformation that gives nature the main role, it is fundamental and necessary to imagine and plan at the same time maintenance, management and communication plans that can accompany the transformation, to ensure its long-term viability.

To make this operational, it is strategic to base analysis and design on elements such as accessibility, proximity and spatial justice, elements that have also been reiterated many times by the New European Bauhaus. In this way, the attempt to guarantee the "right to green" for each citizen is intertwined with the principles of climate neutrality that guide urban planning interventions.

Offering highly innovative tools that can support administrations in the complex task of redesigning cities, districts, and their spaces becomes a priority task for research. Tools that are able to read the territory in depth and know how to listen to all the different actors that animate the ecosystem of reference, to identify solutions that are as suitable as possible to the specificities and that know how to manage in the best possible way the different elements that characterize the landscape.

5.2 Incentivizing Private Sector Involvement

NBS consist of a novel and often little understood value proposition as they can address multiple challenges while benefiting various stakeholders. Nevertheless, the multifunctionality of NBS is linked to complex barriers which impede implementation and upscaling: The “social” dimension of NBS means that it is difficult to monetize most of the co-benefits, even though these contribute to our collective wellbeing [90]. At the same time, this very multifunctionality reflects the problem of “split incentives”, as NBS lead to only partial returns for private NBS investors, thus inhibiting private investments [91].

Ensuring adequate financing is a key factor for the upscaling of NBS. The World Economic Forum (WEF) and United Nations Environmental Program (UNEP) determined that investment in NBS should at least triple by 2030 and increase fourfold by 2050 if we are to meet the set climate change, biodiversity and land degradation targets [92]. Considering that currently the deployment of NBS in Europe relies mostly on public funds, with the private sector covering (by more than 50% of the

90 Beatriz Mayor et al. (2021) "State of the Art and Latest Advances in Exploring Business Models for Nature-Based Solutions" Sustainability 13, no. 13: 7413. https://doi.org/10.3390/su13137413

91 European Investment Bank, Guy Hudson et al. (2023) Investing in Nature-Based Solutions

92 UNEP, WEF, ELD, Vivid Economics, (2021) “State of Finance for Nature” State of Finance for Nature 2021 | UNEP - UN Environment Programme

overall costs) a mere 3% of the NBS projects being implemented, a key for mainstreaming NBS is to boost private sector's involvement [93].

Providing incentives while increasing and sharing knowledge is the way forward. By establishing favourable conditions, NBS will be identified as an opportunity for private sector investment, in the context of creating and capturing the value from the provision of goods, services or information, while yielding the advantages of enhanced resilience and reduced costs [93 94].

In this context, financial incentives and measures should be aligned with Nature's needs and policy instruments. Similarly, "reward" incentives can be established to motivate private entities in implementing NBS, which can also be linked to regulatory requirements [93].

Market-based instruments, such as certification schemes and standards relevant to NBS can allow businesses to market their products and services accordingly [93].

At the same time, facilitating innovative partnerships (whether public- private or private- private) can unlock multiple revenues and benefit streams [93 94]. Such collaborations also contribute to risk-sharing which can be a significant incentive for investors [93].

An integrated approach of the implemented financial strategies and instruments should also address technical capacity building [95]. Knowledge should be strengthened, and practitioners should be sensitised on the role of NBS for climate change adaptation and increased community resilience, towards the creation of green jobs. This can be supported through subsidies for training programs providing technical expertise and enhancing skills in implementing and maintaining NBS.

Nevertheless, it is important to remember that the role of the private sector when it comes to NBS, goes beyond that of financing, investment or even job creation [93]. Private entities often possess specialised know-how and cutting-edge technologies that can enhance the successful implementation of NBS. In that sense, even when the public sector has a leading role, the involvement of private entities should be pursued as early as from the conceptual design and for all the implementation stages to follow. Such collaborative governance can ensure inclusivity, livability and resilience of any implemented NBS [96].

Equally important is the support and promotion of knowledge sharing. Through partnerships between private sector entities and research institutions or NGOs, private actors can be given access to scientific research and data, while receiving valuable guidance on implementing NBS. At the same time, dedicated platforms can allow for knowledge exchange within and across industries, while also providing networking opportunities.

5.3 Public Awareness and Education

With the overall objective to consolidate NBS as a common and popular practice in lieu of traditional practices and conventional approaches, it is necessary to mobilize public support. This can be achieved by promoting awareness on the enhanced value that NBS create for a wide range of stakeholders.

93 ThinkNature H2020- Giorgos Somarakis, et al. (2019). Nature-Based Solutions Handbook. 10.26225/jerv-w202.

94 ThinkNature H2020- Giorgos Somarakis, et al. (2019). Nature-Based Solutions Handbook. 10.26225/jerv-w202.

95 UN Environment Programme (2022). Nature-Based Solutions: Opportunities and Challenges for Scaling Up.

96 Niki Frantzeskaki, et al. (2019). Seven lessons for planning Nature-Based Solutions in cities. https://doi.org/10.1016/j.envsci.2018.12.033

Limited awareness and understanding are significant barriers to scaling up NBS [97]. In this context, effective communication of the lessons learned from realised NBS can stimulate a holistic understanding of how human societies impact ecosystems and biodiversity, while facilitating the operationalisation of innovative solutions and technologies that address a range of environmental as well as societal challenges. Indeed, knowledge sharing from actions already taking place can address existing gaps with respect to i) the feasibility and opportunities of NBS, ii) the associated effectiveness of such solutions, iii) the potential barriers and opportunities, iv) the long-term benefits and v) the contribution of NBS to increasing resilience [98]. Raising awareness among all relevant stakeholders on best practices of NBS implementation along with the associated lessons learnt, while highlighting the associated benefits, the replication and upscaling potential, are crucial steps towards the creation of a solid knowledge base.

The “Fit for 55” package, in accord with SDG10 (Reduced inequalities), strives for a “just green transition”, aiming to ensure that the associated “benefits and opportunities are available to all, as quickly and fairly as possible” [99]. A prerequisite for a “just green transition” is the “just engagement” of citizens. This refers to the need to ensure “procedural justice” in terms of who decides and who participates in the decision-making [100]. In this respect, educating citizens becomes a key driver towards mainstreaming NBS- in line with the NEB core values and working principles. Knowledge empowers local communities to participate in the decision-making and creation of NBS, thus ensuring “procedural justice”.

Education on NBS has the potential to prepare individuals for employment opportunities in "green jobs," but existing knowledge gaps must be addressed to equip younger generations with the skills and awareness needed to support NBS uptake across sectors and scales [101]. NBS-based education promotes inclusion, social cohesion, and reduces inequalities (SDG 10), while also fostering lifelong learning (SDG 4). Schools can serve as innovation hubs for the green transition, employing the Whole School Approach to integrate NBS into curriculum and practices.

However, challenges persist in NBS education, including the need to train educators, access to learning materials and spaces, inadequate funding, and lack of awareness about NBS importance and benefits. Addressing these challenges is essential to ensure effective education on NBS and facilitate its widespread adoption and implementation.

5.4 Data-driven Solutions to empower Environmental Transformation

When it comes to further streamlining and accelerating the deployment of NBS, this can often be hindered by labour-intensive and costly processes of estimating various key criteria related to the proposed NBS (e.g., carbon reductions associated with conservation projects). For example, in forest conservation projects a bottleneck is typically the need for manually measuring individual trees by hand (both height and diameter) at multiple different geographical sites. Furthermore, the monitoring, reporting and verification of these types of efforts are error prone, which means that they may often be seen as financially risky investments. It also makes it possible for companies to engage in

97 UN Environment Programme (2022). Nature-Based Solutions: Opportunities and Challenges for Scaling Up.

98 N. Kabisch et. al. (2016), Nature-Based Solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers and opportunities for action. https://www.jstor.org/stable/26270403

99 EC, “Fit for 55” (2021) IMMC.COM%282021%29550%20final.ENG.xhtml.1_EN_ACT_part1_v8.docx (europa.eu)

100 JUSTNature H2020, Yirang Lim et.al (2023), State-of-the-art Report on Good Practice for Co-governance of NBS

101 NBS EduWORLD H2020, Shreya Utkarsh et. al (2023) Learning from NBS EduSystems inspiring initiatives

greenwashing. In addressing these challenges, ICT solutions (Information and Communications Technologies) play a key role by contributing to the establishment of a knowledge base through monitoring and evaluation. This involves the facilitation of NBS mainstreaming using several tools such as sensors, platforms, or digital twins. Moreover, these technologies are not only essential for sustainable ecosystem management but also play a key role in promoting public awareness. The growing importance of advanced digital technologies and data-driven solutions in transforming the environmental landscape is thus increasingly recognized. These technologies, central to the development of Smart Territories, provide a comprehensive approach to the sustainable management of ecosystems and are integral to the effective implementation of NBS.

Technologies for data acquisition, curation, processing, sharing and exploitation are becoming highly featured. Nonetheless, there is a growing need for more transparent and verifiable data to provide stronger evidence of the impacts of NBS. Artificial intelligence (AI) – coupled with suitable forms and amounts of data – holds great potential in in this regard, as such data-driven methods enable significantly more cost-effective and scalable solutions and can also enable verification and transparency. For example, already today, AI coupled with satellite- and drone-based remote sensing technology can provide reliable and high-resolution data on canopy cover in urban areas [102], carbon sequestration in forests [103], and extension of wetlands and other ecosystems [104].

Another important avenue is AI systems for optimizing the deployment of green (and/or blue) infrastructure (GI) in urban areas [105] [106] [107], where AI can be used for example to optimally balance various criteria and assist in decision making processes. AI is increasingly being used to perform various analyses and predictions that are related to, or can be useful for, GI planning. For example, [108] determine structural heterogeneity of urban forests from satellite data and use this as a proxy for biodiversity, and in [109] an AI model is proposed for improving biodiversity-related decision-making processes. Thus, using AI to generate and power GI analyses is a very promising avenue, as it holds great potential to drastically reduce the necessary resources (expertise, time, and costs) associated with GI planning. The reduced costs and resulting automation would enable the generation of GI analyses with greater coverage and at multiple scales with the same methods, making them useful for several regions or municipalities, potentially enabling cooperation and coordination across legal boundaries.

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102 Kranjčić N, Medak D, Župan R, Rezo M. Machine Learning Methods for Classification of the Green Infrastructure in City Areas. ISPRS International Journal of Geo-Information. 2019; 8(10):463. https://doi.org/10.3390/ijgi8100463

103 Sharma, S., Dhal, S., Rout, T. et al. Drones and machine learning for estimating forest carbon storage. carbon res 1, 21 (2022). https://doi.org/10.1007/s44246-022-00021-5

104 Mainali K, Evans M, Saavedra D, Mills E, Madsen B, Minnemeyer S. Convolutional neural network for high-resolution wetland mapping with open data: Variable selection and the challenges of a generalizable model. Science of The Total Environment (2023). https://doi.org/10.1016/j.scitotenv.2022.160622

105 Fu, G., Sun, S., Hoang, L., Yuan, Z., & Butler, D. (2023). Artificial intelligence underpins urban water infrastructure of the future: A holistic perspective. Cambridge Prisms: Water, 1, e14.

106 Kranjcic N, Medak D, Zupan R, Rezo M. Machine learning methods for classification of the green infrastructure in city areas. IOP Conf. Ser.: Earth Environ. Sci. 362 012079 (2019). https://doi.org/10.1088/1755-1315/362/1/012079

107 Schrodi, S., Briegel, F., Argus, M., Christen, A., & Brox, T. (2023). Climate-sensitive Urban Planning through Optimization of Tree Placements. arXiv preprint arXiv:2310.05691.

108 Bae, Soyeon, et al. “Radar vision in the mapping of forest biodiversity from space.” Nature Communications (2019): 10, 4757

109 Silvestro, D., Goria, S., Sterner, T. et al. Improving biodiversity protection through artificial intelligence. Nat Sustain 5, 415–424 (2022). https://doi.org/10.1038/s41893-022-00851-6

More broadly, AI methods exist and are being developed for predicting all kinds of relevant measures and properties from remote sensing data (e.g., Earth observation from satellite systems). For example, there are publicly available AI models (e.g., [110] [111]) which map each region of a given satellite image into a set of semantic categories (e.g., 'building' or 'pine forest'), at pixel level. Such automatic inferences have an enormous potential to reduce the work and time associated with GI planning, as well as NBS more broadly. Aside from Earth observation satellite data, there are several other important data sources to consider when it comes to AI-enhanced NBS planning and deployment. One increasingly used data modality is sound, such as soundscape recordings from passive acoustic monitoring devices. This type of data already provides invaluable insights to ecologists, biologists and other domain experts working in the fields relevant for NBS, but the insight extraction from this data can be drastically improved and accelerated by AI [112]. An example use-case is measuring sound pollution in urban areas [113], e.g. objectively analyzing the potential decrease of sound pollution from the greening around busy streets.

Another important source of data is that which is enabled from citizen science projects, whereby people use smartphones and other mobile devices to capture varied data that may be relevant for NBS (e.g., images of different species, different types of vegetation, sound recordings). This can provide invaluable additional insights for data-driven analyses and can additionally democratize NBS planning processes and make NBS more socially acceptable. For example, data from social media can provide new insights about the location and quality of GI. In [114], satellite imagery was coupled with social media data, and was subsequently fed to an AI model for identification of green stormwater infrastructure. In this way, potential GI sites could be detected, which in turn could be examined in further detail via on-site surveys.

As for generative AI (Gen AI), in 2023 there were real breakthroughs, as exemplified by the widely popular ChatGPT system from OpenAI. There is large potential for using Gen AI when it comes to visualizing the effect of NBS interventions, which could help increase public acceptance of said solutions; these types of approaches are already being explored even by industry actors, such as *Urbanist AI*. Marrying Gen AI with the emerging field of physics-informed AI [115] is a promising avenue to consider as well, as it would enable accurate simulations of physical phenomena (e.g., extreme rainfall events) and how these affect an urban area before / after implementing a given NBS.

We conclude this sub-chapter by mentioning some limitations and things to consider when it comes to using AI (and other data-driven approaches) for improving the deployment of NBS. One important barrier is access to high-quality and relevant data. In particular, this availability may vary quite drastically between countries and regions within countries, so efforts at improving data-sharing practices are relevant to consider, including emerging approaches such as Data Spaces. Furthermore, the integrity and agency of citizens needs to be protected based on a human-by-design

110 Wu, Ming, et al. "Towards Accurate High Resolution Satellite Image Semantic Segmentation." IEEE Access (2019): 55609-55619

111 Yang, Nalsen and Tang, Hong "Semantic Segmentation of Satellite Images: A Deep Learning Approach Integrated with Geospatial Hash Codes." Remote Sensing (2021): 13(14), 2723

112 Gibb, R., Browning, E., Glover-Kapfer, P., & Jones, K. E. (2019). Emerging opportunities and challenges for passive acoustics in ecological assessment and monitoring. Methods in Ecology and Evolution, 10(2), 169–185. https://doi.org/10.1111/2041-210X.13101

113 Yildirim Y, Dilman M, Muftuoglu V, Demir S. Soundscape Assessment of Green and Blue Infrastructures. Urban Science. 2022; 6(1):22. https://doi.org/10.3390/urbansci6010022

114 Rai, A., & Minsker, B. S. (2016, December). Identifying Green Infrastructure from Social Media and Crowdsourcing-An Image Based Machine-Learning Approach. In AGU Fall Meeting Abstracts (Vol. 2016, pp. IN11B-1618).

115 Karniadakis, G.E., Kevrekidis, I.G., Lu, L. et al. Physics-informed machine learning. Nat Rev Phys 3, 422–440 (2021). https://doi.org/10.1038/s42254-021-00314-5

approach, especially when considering citizen science-based projects. Such a design approach should also ensure that structural and social inequalities between population groups and territories are not increased. If appropriately considered and managed, data-driven solutions have potential to enable a transition to Smart Territories, where ecosystems could be managed intelligently and sustainably, balancing ecological health with socio-economic development.

6 Conclusion

Summary of Key Points

Within the current discourse on promoting NBS to address environmental and socio-economic challenges, it is crucial to examine both urban and rural perspectives alongside implications for the entire built environment.

In urban perspectives, the integration of NBS within Smart Cities frameworks stands out as a key focus. This integration not only promotes biodiversity but also enhances economic viability by creating job opportunities in cities and districts. However, significant obstacles persist, primarily the lack of evidence regarding performance outcomes, coupled with challenges in monetizing socio-economic considerations.

Turning to rural perspectives, embracing NBS entails integrating them with protected areas, managing coastal resilience, and conserving and promoting involved local ecosystems. Despite these potential benefits, current hurdles include a dearth of evidence on performance and difficulty in assessing the benefits of NBS.

Considering the entire built environment holistically, policy recommendations underscore the need for greater awareness and understanding of NBS within the private sector. Monetization remains a challenge, alongside limited public awareness and understanding of NBS. Furthermore, inadequate funding and awareness hinder effective education and implementation of NBS. Finally, restricted access to high-quality and relevant data poses additional barriers across urban, rural, and broader built environment contexts. Addressing these challenges is crucial for realizing the full potential of NBS in addressing environmental and socio-economic needs.

Call to Action

To embrace NBS for sustainable development of the built environment, a shift in mindset must be undertaken first and foremost. This begins with recognizing that areas within the EU can no longer be managed as isolated units but must be understood as integral components of a broader Trans-European Nature Network. As such, they require policies that encompass all facets of these areas and bring about common benefits for everyone.

Addressing the challenges that impede the widespread adoption of NBS in the built environment requires concerted action and collaboration across various sectors. To catalyze meaningful change and unlock the full potential of NBS, stakeholders must take proactive steps to overcome barriers and drive sustainable urban development. Key actions include:

- Increasing awareness of the benefits of NBS by adapting and replicating best practices through standardization and centralized information from successfully implemented projects,
- Promoting public awareness and education about the significance and benefits of NBS to foster greater understanding and engagement,
- Enhancing performance monitoring and evaluation to provide clear communication of costs and benefits, emphasizing not only their economic viability but also their diverse social advantages beyond direct economic returns,
- Promoting greater data sharing to enhance data-sharing practices, including emerging approaches such as Data Spaces, ensuring that data-driven solutions are designed with a human-centered approach to protect citizens' integrity and agency,
- Urging increased investments in research and innovation focused on NBS,
- Leveraging artificial intelligence and other advanced technologies to improve the prediction and analysis of measures and properties relevant to NBS,

- Adapting and replicating best practices through standardization and centralized information.
- Encouraging collaboration and partnerships across public, private, and civil society sectors to develop and execute integrated, large-scale NBS initiatives, maximizing their positive impact on the built environment,
- Providing incentives, increasing knowledge sharing, and identifying NBS as an opportunity for private sector investment,
- Establishing financial incentives and measures to motivate private entities in implementing NBS,
- Advocating for supportive public policies and regulations, incentivizing investments, partnerships, and pilot projects in the NBS domain,
- Integrating NBS into urban planning to enhance city resilience and stormwater management practices,
- Implementing market-based instruments, such as certification schemes and standards relevant to NBS, to increase the dissemination of good practices from the early stages of design,
- Establishing a standardized methodological framework to calculate the health benefits provided by NBS.

By collectively pursuing these actions, stakeholders can pave the way for transformative change, creating more resilient and sustainable urban environments through the widespread adoption of NBS. Furthermore, integrating these solutions into urban planning not only enhances the resilience of the built environment to extreme weather events but also fosters environmentally friendly management practices.

7 Contributors

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The opinions expressed in this document reflect those of the DBE, B4L, and H&R Committees and do not necessarily represent the official positions of the entire ECTP.