Article:
Elmqvist, T., Anderson, P., Andersson, E. et al. (2026) Urban sustainability science: from adaptation to regeneration on the road to 2050. npj Urban Sustainability, 6. 30.

https://doi.org/10.1038/s42949-026-00362-9

npj | urban sustainability

Editorial

Published in partnership with RMIT University

https://doi.org/10.1038/s42949-026-00362-9

Urban sustainability science: from adaptation to regeneration on the road to 2050

Our Editorial team reflects on the journals' first five years and discusses our continued aspiration to be an outlet for thought provoking and effective syntheses of essential advances in urban sustainability science and policy.

A new urban frontier

When *npj Urban Sustainability* was launched in 2021, we framed urbanization as one of the defining processes of the Anthropocene—a process that drives global change, but which also opens opportunities for sustainability action[1]. Now, alongside the 5th anniversary of the journal, we reflect on the state of urban sustainability research and the knowledge gaps that we would like our community to address to support local and global decision-making for sustainability and resilience[2].

The 2020 s have brought converging crises—heat, wildfires, floods, pandemics, economic volatility, and deepening social inequities—testing cities and the systems that sustain them. Yet the same decade has also revealed unprecedented opportunities for rethinking how cities function as living systems that can help stabilise the planet. The transformations envisaged in the 2030 Sustainable Development Agenda, and the new collective vision needed to develop a new Sustainable Development Agenda beyond 2030, depend on harnessing the power of urbanisation to advance the SDGs in an integrated way. Engaging local governments and urban areas in localising the SDGs has become a priority for the international community committed to a global vision of socio-ecological justice and human rights.

The urban decisions made in the next two decades will shape whether societies remain within—or overshoot—the planet's biophysical boundaries. The choices facing mayors, planners, communities, and industries concern not only emissions or efficiency, but the very capacity of cities to regenerate natural capital, buffer risks, and foster equitable wellbeing in a warming and uncertain world. These decisions may need new paradigms, particularly to understand the changing relationships between human societies and ecosystems. The urban environment is a critical site for redefining and transforming social-ecological relations.

As the journal enters its next phase, we look ahead to the coming generation of urban sustainability science. What questions must we ask now to forge the change needed to help our cities thrive under novel climates, resource scarcity, conflicts, demographic shifts, and technological disruption? And how can the research community ensure that evidence translates into equitable transformations?

From resilience to regeneration and restoration

In the early 2020 s, the language of *resilience* dominated urban sustainability discourse. That focus remains vital, but we now need to go further: toward preventive actions and regenerative cities that reduce risk at its source, restore ecological functions, and create equitable net-positive outcomes for nature and people. Understanding the implications of such a regenerative turn and what it means for transforming socio-ecological relations has been one of the most exciting debates of the last five years.

Urban sustainability science must move beyond documenting impacts to designing, testing, and scaling regenerative systems. Advanced nature-based solutions are central to this shift—sponge cities that absorb floods and store carbon, riparian corridors that cool and clean, blue–green networks that reconnect urban, peri-urban, and rural landscapes. Of equal importance is embracing equity, justice, and inclusion in action and innovation to open the opportunities that cities provide to all people, as well as non-human inhabitants. The next challenge is not proof of concept but implementation and evaluation at scale, integrating nature and inclusion into finance, governance, and infrastructure systems that have long been engineered and governed for extraction and control rather than restorative justice in the regeneration of human and natural systems. As the agenda moves towards facilitating action, the debate also centres on impacts, as regenerative responses are not intrinsically good and may have unintended effects on societies, economies, and other aspects of cities and ecosystems.

Water-wise Cities in A Drying and Flooding World

Few challenges will define the coming decades more than water. By the 2040 s, many European, American, Asian, and African cities will experience simultaneous scarcity and flood risk as droughts, heat, and precipitation extremes intensify. Urban sustainability science must help build inclusive approaches to circular water economies—systems that recover, store, and reuse water, close loops between stormwater, wastewater, and supply, and govern cities as part of their wider catchments.

There is a need to develop a people-centred research agenda on the relationship between urbanisation and water, one that addresses the forthcoming challenges while acknowledging the centrality of water to urban living.

Inclusive and context-sensitive development of technologies opens the frontiers of research to the imagination by examining how:

- Non-conventional water sources (rainwater, stormwater, harvested water, greywater, treated effluents) can substitute or recharge declining groundwater,
- Nature-based infiltration and aquifer management to buffer the impacts of water extraction, water scarcity and droughts,
- Urban–rural water compacts to manage shared resources across regional to multi-national basins, and
- Digital twins that simulate basin-scale trade-offs in real time.

At the same time, these topics cannot be developed in isolation from understanding how systems of governance shape and can deliver access to affordable and clean water everywhere in the world. Such work connects water security to biodiversity, soil health, and climate adaptation and requires science-policy-practice coalitions that link hydrologists, engineers, planners, and communities. In line with almost three decades of urban political ecology, there is a need to approach the technification and commodification of water critically, reflecting on the way the

development and management of infrastructure networks have shaped hydro-social relations.

Beyond Zero: Carbon, Materials, and The Circular City

Urban carbon strategies must now extend well beyond energy to understand the social dimensions of transitioning away from fossil fuels. The next wave of sustainability science must focus on embodied carbon—the emissions locked into materials, infrastructure, and construction supply chains. With 80% of 2050's buildings already standing, the core task is how to enact inclusive approaches to deep retrofit: reusing and reimagining the existing urban fabric equitably. The concept of the 'Net-Positive City' has inspired new, technology-led ideas to implement energy-positive buildings with advanced photovoltaics (BIPV), water-purifying infrastructure, and regenerative materials, such as carbon-sequestering cement, that actively enhance its surroundings. Often, Net-Positive building concepts are advanced alongside concepts of ICT-led understandings of circular 'Urban Metabolism', where AI and IoT enable the real-time management of material flows, powered by a decentralized energy landscape of renewable-based microgrids, supported by green hydrogen for storage and peer-to-peer trading via blockchain technologies. There is a need to examine what conditions may help move towards such built environment utopias, while recognising how current conditions may shape their materialization on the ground. Another important question is what alternatives are foreclosed by an overall focus on technologically led carbon actions in the built environment.

Emerging research themes include:

- low-carbon, circular materials (reused aggregates, bio-based construction, recycled steel and aluminium),
- sharing-based planning strategies, such as in-fill developments,
- adaptive reuse and modular design for longevity,
- "urban mining" and metabolism studies that track material flows across city-regions (e.g., predictive waste sorting, industrial symbiosis, and advanced recycling, which transform waste into resources); and
- financial mechanisms for deep retrofits—performance-based contracts, green bonds, and transition credits.

Technology alone will not provide a comprehensive response to the net-zero crisis. The journal is particularly inclined towards work that acknowledges the complex scales of decarbonisation and examines the socioeconomic and political dynamics of infrastructure, transportation, and housing development, planning, and inhabitation from a critical perspective, using technical knowledge in tandem with transdisciplinary science and collaborative decision-making and planning. In an increasingly polarised society, decarbonisation has become a term of contention, pointing towards the need for inclusive research agendas that address the societal decarbonisation challenges that go beyond technological structures.

These efforts align climate mitigation with local employment, skills, and economic resilience. They also raise equity questions: who pays for and benefits from green investment, and who risks harm, exclusion and displacement?

Climate Health and Liveability Under Extreme Heat

By mid-century, extreme heat will become the most lethal climate hazard in cities. The science frontier is now at the intersection of urban climate, public health, and social equity. Urban sustainability research must advance predictive models of heat-health risk, design cooling networks (trees, shade, ventilation, materials), and evaluate interventions for their social distribution and cost-effectiveness. Effectively mitigating threats like extreme heat requires a shift from incremental health interventions or discrete green features to the intentional design of entire health care systems and urban biomes. Examples of this holistic approach include multi-sector strategies, focusing on early warning systems, cooling centres, and energy assistance; they also integrate blue-green infrastructure—such as wetlands, rivers, green roofs and trees—as core components of urban planning, simultaneously bolstering climate adaptation, stormwater management, emergency response and recovery, and public health resilience.

Examples of key questions include:

- Which combinations of measures—cool roofs, shade trees, reflective pavements, water features—achieve the greatest reduction in mortality per funds invested?
- Can adaptive solutions like amphibious architecture and deployable flood barriers enable a dynamic response to climate and environmental threats? If yes, where and how?
- How can interventions be prioritized in informal settlements, marginalized neighbourhoods, schools, and care facilities where heat risk is highest?
- How do urban heat strategies intersect with air quality, energy demand, and equity?
- What are the potential and limitations of predictive modeling and real-time resilience dashboards to provide critical data to guide land-use planning against compound climate events?

Such work requires merging remote sensing, epidemiology, disaster risk management, public health, social data, and participatory mapping—a transdisciplinary frontier for the next decades.

Biodiversity-Positive Cities

Urban sustainability must embrace a richer social and ecological vision. Greening has often been pursued for aesthetic or climate purposes; now, research must target functional biodiversity—the species, interactions, and habitats that sustain urban ecosystem services, ensuring that green spaces aren't just for the privileged. This means that cities should quantify how urban design supports pollination networks, pest control, soil biodiversity, habitat, and genetic connectivity, and how greening serves diverse groups – e.g., the elderly, women, and children.

Methods are evolving rapidly: environmental DNA, acoustic monitoring, and citizen science can reveal biodiversity responses to interventions at unprecedented spatial and temporal resolution. Integrating such data into planning will enable cities to measure not just *more green space*, but better ecological resilience and performance. This research must also acknowledge recent developments in ecological sciences, such as the importance of mutualism in maintaining environmental health.

The global biodiversity framework adopted at COP15 calls for cities to play a proactive role in reversing nature loss. Cities are often located in places with, at least historically, conditions that have produced biologically rich communities, and they are the places where an urbanized human population can meet and form meaningful, reciprocal relationships with each other, and with non-human others. If nature is to provide a fundamental source of adaptation and resilience, then it must also be protected, cherished, respected, and governed for its own sake and resilience. Urban sustainability science has a central role in developing metrics, tools, and narratives that make this ambition credible, actionable, and more inclusive.

Coastal and Ocean–City Interfaces

It is estimated that close to 1 billion people live in low-elevation coastal zones, and urban development is converging with rising seas and declining coastal ecosystems, creating risks. Sustainability science must integrate marine and terrestrial research, focusing on coastal wetlands, mangroves, dunes, and reefs that provide protection, carbon storage, and livelihoods. There is a wide

area of research that remains underexplored about the relationship between coastal development and environmental changes from the impacts of waterfront developments driven by tourism and speculation to the processes of managed retreat that may follow the rise of urban adaptation concerns, or the sitting of extractive industries near urbanised coastal areas. Such research is at its best when engaged with the multilayered set of concerns that shape urban sustainability dynamics, and the concerns outlined in the Sustainable Development Goal 14, of Life Below Water, a Goal towards which progress is considerably lacking.

Future directions:

- comparative studies of managed retreat versus protection, including governance, social contracts and compensation models;
- innovative blue-carbon restoration and its integration into climate finance;
- sediment management and ecosystem-based coastal engineering; and
- the governance of port decarbonization and shipping transitions.

These issues illustrate how the "urban" must now extend beyond city boundaries to the urban–ocean continuum.

Smaller Cities and The Peri-urban Frontier

Most new urban growth this century will occur in small and intermediate cities, and in peri-urban areas often with limited governance capacity and fragmented land use. Research must expand to these smaller cities and peri-urban regions, where agricultural land, biodiversity, and water resources face mounting pressure.

Research can particularly advance by considering how to fosters the planning capacities of smaller cities and of the peri-urban frontier as a space of flows, traversed by a multitude of landscape narratives that compete for space, sometimes with disastrous consequences. Here, the political nature of urban development becomes manifest as it shapes urban frontiers. It is also a boundary generative of inequalities and conflicting ways of being in space. Nowhere more than at the peri-urban frontier is participatory planning more relevant, as it engages complex diversities of original dwellers, the absents and the newcomers.

New forms of technological, social and policy innovations are rapidly shaping smaller cities and the urban frontier, highlighting important knowledge gaps, for example:

- frugal, modular, and decentralized infrastructure systems
- lack of low-cost planning tools
- clashing or disconnected planning systems
- governance innovations for NEXUS solutions (sensu IPBES)
- public transport integration in fast-growing secondary cities.

Supporting knowledge exchange across boundaries is vital for global equity and for bending the curve of unsustainable expansion.

Demographic Transitions: Aging, Shrinking, and Rebalancing Cities

Urbanization in the twenty-first century will not be defined only by expansion. Many cities—especially in Europe, East Asia, and parts of South and North America—are ageing and shrinking, experiencing population decline, labour shortages, and an increasing share of older residents. In Africa and South Asia, cities will continue to grow rapidly, creating stark contrasts between over- and under-urbanized regions. For example, an explosion of informal urban settlement, in Africa and Africa, is expected to account for 40% of the world's population by 2100, the majority being young people living in cities.

A demographic transition to shrinking and aging, as experienced in East Asia and Europe, reshapes housing and transportation demand, infrastructure finance, and service provision, challenging the assumption that urban growth is inevitable or desirable. Urban sustainability science must therefore address how cities can remain livable, equitable, and economically viable amid demographic contraction—rethinking land use, mobility, care systems, and public space for smaller, older populations. Research can illuminate strategies for adaptive reuse of housing, transportation, and infrastructure, intergenerational and health-supportive design, and circular local economies that inclusively sustain wellbeing without expansion. Comparative studies of shrinking cities also offer valuable insights into resource efficiency, degrowth pathways, and regenerative and restorative governance, helping to redefine prosperity in ways compatible with planetary limits. The new data of the World Urbanization Prospects has challenged multiple assumptions about how the urbanised World looks like and opens new possibilities for assessing the collective project of inhabiting the Earth.

Governing Transformations

The governance challenges remain formidable. Cities are changing faster than the institutions designed to support them. Multilevel coordination—between sectors and local, metropolitan, national, and international levels—is essential but often lacking. Over the next 20 years, research must illuminate how city diplomacy, municipal finance, restorative action, and regulatory innovation can drive systemic change. Increasing security issues stemming from geopolitical conflicts and political polarization are a threat to multilevel collaboration and transformative governance. New modes of governance, social and technological innovation, and nature-based solutions are likely to arise as nation-states and groups of nations seek to navigate an uncertain and changing world. The localisation of action continues to be a challenge for achieving the collective, global vision of the SDGs, and there is increasing resistance to existing efforts to decolonise sustainable development.

Important directions include:

- facilitating the development of local and regional programmes for inclusive social and technological innovation,
- integrating risk accounting into municipal budgets and credit ratings, and into insurance,
- embedding nature-based and circular metrics into procurement and planning codes,
- understanding the interconnections between urban governance, social and technological innovations, nature-based solutions, defence and security,
- developing coalitions of cities and urban-relevant actors at multiple levels to facilitate learning and foster capacity for transformative policies,
- analysing how urban governance reforms interact with fiscal, land-use planning, and data regimes.

The central question is how to align city action with changing global frameworks—the Paris Agreement, SDG 11, the Sendai Framework, and the Global Biodiversity Framework—while maintaining accountability and inclusion.

Just Transitions, Informality, and Climate Mobility

Inequalities in access and protection from harm constrain urban action and innovation. While wealthy populations, who disproportionately contribute to climate and environmental change, often have resources to benefit from urban sustainability, marginalized and informal populations lack the resources, options, and decision-making power to prepare for, adapt and transform. If these inequities are ignored, action and innovation can (re)create injustices that weaken social cohesion, trust, and cooperation.

By 2050, more than one billion people may live in informal settlements, and climate-induced mobility could reshape urbanization patterns across continents.

Urban sustainability science must therefore address the equity and justice dimensions of urban sustainability transitions, including who pays, who benefits, who is excluded or harmed and who decides what to do and how.

Research priorities include:

- upgrading informal settlements through co-production, tenure security, and inclusive climate-resilient infrastructure,
- retrofitting, maintaining, and climate-proofing infrastructure,
- exploring effective nature-based solutions for sub-serviced settlements,
- enhancing development opportunities for climate migrants and environmental refugees,
- revitalizing cities through inclusive development of cities and communities,
- developing anticipatory and adaptive planning for internal and cross-border migration,
- quantifying distributional impacts of green investments and ensuring affordability and access
- understanding gendered and generational dimensions of risk and opportunity.

A just transition lens must permeate all domains—from retrofit programs to biodiversity corridors—to ensure that sustainability gains do not deepen inequality.

Data, AI, and The Ethics of the Digital City

Urban data and artificial intelligence are transforming how we monitor, plan, and manage cities. Yet data systems also reproduce inequality and surveillance if governance lags behind technology. The next era of research must develop ethical, open, and interoperable data ecosystems that support sustainability without compromising rights. At the same time, AI systems do not fully appear to live up to their promises and sometimes, unintended consequences appear to override their purported benefits, for example, in education or in addressing the crisis of urban loneliness. Urban environments will be deeply shape by the decisions collectively taken about the management of AI in the production of knowledge.

Priorities include:

- transparent, replicable AI models for energy, water, and mobility management,
- open-access digital twins co-designed with municipalities,
- frameworks for data justice—privacy, consent, and equitable access to information and insights,
- low-cost sensor networks and analytical tools suitable for data-sparse cities, particularly in the Global South,
- upgrading and reconstructing of urban sustainability theories in the era of new data and AI
- the limits of AI against its promises and the alternative technologies and labour practices that it forecloses.

Methods for the Next Generation

The coming decades demand methodological renewal and innovation in urban sustainability science.

- Co-production 2.0: communities and practitioners as full research partners, with data and revenue sharing.
- Comparative experiments: testing interventions across cities to understand context-dependence and scalability.
- Open data and replication: mandatory sharing of code, datasets, and MRV (monitoring, reporting, verification) frameworks.
- Equity and co-benefit reporting: including indicators of justice, health, and biodiversity in all empirical studies.
- interdisciplinary innovation: seeking paths for the integration of multidisciplinary methodologies and problem-solving approaches

Rigorous, transparent, and inclusive methods will strengthen the credibility and usability of urban science in policy and practice.

An Invitation to The Community

As *npj Urban Sustainability* moves into its next phase, we invite contributions that advance these frontiers. We particularly welcome comparative, community-centred, practice-oriented, and policy-relevant research that connects urban transformations to the global sustainability agenda. Studies led from and with the Global South remain a core priority, alongside analyses of small and intermediate cities, peri-urban regions, and informal contexts that represent much of the world's urban future.

We encourage submissions that:

- test new governance and finance mechanisms for regenerative and just cities,
- evaluate large-scale retrofits, circular water systems, and blue–green infrastructure,
- examine data and AI ethics in real-world urban applications,
- analyse interactions between urbanization and biodiversity, climate health, and risk reduction, and
- develop open data, tools, design templates, and protocols for replication.

Looking to 2050: The Measure of Success

By 2050, success in urban sustainability will not be measured only by emission reductions or economic output, but by the quality of life and resilience cities provide under planetary constraints. The science we advance today must help cities:

- engage with the potential for a Sustainable Development Agenda to be deployed beyond 2030,
- reduce heat- and flood-related mortality,
- restore urban biodiversity and ecosystem connectivity,
- decarbonize material and energy systems,
- secure water and food
- enable security, social inclusion and dignity for all residents.

If urban sustainability science is to achieve fundamental and transformative shifts in our relationship with the planet by 2050 it must therefore be both analytical and generative: producing not only knowledge of what is, but imagination for what could be. We look forward to continuing that journey with our global community of authors, reviewers, practitioners and policy makers.

Finally, we believe academic journals, like *npj Urban Sustainability*, have a responsibility to respond to a current troubling drift in many countries where academic freedom is being questioned, scientific evidence that does not align with policy agendas is discounted, and international fora for science-based policymaking are dismissed[3]. Yet for genuinely global challenges—climate change among them—progress depends on sustained and inclusive international collaboration and on maintaining credible pathways through which research can inform public decision-making. This requires more than rhetorical support: it calls for practical protection of academic freedom, including the right to produce and publish evidence even when it contradicts prevailing policies; the freedom to associate and collaborate across borders; and governance arrangements that safeguard open, reasoned deliberation. *npj Urban Sustainability* clearly affirms this responsibility and we will use the journal's platform to uphold scientific integrity, defend the scholarly independence, and strengthen the international scientific cooperation on which effective sustainability policy ultimately depends.

Thomas Elmqvist[1,2] ✉, Pippin Anderson[3], Erik Andersson[1,4], Vanesa Castan Broto[5], Tao Liu[6], Timon McPhearson[7], Anjal Prakash[8], Christopher Raymond[9],

Patricia Romero-Lankao[10], Suneetha M. Subramanian[11] & Xiaoling Zhang[12]
[1]Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden. [2]Tokyo College, University of Tokyo, Toky, Japan. [3]Department of Environmental and Geographical Science, University of Cape Town, Cape Town, South Africa. [4]Department of Environmental Sciences, Faculty of Biological and Environmental Sciences & Helsinki Institute of Sustainability Science, University of Helsinki, Helsinki, Finland. [5]Urban Institute, University of Sheffield, Sheffield, UK. [6]College of Urban and Environmental Sciences, Peking University, Beijing, China. [7]Urban Systems Lab, Department of Environmental Studies, New York University, New York, NY, USA. [8]Bharti Institute of Public Policy, Indian School of Business, Hyderabad, India. [9]Ecosystems and Environment Program, Department of Economics and Management & Helsinki Institute of Sustainability Science, University of Helsinki, Helsinki, Finland. [10]Canada Excellence Research Chair, University of Toronto Scarborough, Toronto, Canada. [11]Biodiversity and Society Programme, Tokyo, Japan. [12]Sustainability X-Lab, Department of Real Estate and Construction, Faculty of Architecture, The University of Hong Kong, Hong Kong, China.
✉e-mail: Thomas.Elmqvist@su.se

Received: 27 November 2025; Accepted: 4 February 2026
Published online: 16 February 2026

References

1. Elmqvist, T. et al. Urbanization in and for the Anthropocene. *npj Urban Sustain* **1**, 6, https://doi.org/10.1038/s42949-021-00018-w (2021).
2. Bai, X. et al. Reimagining urban science for global sustainability: Five strategic research areas. *Glob. Sustainability* **8**, e38, https://doi.org/10.1017/sus.2025.10025 (2025).
3. McDonald, R.I. et al. Uncharted political waters for sustainability. *Nat. Sustain.* https://doi.org/10.1038/s41893-025-01739-x (2025).

Author contributions

T.E. wrote the first draft and all other authors have reviewed the text and contributed with revisions.

Competing interests

T.E. is Editor-in-Chief and all other authors are Associate Editors of *npj Urban Sustainability*. The authors declare no other competing interests.