REIMAGINING CARBON SINK CITIES

HOW TO CATALYZE CARBON REMOVAL FOR SUSTAINABLE, RESILIENT, AND INCLUSIVE CITIES

A VISION DOCUMENT

CITY CDR INITIATIVE
Building Carbon Sink Cities

SOM

CNCA
CARBON NEUTRAL CITIES ALLIANCE

Climate
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IN SHORT

This Vision Document is intended as a discussion starter on how to design the future of our cities in the climate crisis era by integrating carbon sinks in the urban environment. It gives some pointers on potential public interventions, but does not aspire to provide a conceptual or policy framework. Further work is needed to define the pathways for implementation, rooted in sound economic and financial data, with detailed technical definitions, and practical case studies.

EXECUTIVE SUMMARY

Cities are among the most complex living systems on Earth. The ‘urban metabolism’ of a city is shaped by countless flows of materials, energy, water, greenhouse gases, information, capital, climate, flora, fauna and people that are constantly ‘exchanged’ across its permeable boundaries. For over a century, this metabolism has been overwhelmingly extractive—designed to take from the planet’s finite reserves, while externalizing its costs to the atmosphere, ecosystems and communities.

In this Vision Paper, we call for an urban metabolism that transitions cities from extractive engines to regenerative ecosystems.

The Carbon Sink City is a city that is planned and managed so that its systems work together to remove and store carbon while delivering everyday services and protecting nature for collective wellbeing. Carbon flows through the city in much the same way as water or energy: captured in one place, permanently stored or transformed in another, and reused as a feedstock for new products, fuels or energy cycles. Cities embed carbon-conscious design and planning into the very fabric of the urban environment, reframing carbon as a designed-for element of urban metabolism, with a ubiquitous presence of natural and artificial carbon sinks. In this future, cities become restorative systems that actively contribute to climate stability and urban resilience.

Realizing this vision demands collective leadership and local orchestration, ‘situated’ responses, bold investments and a willingness to embrace new models of value, and inclusive governance. This Vision Paper is the result of a collaboration between the City CDR Initiative, SOM, Carbon Neutral Cities Alliance, UN High-Level Climate Champions, XPRIZE, and Conservation International.

1. INTRODUCTION

Cities today sit at the epicenter of the climate challenge. They are both the engines of economic and cultural life and the primary drivers of global emissions, consuming vast quantities of resources and producing waste that reverberates across ecosystems worldwide. Yet, in this challenge lies an unprecedented opportunity: to reimagine cities not as sources of carbon but as sinks—living systems that actively contribute to climate restoration and deliver a wide array of ecosystem services to society.

This vision requires a **paradigm shift** in how we conceive, design, and operate urban environments and the connections with their peri-urban and rural environments. Building on the ancestral knowledge and practices of Indigenous Peoples to achieve long-term sustainability and governance, cities can evolve from extractive engines to regenerative ecosystems. Although deep decarbonization remains the first priority for cities, this evolution cannot be achieved by mitigation alone; it demands systemic approaches to carbon dioxide removal (CDR) and carbon sink development to accelerate and catalyze sustainable finance in urban sustainability.

Carbon removal is defined by the Intergovernmental Panel on Climate Change (IPCC) as human-led activities that actively remove CO_2 from the atmosphere and durably store it in geological, terrestrial, or ocean reservoirs, or in products. Already, promising pathways are emerging.

Architecture and urban design are beginning to demonstrate how the built environment itself can absorb CO_2 at scale by making carbon sinks ubiquitous. Indigenous stewardship practices highlight how human settlements can live in symbiosis with nature, sustaining an ecological balance over generations. Cutting-edge climate science underscores the urgency of coupling emissions reduction with removal to accelerate climate mitigation, balance residual emissions on the path to unavoidable net-zero emissions, and address global temperature overshoot.

An emerging political economy for more radical interventions is already taking shape. Citizens around the world are demanding access to urban green spaces and urban nature-based solutions (NbS). These solutions are at the forefront of addressing climate change impacts in urban planning, practice, and research. Whether called green infrastructure, urban nature, ecosystem-based adaptations, environmental restoration or conservation, cities are increasingly implementing NbS to tackle pressing societal challenges, including food security, water security, human health, disaster risk, natural and economic development.

Building on this trend of bringing nature back to our cities, we believe that combining these perspectives—Indigenous knowledge systems, climate science, urban design innovation and systemic carbon removal—can serve as the foundation of a new urban planning model for the future: the Carbon Sink City.

2. FRAMING CARBON SINK CITIES

How the idea of a city is framed conditions how we think of solutions to meet the needs of citizens. As a space, cities have traditionally been framed as bounded by jurisdictional borders. Trans-boundary environmental and climate challenges, and the global nature of supply chains, have made this frame of reference redundant.

Cities are among the most complex living systems on Earth. Countless flows of materials, energy, water, greenhouse gases, information, capital, flora, fauna and people are constantly 'exchanged' across its permeable boundaries. Cities produce waste that ripples far beyond their administrative borders. For more than a century, this 'urban metabolism' has been overwhelmingly extractive—designed to take from the planet's finite reserves, while externalizing its costs to the atmosphere, ecosystems and communities. To reimagine cities as carbon sinks requires a fundamental transformation: redirecting this metabolism from extractive to regenerative.

This is the basis of the Carbon Sink City: a city planned and managed so that its systems—building fabrics, streets, parks, utilities and supply chains—work together to remove and store carbon while delivering everyday services. Within such a framework, carbon is no longer an unwanted by-product to be minimized, but an essential input that can be captured, stored and circulated as part of the city's operating system. Carbon becomes a resource and even a form of value—a material currency, underpinning a regenerative urban economy.

Urban Metabolism and Carbon Removal

The concept of **urban metabolism** provides a powerful lens for this shift. By understanding cities as interconnected networks of flows—of materials, energy, water and carbon—we can begin to design, measure and redirect these cycles in ways that benefit both people and the planet. To make cities critical contributors to climate restoration and stability instead of drains on the global carbon budget, we must reframe urban metabolism, so that flows of carbon are measured, redirected, stored and reused.

Using urban metabolism as the central lens means three practical shifts. First, carbon is treated like any other urban resource: it is counted, traced, and managed. Second, design and planning decisions are made with the explicit goal of increasing durable carbon storage (in well-managed soils, plants, materials, products and engineered systems) while reducing emissions. Third, decisions are tested against measurable outcomes: net carbon balance for districts or the city, storage permanence (how long carbon stays locked up), and co-benefits such as cooling, biodiversity and jobs.

Urban Sequoia: Proof of Concept at the Building Scale

SOM's **Urban Sequoia** research began with a radical yet deceptively simple question: **What if a building could act like a tree?** This provocation redefined the role of architecture—to design buildings not merely as a container for human activity, but as an active ecological agent, capable of contributing to climate restoration.

The resulting prototype demonstrated the possibility of buildings that absorb more carbon than they emit over their lifespan. By combining biogenic materials, advanced carbon capture technologies and circular design principles, Urban Sequoia shows how the built environment can move from "less harmful" to **net positive** and regenerative. Timber, bio-concrete and biogenic composites store carbon directly in the fabric of the building. Energy-generating facades, bio-based urban systems and direct air capture units integrated into building systems actively remove CO_2 from the atmosphere.

The Urban Sequoia approach is impactful in two additional ways. First, it provides measurable outcomes at a familiar scale: embodied carbon stored in materials, capture rates from integrated units, and lifecycle emissions for

construction and operation. Second, it reveals practical tools that scale: prefabrication and flexible adaptations that prolong a building's lifespan, modularity and design for disassembly and reuse, and circular economy models applicable at local level. These tools move the idea from a single building toward repeatable practice at the city scale.

Scaling Principles into the Urban Fabric

While a single building can demonstrate what is possible, its true power lies in its scalability and replication. The impact of Urban Sequoia grows exponentially when its principles are extended across entire neighbourhoods and city systems. At this scale, the metabolism of the city itself can shift and individual buildings can start to function within the urban ecosystem in ways that resemble a forest ecosystem whereby a 'mother tree' acts as the 'hub' for a vast, underground fungal network. Through this network, these dominant trees share resources and interact with other trees, including different species and their own seedlings.

In addition to urban design embracing the principle of solidarity and creating buildings that 'give back more than they take', we envision a future where streetscapes are designed with carbon-storing pavements that mineralize CO_2 into durable surfaces, parks and landscapes that double as carbon sinks, integrating bio-based capture technologies into living systems, and wastewater processing facilities that remove carbon and as a result increase the ocean's carbon absorption capacity. Streets and corridors become continuous green-blue networks—tree-lined avenues, permeable pavements, pocket wetlands and green roofs—that together increase sequestration, reduce heat and manage stormwater surges. Utilities are repurposed to circulate captured carbon alongside water and energy, storing it permanently or feeding it back into industries where it can be reused.

These interventions, layered across the urban fabric, begin to create a city where carbon is no longer considered waste, but a resource that flows continuously through a regenerative cycle, with excess amounts durably stored across the urban fabric. In this networked model, carbon flows are tracked, transformed and reused across scales, creating local jobs and new economic value while shifting the city's net balance toward removal.

Reframing Carbon as a Designed-for Element

Urban Sequoia provided proof of concept at the building scale. The next step is to imagine how these principles can extend across the layered complexity of an entire city. Although still in its early stages, our research on Carbon Sink Cities points toward the emergence of **a networked carbon economy:** a city economy in which every building, landscape and infrastructure component contributes to absorbing and circulating carbon valued in monetary terms.

In this vision, carbon flows through the city in much the same way as water or energy: captured in one place, permanently stored or transformed in another, and reused as a feedstock for new products, fuels or energy cycles. Facades become harvesters, soils become reservoirs and (existing) distributed systems pipe captured CO_2 into industries that can transform it into synthetic fuels, construction materials or everyday products. The city ecosystem becomes a metabolism—an integrated infrastructure of removal, reuse and regeneration.

Crucially, this vision is not about layering extraordinary technologies onto ordinary systems, but about embedding carbon-conscious design and planning into the very fabric of how cities grow and operate.
By reframing carbon as a designed-for element of urban metabolism, informed by a deep understanding of the natural carbon cycles and ecosystem processes and Indigenous principles on the inseparable relationship between human settlements and the natural environment, cities can become restorative systems that actively contribute to climate restoration and the protection of nature.

3. CARBON SINKS AS A MEASURE OF URBAN RESILIENCE

Carbon removal and the development of urban carbon sinks are part of the quest for more resilient cities. They directly address the causes of climate change induced urban vulnerability and, with the right design, can be integrated into resilience planning to enhance the adaptive capacity of disaster risk management infrastructure. It is the missing piece of the puzzle that builds on similar principles foundational to other climate change determined urban planning visions. Adding the vision of a Carbon Sink City makes for a comprehensive conceptual framework to realize truly resilient cities.

Standing on the Shoulders of Giants

A resilient city is one that can withstand and recover from various internal and external shocks and stresses, such as climate change impacts, economic decline, or social disruption. Beyond bouncing back from adversity, a resilient city can adapt and thrive in the face of sustained challenges. Essentially, a resilient city ensures the continued well-being of its people, institutions, and systems. Urban resilience implies the need for a carefully balanced 'respiratory system' whereby the residual emissions are compensated with carbon removal for cities that can become net-negative.

The concept of cities as carbon sinks builds on earlier work[4] that highlight the manifold opportunities it can unlock. The co-benefits of tethering urbanization demand and consumption patterns to carbon removals are vast. It is also necessary in light of the continued focus on addressing developmental demands in cities, namely around inclusive growth, prosperity, food sovereignty, and the imperative of associated green livelihoods.

Connecting with and learning from this existing body of work on carbon sinks in cities, as well as other urban planning visions that are a response to climate change, is vitally important. The concept of 'sponge cities', for instance, stipulates that cities must become better at absorbing excess water from extreme rainfall, flashfloods, or other extreme water-related challenges caused by climate change. The idea of 'nature-positive cities', meanwhile, calls on cities to actively strengthen, restore, create, and mimic natural ecosystems for a more sustainable balance. Closely related, 'regenerative cities' are cities that build a restorative, net-positive relationship with nature that improves and heals local ecosystems and communities.

Following the same logic as sponge cities, Carbon Sink Cities are highly effective at absorbing carbon through a ubiquitous presence of carbon sinks in the very fabric of the city. As with nature-positive, Carbon Sink Cities actively strengthen, restore, create, and mimic natural ecosystems to realize a sustainable carbon balance. Finally, like regenerative cities, Carbon Sink Cities operate as **foundational nodes in a global carbon removal architecture** that can ultimately help address global temperature overshoot and restore the climate.

Carbon Sink Ubiquity

At a global scale, carbon sinks are ubiquitous. They exist across the planet in large-scale natural reservoirs such as the ocean, forests, and soil, as well as in smaller artificial systems that absorb carbon. This ubiquity is vitally important for the global carbon cycle and enables the Earth to regulate atmospheric CO_2 concentrations. While the capacity of these larger natural sinks is finite and their integrity threatened by human activity and climate change, the development of artificial carbon sinks is a promising emerging complement to protecting and strengthening the existing natural carbon sinks.

Making carbon sinks ubiquitous across the urban environment means embedding CDR physically in existing urban systems and infrastructure, and associated policies, regulations, and governance structures created to manage them. This includes wastewater processing facilities, solid municipal waste and construction and demolition waste management systems, urban green corridors and coastal protection infrastructure. As with other mitigation strategies, the integration of CDR methods into urban systems and infrastructure can leverage synergies with existing climate and environmental priorities, primarily those targeting energy decarbonization, waste recycling, enhancing the quality of air, water, and land, or urban heat island mitigation and disaster risk management infrastructure. Carbon Sink Cities maximize the impact of carbon removal interventions across the urban environment.

4. INDIGENOUS PATHWAYS TO CARBON SINKS

The reimagined concept of Carbon Sink Cities is rooted in ancient ideas on the inseparable relationship between human settlements and the natural environment. Indigenous Peoples manage over a quarter of the world's lands which is critical for stabilizing the climate and maintaining ecosystem services for a healthy planet and community.

Core to Indigenous stewardship is the interconnectedness and mutual interdependence of nature and culture. Indigenous landscapes and seascapes are the manifestation of that interconnectedness underpinned by Indigenous practices, knowledge systems, values, and worldviews. They are biocultural landscapes that represent systems of biological and cultural diversity which are mutually shaped by human cultures, ancestral management of resources and ecosystems, and the natural environment.

Indigenous Peoples contribute to the long-term impact and sustainability of cities in line with climate and nature goals, even when the historical context of the land is not recognized. In fact, the majority of their lands are not legally recognized and neither are the knowledge systems and practices. Explicit recognition can further strengthen their contribution.

Biocultural Landscapes and Indigenous Knowledge for Sustainability and Resilience

The biocultural landscapes framework allows Carbon Sink Cities to mimic multi-functional cultural landscapes that are living systems shaped by Indigenous Peoples' relationship to nature. The concept of designated spaces— for cultural, spiritual, and environmental purposes— such as the sacred forests and waterways, and community conserved areas, can be embedded into contemporary urban planning and designed to foster ecologically balanced, biodiversity-rich, sustainable human settlement. Indigenous world views and knowledge systems play a pivotal role in shaping biocultural landscapes and offer vital contributions to the sustainability and resilience of the Carbon Sink Cities. For instance, Indigenous worldviews, like the **7 Generations Principles**[1], **Kaitiakitanga**[2], or **Sumak Kawsay**[3], provide valuable lessons on forward-looking, long-term, nature-culture-centered planning and stewardship over short term economic growth. Such worldviews can expand the ways people view, engage with, and value their relationship with urban landscapes.

Indigenous People worldwide are the holders of fundamental knowledge on how to design and build communities in symbiosis with nature. Their practices, often millennia-old, are the essential gateway to reimagine how we design contemporary urban clusters, and reinterpret traditions through the lenses of the climate crisis and modern technology. For instance, Indigenous architecture, such as homes, cultural monuments and community structures, and associated crafts, skills and practices, such as the use of locally available grass or culturally important tree species, continues today. By r**ecognizing and embedding nature-positive Indigenous practices and knowledge systems** in urban design, particularly those related to the use and management of plants and bio-based materials, Carbon Sink Cities can support inclusive development with amplified benefits and reduced risks of climate crisis to everyone. This requires the creation of dedicated mechanisms in the international governance of CDR for the inclusion of Indigenous voices.

For cities with an historic presence of Indigenous Peoples, the recognition and integration of Indigenous communities, experts and leadership in local climate action planning can be a form of **social restoration** that makes the Carbon Sink City resilient over time. Cities may establish co-governance arrangements, ecosystem stewardship partnerships and funding for Indigenous-led projects that protect, restore, and manage nature sustainably for traditional practices to inform planning, monitoring and long-term care.

While there is not a single set of 'Indigenous solutions' that can be adopted, they find commonality in serving as holistic approaches that promote sustainability, community wellbeing, reciprocity, and respect for all life forms as integral to a dignified and fulfilling existence. They emphasize the interconnectedness of all things, with any interventions requiring both scientific knowledge and cultural understanding. In their totality, they represent ethical approaches to resource use and public life that prioritize the future over individual or present-day gains.

5. A MULTI-STAKEHOLDER ACTION PLAN

This vision on the future of our cities is not prescriptive. There can be no single solution, as each city has a unique vantage point that is rooted in local present and historical contexts. Instead, it requires a palette of adaptive strategies that is responsive to the local context - whether in rapidly urbanizing tropical regions, arid desert environments or heritage cities already under climate stress.

Each setting presents distinct opportunities to weave carbon removal into the metabolism of urban systems, while also honoring the social, cultural and ecological needs of its communities. Having a set of universal principles can help.

At its core, this vision sees the role of the city radically transformed. It is no longer the primary driver of emissions, but an active agent of restoration; a living, breathing carbon sink that safeguards the climate, and offers healthier, more resilient and more inclusive spaces for its citizens while positively impacting communities further afield. This transition - **from cities as extractive engines to cities as regenerative ecosystems** - represents a scientific and a technical imperative, as well as a profound design opportunity. It calls for new ways of measuring value and internalizing externalities, new forms of collaboration and new frameworks for planning and governance. Most of all, it challenges us to see cities not as passive backdrops to human activity, but as active participants in the restoration of our planet's balance.

Call to Action

The vision is bold but achievable. Realizing this vision requires more than technological innovation; it demands local orchestration, collective leadership, bold investment and a willingness to embrace new models of value, governance and collaboration:

- We call on **national leaders** to recognize the vital role of cities in the restoration of our climate, empower city leaders with the necessary resources, and recognize the roles and contributions of Indigenous Peoples to realize resilient cities and build a net zero future;
- We call on **city operations** to show leadership for local business to follow by embedding carbon removal into urban planning, policy and regulation, supporting investments directly and indirectly, connecting to Indigenous knowledge systems and practices, and ensuring that the next generation of growth is regenerative by design;
- We call on **investors and financial institutions** to pioneer funding pathways that prioritizse carbon-positive infrastructure and reward cities for ecological, as well as economic performance; and
- We call on **designers, engineers and communities** to work in solidarity to develop solutions that are inclusive, adaptable and rooted in cutting-edge science, Indigenous knowledge systems, and time-tested practices.

As we identify the pathways to realize this vision, leaning into Indigenous knowledge is not only inspirational but practical. Local traditions of vernacular dwelling may provide the most applicable principles to reimagine what the next evolution of the city might be in different locations. Implemented through the integration of multiple stakeholder efforts to achieve shared climate ambitions and maximizing net zero benefits to everyone.

Transparency is a vitally important component in this journey. The transition to Carbon Sink Cities must be measurable: cities should set clear separate targets for carbon removal as a complement to deep emissions reduction and track progress with transparent monitoring, reporting and verification systems. This systematic way to track and confirm GHG emissions, reductions, and removals enables the recognition of cities' contributions to international climate commitments such as the Paris Agreement and the Sustainable Development Goals.

6. SIX GROUNDING PRINCIPLES

When guided by these principles, Carbon Sink Cities can become positive feedback loops: urban ecosystems that regenerate their environment, create resilience in the face of a rapidly changing climate, and bring lasting value and prosperity to people worldwide. The opportunity is urgent, the ambition is radical, and the tools are within reach. Now is the moment to act—together—to transform our cities from sources of risk into agents of restoration.

Integrity	Grounding ambition in measurable outcomes, transparency and accountability, connected to international reporting frameworks
Solidarity	Collective responsibility and collaboration across disciplines, sectors and cultures, and within urban planning and design
Inclusivity	Ensuring locally rooted approaches in which all communities benefit from and engage in the transformation
Systemic thinking	Embedding carbon removal into every layer of urban metabolism, while maximizing the impact of interventions across the urban environment
Ubiquity	Making carbon sinks an everyday feature of cities, integrated seamlessly into urban systems, infrastructure and public life
Stewardship	Caring for the environment as an intergenerational responsibility, drawing on both Indigenous knowledge and scientific innovation

[1] The **7 Generations Principle** is an Indigenous philosophy, originating with the Haudenosaunee (Iroquois) Confederacy. It dictates that decisions must consider the long-term well-being and impact on the next seven generations, thereby fostering intergenerational responsibility and solidarity.

[2] **Kaitiakitanga** is a Māori term for guardianship and stewardship, encompassing a deep relationship between people and the natural environment. It involves protecting and preserving the land, sea, and resources for future generations, and is both a spiritual and physical practice.

[3] **Sumak Kawsay** is an Indigenous principle from the Andean and Amazonian regions of South America, meaning “good life” or “plentiful life” in the Kichwa language. It emphasizes collective well-being through living in harmony and balance with nature, rather than a focus on economic growth.

[4] Scholars such as Alan Organschi, (“the Carbon positive city, 2019) have made this argument as well as, “Cities100: Stockholm - World’s First Urban Carbon Sink with Biochar, (2015),” and Cities as carbon sinks-classification of wooden buildings (Ali Amiri et al 2020 Environ. Res. Lett. 15 094076), Reconstructing the Future, Cities as Carbon Sinks (Bauhaus Earth / Hans Joachim Schellnhuber / Rocío Armillas Tiseyra (eds. 2023) and African timber cities: carbon sinks with development benefits? (Mokena Makeka, Mudit Sharma, 2022).