

PERSPECTIVE

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The quadruple helix model in practice: co-creating NBS requires novel governance approaches

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Abstract

Navigating multifaceted transformation processes in cities demands innovative, integrated and collaborative approaches. In this perspective, we argue that the transformative impact of Nature-based Solutions (NBS) on post-industrial communities requires equal collaboration of stakeholder networks anchored in planning and transdisciplinary processes. Our emphasis is on the complex, non-linear co-creation process embedded with social and technical innovations. Living Labs serve as real life settings to successfully test NBS in participatory planning processes to address complex urban spatial, social, ecological and economic challenges. We reflect on the challenges of co-creation, presenting impediments and mitigation strategies enacted by the transdisciplinary research project productive Green Infrastructure for post-industrial urban regeneration (proGireg) based on the quadruple helix model. Such local multi-stakeholder partnerships, often adapted to specific NBS context, can bridge different interests and communication cultures while generating effective collaboration in addressing common urban challenges. The narrative of this perspective underscores the conversion of risks and challenges into opportunities, showcasing innovative collaboration impact not only at the NBS execution level but also its potential to induce a rather needed paradigm shift in urban planning approaches. Transformative change that centers on the willingness for open processes and self-(co-) governance models holds the promise of extending to the integration of NBS and co-creation within the planning culture, urban planning frameworks and climate action plans of public authorities while activating the civil society. We regard these as key drivers for NBS uptake and acceptance and aim at influencing necessary policy changes at different levels to embrace new forms of cooperation.

Highlights

- Living Labs Transform Mindsets: Allow for improvising, learning by doing, adapting to support governance shifts.
- Quad Helix Model Success: Quad helix co-design fosters inclusive, citizen-driven urban regeneration, aiding NBS adoption.



- Community-Driven Planning: Local NGOs are key contacts for municipalities and private sector, bolstering NBS ownership.
- Institutional Backing Vital: Cross-departmental and political collaboration drives NBS integration.
- Funding Critical for NBS: Early financial advocacy ensures long-term maintenance and stakeholder support.

Keywords: Nature-based Solutions (NBS), Co-creation, Interdisciplinary, Transdisciplinarity, Urban regeneration, Innovation, Living Lab, Governance, Co-design, Post-industrial cities, Quadruple helix model, Local communities

Policy recommendations

1. Establish enabling governance frameworks: Fostering co-creation at local administrative level in Living Labs.
2. Apply tailored quad helix model in NBS co-creation processes to generate new social networks and innovation.
3. Align policies for early-stage co-creation processes and shared (co) governance frameworks with adequate financial means at EU, national and local level.
4. Empower Activism: Boost bottom-up NBS initiatives for shared community co-ownership, supported by government.
5. Formalize Informal Tools: Integrate community-driven planning into formal urban frameworks.

NBS co-creation requires paradigm shifts in planning

Cities will be strongly impacted by the ongoing transformations of climate change and towards a post-industrial and post-fossil society. Nature-based Solutions (NBS) are increasingly used to shape sustainable urban transformation and regeneration processes, yielding multiple spatial, social, ecological, and economic benefits (Nesshöver et al. 2017, Frantzeskaki et al. 2017). Benefits range from enhancing green infrastructure systems to improving climate resilience, fostering biodiversity, building local economies and increasing social inclusion (Bauduceau et al. 2015). Navigating these multifaceted transformation processes in cities demand innovative, integrated and collaborative approaches. This prompts an essential question: Can conventional procedures, governance, and solutions truly drive societal and technological change, even if it means confronting the possibility of failure? Despite the increasing recognition of NBS and co-creation concepts in research and practice, planners continue to struggle to implement and integrate them into planning practice and urban planning frameworks (Collier et al. 2023; Hölscher et al. 2023). Urban laboratories (Living Labs) represent settings for developing and implementing NBS, striving on the commitment to testing new ideas and concepts to support “transformational learning, relational thinking, and transparency” (Bradley, Mahmoud, Arlati 2022), while assisting in reducing resistance to flexible approaches and shared governance models within local authorities. Mahmoud & Morello (2021) argue that to deliver multiple

social, economic and ecological benefits, planning and design must include citizens in the co-creation process of urban greening, from ideation to construction and management. For example, transdisciplinary, reflexive and adaptive approaches based on equal collaboration deviate from traditional planning culture of public authorities (van der Jagt et al. 2019).

Admittedly, managing inter- and transdisciplinary processes, which require a comprehensive understanding of urban complexities are demanding. Co-creation processes can potentially extend already lengthy bureaucratic procedures even further and need extra resources. However, we argue that collaboratively developing NBS tailored to the local context should involve the active participation of multi-stakeholder networks including local communities throughout co-creation phases (co-design, co-implementation, and co-maintenance). This approach creates outcomes and benefits that are mutually valued, fostering shared ownership of implemented NBS. Co-creation processes based on the engagement of local stakeholder constellations including industry, civil society, academia and local government enable more inclusive NBS interventions with added value than traditional participatory practices. Frantzeskaki, Mahmoud and Morello (2022) point out that for an integrated urban planning approach traditional governance structure and entrenched institutional landscapes need to be challenged. A move to systemic planning and flexible governance structures are particularly resonant in the context of NBS in urban regeneration that address a diversity of policy goals (Kiss et al. 2022). Such solutions often require a departure from traditional, top-down planning approaches at different scales, not least at the political level to address the challenges associated with multiple scales, uncertainty of implementing new NBS projects, multi-stakeholder participation, and adaptive co-management in the integration of NBS (Wilk, Säumel, Rizzi 2021). This requires a diverse set of actors bridging different backgrounds, cutting across disciplines and building on participation at all levels (EU New European Bauhaus 2023) to establish a European community of practice for NBS. Until the 1990s, innovation literature was centered on Research and Development (R&D), the participation of societal actors marginalized, and societal advancement seen as a result of scientific findings and economic development (Schütz et al. 2019). While many EU funding programs emphasize the importance and value of NBS co-creation, for cities outside of such funded projects time and resources for a comprehensive process to transform neighborhoods are limiting factors. The authors argue that systematic engagement of relevant stakeholders throughout co-creation processes ensure each expertise and insights are considered, contributing to the overall success and sustainability of urban regeneration initiatives and NBS mainstreaming.

EU H2020 research project: productive Green Infrastructure for post-industrial urban regeneration (proGReg)

Post-industrial cities are cities in transition and prone to change, therefore valuable environments for disrupting the status quo. The 5-year research project proGReg (2018–2023) created productive green infrastructures with NBS that helped improve living conditions, reduce vulnerability to climate change, while providing measurable benefits to citizens and entrepreneurs in post-industrial urban districts across Europe. Key research questions included:

- How can a set of eight NBS types be adapted to specific local contexts in a Living Lab approach in Front-Runner Cities (FRC)?
- How can the quadruple helix stakeholder model ensure implementing and sustaining NBS long term?
- How to make them replicable in Follower Cities (FC) and other urban contexts with appropriate urban planning guidelines?

ProGReg collaboratively implemented context specific NBS in Living Labs in four FRC: Dortmund (Germany), Turin (Italy), Zagreb (Croatia) and Ningbo (China) (Fig. 1). The experiences of NBS implementations in FRCs supported the four Follower Cities (FCs) Cascais (Portugal), Cluj-Napoca (Romania), Piraeus (Greece) and Zenica (Bosnia and Herzegovina) in developing local replication strategies for embedding NBS in urban regeneration processes (Fig. 1).

The inter-and transdisciplinary Living Labs function as user-centered open innovation formats where different local stakeholders test NBS in real-life settings (Fig. 2).

Each Living Lab presents a unique set of challenges and opportunities to locally adapt and co-create a set of eight different NBS types with the aim of improving the green infrastructure systems (GI) in each of the cities (Fig. 3). This requires a deep understanding of the formal and informal local stakeholder landscape, development approaches, and urban revitalization initiatives. Citizen engagement in proGReg is a strategic approach that aims to foster better NBS co-ownership by local communities beyond short-term project involvement.

Innovation in proGReg extends beyond mere technological advancements. Therefore, proGReg promotes a new understanding of GI as a common urban resource for implementing NBS, such as community-based urban gardens or green roofs and walls on privately owned buildings. Such approaches need to acknowledge that public and private goods can be managed more effectively when both public and private actors are involved (Zingraff-Hamed et al. 2020). The Living Lab and NBS co-creation processes with local communities from planning, co-design and co-management introduces new models of



Fig. 1 Structure of proGReg including four Front-runner cities and four Follower cities (ICLEI)

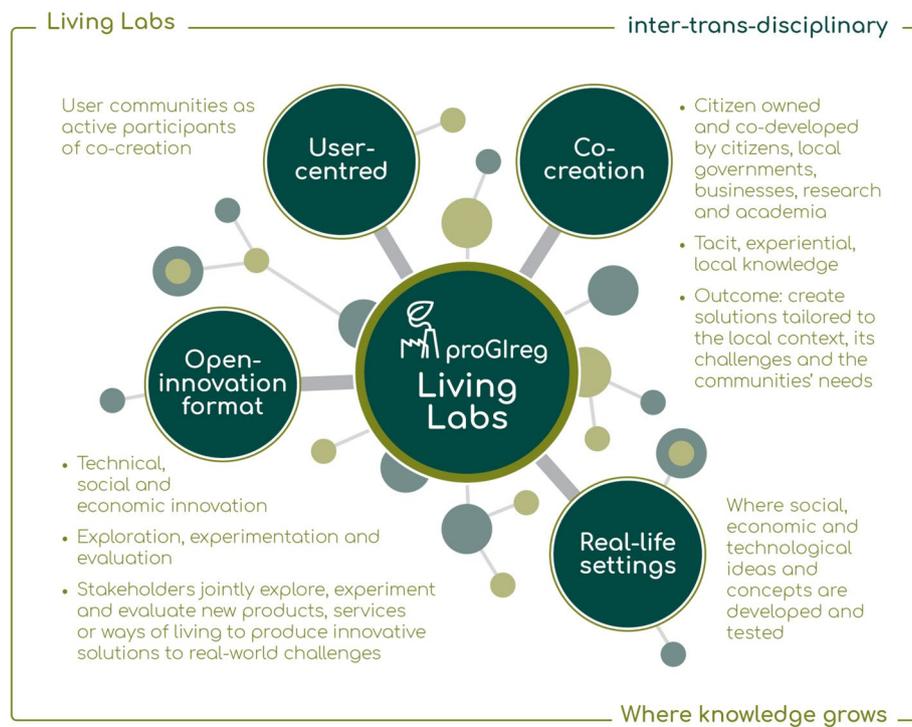


Fig. 2 Outline of the proGReg Living Lab approach (RWTH/ICLEI)

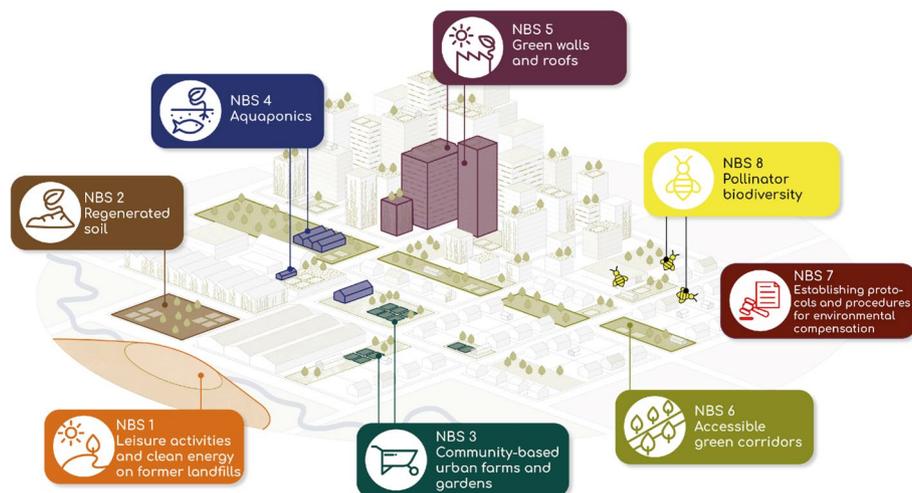


Fig. 3 Spatial representation of eight NBS adapted in proGReg's four Living Labs (RWTH)

shared and self-governance and provides guidance how actors from state, market and civil society can join forces.

For example, the “Regulation on Governing the Urban Commons in the City of Turin” (2020) is an innovative tool to provide a legal framework for common goods governance, endorsing shared and self-governance. It allows individuals, citizen groups, organizations and other non-profit entities to propose schemes for public use and maintenance of underutilized common spaces. Based on this novel governance regulation, the Turin

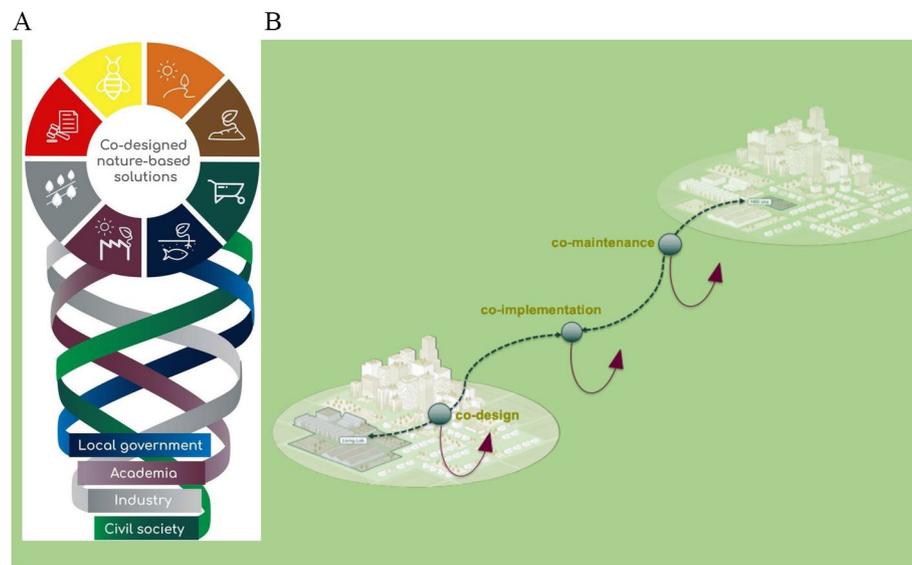


Fig. 4 Quad helix model, modified by **a** proGReg (ICLEI) and **b** Co-creation phases (RWTH) Note: Symbols in circle denotes NBS types

Living Lab initiated the creation of the urban food garden “Orti Generali” on 3-hectare land owned by the municipality through participatory processes involving various stakeholders, including the municipality, voluntary associations, gardeners, volunteers, and local residents. “Orti Generali” operates as a social enterprise with a significant trajectory for social inclusion and land revitalization. Co-managed by non-governmental actors under a 15-year lease, it exemplifies a collaborative and flexible governance structure.

Local quadruple helix stakeholder networks drive NBS uptake and acceptance

The quadruple helix model was introduced by Elias G. Carayannis and David F.J. Campbell in 2009 as an Innovation System Model, extending the triple helix framework of government, university and industry to include the civil society into the intertwined stakeholder mix, highlighting the significance of citizen involvement in the innovation ecosystem (Höglund and Linton 2018). This theoretical model provides insights into enablers and enactors to model the roles, behaviour and dynamics of innovation ecosystems (Carayannis et al. 2017). It also tackles modern challenges by synthesizing knowledge from various sectors and fostering collaborative solution development, particularly in EU projects in the fields of sustainable development and Nature-based Solutions (Carayannis and Rakhmatullin 2014). From the outset, proGReg adapted the quad helix approach by configuring its partner structure to reflect the model and continued to apply it at each scale from FRC/FC and Living Lab level down to each NBS. This enabled establishing contextual local multi-stakeholder co-creation processes involving active participation of local authorities, academia, industry and local communities (Fig. 4a). This strategy involves active participation of local authorities, academia, industry, and civil society (Fig. 4a) across all stages of co-design, co-implementation, and co-maintenance of NBS (Fig. 4b).

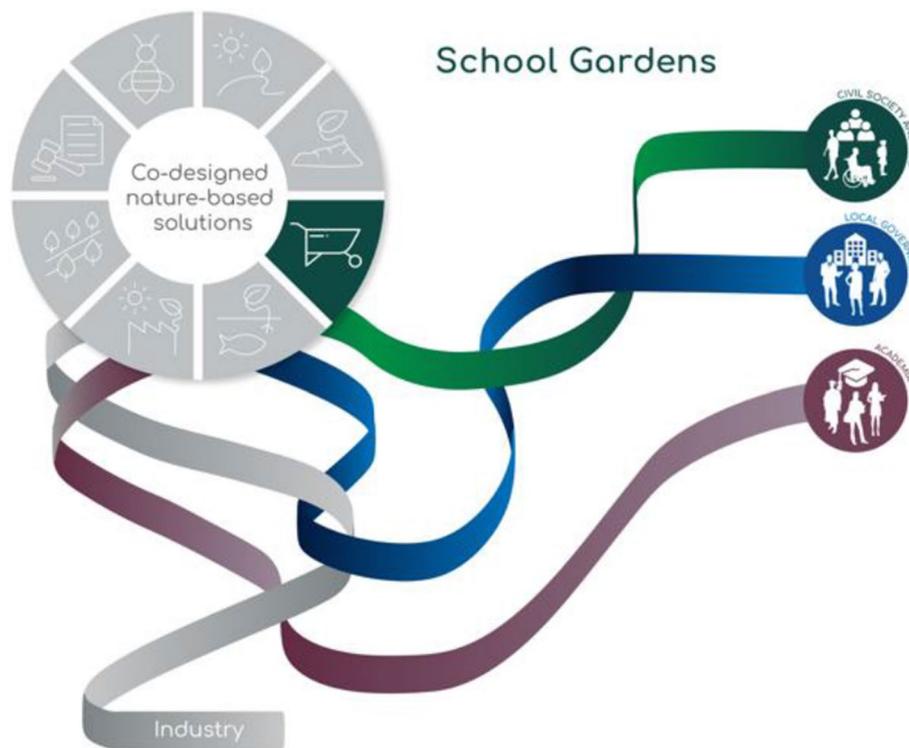


Fig. 5 Adapting the quad helix to NBS Urban Gardening in the Turin Living Lab (RWTH)

Identifying, analyzing, mapping, and evaluating local stakeholder networks during the iterative co-creation process (Fig. 4b) facilitate citizen engagement. Assigning roles and responsibilities to each stakeholder can unveil power structures and thus support managing the often-complex co-creation processes. It emerged that local partnerships need to be adapted by type of NBS or clusters of similar NBS given specific expertise required to guide and manage co-creation processes. Figures 5 and 6 illustrate two examples of NBS “Urban Gardening” (symbolized by the green cart icon) on how partnerships vary by the same NBS type across proGIreg in the Living Labs Turin and Zagreb. While in the Turin Living Lab the implementation of a school garden was mainly done by non-governmental stakeholders and no industry necessary (Fig. 5) due to its low complexity, the therapeutic garden in the Zagreb Living Lab required the engagement of all quad helix actors to address the target groups’ special needs during co-design and implementation (Fig. 6).

NBS implementations in the Living Labs showed that continuous community engagement is challenging, therefore understanding the depth of engagement per NBS and co-creation phase helps managing expectations of stakeholder participation across phases. Figure 7 illustrates an example of fluctuations of the level of stakeholder involvement and contributions based on specific requirements and objectives of each co-creation stage. In all Living Labs, the local government took on the role of coordinating, and sometimes implementing the NBS projects, ensuring the integration of various stakeholders according to the quad helix approach. Similar to the NBS Therapeutic Garden in the Zagreb Living Lab, co-creating an outdoor



Fig. 6 Adapting the quad helix to NBS Urban Gardening in the Zagreb Living Lab (RWTH)

and indoor green wall at a homeless shelter in the Turin Living Lab required technical expertise to co-design and construct the solution and academic advice on suitable plants. Local NGOs took on a key facilitator role while residents of the shelter now help to maintain the NBS after being trained (Fig. 7).

Building local quad helix partnerships in the Living Labs has been essential for the success of NBS initiatives. This approach encouraged collaborations that empower communities to take an active role in improving their living conditions, ensuring solutions are relevant, targeted and applicable to the characteristics of each community.

Role of facilitators in transforming traditional planning practices

NBS implementations across cities highlight the key role of locally active NGOs in facilitating dialogue between local authorities, across departments and the civil society in co-creation processes (Collier et al. 2023, Hölscher, K., Frantzeskaki, N., Collier, M.J. et al. 2023, Kiss et al. 2022, Frantzeskaki 2019). Tapping into different types of knowledge, perspectives and needs while communicating the potential NBS benefits also helps to gain the trust of vulnerable groups. Several implemented urban gardens target marginalized groups, which are often not heard in classic participation processes (Kiss et al. 2022). For instance, NGOs were instrumental in co-creating urban gardens engaging refugees in the Turin Living Lab and people with disabilities in the therapeutic garden in the Zagreb Living Lab. It was the involvement of interest groups of disabled people that kick-started the idea of having a dedicated therapeutic garden. Led by the municipality, the co-design process involved interest groups, designers and residents to tailor the

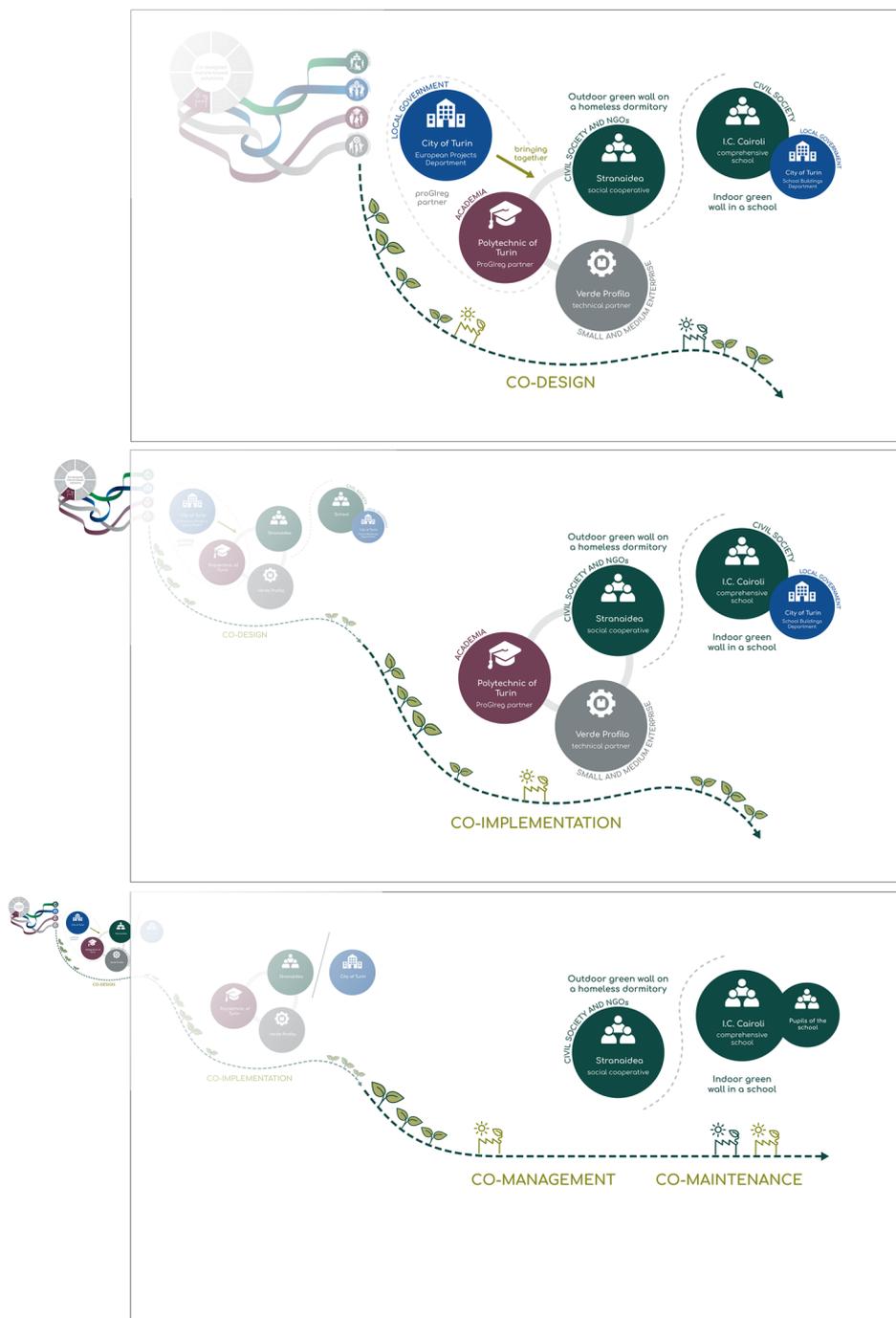


Fig. 7 Stakeholder engagement by co-creation phase of NBS indoor and outdoor green wall in Turin Living Lab (RWTH)

garden to the specific needs of physical and mental impairments. The maintenance is shared by the municipality and the interest group.

This sparked a wider call for procedural innovations within urban planning at the municipality of Zagreb, who is now aiming to integrate co-design into early planning

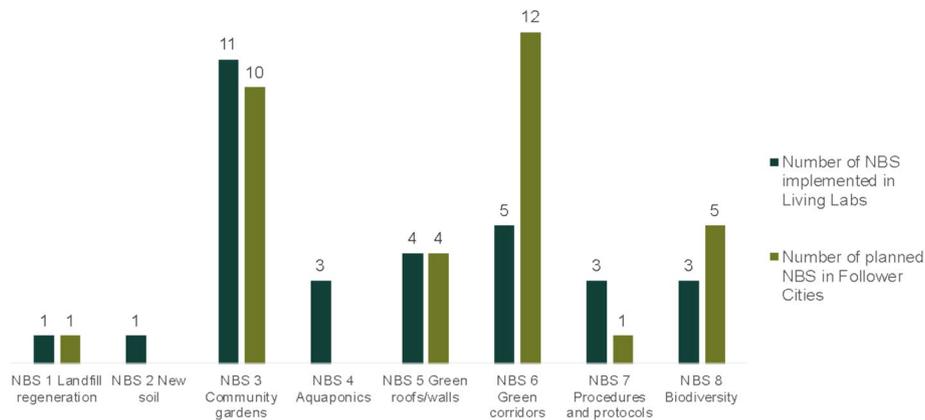


Fig. 8 Number of implemented NBS in FRC and planned NBS in FC (RWTH)

phases, focusing on the green transition with NBS within its decarbonization strategy. The municipality argues that early involvement of local stakeholders enhances the detection of opportunities for achieving set goals and should therefore be anchored in urban planning processes. However, not all proGIreg project partner cities are fully aligned in their approach to early-stage co-creation with local communities. Experts within various tiers of the respective local governments express apprehension about the risks of mis-managing public expectations, especially when participatory processes are introduced seemingly too early in complex urban regeneration initiatives. But the authors argue that exactly this transparency of the complexity could generate more trust and buy-in among citizens for NBS measures.

Planned and implemented NBS in proGIreg

Figure 8 provides an overview of implemented and planned NBS; a total of 30 NBS have been implemented in the LLs across the set of eight NBS types. Based on the experiences collected in the FRCs, the four FCs developed strategic urban plans to integrate 33 NBS into future local planning frameworks.

The graph also highlights the wide uptake of the NBS “Community-based urban farms and gardens” across FRCs and FCs, underscoring the suitability of co-creating different types of urban gardens together with local communities of and at varying scales, supported by novel governance arrangements and business models. The number of urban gardens planned in FCs indicate its replication potential across most urban fabrics and European cultures. When asked to reflect on the achieved or planned impact of NBS interventions towards the project end, partner cities voted urban gardens as “favorite NBS” given their relative ease of co-designing and co-managing, and the multiple benefits urban gardening solutions offer for a neighborhood and its residents. In addition, one observation from proGIreg NBS implementations in FRC is the cost-effectiveness of classic soil-based urban gardens, particularly when communities actively engage in co-implementing the solution. As in other EU H2020 NBS projects such as Connecting Nature, FCs developed urban plans to include urban garden networks that are aligned with green infrastructure, health, and well-being policies, e.g. by creating bicycle and pedestrian connections (Hölscher, K., Frantzeskaki, N., Collier, M.J. et al. 2023).

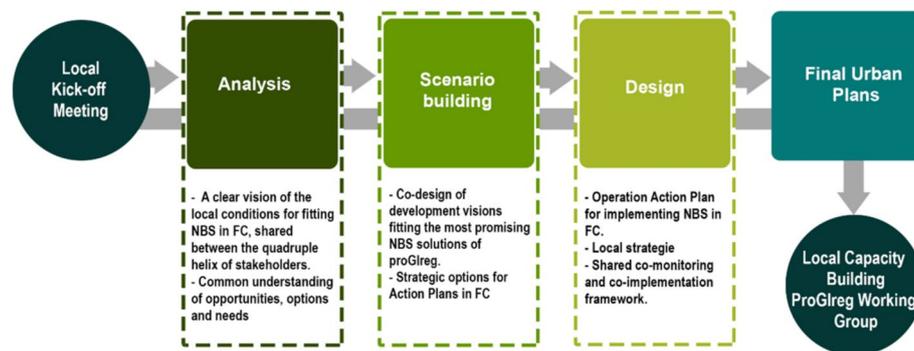


Fig. 9 Main co-design work steps of the Roadmap process (URBASOFIA)

Adapting co-design in follower cities

Replicating tested NBS from FRCs to FCs is central to proGReg, aiming to validate the quad helix approach's adaptability and transferability for urban planning and regeneration. Continuous exchanges between FRCs and FCs facilitated learning from implementation barriers, refining replicable NBS co-creation strategies. Unlike the experimental NBS in the Living Labs, replication in FCs is more strategic, aligning with long-term urban planning to embed NBS in each Urban Regeneration Area (URA) and benefiting from insights into both potential and challenges. Following proGReg's step-by-step Roadmap (Papina 2023), identifying local strengths and needs led to an intensive co-design process with quad helix stakeholders, developing tailored NBS options (Fig. 9). Outcomes are integrated in urban plans, prominently featuring green corridors and community gardens due to their synergies, combining pollinator-friendly vegetation with urban gardening to reconnect citizens with nature.

Applying the quad helix model for co-design was culturally novel in FC Cluj-Napoca and Zenica, especially for municipalities and citizens unaccustomed to such engagement given its communist and socialist history. Under the leadership of the municipalities (based on the proGReg structure) and in collaboration with relevant stakeholders, local communities and embedded NGOs built strong stakeholder networks to ensure project relevance and promote community ownership. Co-design and scenario-building roadmap steps helped local communities understand their empowerment in shaping ideas for NBS implementations. The newly introduced co-design approach in Cluj-Napoca highlighted the potential to enhance informal community gardens around housing estates and create synergies with green corridors, but it also revealed a need to mediate between diverse citizen interests. To support this, the municipality involved an NGO for the first time. Now a Horizon Europe URBREATH project Front-runner city, Cluj-Napoca focuses on advancing multifunctional urban gardens. Its Final Urban Plan, developed in proGReg, has become a model for piloting impactful NBS. FC Zenica's ambitious urban plan integrates complex NBS interventions, such as renaturing a former landfill and connecting a fragmented green infrastructure (GI) system. Collaborative, inter-departmental efforts aligned ongoing projects and investments with new co-designed NBS concepts. It was new to include all four quad helix stakeholders: industry, University of Mostar, NGOs, residents, and private landowners for green roof initiatives. The municipality highlighted that co-design transformed its planning culture, fostering

citizen-centered, innovative solutions. Given proGIreg's timing with the local planning cycle and political support led to fully embedding the urban plan in the city's Development Strategy 2023–2027. The NBS replication strategy of Piraeus aims to expand and improve its urban GI system by integrating urban gardens into neighbourhood schools and school curricula. Engaging multiple stakeholders ranging from international university student competitions, schoolteachers, students, their parents and the active involvement of the vice mayor of Piraeus sparked a series of small-scale urban gardening and greening actions in other schools. However, political personnel changes have stalled the envisaged roll-out of school greening at the city level.

International replication of NBS based on quad helix co-creation in Europe and other world regions processes is most likely to take place in the context of research projects. Cities are mostly unfamiliar with and may not be ready for this level of multi-stakeholder engagement in the perceived sovereignty of local authorities. It also raises the question whether other quad helix stakeholders can initiate such processes, and to what extent it will be supported by cities? The developed replication roadmap could assist all involved when following a structured yet adaptable approach to achieve common goals, independent on who is the driving force from the outset. Applying the quad helix approach in FRC Ningbo in China proved challenging; not just the Covid pandemic hampered active engagement of the civil society during the 3-year funding period, but also political culture and Chinese administrative systems.

Barriers and enablers to mainstreaming NBS

Overall, municipalities find it challenging to engage in co-design processes often constrained by tight timelines, budget constraints and personnel shortages. The complexity of administrative and planning frameworks poses significant challenges to co-creating NBS. Therefore, applying the quad helix model in co-creation processes can assist in creating a mutual understanding and knowledge base, which supports local community initiatives and private sector stakeholders in handling bureaucratic and financial hurdles. Implementing large and complex NBS in the FRC Dortmund (two aquaponics greenhouses, and path connection at a former landfill site), required a nuanced understanding of the regulatory landscape and effective strategies in dealing with soil contamination in post-industrial areas. In addition, experimenting with the quad helix model for co-creating NBS in Living Labs also led to changes in thinking about co-ownership and the involvement of different stakeholders in the long-term management of NBS, an area traditionally left to local authorities. Work carried out in the proGIreg Living Labs on overcoming barriers showed that by recognizing and navigating implementation barriers and leveraging enablers, stakeholders can streamline the process and increase the likelihood of successful NBS replication and long-term viability of NBS projects. Both NBS implementations in FRC and replication processes in the FCs revealed a set of distinct enablers (Table 1):

Policy recommendations for leveraging collaborative trans-disciplinary processes to mainstream NBS

To facilitate a successful transition to productive Green Infrastructure it is imperative to activate effective levers, which consider diverse cultural contexts on national, regional, and local levels. Shared governance as practiced at the Orti Generali in the Turin Living Lab demonstrates that active participation of local communities in decision-making processes becomes a linchpin for the successful implementation of NBS. This shift in perspective encourages a more democratic and community-driven urban planning ethos as is the case at the Zagreb municipality. The significance of adopting a cross-sector collaboration urban planning culture, coupled with a willingness to embrace more open processes anchored in urban planning frameworks cannot be overstated. The city of Zagreb is open to adopt a systemic approach in the face of sometimes deep-rooted silo thinking and reluctance to involve different stakeholders into administrative processes, and the city of Turin has taken first steps towards co-governance by redefining the management of urban commons. However, not all proGIreg partner cities are equally advanced. Particularly, if the goal is to foster more inclusive and collaborative governance for co-design and co-management of NBS in local communities, a fundamental shift in the prevailing mindset is indispensable, transcending conventional boundaries. Arguably, this transition will take time and perhaps more Living Lab experiences are needed to get used to new ways of working.

At policy level, leveraging innovative ideas need to be aligned with the following policy recommendations:

Policy support for Living Lab approach at all levels of government

The concept of experimenting with NBS in Living Labs illustrates the impact of collaboration and localized innovation in shaping resilient and sustainable urban futures. Co-creating the eight proGIreg NBS types within different real-life contexts showcases the potential for collective efforts in driving positive change. The outcomes are clear evidence that NBS have agency to strengthen the green infrastructure system while being highly supported by the local community. However, familiarizing municipalities further with this type of approach should be supported by Research and Innovation policy at regional and local levels.

Applying context-specific quad helix model for innovation and co-creating NBS

Operationalising the theoretical framework of the quadruple helix model for contextualized NBS demonstrates the potential of applying it in co-creation processes to generate positive impacts in the Living Labs. Generating new social networks for co-creating NBS fosters needed collaboration, sharing knowledge, and enhancing communication among diverse stakeholders, notably the inclusion of vulnerable groups.

Establishing enabling governance structures fostering co-creation at local administrative level

Creating an environment where representatives from government, industry, academia, and civil society collaborate in shaping the NBS agenda may require a LL clause or legal

Table 1 Enablers for NBS uptake against evidence from proGReg

Enabler	Description	proGReg evidence
Stakeholder engagement	<ul style="list-style-type: none"> ■ Awareness raising of NBS impacts among the public, local communities, and different municipal departments about NBS benefits and co-benefits promotes greater NBS co-management but requires continuous reiteration ■ Actively involving the community, promoting local ownership, and garnering public support enhance the feasibility and resilience of NBS initiatives ■ Building Trust and Transparency among stakeholders through transparent communication 	<p>Many implemented NBS in proGReg Living Labs achieved project acceptance, cooperation, and sustained co-maintenance, e.g. urban gardens such as Orti Generali, training homeless people to maintain the outdoor green wall in Turin, church community and residents of the urban food forest in Dortmund</p>
Institutional support and governance	<ul style="list-style-type: none"> ■ Political backing, whether by local authorities and political representatives provides the necessary resources, regulatory backing, and strategic alignment for successful NBS adoption ■ Municipality interdepartmental horizontal collaboration in different stages of NBS co-creation is essential for managing stakeholder expectations and capabilities, notably in complex NBS interventions such as in Dortmund ■ Willingness for Shared (or Co) Governance and Flexibility: Embracing or introducing shared governance frameworks in line with new policies promotes successful collaboration and replication of NBS 	<p>Political support in Piraeus and Zenica has driven both planning with and co-designing NBS. On the downside, reliance on political figures makes governance of NBS vulnerable to change and should therefore be more firmly anchored in planning frameworks to ensure long-term impact</p>
Financial support	<ul style="list-style-type: none"> ■ Adequacy of Financial Means for Implementation and Long-Term Maintenance: To ensure effective NBS execution and in particular long-term maintenance, advocating NBS as cost-effective solutions early can convince municipalities, private sector or other sources available to provide sufficient financial support 	<p>Dortmund municipality took on the maintenance for 4 out of 5 implemented NBS In Turin, long-term maintenance could not be secured for all its 17 implemented NBS</p>
Knowledge and capacity building	<ul style="list-style-type: none"> • Support of NBS integration into communities through building knowledge and expertise networks on NBS for environment, economic and socio-cultural contexts • Exchanges with cities, researchers, SMEs and NGOs to build bridges for science-supported implementation of NBS 	<p>Replication events held in FRC for replicating and upscaling of NBS within the city Generated social networks in its Living Labs for upscaling and replicating NBS</p>
Long-term sustainability and management	<ul style="list-style-type: none"> ■ Synergy with other public and private projects for the future operation and management of NBS projects and Integration into existing GI plans ■ Ongoing monitoring and evaluation of the outcomes of NBS projects would ensure they continue to provide ecological, social, and economic benefits over time 	<p>Aquaponics system in the Dortmund Living Lab is integrated in the International Garden Exhibition 2027</p>

framework for cities that enables experimentation outside of research projects. Fostering a culture that involves daring to stretch boundaries if needed to ease bureaucratic procedures would support mainstreaming NBS on a wider scale. Similarly, co-management efforts must extend to civil society, emphasizing shared and self-governance, and thus co-ownership.

Integrate informal planning instruments into formal planning frameworks to ensure legitimacy and consistent implementation of NBS

While cities increasingly adopt informal planning instruments fostering community participation in urban planning, reflecting international frameworks such as the UN Sustainable Development Goals (SDGs), EU policies and the Leipzig Charter. However, their effectiveness often hinges on local political climates, strategic goals, and project prioritization. A key obstacle is the lack of integration of informal instruments into planning legislation, which would grant them the legitimacy needed for consistent and impactful implementation of NBS.

Empowering and supporting social activism for community co-ownership of NBS

Bottom-up initiatives such as the urban garden Orti Generali in the Turin Living Lab or the food forest in the Dortmund Living Lab on church-owned ground can serve as catalysts for change, empowering communities to actively participate in the decision-making process. This approach democratizes planning and shifts power structures from local authorities as the sole provider of green infrastructure towards local communities. Linking Living Lab visions and NBS activities to existing and planned strategies contributes to integrated and interconnected development and long-term sustainability of NBS. This integration aligns NBS activities with overarching urban strategies and broader city policies.

Finally, anchoring co-design processes early in urban planning should be driven by policy, emphasizing the importance of community input from the outset to ensure seamless integration of NBS into sustainable urban development.

Mandate early-stage open co-design processes with adequate financial commitments at EU policy level

At EU level, fostering co-creation involves addressing citizens directly and placing greater confidence in civil society. Open processes, mandatory in the case of any EU investments, should be supported by financial commitments to ensure success.

Abbreviations

FRC	Front Runner Cities
FC	Follower Cities
GI	Green Infrastructure
NBS	Nature-based Solutions
proGireg	Productive Green Infrastructure for post-industrial urban regeneration
SDG	Sustainable Development Goals
URA	Urban Regeneration Area

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Corresponding author and last named are the main contributors. The other authors have contributed specific case studies from the partner cities.

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Data availability

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References

- Bauduceau, N., Berry, P., Cecchi, C., Elmqvist, T., Fernandez, M., Hartig, T., Krull, W., Mayerhofer, E., N, S., Noring, L., Raskin-Delisle, K., Roozen, E., Sutherland, W., & Tack, J. (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'. Publications Office of the European Union. <https://doi.org/10.2777/765301>
- Bradley, S.; Mahmoud, I.; Arlati, A. (2022): Integrated Collaborative Governance Approaches towards Urban Transformation: Experiences from the CLEVER Cities Project. Sustainability, Vol.14, 23. MPDI
- Carayannis, Elias G.; Rakhmatullin, Ruslan (2014): The Quadruple/Quintuple Innovation Helixes and Smart Specialisation Strategies for Sustainable and Inclusive Growth in Europe and Beyond. In: J Knowl Econ 5 (2), P. 212–239.
- Carayannis EG, Campbell DFJ. "Mode 3" and "Quadruple Helix": toward a 21st century fractal innovation ecosystem. Int J Technol Manage. 2009;46(3/4):201. <https://doi.org/10.1504/IJTM.2009.023374.ISSN0267-5730.S2CID1444029>.
- Carayannis, E., Grigoroudis, E., Campbell, D., Meissner, D. (2017): The ecosystem as helix: an exploratory theory-building study of regional co-opetitive entrepreneurial ecosystems as Quadruple/Quintuple Helix Innovation Model. <https://doi.org/10.1111/radm.12300>
- City of Turin: Regulation on Governing the Urban Commons in the City of Turin (2020). http://www.comune.torino.it/benicomuni/eng_version/index.shtml. Accessed Nov. 11th 2023
- Collier, M.J., Frantzeskaki, N., Connop, S., Dick, G., Dumitru, A., Dziubala, A., Fletcher, I., Georgiou, P., Hölscher, K., Kooijman, E., Lodder, M., Madajczyk, N., McQuaid, S., Nash, C., Osipiuk, A., Quartier, M., Reil, A., Rhodes, M., Rizzi, D., Vandergert, P., Van De Sijpe, K., Vos, P., Xidou, (2023): D. An integrated process for planning, delivery, and stewardship of urban nature-based solutions: The Connecting Nature Framework, Nature-Based Solutions, Volume 3, 100060, ISSN 2772–4115, <https://doi.org/10.1016/j.nbsj.2023.100060>.
- EU New European Bauhaus (2023): https://new-european-bauhaus.europa.eu/about/about-initiative_en. Accessed Nov. 11th 2023
- Frantzeskaki N. Seven lessons for planning nature-based solutions in cities. Environ Sci Policy. 2019;93:101–11.
- Frantzeskaki N, Borgström S, Gorissen L, Egermann M, Ehnert F. Nature-Based Solutions Accelerating Urban Sustainability Transitions in Cities: Lessons from Dresden. Genk and Stockholm Cities. 2017. https://doi.org/10.1007/978-3-319-56091-5_5.
- Frantzeskaki, N., Mahmoud, I.H., Morello, E. (2022). Nature-Based Solutions for Resilient and Thriving Cities: Opportunities and Challenges for Planning Future Cities. In: Mahmoud, I.H., Morello, E., Lemes de Oliveira, F., Geneletti, D. (eds) Nature-based Solutions for Sustainable Urban Planning. Contemporary Urban Design Thinking. Springer, Cham. https://doi.org/10.1007/978-3-030-89525-9_1
- Höglund, Linda; Linton, Gabriel (2018): Smart specialization in regional innovation systems: a quadruple helix perspective. In: R & D Management 48 (1), P. 60–72.
- Hölscher, K., Frantzeskaki, N., Collier, M.J. et al. Strategies for mainstreaming nature-based solutions in urban governance capacities in ten European cities. npj Urban Sustain 3, 54 (2023). <https://doi.org/10.1038/s42949-023-00134-9>
- Kiss B, Sekulova F, Hörschelmann K, Salk CF, Takahashi W, Wamsler C. Citizen participation in the governance of nature-based solutions. Environ Policy Gov. 2022;32(3):247–72. <https://doi.org/10.1002/et.1987>.
- Mahmoud, I., Morello, E. (2021). Co-creation Pathway for Urban Nature-Based Solutions: Testing a Shared-Governance Approach in Three Cities and Nine Action Labs. In: Bisello, A., Vettorato, D., Ludlow, D., Baranzelli, C. (eds) Smart and Sustainable Planning for Cities and Regions. SSPCR 2019. Green Energy and Technology. Springer, Cham. https://doi.org/10.1007/978-3-030-57764-3_17
- Nesshöver, C., Assmuth, T., Irvine, K.N., Rusch, K.M., Waylen, K.A., Delbaere, B., Haase, D., Jones-L Walters H Keune E Kovacs K Krauze M Külvik F Rey J Dijk van OE Vistad ME Wilkinson H Wittmer 2017 The science, policy and practice of nature-based solutions: An interdisciplinary perspective, Science of The Total Environment, Volume 579, 2017, p ISSN 1215–1227 0048 9697 <https://doi.org/10.1016/j.scitotenv.2016.11.106>
- Papina, C.L. (2023): Report on Urban Plans in FC, D2.9, proGReg. Horizon 2020 Grant proGReg-LL Turin- NBS_3-Orti-Generali https://progireg.eu/fileadmin/user_upload/Turin/NBS_3OrtiGenerali_Details.pdf Agreement No 776528, European Commission. Access via: https://progireg.eu/fileadmin/user_upload/Resources/D2.9_Report_on_the_final_Urban_Plan_20231006.pdf

- Schütz F, Heidingsfelder ML, Schraudner M. Co-shaping the Future in Quadruple Helix Innovation Systems: Uncovering Public Preferences toward Participatory Research and Innovation. *She Ji: the Journal of Design, Economics, and Innovation*. 2019;5(2):128–46.
- van der Jagt APN, Smith M, Ambrose-Oji B, Konijnendijk CC, Giannico V, Haase D, Laforteza R, Nastran M, Pintar M, Zeleznikar S, Cvejic R. Co-creating urban green infrastructure connecting people and nature: a guiding framework and approach. *J Environ Manag*. 2019;233(2019):757–67. <https://doi.org/10.1016/j.jenvman.2018.09.083>.
- Wilk, B., Säumel, I. and Rizzi, D. (2021): "Collaborative Governance Arrangements for Co-creation of NBS"; Croci, E. and Lucchitta, B. (Ed.) *Nature-Based Solutions for More Sustainable Cities – A Framework Approach for Planning and Evaluation*, Emerald Publishing Limited, Bingley, pp. 125–149.
- Zingraff-Hamed A, Huesker F, Lupp G, Begg C, Huang J, Oen A, Pauleit S. Stakeholder mapping to co-create nature-based solutions: Who is on board? *Sustainability*. 2020;12(20):8625.

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