Growing to Its Potential

The Value of Urban Nature for Communities, Investors, and the Climate

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Authors

Authors
Zach Clayton
Michael Donatti
Jacob Korn
Emma Loewen
Julia Meisel
Rushad Nanavatty
Lindsay Rasmussen
Mia Reback

Authors are listed alphabetically. All authors are from RMI unless otherwise noted.

Contacts
Rushad Nanavatty, rnanavatty@rmi.org
Julia Meisel, jmeisel@rmi.org

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Contributor
Yuchen Wu, RMI

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Brett KenCairn, City of Boulder
Angela Tovar, City of Chicago
Oliver Kroner, City of Cincinnati
Felipe Maia Ehmke and Gisele Rosario Medeiros, City of Curitiba
Johana Clark, Paula Paciorek, Laura Patiño, and Priya Zachariah, City of Houston
Julie Donna and Sumedha Rao, City of Louisville, Office of Advanced Planning and Sustainability
Jessica Brooks, Emily Hill, Edward Lennon, and Rajesh Rajan, City of Philadelphia, Philadelphia Water Department
Mark Hartman, City of Phoenix
Sarah Yeager, City of Pittsburgh
Laila Atalla, City of Sacramento
Yael Kisel, City of San Jose
Mazdak Arabi, Colorado State University Department of Civil and Environmental Engineering
Kurt Shickman, Adrienne Arsht-Rockefeller Foundation Resilience Center
Ucha Abbah and Frances Acuña, Go! Austin/Vamos! Austin
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Torin Dunnavant and Jessica Sanders, Sacramento Tree Foundation
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Mariela Alfonzo, State of Place
Taj Schottland and Brendan Shane, Trust for Public Land
Clément Charnaillat, Irene Fagotto, and Ben Hickman, United Nations Environment Programme
Alexis Ellis, Eric Greenfield, and David Nowak, United States Forest Service
Paul Osmond and Mat Santamouris, University of New South Wales
Rahul Goel, University of Cambridge, School of Clinical Medicine
Kevin Lanza, University of Texas, Health Science Center
Helen Toxopoeus, University of Utrecht
Tedward Erker, University of Wisconsin, Department of Statistics
August Williams-Eynon, Urban Land Institute
Jackie Cole, Veritable Good
Aaron Davitt, Henry Richardson, and Lekha Sridhar, WattTime
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*The affiliations listed are at time of contribution to this report. The organizations of the above contributors may have changed since publication.

About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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Executive Summary

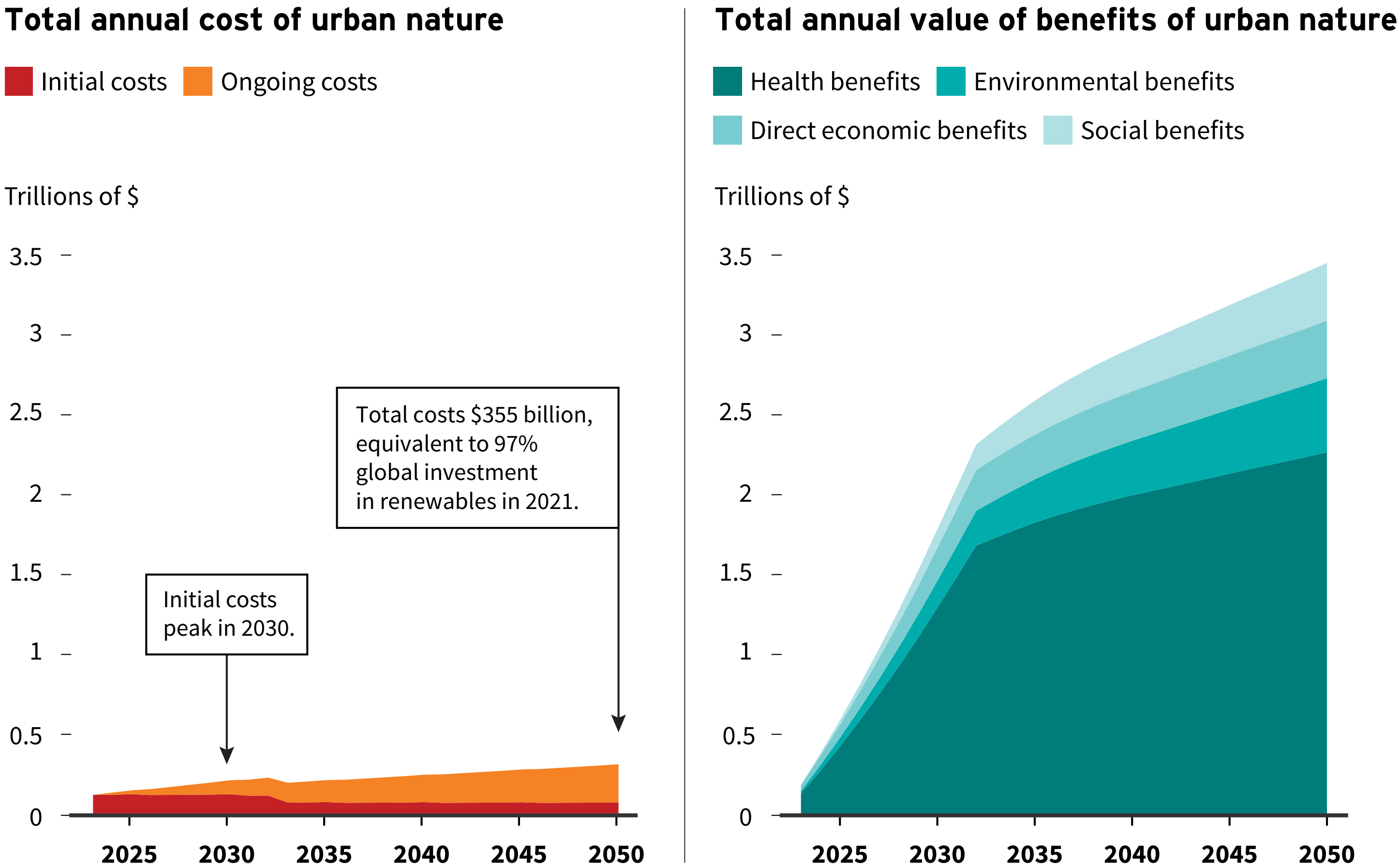
Momentum is growing to address the urgent challenges of climate change, ecosystem degradation, and rapid urbanization. With cities expected to house 68% of the world's population by 2050, warming twice as fast as the global average, and disproportionately affected by storms, droughts, and coastal flooding, we need to use every tool at our disposal to ensure a low-carbon, livable, resilient, and equitable urban future. One frequently overlooked tool with great potential is urban nature — cities' forests, parks, street trees, green stormwater infrastructure, and bodies of water. The benefits urban nature provides include jobs, higher property values, improved physical and mental health, pollution mitigation, heat mitigation, lower energy bills, safer streets, flood protection, biodiversity, and community connectedness. Strategic and systematic investment in urban nature can unleash these benefits to help cities meet climate, quality-of-life, resilience, and equity goals.

But the economic value of these benefits is not always well quantified, and potential funders struggle to build a business case for investments in urban nature. Local governments have to bear most of the costs of providing and maintaining these resources, while property owners, businesses, insurers, and the general public enjoy the benefits.

It doesn't have to be this way. Urban nature is not merely a cost to bear but an enormous investment opportunity. Its many benefits have substantial economic value that outweighs its cost at the city scale, globally, and over time — but we will only realize those benefits with investment. Our analysis found the following:

- Spending **$7 trillion** on urban nature globally could create **$59 trillion** in net benefits between 2023 and 2050 — a benefit-cost ratio of **nine-to-one** (Exhibit ES 1).
- By 2050, annual net benefits could be **$3.1 trillion** per year.
- Annual investment in urban nature needs to increase on average to **$98 billion**, or three times current levels, to achieve these results. (For comparison, this is around how much the European Union spent on renewable energy subsidies in 2019.[1])

Exhibit ES 1 **The global investment opportunity for urban nature: benefits are nine times greater than costs**



Source: RMI

Our analysis of the global costs and benefits of urban nature focused on seven common forms: green roofs, coastal wetlands, other bodies of water (including those outside cities that supply water to cities), mangroves, street trees, urban forests, and grassy parks and other open green spaces.

Urban nature provides tangible energy, carbon, and cost savings that also make the case for increased investment at the city scale. However, there is little quantified data on these savings, making it hard for cities to know how to best integrate urban nature into their climate mitigation toolbox or in which city projects to invest their limited resources. This information is especially important because targeting urban nature to benefit low-income and historically disadvantaged communities can be a powerful tool to reduce inequity and provide household energy and transportation cost savings where they are needed most.

To help fill this gap, this report shares novel quantified estimates of urban nature's energy, carbon, and cost savings potential for buildings, stormwater management, and transportation in six cities around the world: Abidjan, Côte d'Ivoire; Ahmedabad, India; Austin, Texas, USA; Curitiba, Brazil; Houston, Texas, USA; and Sacramento, California, USA (Exhibit ES 2). In most cases, the financial savings generated by urban nature — including reduced energy consumption, avoided power generation buildout, lower initial infrastructure costs, and avoided transportation fuel or power expenditures — outweighed its costs.

Exhibit ES 2 Modeled energy, carbon, and cost savings from urban nature in six cities

Abidjan and Sacramento

	Abidjan	Sacramento
Avoided energy consumption and spend in 2050	35–36 GWh (0.2%–0.5%), saving $13 million annually	30–41 GWh (0.2%–0.3%), saving $17 million–$22 million annually
Avoided peak demand and investment by 2050	25–74 MW (0.5%-2.5%), saving $51 million–$63 million investment	56–111 MW (1.2%–3.2%), saving $78 million–$155 million investment
Avoided cumulative emissions through 2050	534,000–541,000 mt CO_2e (0.9%–1.5%)	32,000–41,000 mt CO_2e (0.2%)

Percent values in parentheses reflect shares of anticipated 2050 business-as-usual totals. Avoided investment is only from avoided new power generation capacity. Avoided emissions are from power consumption, but do not include other potential avoided categories of emissions.

Source: RMI

Exhibit ES 2 Modeled energy, carbon, and cost savings from urban nature in six cities

Ahmedabad and Houston

	Ahmedabad	Houston
Improved stormwater management by 2050	Retain 1.7 million more cubic meters of runoff from a 13-cm rainfall event by maintaining 15% green cover	Retain 3–5 more cm of rainfall, reducing runoff by 7%–10% and increasing infiltration by 4%–5% increase compared to grey infrastructure
Avoided embodied carbon emissions through 2050 compared to grey infrastructure	21,000–46,000 mt CO_2e (40%–87%)	116,000–199,000 mt CO_2e (13%–22%)
Construction and maintenance cost savings through 2050 compared to grey infrastructure	$173 million–$323 million (50%–92%)	$2.6 billion–$12 billion (10%–44%)

Source: RMI

Exhibit ES 2 Modeled energy, carbon, and cost savings from urban nature in six cities

Austin and Curitiba

	Austin	Curitiba
Annual vehicle kilometers traveled reduction by 2050	43 million km (0.4%)	16 million km (0.2%)
Individual household transportation cost savings	$2,500–$4,250 (21%–35%)	$700 (7%)
Citywide health cost savings through 2050	$1.5 billion	$1.1 billion

Percent values in parentheses reflect shares of current-day baselines. Results for Austin reflect modeling trees along streets and in the areas around transit stops; results for Curitiba reflect street trees only.

Source: RMI

These are the main findings from our analysis:

- **Buildings —** Building-adjacent trees, overall city tree canopy, and green roofs reduced building energy use and peak demand associated with mechanical cooling. Within a city, adding nature was able to reduce buildings' power consumption by over **1%** and overall peak demand by **1%–3%**. These reductions translated into savings of about 12% of typical household energy costs.

- **Stormwater management —** Distributed green stormwater features like rain gardens, grassy parks, infiltration trenches, and natural lakes reduced embodied carbon by decreasing the need for new conventional "grey" infrastructure, like large concrete basins and tanks. Preserving and enhancing natural assets to act as green stormwater features made it possible to avoid up to **87%** of the embodied carbon of grey infrastructure. Converting existing impervious (nonpermeable) developed area to natural features was able to reduce embodied carbon by over **20%**.

- **Transportation —** As an element of street design, street trees can encourage more public transit use as well as walking, cycling, and other active forms of transportation in lieu of private car use. Street trees could reduce a city's annual vehicle kilometers traveled by **0.2%–0.4%**, the equivalent of taking 4,200 cars off the road in 2050 in a city like Austin. Individual households could save up to 35% on annual transportation costs, and the city could see up to $1.5 billion in health benefits.

Even though the benefits of urban nature are clear, the investment urgently needed to unlock its full potential is missing. Public finance has a foundational role in supporting urban nature, and governments and development finance institutions need to scale up this support. But governments should not have to bear all the costs. Private actors (impact investors, real estate developers, insurers, and the healthcare industry), as beneficiaries of urban nature, need to partner with cities to develop new funding and financing models. Promising opportunities include advance market commitments, multi-benefit credits, and action by insurers.

Urban nature offers a value proposition that the world can't afford to pass up. Among its many benefits, nature is an essential tool for decarbonizing cities — and doing so more equitably. Local governments should plan and budget for urban nature in accordance with this value, but they should not have to bear the concentrated costs of a solution with such diffuse benefits. We call on the whole of the international financing community to partner with governments and civil society to create and scale the financing solutions we need to unlock urban nature's full benefits.

Urban Nature: A Growing Solution for Climate and Society

Momentum is growing to address the urgent — even existential — challenges of climate change, ecosystem degradation, and rapid urbanization. Cities are expected to house 68% of the world's population by 2050, are warming twice as fast as the global average, and are disproportionately affected by storms, droughts, and coastal flooding.[2] We need to use every tool at our disposal to ensure a low-carbon, livable, resilient, and equitable urban future. Why then, at a moment when every effort counts, is urban nature — features such as forests, parks, street trees, green stormwater infrastructure, and bodies of water — often overlooked or underappreciated?

Urban nature provides a vast array of benefits — jobs, improved physical and mental health, pollution mitigation, heat mitigation, lower energy bills, safer streets, flood protection, and more. Strategic and systematic investment in urban nature, especially in low-income and historically disadvantaged communities, can unleash these benefits to help cities meet climate, quality-of-life, resilience, and equity goals.

Barriers to Expanding Urban Nature

Despite these benefits, local governments and private actors fall short when investing in and deploying urban nature, often facing both financial and informational challenges.

Funding Gaps

Funding for nature-based solutions globally is overwhelmingly from public sources, and local governments usually bear most of the costs while property owners, businesses, insurers, and the general public enjoy the benefits.[3]

It doesn't have to be this way. Urban nature is not merely a cost to bear but an enormous investment opportunity. Its many benefits have economic value that substantially outweighs costs at the city scale, globally, and over time. Spending $7 trillion on urban nature could create $59 trillion in net benefits globally between 2023 and 2050 — a benefit-cost ratio of nine-to-one. But we are currently massively underinvesting in urban nature; we need to triple annual spending to unlock those full benefits.

Information Gaps

A key barrier to action is lack of information. There are gaps in the literature on the benefits and costs of natural features in cities, including less study of cities in low-income and lower-middle-income countries and of the range of energy and carbon savings benefits. Experts and technical assistance providers need a robust body of quantified data to provide guidance for policymakers, solutions providers, and the public. The full economic value of these benefits isn't always well quantified either, and potential funders struggle to build a business case for investments in urban nature. Robust quantification of all benefits and costs is necessary to comprehensively monetize externalities and public goods.

Another quantification gap is in how nature can help cities reduce energy use and carbon emissions. Our modeling in six cities affirms urban nature's climate change mitigation potential, estimating the potential to lower building energy demand and defer power infrastructure buildout, avoid high-carbon conventional "grey" stormwater infrastructure, and reduce private car use and vehicle kilometers traveled (VKT), facilitating walking, biking, or public transit use instead. These outcomes also lower household energy and transportation costs and provide substantial health benefits. Targeting urban nature investments so benefits accrue to low-income and historically disadvantaged communities can have a powerful equity effect as well, helping reverse decades of underinvestment in these neighborhoods.

This report aims to fill a key gap in the literature by quantifying the energy, carbon, and cost savings from urban nature in different types of cities. We intend for our results to be indicative and informative for policymakers and potential investors. However granular data for many geographies is limited, so our models are not universally applicable or accurate.

Summary of Analyses

We conducted analyses in two areas to derive the results and insights presented in this report: a global analysis of the investment size, costs, and benefits of urban nature, and separately, six city-level analyses to demonstrate the energy and carbon savings from increasing urban nature. For both, costs were divided into two categories — initial (establishment) and ongoing (operations and maintenance). The results are presented here for the years 2023 to 2050.

The first analysis of the global investment potential of urban nature, presented in chapter 4, looks at the potential to protect, restore, and enhance seven types of urban nature commonly found in cities. These are green roofs, coastal wetlands, other bodies of water (including those outside cities that supply water to cities), mangroves, street trees, urban forests, and grassy parks and open green spaces. For a holistic picture of how urban nature benefits city residents, four broad categories of benefits were included: direct economic (e.g., job creation and direct cost savings), environmental (e.g., reduction in greenhouse gas emissions and improved stormwater management), health (e.g., increased opportunities for physical exercise and reduced healthcare spending), and social (e.g., opportunities for recreation and cultural expression).

The second set of analyses (presented in chapters 5–8) focuses at the individual city scale and estimates the climate mitigation benefits and economic benefits and costs of increasing the amount of nature in a city. We modeled three areas in two cities each: the effects of trees and green roofs on building energy use, of rain gardens and lakes on embodied carbon for stormwater management, and of street trees on transportation and vehicle kilometers traveled. Each city represents a set of characteristics that can provide a point of comparison for other cities.

To establish scenarios and methodologies for both analyses, we consulted relevant existing tools where available, conducted a wide literature review, and engaged heavily with experts and local and regional stakeholders.

A separate **methodology** document that accompanies this report provides details about our methods, assumptions, and data sources for anyone looking to build off our work or perform a similar analysis for their own city.

The Case for Action

This report provides local governments and the international finance community with a detailed account of urban nature's many benefits, quantifies its value, and presents our analysis of its energy-saving and carbon-reduction potential. This is a call to action for governments to scale up their funding and policy support for urban nature and for the finance community to work with insurers, real estate developers, property owners, utilities, and governments to develop and scale up innovative financial solutions to support the deployment of urban nature at scale.

Understanding Urban Nature

Most people have positive feelings about nature, but to city-dwellers, nature can feel like something distinct, "out there," not part of the urban fabric. When we view nature as separate from us, we become detached from the responsibility we have for it — a tendency that has helped lead us to our current climate and biodiversity crises.

Historically, many of the world's greatest cities have incorporated nature, with some even being defined by it. Examples include the *chinampas* or floating gardens of Mesoamerica, the Mughal gardens constructed in South and Central Asia in the 16th to 18th centuries, the Renaissance gardens of Europe, and the public parks movement in the United States in the mid-1800s.[4]

Globally, as urban land expansion outpaces urban population growth, we need to find space for nature in cities.[5] Areas of new development and major redevelopment offer an opportunity for intentional planning of new neighborhoods, and even new cities, in which nature is an integral part of the urban landscape, able to fully offer its myriad benefits. Dense and densifying cities have more constraints, but they can still take advantage of key moments in planning and redevelopment to integrate smaller natural features into the existing urban fabric or reinvigorate existing but degraded green spaces.

Ibirapuera Park in São Paulo, Brazil, is part of the city's cultural identity. It receives over 18 million visitors per year.[6]

Exhibit 1 **Urban nature as an integral part of a sustainable city**

Urban nature helps reduce building energy use and carbon emissions by providing shading, ambient cooling, and insulation that reduce cooling and heating loads.
Rain gardens and bioswales help retain stormwater and reduce urban flooding, while also supporting biodiversity.
Parks and other open green spaces provide cooling and stormwater management, recreation, wildlife habitat, and food production opportunities.
Green corridors reduce heat and encourage walking, cycling, and public transit use. They also support biodiversity and urban wildlife.
Urban nature supports more public transit use, walking, and cycling instead of private car use by enhancing thermal comfort on sidewalks and in bike lanes.

How we are defining urban nature in this report

This report uses the term *urban nature* to refer to vegetated spaces and natural water bodies in cities, publicly and privately owned, ranging in size from a single street tree to an urban forest or coastal wetland. The focus of this definition is purposely limited to vegetation and blue spaces, and we do not examine other critical elements of healthy ecosystems, such as animal and fungal life, that both support and are supported by these vegetated spaces and that occupy other niches in the urban fabric.

There are many terms for natural areas and features that exist within cities — including nature-based solutions, nature-based infrastructure, green infrastructure, and natural climate solutions. In this report, *urban nature* is intended to encompass these concepts.

This chapter and the next describe urban nature and the range of benefits it provides; show how investment in urban nature can reduce inequity by ensuring that benefits accrue to low-income, vulnerable, and historically disadvantaged communities; and lay out the challenges facing cities that seek to deploy urban nature at scale.

Nature takes many forms throughout cities. These include trees, in either small or large groups; linear green spaces and open green spaces; blue spaces (natural and constructed bodies of water); and building features. Water features provide evaporative cooling, thermal storage, and freshwater supply. Trees and other plants reduce runoff, increase water infiltration into soil, support groundwater resources, reduce soil erosion, and provide cooling through both shade and evapotranspiration (especially through trees).[i]

Large features like urban forests, rivers, and lakes can affect significant portions of a city, while smaller features like parks and ponds have neighborhood-scale impacts. Individual trees next to buildings, street trees, and green roofs mostly affect individual buildings, although together they can have street-level and neighborhood-level effects.

Nature outside a city can also affect conditions within it. For example, healthy watersheds upstream from cities protect the quality of the cities' water supply.[7] Urban environments also have impacts beyond their borders, and improvements within the city limits can provide benefits to surrounding areas such as pollution mitigation and water management.

This report focuses on nature within a city, while recognizing that peri-urban areas are also relevant and that coordination across jurisdictions (e.g., through a metropolitan planning organization, council of governments, or city–county coordination body) can be a beneficial way to plan and manage nature inside and outside the city. Exhibit 1 summarizes key types of urban nature, and the text that follows discusses several of these categories in more detail.

i Evapotranspiration is the process by which plants take in water from the soil and then release it as water vapor into the atmosphere.

Urban Trees

Trees are one of the most visible forms of urban nature, showing up individually on streets and adjacent to buildings, in small groups in parks, and in large numbers in urban forests. Trees provide substantially more cooling via shading, evapotranspiration, and water absorption than other types of vegetation (e.g., shrubs and grasses).[8] In arid environments, native plants provide less evapotranspirative cooling because they are xerophytic, or adapted to survive with little water.[9] Such trees still provide direct shading. Configurations of urban trees include the following:

- **Street trees:** Planting trees along a street keeps pedestrians, cyclists, and outdoor workers (e.g., street vendors) cooler and safer. They can also shade nearby buildings and help manage stormwater. Most street trees are in public rights-of-way, but trees on private property can serve the same purpose if they shade sidewalks.

- **Wooded parks, urban forests, and food forests:** Small groups of trees can be valuable additions throughout cities, for example in pocket parks (small neighborhood parks, sometimes converted from vacant lots) and on private property.[10] Larger groups of trees may be part of a larger park or form an urban or peri-urban forest. These may be remnants of forests that shrank with urbanization, or new, intentionally planted features, like Miyawaki forests (small, dense, multi-species plots) or food forests (trees planted to provide food for nearby residents). Both small groups of trees and urban forests can contribute to significant cooling beyond their boundaries in large areas downwind.[11]

- **Mangroves:** Acting as protective coastal barriers, mangroves can play a crucial role in preventing erosion and mitigating the impacts of storms and floods.[12] They also serve as powerful carbon sinks, sequestering up to four times as much carbon as tropical rainforests, and provide breeding grounds for a wide range of marine species, helping to sustain many local economies.[13]

Street trees in New York City. In 2016, New York City completed the MillionTreesNYC initiative to plant 1 million trees and increase the city’s overall tree canopy to over 20%. The project has led to $27 million per year in energy savings as well as the removal of 2,200 tons of air pollution and 42,000 tons of carbon each year.[14]

Linear Green Spaces

On-road green corridors and off-road greenways are, respectively, longer stretches of roads and off-street paths with street trees and often other vegetation and shading structures. Green corridors reduce heat along key routes and may incentivize walking, cycling, and micro-mobility (such as use of scooters or skateboards) by providing individuals with a shaded space to exercise or commute that is protected from larger vehicle traffic. Linear green spaces can serve as urban wildlife corridors that reduce habitat fragmentation and enhance biodiversity. They also reduce flooding and polluted water discharges.[17]

A green corridor in Medellín, Colombia, before (top) and after (bottom) the project. Medellín is combating rising heat due to urbanization with a 20-kilometer connected network of green corridors. The project provides residents with shady routes for active transportation and recreation, helps sequester carbon dioxide (CO_2), and improves air quality and biodiversity.[15] The project is estimated to have reduced the urban heat in Medellín by 2°C (3.6°F) since 2018.[16]
Source: Photo courtesy of EstudioCentral, Bajkdanyna Estrada

Open Green Spaces

Open green spaces, where trees are not the primary feature but may be present, include parks, grasslands, gardens of varying sizes, and urban agriculture. As spaces with fewer impervious surfaces,[ii] these permeable areas provide stormwater management as well as cooling and opportunities for recreation and food production.[18]

Bishan-Ang Mo Kio Park in Singapore. In 2012, Singapore completed a major project in Bishan-Ang Mo Kio Park, its biggest park (62 hectares or 153 acres), to naturalize a concrete storm drain with vegetated banks. The floodplain plays an important role in the Singapore National Water Agency's flood risk mitigation strategy and has led to savings of $57 million in capitalized expenditures and other benefits like improved air quality, sequestration of greenhouse gas emissions, and increased recreation.[19]

ii Impervious surfaces like roads, parking lots, and roofs prevent water from infiltrating into the ground. Stormwater runoff increases as impervious cover increases.

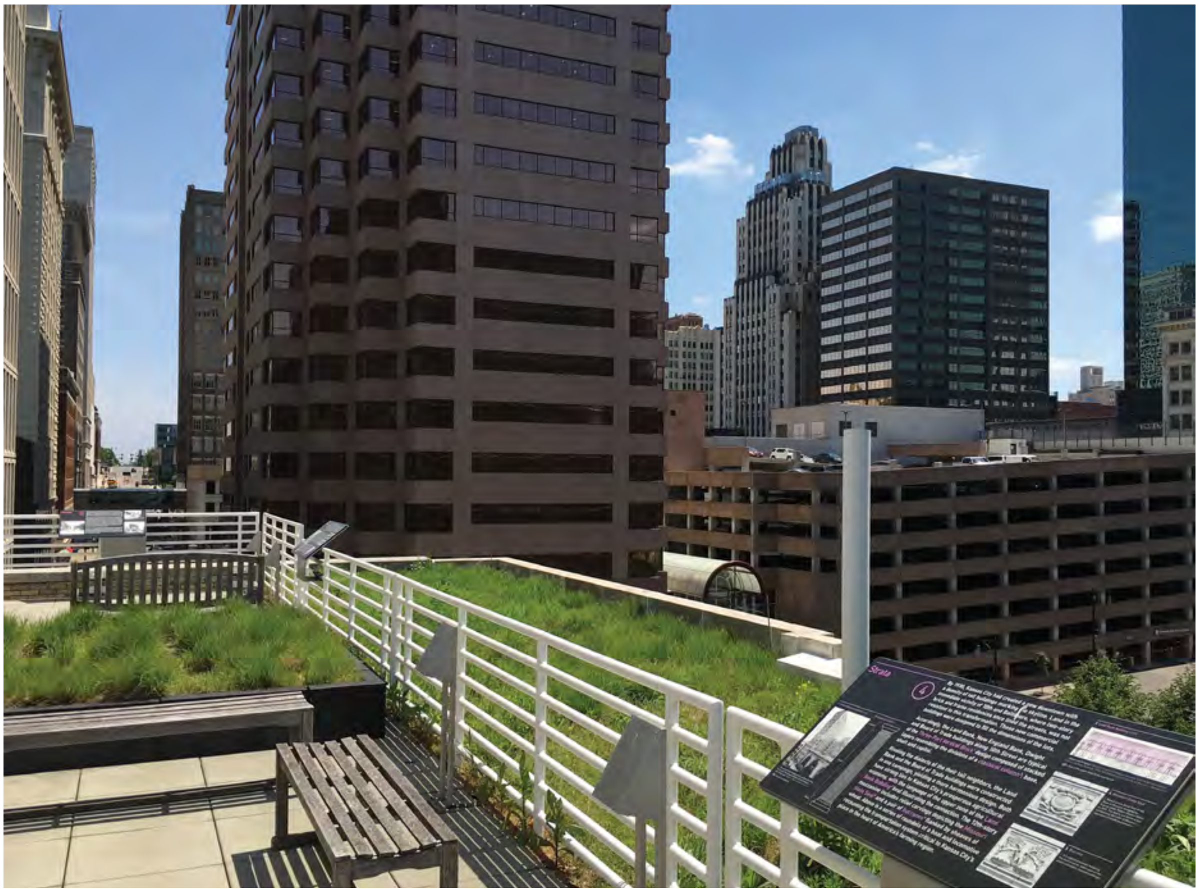
Blue Spaces

Water is a critical part of nature in cities, providing many of the same biodiversity, recreation, carbon sequestration, and cooling benefits as vegetation. Blue spaces, whether natural or constructed, may include lakes or ponds, rivers, streams, canals, reservoirs, coastlines, and wetlands, including salt marshes.[20] Blue spaces play an important role in helping cities adapt to a range of threats from climate change.

Wetlands in Colombo, Sri Lanka. Colombo is highly vulnerable to flooding but has heavily invested in upgrading its surrounding wetlands network by combining green and grey infrastructure to mitigate the impacts of future flooding events. The investments have boosted the wetlands' retention capacity, providing up to 232,000 residents with greater flood protection, and increased the wetlands' recreation potential.[21] Source: Martin Seemungal/ The International Water Management Institute, Colombo wetlands, July 27, 2018, online image, Flickr, **https://flic.kr/p/2mDgJau**

Green Building Features

Building features such as green roofs and green walls or facades provide benefits to building occupants and the external environment. Green roofs consist of a layer of vegetation — ranging from small plants like sedum to lawns, shrubs, and trees — on a roof. Green walls are vertical configurations of vegetation that may be freestanding, be attached to building walls, or constitute the wall itself. They may form interior or exterior walls. Green roofs and exterior green walls can provide substantial building insulation, and they cool the area immediately around the building as well. However, these features can be expensive to install and maintain and need to adhere to building structural requirements.[22]



Green roof in Kansas City, Missouri, USA. Kansas City installed 42,000 square meters (over 450,000 square feet) of green roofs between 1999 and 2015 to improve the city's air and water quality. The roofs save an estimated $41,000 in energy costs annually and are estimated to sequester and store 1,150 tons of CO_2 per year.[23] This photo looks southeast from the Kansas City Central Public Library's green roof. Source: Photo reproduced by permission from the Kansas City Public Library, "'What Surrounds Us': Central Library Rooftop Offers Self-Guided Tour of KC Skyline, Past and Present", July 13, 2017, **https://kclibrary.org/blog/what-surrounds-us'-central-library-rooftop-offers-self-guided-tour-kc-skyline-past-and-present**

Not just planting trees: the importance of carefully designed and locally appropriate interventions

Urban nature does not provide one-size-fits-all benefits, and poorly designed or maintained features can have negative unintended consequences. Non-native, non-locally adapted species can crowd out local species, reduce biodiversity, or consume too much water.[26] In hot and humid climates, the added humidity from vegetation or heavy irrigation can increase discomfort. Planting trees that block cooling breezes from reaching a naturally ventilated building can worsen indoor heat and humidity. In contrast, design elements like terraces and green walls can add evaporative cooling that well-designed ventilation can capture. Urban nature projects need to incorporate native, locally adapted species and be planned in concert with urban and building design to maximize their benefits.

Mixed Blue-Green Features

Green and blue features often appear together. Mixed features include mangrove forests, sand dune ecosystems, reefs, and stormwater management features like bioswales and rain gardens.[24]

Mangroves in Lakshmipur, Bangladesh. Bangladesh is experiencing the impacts of sea level rise and increasingly powerful cyclones. To mitigate these climate change impacts, Lakshmipur embarked on a major effort to restore mangroves, increasing coverage from 138 hectares (343 acres) in 2012 to 900 hectares (2,224 acres) in 2022, which will help limit the storm surge from major rainfall events.[25] Source: Wikimedia

Benefits of Urban Nature

Urban nature can and does provide enormous benefits for all city residents, including improving health outcomes, fostering social cohesion, advancing equity, creating education and recreation opportunities, enhancing biodiversity, and supporting both climate change mitigation and adaptation. These benefits show up in the economy in the form of jobs, lower healthcare costs, reduced storm damage, energy savings, increased property values, and more.

Understanding the full range and magnitude of these benefits is critical to giving urban nature its due — that is, appropriately valuing and investing in it — in the urban century. Urban nature's ecosystem services in cities are worth $3.4 trillion or more annually.[27] Globally, natural climate solutions could provide 37% of the cost-effective mitigation needed by 2030 to stabilize global warming below 2°C.[28]

This chapter describes urban nature's economic, health, social, and environmental benefits, presents some illustrative examples, and shows how nature can be used to improve equity in cities. The following chapter presents a quantitative analysis of the benefits and costs of urban nature.

There is significant overlap in the categories of benefits discussed below. For example, reducing air and water pollution has substantial health benefits. Further, most benefits can reduce inequity when planned to meet the needs of disadvantaged communities. The list below can be organized differently depending on how a city wishes to prioritize benefits, and it is not intended to be exhaustive.

Direct Economic Benefits

Nearly all of urban nature's benefits provide economic value, whether they are monetized or not. Direct economic benefits include job creation, tourism revenue, increased property values, food and resource production, energy savings, and cost savings when green infrastructure is cheaper than grey infrastructure.

- **Job creation:** Investment in urban nature and land conservation could create over 59 million jobs by 2030, equivalent to 1.5% of the projected global labor force in that year.[29]
- **Infrastructure cost savings:** Nature can provide many of the same functions as grey infrastructure, including wastewater treatment, coastline protection, flood prevention and floodwater management, and water filtration. On average, green infrastructure costs half as much, generates almost 30% more value, and could save almost $250 billion annually.[iii,30]
- **Tourism revenue:** Natural features can be a significant draw for tourism. For example, Central Park in New York City attracts 42 million visitors each year, generating over $1 billion in annual economic activity and supporting 5,000 local jobs.[31]

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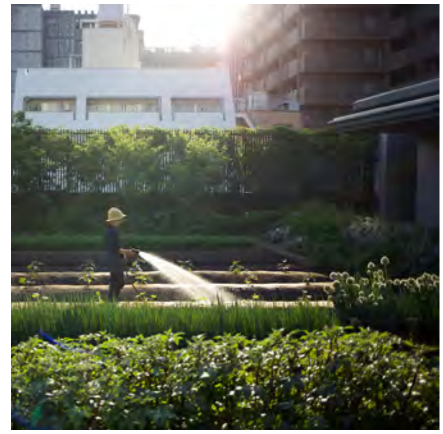
iii The International Institute for Sustainable Development found that green infrastructure could replace 11%, or $489 billion, of the estimated $4.29 trillion needed annually for infrastructure (assuming all grey infrastructure). But because of green infrastructure's cost savings, the actual cost would be only $241 billion, saving $248 billion.

- **Increased property values:** A study in the Netherlands found up to a 28% increase in house prices due to environmental factors. Prices for homes overlooking water or those overlooking open space were 6%–12% higher than those with less attractive views.[32]

More indirect economic benefits flow from urban nature's health, social, and environmental benefits. These include healthcare savings and avoided damages from flooding, wildfires, and extreme heat. The sections below describe these benefits.



Urban nature's direct economic benefits support and protect livelihoods for many urban dwellers. City workers plant new trees along a new subway line in Amsterdam, the Netherlands (left). A street vendor in Mumbai, India, works under the shade of a banyan tree (center). A gardener waters plants in an urban rooftop garden in Kyoto, Japan (right). Source: David Brossard, In the Shade of the Banyan Tree, February 22, 2014, online image, Flickr, https://www.flickr.com/photos/string_bass_dave/15107936602/ (center); Helvetica60kg, Rooftop farmer, May 10, 2014, online image, Flickr, https://flic.kr/p/nyLhdu (right)

Health Benefits

Many studies show connections between exposure to nature (including urban green spaces) and improved physical and mental health. However, few of these studies have focused on low-income countries. Key ways that urban nature can benefit residents' health are listed below.

- **Reducing extreme heat:** The cooling effect of nature mitigates urban heat islands and extreme heat, reducing heat-related illnesses and mortality. Placing natural features throughout a city provides cooling at the building scale, increasing hours-of-safety indoors, and at the block and neighborhood scales, making it safer to be outdoors for longer periods of time, which is especially important for outdoor workers.[iv,33]

- **Reducing pollution and associated health impacts:** Trees (and to a lesser extent other vegetation) remove air pollutants like carbon monoxide, ozone, nitrous dioxide, sulfur dioxide, and particulate matter. Investing in street trees in just 245 cities could reduce air pollution exposure for 180 million people, or 20% of those city's residents, saving between 11,000 and 36,000 lives annually.[34] Trees also play an important role in reducing stormwater runoff, helping to lower pollution in urban water. Using nature to block or filter pollution can be an effective way to improve health in neighborhoods with a high pollution burden.

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iv The term *hours-of-safety* refers to the amount of time conditions in a home remain safe without heating or cooling.

- **Enabling activities that improve physical health:** Green and blue spaces provide opportunities to play sports, walk, run, bicycle, skateboard, swim, kayak, and do other activities that can improve health.[35] The health benefits of traveling to natural spaces via active modes of transportation,[v] like walking and biking, are also significant. Increasing the amount of active transportation in cities to the level needed to meet the Paris Agreement — with nature serving as vital enabler — could avert over 1 million premature deaths by 2040.[36]

- **Improving mental health:** Time spent in and near nature can improve overall wellbeing, including reducing depression, anxiety, uncertainty, and stress.[37] These benefits may be a result of nature itself, or of other factors that affect mental health, like improved physical health (for the reasons described above), physical activity and recreation, and reduced noise pollution. However, only an estimated 13% of urban residents live in neighborhoods with more than 20% forest cover, the amount found to protect against depression and stress.[38]

Only 13% of urban residents live in neighborhoods with more than 20% forest cover, the amount found to protect against depression and stress.

The positive health benefits of nature greatly outweigh the risks, but there are a few risks to note. Plants produce biogenic volatile organic compounds, which contribute to ozone formation, and pollen can cause seasonal allergies. Species selection can manage both these challenges.[39] Information that is geographically, contextually, and culturally specific will help all cities plan green spaces that provide the desired health benefits.

Tree planting as part of the Green Heart program in Louisville, Kentucky, USA. Louisville suffers from poor air quality and is losing 54,000 trees annually to development and urban sprawl. The city implemented the Green Heart project, which seeks to improve local air quality as well as increase physical activity, health, and social cohesion by planting trees and other greenery in targeted communities across the city.[40] Source: ulmedicine, 2019 South Louisville Tree Planting, October 14, 2019, online image, Flickr, https://flic.kr/p/2huXpnj

v Active transportation is any form of transportation that is self-propelled, such as walking or biking.

Social Benefits

The feelings of wellbeing that nature can evoke can increase social interaction. Having access to green spaces, especially high-quality ones, can "facilitate positive social experiences," which could include social cohesion, social support, feelings of attachment to a place, belonging, and empowerment.[41]

- **Social interaction:** Nature provides places outside of work and home, or "third spaces," where individuals can come together. [42] These spaces allow people of different classes, races, and ethnicities to come together, helping to build greater social cohesion. Research has also shown that the feelings of social cohesion created by community green spaces can lead to increased resilience during disasters by creating bonds between neighbors, facilitating human interaction, and strengthening trust.[43]

- **More equitable cities:** Investing in green and blue spaces in historically underserved communities, which often lack natural areas due to the legacy of redlining and other exclusionary housing practices, can remedy inequities and ensure that nature's economic, environmental, and health benefits are available to these communities.

- **Cultural value:** Urban nature can provide residents with spaces to practice important cultural, spiritual, and religious traditions, thereby maintaining their heritage.[44] By seeking guidance from local communities, including indigenous peoples, throughout the development of a project, policymakers can ensure that investments in urban nature promote a sense of belonging and align with local residents' desired uses of the space.[45]

A member of parliament visiting a Miyawaki forest in Delhi to meet with the community organization that manages the forest. Outdoor spaces proved critical for social interaction during the COVID-19 pandemic. Source: Photo courtesy of RISE Foundation, **https://ngorisefoundation.com/2021/06/20/miyawaki-urban-forest-is-center-of-attraction/**

Climate Change Mitigation and Other Environmental Benefits

It goes without saying that natural spaces benefit environmental quality and ecological health. While many of these benefits are well known, the increasingly important role of urban nature in climate change mitigation is less understood.

Studies go back years on how much trees can reduce building energy use, but the literature is fragmented and site-specific with little synthesis of results. Guidance on green stormwater infrastructure is largely silent on energy and embodied carbon.[vi] And there has been almost no study of the impact of trees on active transportation and public transit, with recent research only starting to tease out the relationship.[46] Local governments are left either without awareness of these opportunities or without the information they need to make their case for nature as a cost-effective climate solution. We aim to fill some of these gaps in this report.

Nature's climate mitigation benefits include its ability to:

- Reduce energy use and carbon emissions in buildings.
- Reduce energy use, carbon emissions, and embodied carbon in urban water management systems.
- Reduce VKT, energy use, and emissions in transportation.
- Sequester and store carbon.

In most of these cases, the potential emissions reductions depend on how much emitting technologies are used. Keeping buildings cooler doesn't reduce energy use in buildings that don't use mechanical cooling such as air conditioning (AC), and shading sidewalks doesn't reduce driving for residents who don't drive. This is most likely to be the case in low-income communities. Even when it does not reduce the use of emissions-generating technologies, urban nature still improves safety, comfort, and quality of life.

Nature also plays an important role helping cities to:

- Increase resilience and adapt to climate change.
- Maintain and enhance biodiversity.
- Reduce air and water pollution.

Reducing Building Energy Use

Rapid adoption of mechanical cooling is a significant driver of electricity demand, especially in emerging economies. The total power capacity needed to meet the escalating demand for space cooling is expected to rise 395%, from 850 gigawatts (GW) in 2016 to 3,350 GW in 2050. This increase of 2,500 GW is equal to the current total generating capacity of the United States, Europe, and India combined.[47] Most of this growth is projected to occur after 2030 as incomes and populations grow, temperatures rise, and preferences change in developing countries.[48]

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vi Embodied carbon is the carbon emissions associated with a product's entire lifecycle: material extraction and manufacturing, transportation, construction, maintenance, and disposal or rehabilitation at end of life.

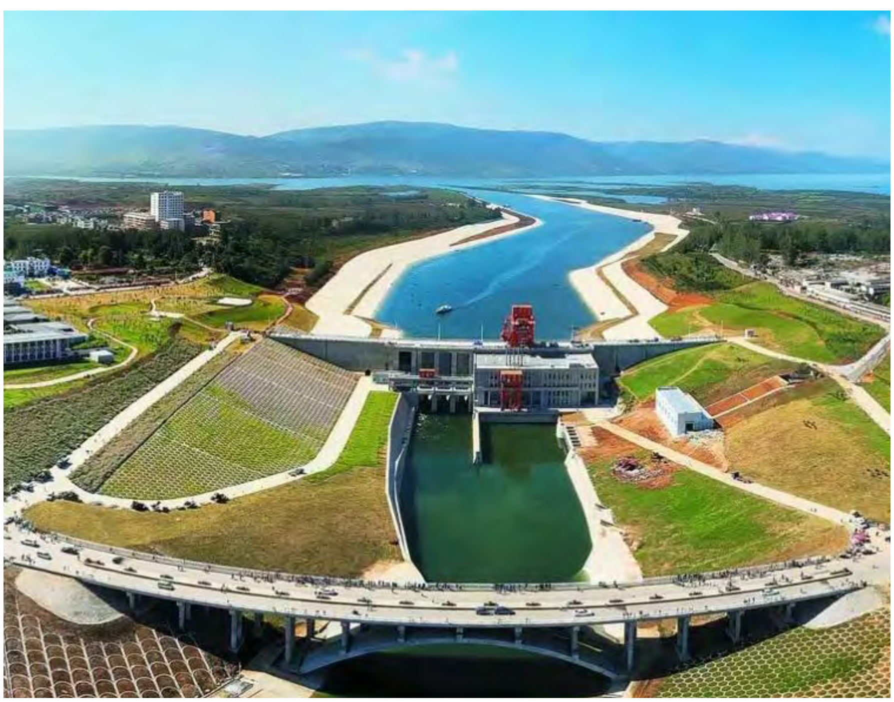
Trees, green roofs, and green walls and facades can reduce energy use in buildings by reducing the need for mechanical cooling through direct shading, ambient cooling, and insulation. Planting as many street trees as possible in 245 of the world's largest cities could reduce residential electricity use by about 0.9%–4.8% annually (9.3 billion to 48 billion kilowatt-hours [kWh]) and reduce emissions by 0.9%–4.6% (4.3 million to 22 million metric tons of CO_2 equivalent [mt CO_2e]).[49] Energy and emissions savings can be larger depending on the region and climate. For example, urban forests in the United States reduce building energy use by 7.2%, and emissions by about 43.8 mt CO_2e, annually.[50]

By reducing energy use and lowering peak demand, urban nature can reduce power sector costs and emissions in two ways — it can delay or avoid the need to build new electric grid infrastructure, and it can reduce the need for peaker plants, which come online only during peak demand and are often fueled by natural gas and petroleum.[51]

Reducing Grey Infrastructure in Water Management

Urban nature can also reduce emissions related to drinking water, stormwater, and wastewater management. Some of the biggest reductions come from green stormwater infrastructure displacing grey stormwater features — like concrete, metal, and plastic pipes, basins, and tanks — and thus avoiding the emissions associated with those materials. Our modeling shows that green infrastructure can perform as well as grey infrastructure, while reducing embodied carbon emissions by over 20% when converting existing impervious cover and by up to 87% when conserving natural assets in areas of new development.

Energy used to extract, distribute, and treat water and wastewater is projected to double between 2014 and 2040. This is largely driven by measures to address water scarcity — including desalination and large-scale and long-distance water transfer — and increased demand for wastewater treatment.[52] Urban nature can support groundwater recharge by allowing precipitation to infiltrate the ground, reducing the need for long-distance water transport and desalination and the associated operational and embodied carbon emissions.



A pumping station along the Central Route of China's South-to-North Water Project. China is currently building the world's largest water-transfer project, with the goal of moving 44.8 billion cubic meters of water across the country every year. The Eastern Route alone requires 23 pumping stations with an installed capacity of 454 MW, enough to power 1.2 million households. Source: South-North Water Transfer Project Central route starting point taocha, licensed under CC BY-SA 4.0

Green stormwater infrastructure provides a critical service by reducing stormwater runoff and flooding; tree cover in megacities was shown to provide a median annual value of $11.3 million per city (or $20,000 per km^2) in avoided stormwater processing by reducing the volume of stormwater runoff.[vii,53] Avoided stormwater processing should in turn reduce the energy required for treatment, but the literature on this topic is scant, and city officials we spoke to for our analysis didn't monitor this relationship. Given that water treatment is one of the top municipal energy consumers, attention to how to reduce treatment energy on lower volumes of water would be valuable.

Reducing Vehicle Kilometers Traveled

Urban nature is one tool in the toolbox to decarbonize urban transportation and make cities work better for people, not cars. Cooler, more shaded sidewalks and streets, along with good public transit, high-quality sidewalks, other street design elements, urban design, and policy solutions (e.g., congestion pricing), can help support public transit, walking, and cycling instead of private cars.

Many behavioral and economic factors affect the choice of transportation, but research shows that trees in addition to other microfeatures such as sidewalks and benches could reduce VKT in cities by up to 13%. Spatial planning that supports compact cities with walking, cycling, and low-emissions public transit, building design for passive heating, cooling, and lighting, and urban green infrastructure can reduce citywide greenhouse gas emissions 23%–26% by 2050.[54]

While street trees alone won't stem the tide of new cars or get drivers to take the bus, they are part of a set of solutions that could maintain and increase the share of nonmotorized transport in a city while also providing critical health and equity benefits. Vehicle emissions are the top source of air pollution in many cities globally and cause hundreds of thousands of premature deaths annually, with large numbers in China and India.[55] Cooler, less polluted streets are beneficial for all individuals and particularly important for the many people for whom walking or cycling is the only transportation option, as well as for outdoor laborers and street vendors exposed to vehicle emissions for long periods of time.

Sequestering and Storing Carbon

Trees, mangroves, tidal marshes, and seagrass beds act as carbon sinks, storing CO_2 that would otherwise be released into the atmosphere. For example, planting street trees to their maximum potential in 245 of the world's largest cities would increase net carbon sequestration by 2.7 million to 13 million mt CO_2e.[56] Mangroves alone can sequester carbon up to 400% faster than land-based tropical rainforests.[57] Conversely, the degradation of these ecosystems releases significant CO_2 into the atmosphere, making their preservation and restoration critical to mitigate the effects of climate change.

Increasing Resilience to Climate Change

Nature can enhance urban resilience to the impacts of climate change — including sea level rise, hotter temperatures, stronger storms, and drought. Strategic use of urban nature helps cities and local communities mitigate heat and enhance coastal resilience.

vii In cities with combined stormwater and sewer systems, captured stormwater goes to the wastewater treatment plant. Otherwise, stormwater outflow is typically untreated.

Extreme heat is already one of the primary weather-related causes of death globally, and the world's cities are heating up at twice the global average.[58] During periods of extreme heat, the cooling effect of nature makes it safer to be outdoors and increases hours-of-safety indoors, contributing significantly to health equity. Trees can reduce air temperatures, mitigating the urban heat island effect, and can reduce electricity consumption by lowering the need for AC.[59] For example, Penang Island in Malaysia is implementing a climate adaptation program that will reduce the heat island effect through urban greening and will mitigate flooding through improved stormwater management. These interventions will reduce the threats to human life, property, and infrastructure from extreme weather events.[60]

Coastal and marine ecosystem services are vital for protecting coastal urban areas from extreme weather events. Mangroves, coral reefs, and seagrass beds are key assets for preventing erosion to coastal communities by helping to reduce the intensity of storm surges and tidal waves. Mangroves can be up to 50 times more cost-effective than cement seawalls at protecting coastlines from flooding and major storms, while also delivering significant carbon sequestration.[61] A global analysis found that without mangroves, global flood damage would cost an additional $65 billion a year and 15 million additional people would be at risk of flooding events. In the US state of Florida, mangroves prevented $1.5 billion in flood damages and protected over half a million people during Hurricane Irma in 2017. Researchers found damages from the storm to be 25% lower in counties where mangroves were present.[62] Similarly, in the Philippines, mangroves reduce flood damages to property from extreme weather events by 28% per year.[63]

Maintaining Biodiversity and Reducing Pollution

In addition to energy savings and carbon emissions reduction, urban nature provides many other ecosystem services such as maintaining biodiversity and improving environmental quality.

Unfortunately, much of the urban expansion expected through 2050 is likely to occur in biodiversity hotspots around the world and threaten the survival of hundreds of species.[64] Urban and suburban areas can contain relatively high levels of biodiversity and serve as critical habitats for endangered species.[65] Limiting sprawl as cities grow and preserving and protecting existing habitats can help maintain biodiversity and healthy ecosystems.

Additionally, urban nature can help prevent and mitigate the impacts of air and water pollution on the health of humans and other species. For example, urban trees can help prevent air pollution that can cause acid rain, and urban wetlands can help prevent sewer overflows, which damage ecosystem health.[66]

Advancing Equity with Urban Nature

Urban nature holds enormous potential to improve the quality of life for all urban residents and can help establish environmental equity. However, in practice, nature in cities often fails to benefit historically disadvantaged, low-income, and other vulnerable communities. These groups often have less nature in their neighborhoods compared to wealthier neighborhoods, and the green and blue spaces they do have are often of lower quality and smaller. Planning processes and greening plans often exclude or overlook these groups, leading to urban nature that locks in or creates inequity instead of addressing it.[67]

Around the world, the distribution of green space is not always equal.[68] Research by the Trust for Public Land showed parks in majority non-White neighborhoods in the United States are half as large as, and serve nearly five times more people than, parks in majority-White neighborhoods. In Santiago, Chile, the five wealthiest municipalities had, on average, access to more than five times the amount of public green space as the five poorest municipalities.[69] These examples show how design and implementation of urban nature can fail some residents by leaving their neighborhoods without amenities.

Local governments should plan and design urban nature to provide access and direct benefits to low-income and disadvantaged communities. And they should seek the active participation of these communities to create inclusive spaces that align with their interests and desired uses.[70]

A common challenge is that adding urban nature to a neighborhood often raises property values and housing costs. This can (but does not always) lead to displacement when residents can no longer afford to remain in their communities.[71] Preventing displacement is a complex challenge, but using a suite of context-specific and locally driven policies and programs, such as working with community-based organizations and minimizing financial or other barriers to access the spaces, can reduce displacement pressures, stabilize low-income communities, and align development and investment with community priorities.[72]

Quantifying the Value of Urban Nature

The many economic, environmental, health, and social benefits of urban nature have substantial value in the real economy that outweigh costs. Our analysis found that spending $7 trillion on urban nature globally could create $59 trillion in net benefits in cities between 2023 and 2050, at a benefit-cost ratio of nine-to-one.

However, annual new investments in urban nature need to increase on average to $98 billion, or three times the current investment level, through 2050 to achieve these results. For a single urban nature project, the full value of the benefits almost always outweighs the costs, with individual project benefit-cost ratios as high as 46–to–1. The enormous value that urban nature provides to communities, combined with its alarming investment gap, indicate the need for the global funding and financing community as well as national, regional, and local governments to support the deployment of urban nature at scale.

While different research efforts have quantified the global investment required to provide different ecosystem services, very few estimates exist for the value of nature in cities.[viii] Without a full accounting of the benefits and costs of urban nature, key actors — like local governments, urban planners, real estate developers, and potential investors — undervalue nature as a solution to many urban issues compared with conventional infrastructure. Undervaluation in turn creates underinvestment.

While nature's intrinsic and sometimes ineffable value — especially as the world confronts its biodiversity and climate crises — should not be obscured (as was discussed in the previous chapter), quantifying and ideally monetizing its benefits is important, and perhaps essential to attracting more investment. Governments — driven by public purpose — should look for opportunities to share costs and save money while also recognizing their responsibility to provide for and protect their residents and our environment (of which our economy and society are subsets — not the other way around).

Our analysis provides governments and investors with a comprehensive valuation of urban nature's true costs and benefits, to help justify further investment in, policy support for, and deployment of urban nature.

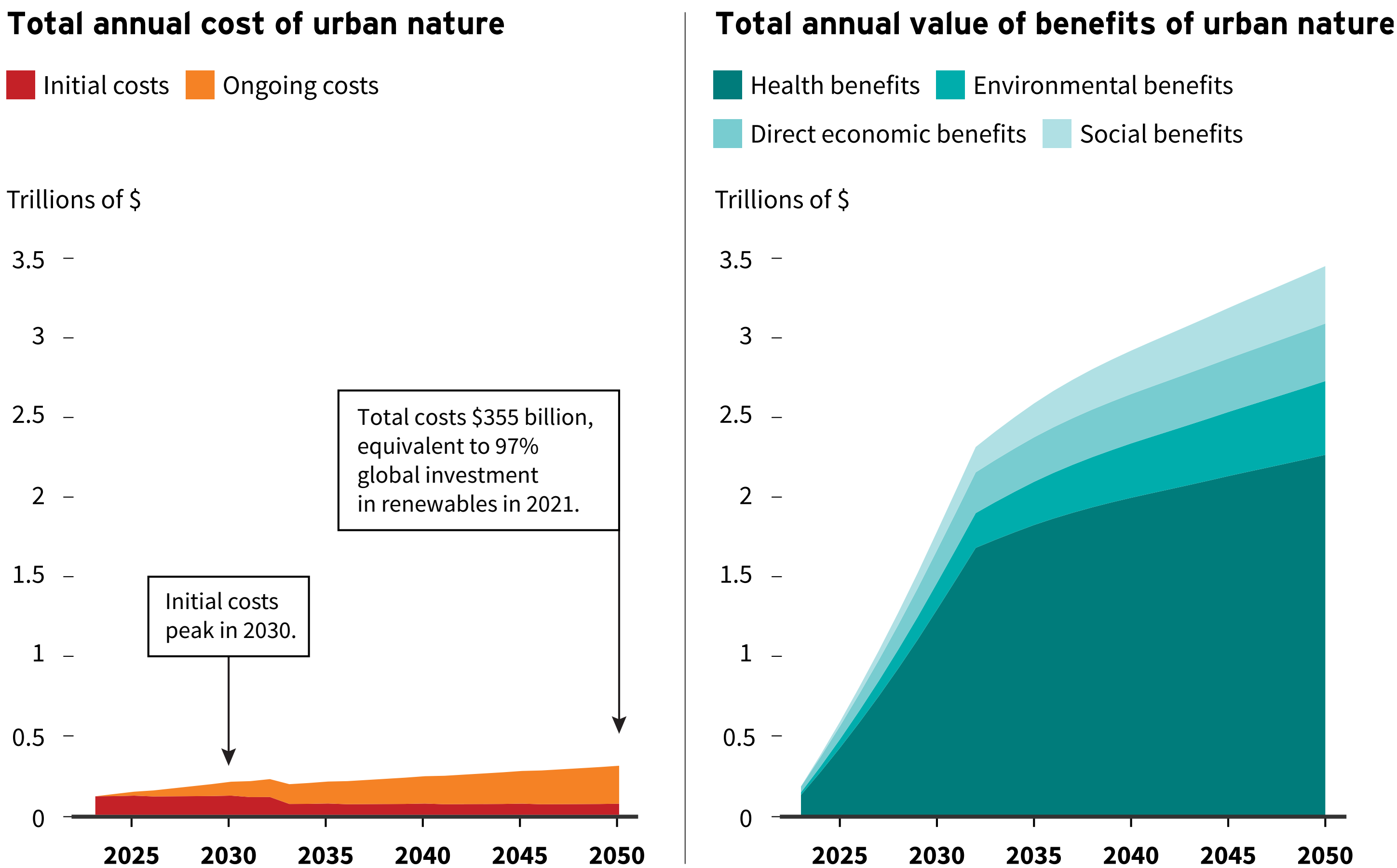
Investing in Urban Nature Reaps Huge Rewards

Our analysis estimated that total spending (initial investments and ongoing costs) of approximately $7.2 trillion on urban nature globally between 2023 and 2050 would create cumulative global net benefits equal to $59 trillion. This equates to an average annual investment of $98 billion and average annual net benefits of $2.1 trillion. The ratio of total gross benefits ($66 trillion) of urban nature to all costs of

viii Other groups working on estimating the value of nature include the Cornell Atkinson Center for Sustainability, International Institute for Sustainable Development, Paulson Institute, Nature Conservancy, UN Environment Programme, and World Economic Forum, and previously NATURVATION.

urban nature (approximately $2.7 trillion in initial costs and $4.4 trillion in ongoing costs) through 2050 is approximately nine-to-one (Exhibit 2).[ix] This is likely an underestimate of the total benefits of urban nature, as it excludes benefits that are hard to monetize or that have very different values globally (e.g., land value).

Exhibit 2 Urban nature's projected benefits and costs, 2023–2050: benefits projected to outweigh costs by nine times by 2050



Source: RMI

The numbers from our analysis show the immense value of urban nature and the investment opportunity it offers. By 2050, annual net benefits from urban nature could be as much as $3.1 trillion. The high return on investment that urban nature could generate is in line with the high social returns of other environmental measures. For example, the United States Clean Air Act has been regulating air pollutants since the 1970s. It is estimated to still save 370,000 lives each year, producing $3.8 trillion in annual economic benefits — 32 times the cost of implementing it.[73]

ix Initial and ongoing costs do not sum exactly to total costs due to rounding.

However, there is also a large investment gap that needs to be filled. To realize the full benefits, annual investment (i.e., the amount of investment needed to cover the cost of new projects every year) in urban nature from 2023 through 2030 needs to be on average $135 billion, or four times higher than the current level. After 2030, average annual investment needs to be $83 billion. A different analysis estimated that annual investment in urban nature was just $28 billion in 2019 (equivalent to $32 billion in 2022 dollars).[74] This leaves an average global investment gap of $107 billion per year from 2023 through 2030 — a significant sum, but only a little more than 1% of what cities globally are expected to spend on infrastructure in 2030.[75] When including ongoing costs like maintenance in addition to initial investments, total annual spending on urban nature would need to rise to $355 billion in 2050 — as much as global investment in renewable energy in 2021.[76]

The cost and benefit values presented here are estimates, and each is one point in a range of possible values. The benefit values are likely underestimates, and the costs could be higher or lower depending on assumptions used, such as number of trees or area available for restoration, the cost to implement or maintain, assumptions about urban population growth, and the number of people who benefit from investments. On the benefits side, the total net benefits through 2050 may be as high as $79 trillion — $21 trillion more than our estimate.

Building the Valuation: Calculating Benefits and Costs of Urban Nature

To estimate the investment opportunity urban nature offers and the value that investment would create, we conducted a meta-analysis of the literature on the need to restore, enhance, and add nature in cities by 2050. We assessed benefits and costs across seven categories of urban nature: green roofs, bodies of water (including those outside cities that supply water to cities), coastal wetlands, mangroves, street trees, urban forests, and grassy parks and open green spaces.

Benefits included in the analysis were as follows:

- **Direct economic benefits:** job creation, business value created, and direct cost savings
- **Environmental benefits:** reductions in air pollution, reduction in greenhouse gases, carbon storage and sequestration, increased biodiversity, improved stormwater management, and climate resilience
- **Health benefits:** reduced health care spending and lives saved, largely due to reduced temperature, reduced pollutants, and increased physical activity
- **Social benefits:** aesthetic value, cultural value, and recreation

We attempt to reflect technical feasibility, area available, complementary interventions (e.g., cool roofs and rooftop solar versus green roofs), and economically optimal uses. Costs were divided into two categories: initial costs (for starting projects) and ongoing costs (for maintenance and ongoing upkeep).

We use median and mean values, as appropriate, to choose investment sizes, their initial and ongoing costs, benefits, and their monetization. We size benefits to accrue over time as investments increase and projects reach maturity. The benefits we include are those that have been assigned a monetary value. More information on how investments, costs, and benefits were sized is available in the **methodology**.

How the Costs and Benefits of Urban Nature Evolve Over Time

Initial costs for starting urban nature projects dominate total costs for urban nature for the first 10 years. This is also true for each intervention type (e.g., tree planting, green roof installation, and wetland restoration). Over time, ongoing costs drive total costs because less nature is being added relative to the amount being maintained (Exhibit 3). Cumulatively through 2050, initial costs are estimated at $2.7 trillion and ongoing costs at $4.4 trillion, for total spending of $7.2 trillion. For comparison, $2.7 trillion is 34% of the global total ($8.1 trillion) that the UN Environment Programme estimates is needed for all nature-based solutions globally — but that number is probably an underestimate, as it does not include common urban solutions (e.g., green roofs).[77]

Green roof installation in Maryland (left) and tree planting at the Wood River Wetland in Oregon (right). Many of the benefits of urban nature are derived from human–nature interactions, including direct economic benefits from green jobs. Investments in urban nature have the potential to create over 21 million jobs by 2030, including 4 million jobs related to urban bodies of water and coastal wetland restoration, over 500,000 jobs in urban green roofs, and over 200,000 jobs in coastal wetlands protection.[78] Source: Department of Energy Solar Decathlon, Maryland: Installing Green Roof, July 7, 2011, online image, Flickr, https://flic.kr/p/a1MjvP (left), Bureau of Land Management, NPLD at the Wood River Wetlands, September 25, 2021, online image, Flickr, https://flic.kr/p/2mvnDY1 (right)

Exhibit 3

Average annual costs and benefits of urban nature

Billions of $

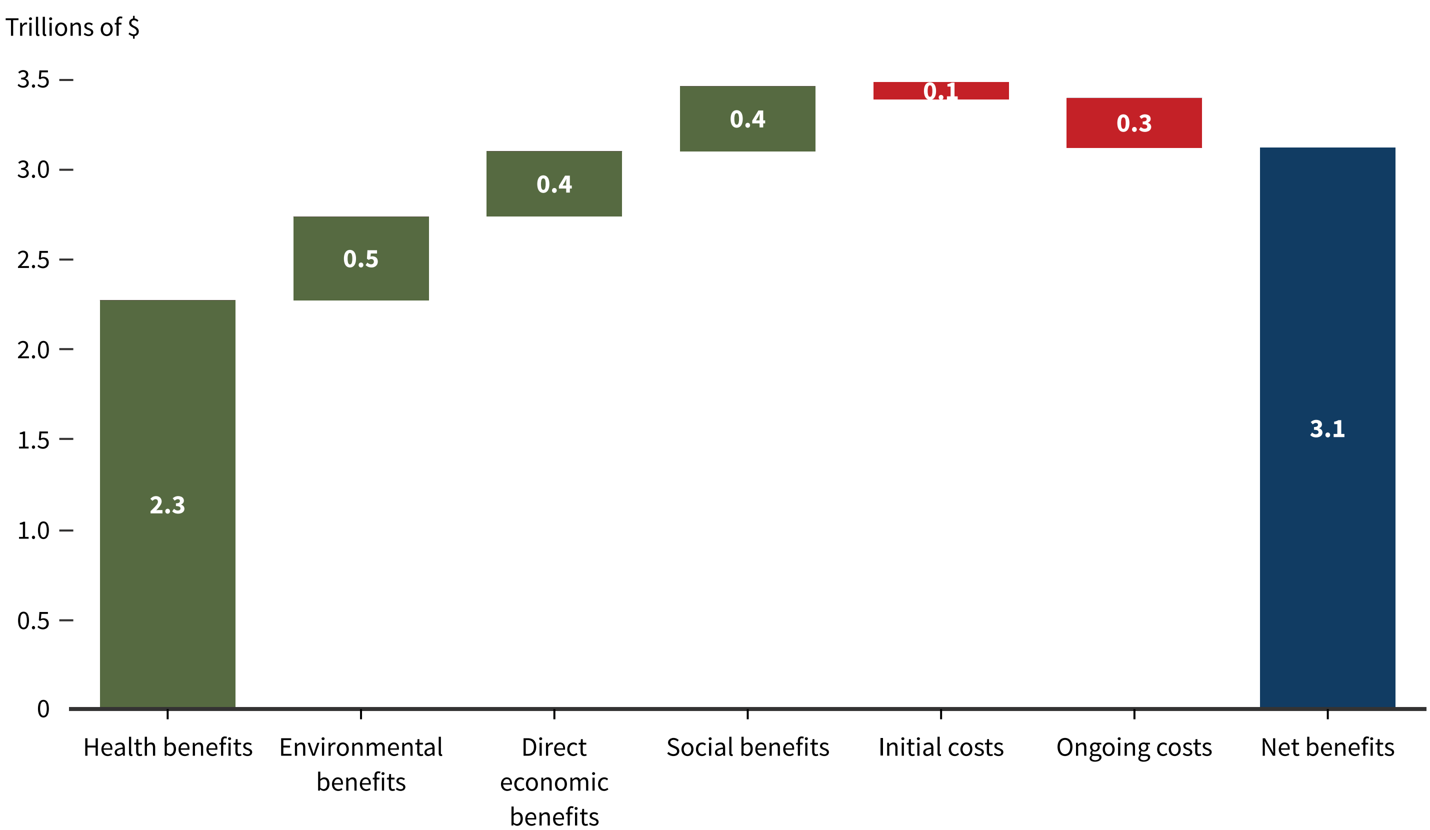
	2023–2030	2031–2040	2041–2050	2023–2050
Initial costs	140	89	78	98
Ongoing costs	51	160	240	160
Benefits	960	2,600	3,200	2,400
Net benefits	770	2,400	2,900	2,100

All values are in May 2022 dollars. Totals do not sum due to rounding.

Source: RMI

Initially, the biggest and most immediate benefits urban nature provides are direct economic benefits such as job creation, cost savings, and revenue generated. Over time, the value of other benefits — such as environmental, health, and social benefits — increases as trees mature and healthy ecosystems establish themselves. By 2050, each value stream on its own is expected to outweigh the total costs of urban nature (Exhibit 4). The largest contributor to benefits is avoided healthcare costs and lives saved as a result of reductions in urban air pollution and temperatures, as well as from increased physical activity encouraged by access to urban nature.[x] The investment in urban nature shown here has the potential to create $37 trillion in cumulative health benefits and lives saved. Even excluding lives saved, the total benefits of urban nature still outweigh the costs four-to-one.

Exhibit 4 Projected annual benefits and costs of urban nature in 2050



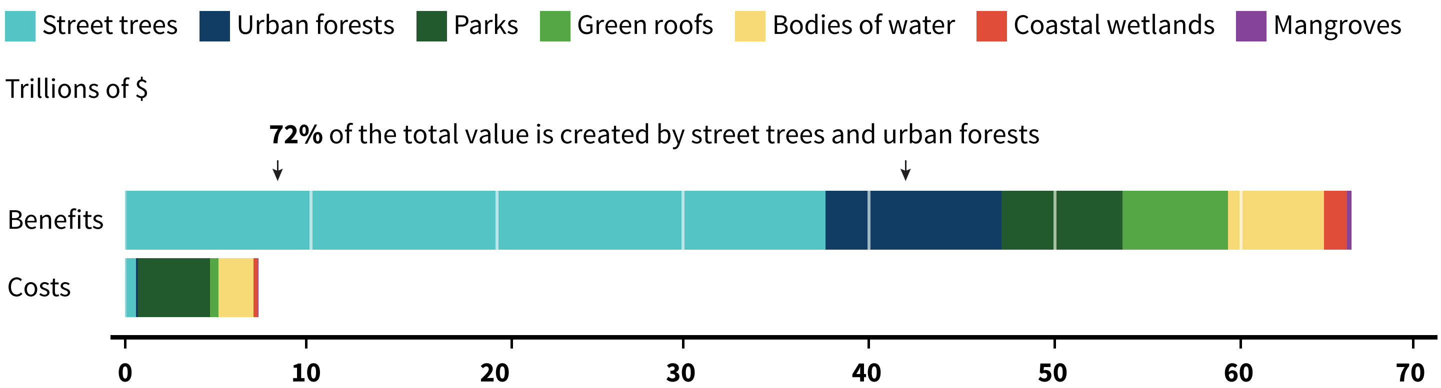
Source: RMI

x Lives-saved values were calculated using the value for a statistical life as defined by the United States Environmental Protection Agency, which recommends that a "central estimate of $7.4 million ($2006), updated to the year of the analysis, be used in all benefits analyses that seek to quantify mortality risk reduction benefits regardless of the age, income, or other population characteristics of the affected population." Source: US EPA, "Mortality Risk Valuation," Overviews and Factsheets, (April 20, 2014), https://www.epa.gov/environmental-economics/mortality-risk-valuation.

How Net Benefits Vary by Type of Urban Nature

Costs and benefits vary by type of urban nature project, but when looking holistically at all the potential benefits discussed here, all types of nature included in this analysis have a positive benefit-cost ratio (Exhibits 5 and 6). These range from 1.7–to–1 for investments in new parks (open green spaces, not including the costs of or benefits from non-nature recreation facilities or other amenities) to 82–to–1 for urban forests.

Exhibit 5 Cumulative costs and benefits of different types of urban nature



Source: RMI

Cities can achieve the greatest benefits by investing in trees: urban forests, street trees, and coastal mangroves. Of the total value we identify here for urban nature, 72% is created by urban forests and street trees. Investing an average of $25 billion per year in urban trees could yield an average of $1.7 trillion per year in benefits. This level of investment is globally achievable. For comparison, the United States Inflation Reduction Act, passed in August 2022, allocates $1.5 billion to urban forests in the United States alone.[79]

Because the benefits of urban trees tend to occur within a few hundred meters of their location, planting urban trees in areas with the least amount of tree canopy can yield significantly higher returns on investment than the average returns of planting elsewhere in cities.[80]

Who Pays and Who Benefits from Urban Nature

One key challenge for deploying urban nature at scale is the mismatch between the party that pays for the projects and the beneficiaries (Exhibit 6). While the benefits of urban nature greatly outweigh costs, this mismatch between investors and beneficiaries hinders investment. Typically, a single entity (usually public, and typically a local government) is responsible for initial costs, while the benefits accrue to others — developers, property owners, insurance companies, or the public at large — over time. As a result, it can be challenging to assess each benefit's value and how each is shared across the various beneficiaries. Additionally, this mismatch makes it more challenging for investors to capture value to recoup their investments, as the beneficiaries may not be directly connected to the parties responsible for the investment and upkeep.

Exhibit 6 **Who pays for urban nature and who benefits**

Dollar values in millions

Type	Useful life (years)	Average annual initial costs	Average annual ongoing costs	Average annual benefits	Benefit-cost ratio	Who pays	Who benefits
Urban forests	100+	$1,430	$2,689	$338,209	82	City, philanthropy	City, public
Street trees	13–50+	$10,500	$10,990	$1,345,667	64	City, property owner, philanthropy	Building user, commuter, public
Mangroves	100+	$183	$110	$7,632	26	City or other government entity, developer	City, public
Green roofs	50	$12,504	$3,501	$202,607	13	Building owner, developer	Building user
Coastal wetlands	100+	$5,684	$3,183	$44,503	5	City or other government entity, developer	City, public
Bodies of water	100+	$18,269	$49,326	$183,669	3	City or other government entity	City, public, peri-urban communities
Parks	100+	$49,364	$91,902	$232,396	2	City or other government entity, nonprofit	Public

Source: RMI

The City-Level Perspective

While this type of global analysis should be helpful to cities when making the case for urban nature, they may face difficulties using it to inform their investments and programs. Cities and other key actors face challenges with the measurability of nature's many benefits, including measuring benefits that emerge over time (e.g., that increase as trees reach maturity) and that are shared across a large number of beneficiaries.

While many resources exist to help cities learn from one another, cities still face challenges comparing investments, especially since there is no standardized approach to quantifying benefits. While this analysis does not offer such standardization, it makes the case that cities and other actors should look across benefit types when considering urban nature. To offer real-world lessons learned and demonstrate the value that urban nature can create at the city or project scale, examples follow of cities that are implementing different urban nature interventions and their associated costs and benefits.

Medellin, Colombia: Green Corridors[81]

- **Achievements:** The project delivered an interconnected network of greenery across the city. The network connects existing green spaces, improves urban biodiversity, reduces the urban heat island effect, soaks up air pollutants, and sequesters CO_2.
- **Area and number of people served:** 2.5 million people served by 30 corridors totaling 20 km.
- **Investment:** $16 million initial costs; $1.2 million ongoing costs for maintenance in the first 10 years.
- **Benefit:** $630–$814 million between 2020 and 2030.
- **Benefit-cost ratio:** range of 36–to–1 to 46–to–1.
- **Project benefits assessed:** urban cooling, carbon sequestration, recreation, and employment.

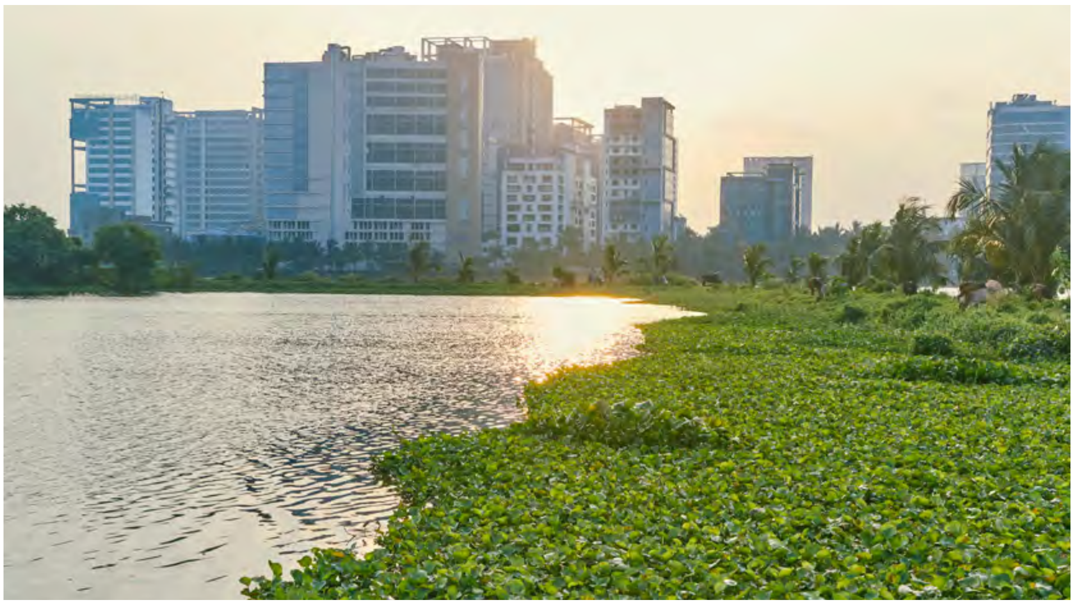
A tree-lined green corridor in Medellin, Colombia.

East Kolkata, India: Natural Wetlands[82]

- **Achievements:** The city prioritized preserving and restoring its 12,500 hectares of natural wetlands to treat wastewater, avoiding a new wastewater treatment plant. The wetlands treat more than 80% of the metropolis's sewage, which takes the form of approximately 950 million liters of wastewater entering the wetlands daily.

- **Benefit:** Savings of $59 million per year in avoided sewage treatment costs.

- **Other project benefits:** carbon storage, biodiversity, food production, employment opportunities, and flood protection.



Large fisheries surround the East Kolkata wetlands complex (above). The network of constructed and natural wetlands is one of the world's largest organic sewage management systems (below).

Colombo, Sri Lanka: Wetlands[83]

- **Achievements:** The city's natural and constructed wetlands play a crucial role in mitigating the impacts of flooding on the low-lying city. The project has increased the drainage capacity of the system by 110 cubic meters and included the rehabilitation of numerous public spaces and roads.

- **Number of people served:** 232,000 people experience reduced flooding.

- **Investment:** $213 million initial costs.

- **Benefit:** $2.7 million to $5.5 million per year in climate regulation, freshwater supply, water cycle regulation, food security, erosion regulation, pollination, carbon sequestration, and biodiversity benefits; an additional $95 million to $106 million in potential recreation benefits per year.

- **Benefit-cost ratio:** range of 4.6–to–1 to 5.2–to–1 over 10 years; two-year payback period.

- **Project benefits assessed:** flood mitigation, climate regulation, recreation, food production, and carbon sequestration.

Wetlands surround Colombo, Sri Lanka.

How Urban Nature Saves Energy and Reduces Carbon Emissions

Adding more nature into existing built-up areas is a key tool to help local governments address inequities in the built environment and lower the energy requirements and emissions of new development. This chapter summarizes our findings on urban nature's energy and carbon savings potential in six cities around the world, in three focus areas:

1. **Buildings:** how building-adjacent trees, overall city tree canopy, and green roofs reduce building energy use and peak demand

2. **Stormwater management:** how a distributed system of green stormwater features like rain gardens, grassy parks, infiltration trenches, and natural lakes reduces embodied carbon by decreasing the need for large new concrete basins and tanks

3. **Transportation:** how street trees encourage a mode shift to greater use of public transit as well as walking, cycling, and other active forms of transportation by reducing private car use

Detailed results of modeling on these three focus areas follow in chapters 6–8. Overall, we found that adding more urban nature can do the following:

- Reduce buildings' power consumption in a city by over **1%** and a city's overall peak demand by **1%–3%**, by reducing the need for mechanical cooling. For a fast-growing city of 5.5 million, like Abidjan, Côte d'Ivoire, this could defer the need for up to **74 megawatts (MW)** of power generation capacity by 2050, equivalent to turning off 33,000 typical residential AC units.[84]

- Avoid up to **87%** of the embodied carbon in grey stormwater management infrastructure by putting natural green infrastructure in place when conserving and enhancing natural assets in areas of new development, and reduce embodied carbon by over **20%** when converting existing impervious developed area. For a city like Houston, Texas, USA, converting existing impervious cover to green stormwater management would avoid approximately **199,000 embodied** mt CO_2e through 2050, equivalent to the carbon sequestration from 3.3 million tree seedlings grown for 10 years.[85]

- Reduce annual VKT by **0.2%–0.4%**, equivalent to taking **4,200 cars** off the road in 2050 in a city like Austin, Texas, USA. A household that switches from driving to walking or public transit could save **7%–35%** in annual transportation costs, up to **$4,250**, or over two months of the median rent in US cities.[86]

These results validate the importance of urban nature as a tool in cities' climate action toolkits, especially considering that even greater energy and carbon savings and improved cost-effectiveness are likely when using nature to achieve multiple benefits at once (which we did not model). We hope these results help cities make the case for more robust policies and funding supporting urban nature as a strategy for climate mitigation, adaptation, and beyond. The analyses of six cities show the diversity of urban nature solutions and their relevance across a range of urban typologies. Although our focus is on specific natural features, a range of complementary strategies (such as compact urban form, complete streets, permeable pavement, and cool roofs[xi]) must work in tandem with urban nature to increase climate and other benefits.

City-Specific Findings by Focus Area

This section summarizes findings in the three focus areas introduced above (buildings, stormwater management, and transportation) with examples from the six cities that were the focus of this analysis.

Buildings

Urban nature can cost-effectively mitigate building energy consumption for cooling during warm or hot weather. The reduced energy consumption of buildings translates into reduced energy consumption costs for customers (especially low-income customers), fewer emissions from power generation (and associated health impacts), and less need for investment in new power infrastructure. In addition, because urban nature lowers ambient temperatures, it can protect residents against the health impacts of heat where and when mechanical cooling is unavailable. Exhibit 7 visualizes some of the benefits we modeled for Abidjan, Côte d'Ivoire, and Sacramento, United States.

Exhibit 7 **Planting trees and installing green roofs in Abidjan and Sacramento cost-effectively reduced energy consumption and associated emissions**

xi Complete streets are streets that enable safe mobility for people of all ages and abilities, regardless of whether they are traveling by car, foot, bicycle, or public transit.

Abidjan, which aims to reverse decades of deforestation, could avoid up to **36 GWh** by 2050 with increased tree canopy and green roofs.[87] This would save households and businesses approximately **$13 million** annually in electricity bills and reduce greenhouse gas emissions by **534,000–541,000 mt CO_2e** cumulatively through 2050 (**0.9%–1.5%** of cumulative power consumption emissions in the city without additional urban nature), mostly through tree planting.

Urban nature could slow growth in electricity demand as Abidjan's use of mechanical cooling increases from about 2.5% of households in 2022 to as much as 15% in 2050, at the same time as population doubles.[88] Our modeling shows that increasing citywide tree canopy, including through building-adjacent tree planting, could avoid **9–14 MW** in peak demand in 2030 and **25–74 MW** in peak demand in 2050 (**0.5%–2.5%** of 2050 projected peak demand in Abidjan), saving an additional **$51 million to $63 million** in investment in new power generation capacity, or one to two typical peaker plant units.[89]

While increasing the overall tree canopy accounts for the largest share of energy savings in Abidjan, planting building-adjacent trees is comparably cost-effective, costing **$14 million to $27 million** cumulatively through 2050 (including both initial and annual maintenance costs) and paying for itself within 15–20 years from energy savings and avoided new generation investment.

Sacramento, California, USA, which aims to address green cover and temperature inequities across neighborhoods, could at the same time reduce annual electricity consumption by **30–41 GWh in 2050** with increased tree canopy and green roofs, saving **$17 million to $22 million** annually for customers (about one-eighth of typical monthly energy expenses for some households[90]) and **32,000–41,000** in cumulative metric tons of greenhouse gas emissions through 2050.

Urban nature in Sacramento can also reduce peak electricity demand by **28–56 MW** in 2030, saving **$39 million to $78 million** in power generation investments through 2030. By 2050, urban nature could reduce peak demand by **56–111 MW**, bringing the total savings in reducing investments in power generation to **$78 million to $155 million**, which is **1–1.5 times** the utility's current annual spend on new generation.[91] Targeted tree planting and overall canopy increase share credit for the vast majority of savings, paying for themselves within 15 years based on energy consumption savings alone (without accounting for the added benefit of avoided generation investment).

Stormwater Management

In Ahmedabad, India, natural measures to capture monsoon floodwaters could prevent the need to build new grey stormwater basins in urban expansion zones, avoiding emissions and lowering costs while keeping residents safe. The city could avoid over **46,000 mt CO_2e** in embodied carbon and save over **$323 million** by 2050 by preserving existing lakes and expanding natural depressions to capture stormwater instead of building conventional concrete basins. This green approach would have only **13%** of the emissions and **8%** of the cost of a grey infrastructure approach. Preserving natural areas, especially wetlands and low-lying areas, in growing cities prevents development where flood risk is highest and retains space for stormwater management as impervious surfaces spread. Natural lakes would have the added benefits of supporting biodiversity and providing recreation opportunities, and they can also mitigate water stress by increasing groundwater recharge.[xii]

xii A city's water stress is measured as the demand for water divided by the city's available water.

Preserving nature does not need to be at the expense of promoting human-centered urban development; smart growth can allow both.

Preserving nature does not need to be at the expense of promoting human-centered urban development; smart growth can allow both. In the area east of Ahmedabad that we studied, the city can meet its 15% green cover goal, preserve lakes for stormwater management, preserve productive agricultural land, and maintain a livable density for its growing population. In fact, by meeting a 15% green cover goal in this area, the city can avoid **1.7 million cubic meters** of runoff from a very high intensity storm (13 cm), which can save **$173 million** through 2050.

In Houston, adding small green stormwater features throughout the city could reduce stormwater runoff by **4.8 cm** (1.9 inches) or **10%**, avoiding **199,000 mt CO_2e** (**22%**) in embodied carbon through 2050 compared with large concrete basins and tanks. A hybrid approach combining green features with low-impact grey features like infiltration trenches, sand filters, and small detention basins could reduce runoff by **3.3 cm** (1.3 inches) or **7%** and avoid **116,000 mt CO_2e** (**13%**) in embodied carbon through 2050, compared with grey infrastructure. These solutions are also more cost-effective — green and hybrid infrastructure would save the city about **$2.6 billion** or **$12 billion**, respectively, over 30 years relative to constructing and maintaining grey infrastructure (10% or 44% savings of total cost).

The green and hybrid scenarios require substantially more land area to manage the same amount of stormwater as the grey scenario (19.2 square kilometers and 17.6 square kilometers through 2050, respectively, compared with 6.4 square kilometers of grey infrastructure). But even the green scenario requires only around 1% of the city's land area, and green features like pocket prairies, grassy sunken parks, and rain gardens with biodiverse plants provide valuable benefits and community amenities that grey infrastructure does not.[92] Green and hybrid features provide flexibility, scaling up or down in size, fitting where small amounts of impervious ground can be converted, and offering different configurations to meet site-specific stormwater management needs and community priorities.

Green features alone cannot solve Houston's flooding challenges when so many residents already live in flood-prone areas. But green and hybrid infrastructure could play an important, climate-friendly role in urban design that sites housing in areas with better flood protection and preserves or converts flood-prone areas into green and blue spaces. Exhibit 8 visualizes some of the benefits for Ahmedabad and Houston.

Exhibit 8

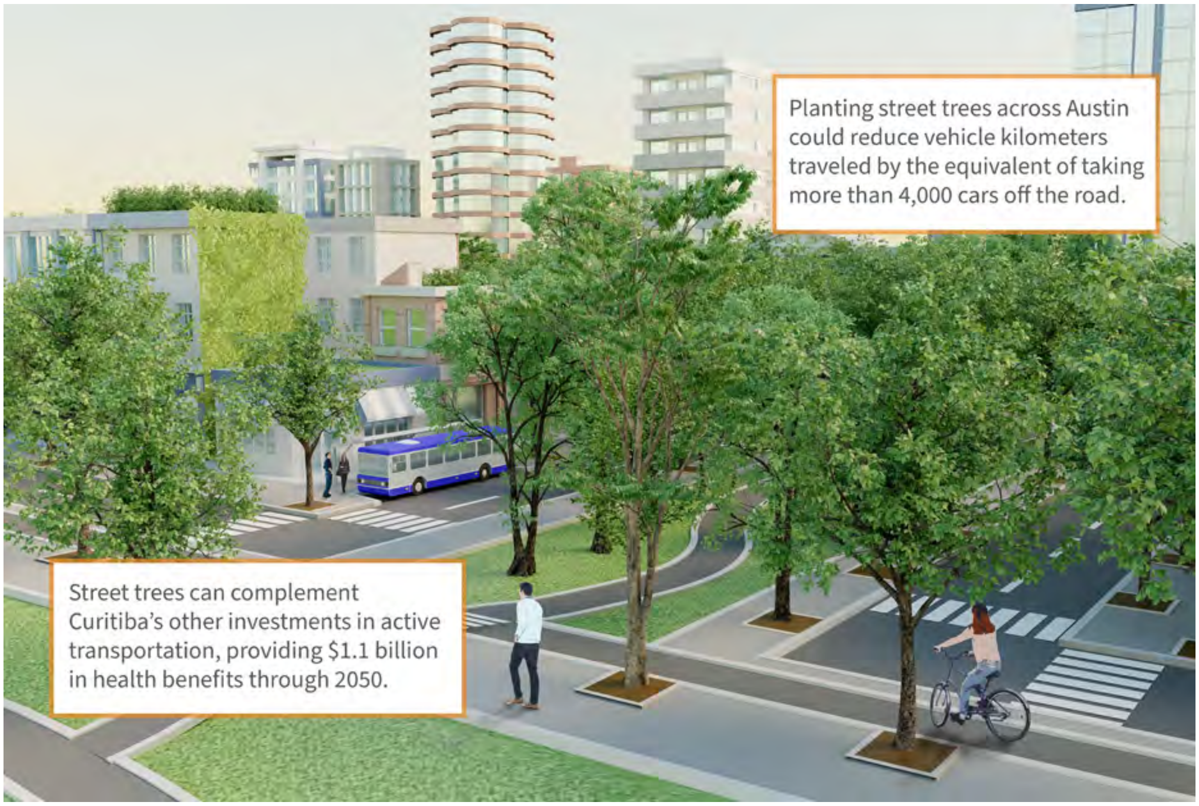
Urban nature better managed rainfall in Ahmedabad and Houston, while costing less and leading to lower emissions than the grey alternative

Transportation

Street trees, alongside other street design features, can support active transportation and public transit usage, incentivizing a "mode shift" away from private vehicles (Exhibit 9). Our analysis is based on observations of the amount of tree canopy cover and the number of residents' trips by different transportation types ("mode share"). Daytime air temperatures along streets are substantially reduced once tree canopy cover reaches 40%, thereby providing thermal comfort to bicyclists, pedestrians, and commuters using public transit.[93] We observed streets and the areas around transit stops to see if the mode share was different for locations with high canopy cover and low canopy cover. This is a topic with little research, and while we did not derive a statistical relationship between tree shading and mode share, our findings in Austin and Curitiba show that this is an area deserving further study.

Exhibit 9

Planting street trees complemented other investments in active transportation to reduce VKT and improve health outcomes in Austin and Curitiba



In Austin, increasing tree canopy cover to 40% along viable streets and the areas near transit stations could reduce annual VKT by **31 million km** by 2035 and nearly **42 million km** by 2050. This is equivalent to taking almost 1,000 cars off the road for a year for 2035 and 4,200 cars for 2050.[94] Those 2035 driving reductions correspond with a reduction in electric vehicle (EV) electricity consumption that would avoid **0.1%** of Austin's projected 2035 EV demand, and a reduction in gasoline consumption that would avoid **0.06%** of Austin's projected 2035 gasoline demand.[95] Transportation-related emissions — from both on-road gasoline emissions and power grid generation emissions — would accordingly decrease by **3,700 mt CO_2e** in 2035. Additionally, reduced private car usage could save Austin households **$2,500–$4,250** in transportation costs each year (21%–35% of 2017 average household transportation costs in Austin) and deliver up to **$1.48 billion** in health benefits for the 2035–2050 period.[96]

In Curitiba, Brazil, increasing tree canopy cover to 40% along streets could reduce annual VKT by **15 million km** (equivalent to taking 1,800 cars off the road for the entire year[97]) in 2035 and by **16 million km** (equivalent to taking 2,000 cars off the road for the entire year[98]) in 2050. Avoiding private vehicle use — from both EVs and internal combustion engine (ICE) cars — therefore reduces electricity consumption by **0.04%** of Curitiba's projected 2035 EV demand and gasoline consumption by **0.05%** of the city's projected 2035 fuel demand.[99] Furthermore, transportation-related emissions would decrease by **1,140 mt CO_2e** in 2035, consisting of both on-road emissions from ICE cars and power grid emissions from EVs.[100] Curitiba residents would directly benefit from reduced private vehicle usage, too. Households could save $700 in transportation costs each year (7% of 2017 average household transportation costs in Curitiba[101]), and the city would achieve up to **$1.1 billion** in health benefits through 2050.

Summary of City Modeling

The city-based modeling presented in this chapter (and presented in more detail in chapters 6–8) projects the costs and benefits, by focus area, of adding new urban nature features, across a time frame spanning 2023–2050, for six cities representing a range of urban characteristics (Exhibit 10). To select the study cities, we first developed several typologies (groups of characteristics representative of many cities) and then chose cities that represented different typologies and different geographic areas and had good data availability.

Exhibit 10 **Characteristics and typologies represented in modeled cities**

Focus area	Characteristics evaluated	City typologies	Example cities
Buildings	• Thermal stress (heat, humidity, water availability) • Density • Stage in urban development or projected growth	1. Hot and humid, moderate to high water availability, high density, rapidly growing city 2. Hot and dry, low water availability, low density, low to moderate growth	1. **Abidjan,** Chennai, Jakarta, Kinshasa, Lagos, Manila, Miami, Mumbai 2. **Sacramento,** Austin, Marrakech
Stormwater management	• Density • Extent of green cover • Monthly distribution of rainfall and and projected future rainfall	1. High density, low green cover, heavy seasonal rainfall, flooding challenges, water supply challenges, potentially arid 2. Low density, low green cover, humid with substantial year-round rainfall, flooding challenges	1. **Ahmedabad**, Addis Ababa, Chennai, Dhaka, Jakarta, Mumbai, Phoenix, Tucson 2. **Houston**, Brisbane, Chicago, New Orleans
Transportation	• Thermal stress • Extent and quality of existing public transit and active transportation infrastructure • Personal car use	1. Hot and dry or hot and humid, low to medium level of existing public infrastructure, high personal car use 2. Hot and humid, high level of existing public transit and active transportation infrastructure, low personal car use	1. **Austin** Los Angeles, Sacramento 2. **Curitiba**, Bogotá, Medellín, Taipei

For each focus area, we analyzed two different typologies and selected one city to represent that typology in our model.
Example cities included in our analysis are **bolded.**

Source: RMI

A well-planned urban nature feature can yield multiple benefits

While this study only modeled one focus area per city, a local government would likely find it more effective to develop an urban nature plan that produces multiple benefits. For example, street trees that shade buildings, sidewalks, and bike lanes can reduce building electricity use and influence mobility choices while also providing some stormwater management. Integrating green stormwater management features like rain gardens with street trees captures additional stormwater runoff and offers an opportunity to improve or restore biodiversity. As a result, in each focus area, the modeled energy and carbon reductions as well as the cost savings are likely an underestimate, and the payback time likely an overestimate.

Different types of urban nature were considered for the different focus areas: trees and green roofs for buildings, rain gardens and lakes for stormwater management, and street trees for transportation. We considered both initial and ongoing costs from adding more urban nature features; the benefits we considered vary by focus areas, as evident in the results. Where possible, we considered projected changes over time in tree and vegetation growth, building and vehicle electrification, electric grid emissions intensity, and technology improvement. We developed model methodologies tailored to each focus area and (in some cases) to each city. A separate **methodology** document that accompanies this report provides details about our methods, assumptions, and data sources.

Urban Nature as Cost-Effective Climate Mitigation

The results of our analyses — some of the first of their kind at the city level — show that local governments can use nature as one of their tools for meeting emissions reduction goals while also providing a public good. While we study buildings, stormwater management, and transportation separately, the reality is that nature delivers benefits across multiple areas; a well-positioned street tree can shade a building, absorb water during a heavy rainfall event, and help encourage active transportation.

In most cases, the financial savings (from reduced energy consumption, avoided new power generation buildout, lower initial infrastructure costs, and avoided transportation fuel or power costs) outweigh costs — reflecting at the city level what chapter 4 showed globally. Targeting urban nature to benefit low-income or historically disadvantaged communities (e.g., through savings on household energy bills and transportation costs) can be an important tool for promoting equity, especially given the inequitable distribution of green spaces in so many cities.

We recognize that much more work remains to improve understanding of urban nature's climate mitigation benefits, including in other city typologies, and especially in the global South. We invite academics and researchers, in partnership with local government, to perform additional analysis, further synthesize findings, and interpret this information for policymakers.

The next three chapters explore some potential returns on investment in urban nature in these three focus areas — buildings, stormwater management, and transportation — as they could play out in the six cities that are the focus of this study.

Buildings — Energy, Carbon, and Cost Savings

Buildings can be the source of 40%–50% of a city's direct (Scope 1 and 2) greenhouse gas emissions, mostly through the energy they consume. Urban nature can meaningfully and cost-effectively reduce building energy consumption, especially for cooling during hot weather. This can reduce business and household energy costs, avoid emissions from additional cooling power generation, and reduce the need for costly new power generation capacity.

To estimate this potential impact, we modeled adding three features that reduce the amount of mechanical cooling required for thermal comfort in buildings: planting building-adjacent trees, which both provide direct shade on buildings and reduce surrounding air temperature (ambient cooling); increasing the overall urban tree canopy, which provides ambient cooling; and installing green roofs, which provide shade, insulation, and ambient cooling. Exhibit 11 summarizes our high-level findings for Abidjan and Sacramento, which we detail later in the chapter. While the total energy and carbon savings across the cities we modeled are a fraction of each city's total consumption, the impact is still notable, especially in energy cost savings for low-income households. Energy savings are not the only benefit — reducing ambient temperatures can mitigate heat-related health impacts for people without access to AC.

Exhibit 11

Modeled natural features reduced energy consumption, peak demand, and associated emissions in Abidjan and Sacramento

	Abidjan	Sacramento
Avoided energy consumption and spend in 2050	35–36 GWh (0.2%–0.5%), saving $13 million annually	30–41 GWh (0.2%–0.3%), saving $17 million–$22 million annually
Avoided peak demand and investment by 2050	25–74 MW (0.5%-2.5%), saving $51 million–$63 million investment	56–111 MW (1.2%–3.2%), saving $78 million–$155 million investment
Avoided cumulative emissions through 2050	534,000–541,000 mt CO_2e (0.9%–1.5%)	32,000–41,000 mt CO_2e (0.2%)

Percent values in parentheses reflect shares of anticipated 2050 business-as-usual totals. Avoided investment is only from avoided new power generation capacity. Avoided emissions are from power consumption, but do not include other potential avoided categories of emissions.

Source: RMI

In both cities we modeled for this chapter — Abidjan and Sacramento — tree planting (building-adjacent trees and increased overall canopy) offers the highest return on investment from a building energy perspective. In fact, tree planting accounts for over 99% of the energy impacts we modeled in both cities. As green roofs carry higher initial and annual maintenance costs, we did not find an energy benefit-cost case for green roofs in our model. Green roofs should be considered, though, where tree planting is not feasible, such as very dense areas, and for their non-energy benefits.

Abidjan has a deforestation trend the city is committed to reversing, and our findings provide further rationale for this goal.[102] We found that urban nature has the potential to reduce Abidjan's annual electricity consumption by as much as 36 GWh (0.5% of anticipated consumption) in 2050, with the largest share of savings from overall tree canopy increase. This translates to an emissions reduction of 541,000 mtCO_2e by 2050, or the emissions savings from taking 117,000 gas-powered cars off the road for one year.[103] It also equates to $13 million in annual electricity bill savings for residents by 2050.

Trees line the waterfront in downtown Sacramento (at top). Abidjan's city center, including St. Paul's Cathedral, stands adjacent to greenery on the waterfront (above).

Like many cities globally, Abidjan is expecting an increase in mechanical AC adoption, which will increase energy consumption and emissions. AC use peaks when outdoor temperatures are highest, contributing greatly to city peak energy demand. Urban nature can slow this demand by reducing the amount of cooling needed in buildings. In Abidjan, urban nature could provide up to 2.5% (74 MW) reduction in anticipated peak demand in 2050. This reduction translates into $63 million in avoided new grid generation capacity investment through 2050. The reduced demand also avoids the need for one to two typical peaker plant units. While buildings with AC (around 2.5% of urban households in 2022[104]) will see the energy savings from urban nature, its cooling effect is especially important for the health and safety of households without AC.

In Sacramento, the measures modeled have the potential to reduce annual electricity consumption by up to 41 GWh (0.3% of the city's anticipated power demand) in 2050. These savings are largely driven by tree planting, which is roughly equal for building-adjacent trees and overall increase in urban canopy. This translates to emissions savings of 0.24% (41,000 mtCO_2e) in Sacramento by 2050 (about a tenth of the savings in Abidjan, a result of Sacramento's smaller population and California's cleaner grid). These energy savings also mean up to $22 million annually in savings for customers by 2050, and individual homes could save as much as $22 per month, or about 12% of their current average electricity spend, by 2050.[105]

As in Abidjan, urban nature in Sacramento could reduce peak demand by up to 3.2% (111 MW) in 2050, relative to the city's anticipated peak demand in that year, potentially saving $155 million in investment in new power generation. Tree planting efforts are not new to Sacramento, where more trees can further alleviate canopy and temperature inequities across neighborhoods.

Abidjan

Abidjan is Côte d'Ivoire's economic center and home to over 5.5 million people; its population is expected to grow to over 10 million by 2050.[106] Population growth will require new buildings, especially housing, for which demand is expected to increase by 40,000–50,000 units each year.[107] We estimate that AC adoption in Abidjan will increase in line with country-wide GDP growth, from about 2.5% of urban households today to 15% in 2050.[108] Abidjan also faces significant deforestation. The Abidjan Autonomous District experienced a 40% reduction in tree canopy cover between 2000 and 2021, and over the past 60 years, around 85% of Côte d'Ivoire's forest cover has been lost.[109] Abidjan aims to reverse this trend, prioritizing improved air quality, urban planning, and urban infrastructure.[110] Urban nature investments can support these priorities.

Reductions in Energy Consumption and Associated Emissions

We project that planting building-adjacent trees, increasing the urban canopy, and installing green roofs can reduce building energy use by up to 36 GWh per year (0.5% of the city's anticipated power consumption) by 2050. This would avoid a cumulative 541,000 mt CO_2e of emissions by 2050. In 2050 itself, avoided emissions would be 25,500 mt CO_2e, making up about 1.4% of the city's anticipated 2050 power consumption emissions; this is equivalent to not burning over 11 million liters of diesel.[111]

Most of the savings come from increasing urban canopy, which contributes up to 97% to the total energy savings, followed by building-adjacent trees, then green roofs. Increasing urban canopy to 30% would require the planting of about 1.1 million trees, avoiding about 527,000 mt CO_2e through 2050.

Dense tree canopy in Abidjan's Banco National Park (upper right of image). Some green space is also visible throughout the city. Source: Google Earth, 5°21', 4°03', accessed August 15, 2022

Planting one or two building-adjacent trees per modeled property (21,300–42,800 trees total) contributes 3%–6% of the total energy savings modeled in Abidjan, respectively. This can reduce building energy use by 1,120–2,240 MWh in 2050, translating to an emissions savings of 7,000–14,000 mt CO_2e by 2050. Energy savings from building-adjacent trees increase over time as trees mature and provide additional shading. The green roofs we modeled contribute least to energy savings in Abidjan. Adding green roofs to about 30% of new buildings, resulting in 1.2 million square meters (12.9 million square feet) of green roofs, could reduce building energy use by up to 10 MWh, saving 140 mt CO_2e by 2050. This is, at most, 10% of the impact of building-adjacent trees.

Reductions in Peak Demand and Associated Investment in Power Generation Capacity

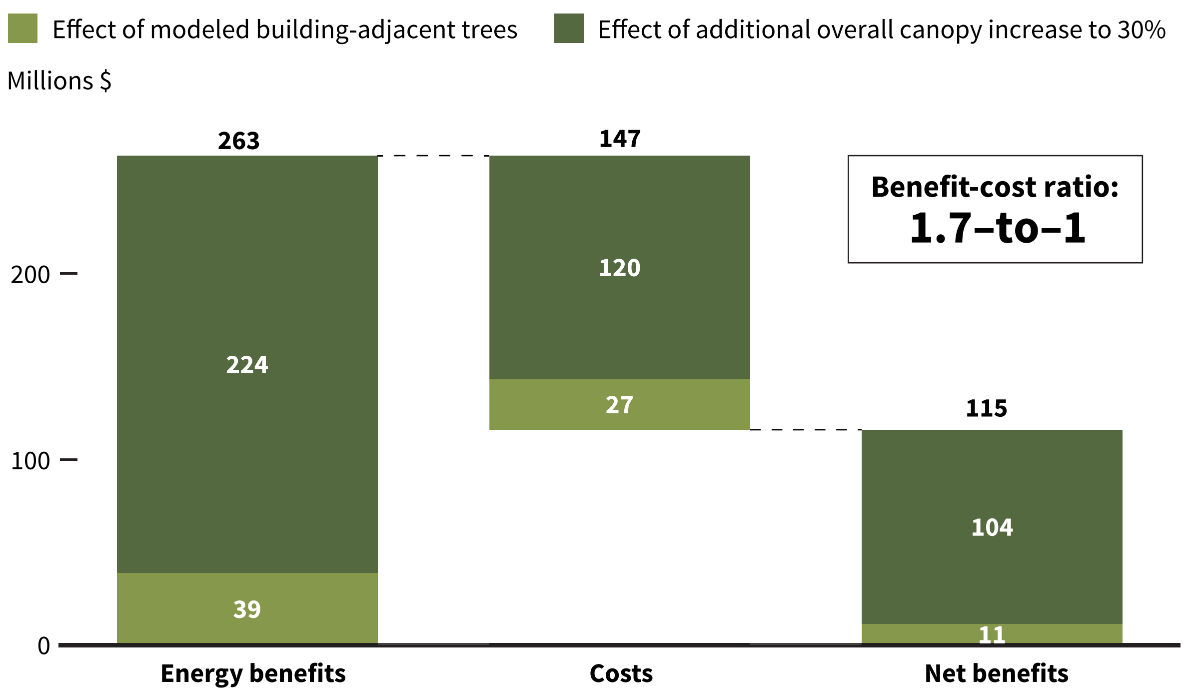
In addition to reducing energy consumption, urban trees could reduce peak demand by up to 14 MW (1.0% of anticipated peak demand in the city) in 2030 and up to 74 MW (2.5%) in 2050. This translates to $63 million in avoided investment in new power generation through 2050 by avoiding building or running two new gas peaker units. Once again, increasing overall urban canopy to 30% has the greatest impact, avoiding more than 18 MW in peak demand. Planting one building-adjacent tree per property could reduce peak demand by as much as 1 MW in 2030 and 7 MW in 2050. Planting two building-adjacent trees per property greatly increases the reduction in peak demand to about 6 MW in 2030 and 56 MW in 2050, contributing up to 44% of the total peak demand savings potential we modeled. While we did not model the impact of green roofs on peak demand, green roofs would increase the overall reduction.

Economic Results

We found that planting urban trees can provide over $115 million in net savings between 2022 and 2050 (including energy bill savings and avoided investment in additional power generation capacity, see Exhibit 12). Citywide, our model suggested that urban trees would have a benefit-cost ratio of up to 1.7 by 2050 for building energy-related benefits alone. Adding other benefits like public health, property values, and social and recreational value would increase the benefit-cost ratio further.

Exhibit 12

Urban trees in Abidjan — projected costs and energy savings, 2050



Effect of modeled building-adjacent trees reflects planting two trees by about 21,000 buildings for a total of about 42,000 trees. Totals do not sum due to rounding.

Source: RMI

While the modeled tree planting would entail initial costs up to $39 million and $147 million cumulatively through 2050, it would pay for itself in 15 years (through avoided energy consumption and avoided power generation). We assumed all tree planting occurs in year one, leaving annual maintenance costs (and replacement costs for trees that do not survive) for subsequent years.

Energy savings from one or two building-adjacent trees alone provides $7–$11 million in net benefits, respectively, between 2022 and 2050, with an initial cost of $780,000–$1.6 million and an annual maintenance cost of 10%–20% of the initial cost. (Maintenance increases over time, reflecting both new plantings adjacent to new construction and replacement for tree mortality.) The payback timeline depends on when exactly investment in new power generation is avoided.

As noted in the chapter introduction, green roof energy savings do not outweigh their initial installation costs. Green roofs provide many benefits not quantified in this exercise (e.g., reduced peak demand, stormwater management, and improved air quality), making them appropriate in some cases.

Sacramento

Sacramento is the capital city of the US state of California. In contrast to Abidjan, Sacramento is a medium-sized city with low expected population growth. It is projected to increase from 525,000 people in 2020 to up to 630,000 in 2050.[112] The city has hot and dry summers, and temperature differences between neighborhoods with more tree cover and those with less can reach 6°C (10°F).[113] Partly to address this heat disparity, Sacramento has a goal to increase its tree canopy cover from 19% to 35% by 2045.[114]

Sacramento has long recognized some of the benefits of urban nature, especially tree planting. Since 1990, the Sacramento Municipal Utility District (SMUD) has partnered with the Sacramento Tree Foundation through the Free Shade Tree Program to plant over 600,000 trees, reaching over 70% of SMUD customers.[115] SMUD launched the program with the express purpose of reducing summer electricity demand after a 1989 decision to shut down a nuclear power plant that accounted for 30%–40% of power generation. The program is now focused on carbon sequestration.[116]

Reductions in Energy Consumption and Associated Emissions

We found that planting building-adjacent trees, increasing the urban canopy overall, and installing green roofs can reduce building energy use in Sacramento by up to 41 GWh (0.3% of anticipated citywide power consumption) in 2050. In Sacramento, building-adjacent trees contribute up to 50% of these total energy savings, about equal with savings from overall canopy increase. Green roofs provide the smallest portion of modeled energy benefits.

Energy savings increase over time as trees mature (increasing canopy cover and associated shading and ambient cooling) and additional green roofs are installed. Together, these features' energy consumption savings would avoid emissions of up to 41,200 mt CO_2e by 2050, equivalent to taking 8,600 ICE cars off the road for a year.[117]

For building-adjacent tree planting, we modeled both one and two trees per eligible building as conservative estimates, with the energy and carbon impacts doubling when a second tree is added. Sacramento's Free Shade Tree program has historically provided an average of four trees per participating residence, so the potential may be even higher than our results suggest.[118] In our modeling, building-adjacent trees reduce energy consumption by up to 260 kWh in 2050 per building, through shading and ambient cooling. (We found that shading accounts for 70% or more of these trees' cooling impact, with the rest from ambient cooling through evapotranspiration.) At the city level, planting 53,400–106,900 trees can reduce energy use in buildings by 11–21 GWh annually by 2050.

Trees shade buildings and a walking path in downtown Sacramento. Source: Photo by **A. Davey**, licensed under **CC BY-NC-ND 2.0** (via **California Sun**)

Our model suggested that increasing city canopy cover from 19% to 35%, planting roughly 628,000 trees, could reduce current annual building energy consumption by up to 48 GWh.

In our model, green roofs provide up to 6% of estimated energy consumption savings. Adding 1.4 million square meters (15 million square feet) of green roofs on 60% of new and 36% of existing pre-1945 buildings (about 11,000 new and 400 existing buildings) could reduce citywide building energy use by 60 GWh each (120 GWh total) for existing buildings and new buildings through 2050 (6.6 GWh in the year 2050). This would avoid over 6,500 mt CO_2e of emissions through 2050, the vast majority (4,900 mt CO_2e) by 2030.

In Sacramento, the emissions reductions from our model features total 41,000 mt CO_2e by 2050. These, combined with sequestered carbon from urban nature (not quantified), support the city's target of carbon neutrality by 2045.[119] This also supports a near-term goal (as shared by SMUD and the Sacramento Tree Foundation) to sequester and store 90,000 mt CO_2e from new tree plantings over the next three to four years. The avoided emissions we've quantified would contribute to over 40% of this goal.[120]

Annual avoided emissions from energy savings are projected to decline over time as Sacramento pursues continued decarbonization of its electric power supply. Modeled annual emissions savings approach zero by 2050 (in fact, SMUD has a goal to provide 100% clean electricity by 2030). Urban nature can support SMUD's clean energy goal and help reduce the costs of the transition to renewable energy by reducing energy consumption and peak demand.

Reductions in Peak Demand and Associated Investment in Power Generation Capacity

We found that together, planting trees adjacent to buildings and increasing the overall urban canopy can reduce peak demand in Sacramento by up to 56 MW in 2030 and 111 MW in 2050, 1.9% and 3.2% of SMUD's anticipated power demand in those years. Even a small percentage in avoided peak demand has a big impact — 3.2% translates to $155 million of avoided investment in new power generation through 2050.

While the energy savings benefits of building-adjacent trees and increased urban canopy were about equal, we saw significantly more peak demand reduction benefits from building-adjacent trees. In fact, building-adjacent trees account for up to 110 MW of peak demand reduction by 2050, or over 99% of the total reduction, with the remaining 1 MW or so from increasing urban canopy overall. While we did not model the impact of green roofs on peak demand as part of this exercise, quantifying that impact would certainly increase the overall benefit.

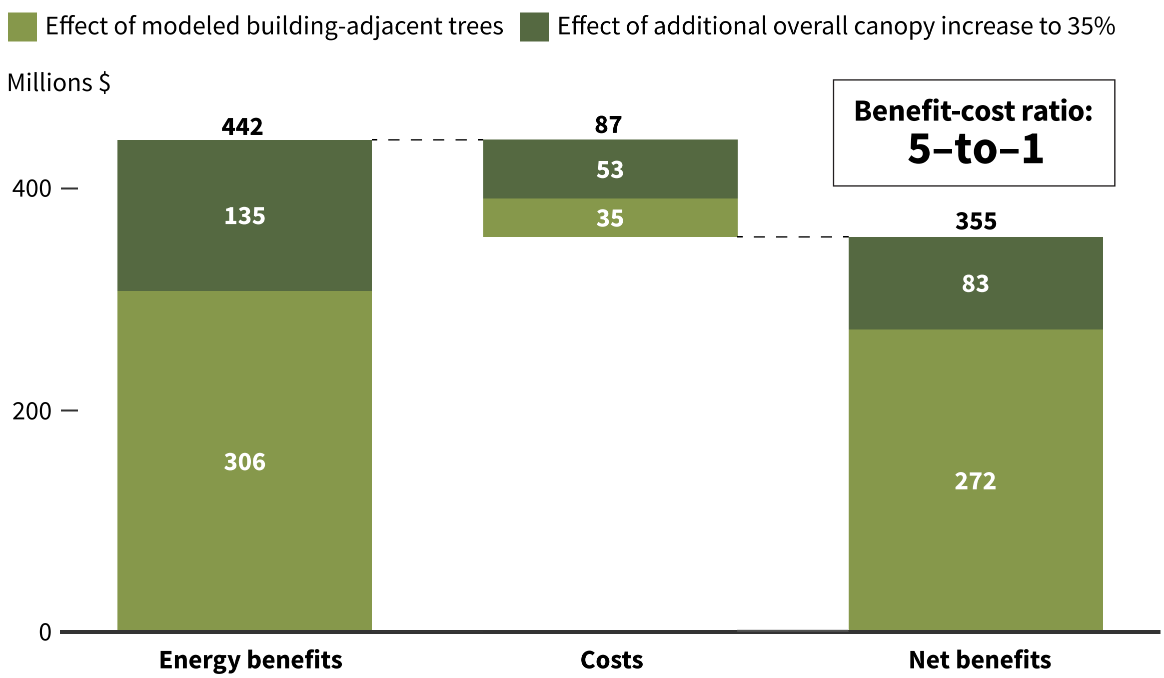
Lowering peak demand also helps support renewable energy advancement by reducing the need to build out energy storage as a complement to solar and wind power. This would reduce SMUD's capital outlay, while supporting its goal to provide 100% clean electricity in 2030.[121] Though Sacramento's population is only expected to grow modestly, average temperatures in the region are likely to rise with global warming.[122] The impact of urban nature on reducing peak demand can partly counteract the expected demand increase from rising temperatures and an increasing population.

Economic Results

We found that planting urban trees can provide up to $355 million in net energy savings (from reduced energy consumption and avoided investment in power generation capacity) between 2022 and 2050. Citywide, we model that urban trees have a benefit-cost ratio up to 5 in Sacramento. Adding urban trees will cost about $23 million initially and $87 million cumulatively through 2050, but will pay for themselves within a few years. Even without accounting for avoided investment in power generation (just quantifying the avoided energy consumption spend), payback can arrive within 11 years of planting. Exhibit 13 displays the benefit-cost ratio for tree planting in Sacramento (assuming two building-adjacent trees per modeled building).

Exhibit 13

Urban trees in Sacramento — projected costs and energy savings, 2050



Effect of modeled building-adjacent trees reflects planting two trees by about 53,000 buildings for a total of about 107,000 trees. Totals do not sum due to rounding.

Source: RMI

Tree planting, whether adjacent to buildings, along streets, or in parks, provides a rapid financial return. Planting one or two building-adjacent trees will cost $2 million to $4 million initially, but can provide $140 million to $270 million in net energy benefits through 2050. We assumed planting all trees in year one, leaving annual maintenance (and, as needed, replacement) costs in subsequent years. Even without the avoided generation benefit factored in, payback occurs after just five years.

Increasing urban canopy cover to 35% (aligned with Sacramento's goal) and planting up to 628,000 trees (including building-adjacent trees) would cost $23 million initially and $2.3 million a year in maintenance. However, the model tree canopy increase would provide over $80 million in net energy benefits by 2050, with a payback period of about 16 years. SMUD estimates a planting potential of approximately 5 million additional trees in the city, indicating that the features we modeled are quite feasible.

In Sacramento, as in Abidjan, the projected energy consumption savings for green roofs alone do not outweigh the initial installation costs.

Insights

Emissions reduction potential hinges on the power generation mix.

Although Sacramento and Abidjan see similar energy consumption savings, cumulative emissions savings by 2050 are as much as 20 times greater in Abidjan, largely driven by the higher emissions intensity of Abidjan's grid.[123] This shows that urban nature's ability to lower peak demand is particularly important for helping the grid keep up with growing demand, reducing the need to build out additional energy generation, transmission, and distribution infrastructure, and avoiding the less efficient and more polluting fossil-fuel-based generation that typically meets peak demand.

We assumed that heat and associated AC use are the key drivers of peak demand. While this has historically been true, increased electrification might shift the hours of peak demand in some cases. Forecasts vary for how demand and consumption may shift in Abidjan and Sacramento, driven by population and economic growth, AC use, transportation and vehicle electrification, and energy efficiency measures. We account for some scenarios in both cities, reflecting the uncertainty in demand and consumption.

Cost savings hinge on the adoption of mechanical cooling.

Payback from energy savings arrives more slowly in Abidjan, driven by lower rates of AC adoption. Although increasing canopy citywide lowers heat stress for all buildings, household energy savings are limited to those using AC. Abidjan's share of households and buildings with AC is expected to grow but to still remain under 20% by 2050.[124]

The placement of trees and their orientation to buildings is critical.

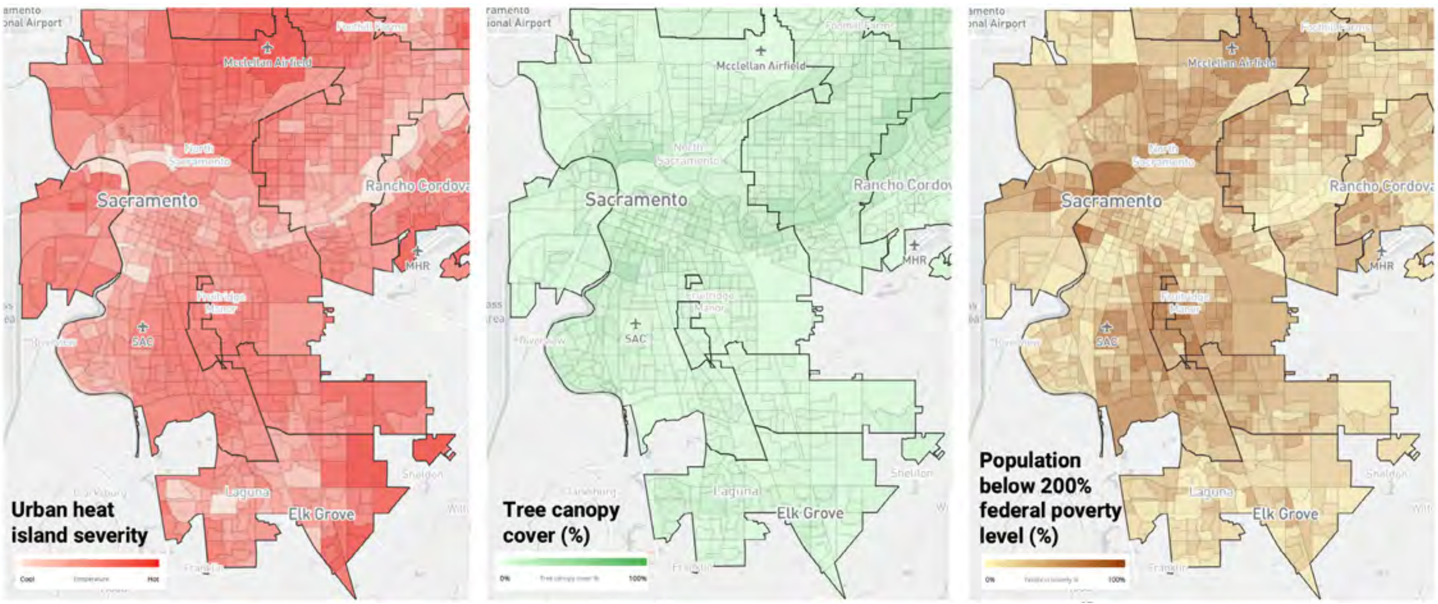
For building-adjacent trees, orientation is critical. In the northern hemisphere, trees planted to the west of buildings provide shading at the warmest times of day. On average, in Sacramento, western-oriented trees provide two to three times the energy savings of southwest-oriented trees and three to four times the energy savings of south-oriented trees, and in Abidjan, one to two times and two to three times, respectively.[125]

In cities with winter heating demand in buildings, including Sacramento, the shading from building-adjacent trees can reduce solar heat gain, which can increase heating energy demand. This effect is greater (in the northern hemisphere) for trees planted to a building's south. Planting trees to a building's southwest or west has less heating penalty, and planting deciduous trees that lose foliage in the winter mitigates this penalty even more.

The cooling and energy savings potential of urban nature is greatest in low-income neighborhoods.

Taking Sacramento as an example, the correlation between inadequate tree canopy, poverty, and high average temperatures is clear. Among census block groups where median household income is at 80% or below the city's median, the average measured surface temperature is over 1.5°C (2.7°F) higher than the average in census block groups averaging at or above the city's median income.[126] Exhibit 14 shows how the urban heat island effect varies across Sacramento neighborhoods. These same areas are on average 4–5 percentage points farther from the canopy cover threshold for increased thermal comfort and health benefits, which American Forests generally sets around 40% for Sacramento neighborhoods.[127]

Exhibit 14 **Urban heat compared with tree canopy and poverty rates across Sacramento**



Source: American Forests, Tree Equity Score, 2021, https://treeequityscore.org

The contrast is even starker when looking at specific block groups. Communities with just a 10% tree canopy cover can be as much as 5.5°C (10°F) hotter than communities with 30%–40% or more tree canopy cover closer to downtown. This inequity tracks with median household income, but it also tracks with racial demographics. Those areas at 80% or below the city's median household income average over 70% people of color, compared with under 50% for the areas at or above the city's median. By targeting new urban nature features to communities that are currently under-canopied, cities can reduce inequities and fight high energy burdens. Planting two building-adjacent trees can save a household as much as $255 on energy annually by 2050.[xiii]

xiii Energy burden is the share of household income spent on energy.

Stormwater Management – Carbon and Cost Savings

Grey urban stormwater management — such as large retention basins, channels, pipes, and tanks — is emissions-intensive and requires a substantial amount of concrete, steel, and plastic. We estimate that the embodied carbon in the materials of Houston's existing stormwater pipe network is about 300,000 mt CO_2e — about equal to the carbon sequestered by 1,400 square kilometers of forests in a year.[128]

As cities face increasing water management challenges from extreme rainfall and urban growth, the embodied carbon of stormwater infrastructure could be significant. We modeled how urban nature can capture rainfall and reduce runoff with lower carbon and lower cost than grey infrastructure in Ahmedabad and Houston (Exhibit 15 summarizes our high-level results).

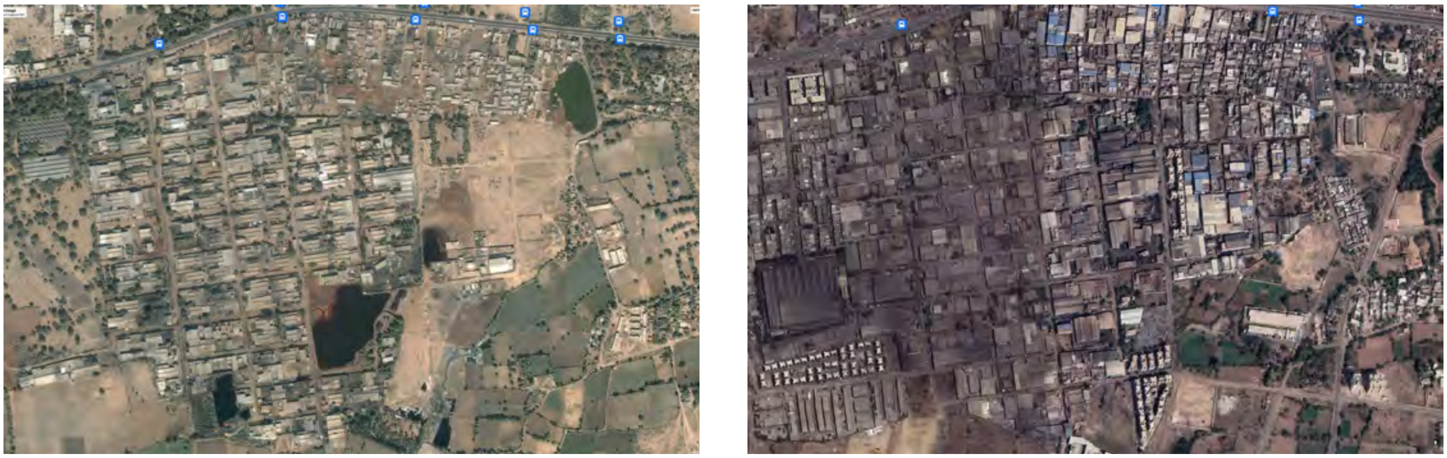
Exhibit 15

Modeled natural features improved stormwater outcomes, were less emissions-intensive, and cost less than the grey alternative in Ahmedabad and Houston

	Ahmedabad	Houston
Improved stormwater management by 2050	Retain 1.7 million more cubic meters of runoff from a 13-cm rainfall event by maintaining 15% green cover	Retain 3–5 more cm of rainfall, reducing runoff by 7%–10% and increasing infiltration by 4%–5% increase compared to grey infrastructure
Avoided embodied carbon emissions through 2050 compared to grey infrastructure	21,000–46,000 mt CO_2e (40%–87%)	116,000–199,000 mt CO_2e (13%–22%)
Construction and maintenance cost savings through 2050 compared to grey infrastructure	\$173 million–\$323 million (50%–92%)	\$2.6 billion–\$12 billion (10%–44%)

Source: RMI

In Ahmedabad, proactive conservation of lakes and wetlands in new growth zones can capture intense rainfall for less cost and embodied carbon than concrete basins. Past development has filled in and paved over many of Ahmedabad's numerous lakes and wetlands, eliminating their crucial ability to absorb flooding. We found that, if preserved or enlarged, the existing lakes and wetlands across a 94 km^2 eastern expansion zone can handle the same volume of stormwater runoff as grey infrastructure, saving money and carbon. By preserving these natural lakes and wetlands, the city can also guide residential and commercial development away from low-lying areas, increasing resilience to flooding and reducing the need for energy- and cost-intensive pumping to mitigate flooding.



Development in Ahmedabad has often paved over existing lakes and wetlands. On the left is a satellite image of eastern Ahmedabad from 2000, showing four lakes (dark blue areas in the bottom left and middle, and dark green areas in the upper right). The 2022 image on the right shows development on those sites. Source: Google Earth, 23°01'14.77"N 72°40'59.24"E, accessed August 15, 2022

In Houston, distributing small green stormwater features, including rain gardens, infiltration trenches, small grassy parks, and other low-impact features across the existing built landscape can capture more stormwater runoff than large grey infrastructure for less embodied carbon and cost.

Beyond carbon and cost savings, urban nature and low-impact hybrid features reduce average annual runoff and increase infiltration as they capture and infiltrate rainfall, whereas concrete basins and tanks hold water temporarily and release it later. By infiltrating stormwater runoff, urban nature augments groundwater recharge.[xiv] Houston and Ahmedabad are projected to have high and extremely high water stress in 2030, respectively. Stormwater management strategies that increase infiltration and aquifer recharge can help decrease the need for energy-intensive future water sources like desalination and potable wastewater reuse.[129]

In both Ahmedabad and Houston we modeled three scenarios: a green scenario, a low-impact grey (Ahmedabad) or hybrid green-grey (Houston) scenario, and a grey infrastructure scenario. In both cities, the green scenario relied on primarily nature-based approaches (preserving existing lakes in Ahmedabad, adding new rain gardens in Houston); the low-impact grey or hybrid green-grey scenario relied on a mix of nature-based approaches and lower embodied carbon grey infrastructure (such as rock-and-wire-mesh-lined lakes in Ahmedabad and sand filters in Houston); and the grey infrastructure scenario relied on building out new concrete-based stormwater capture and retention infrastructure.

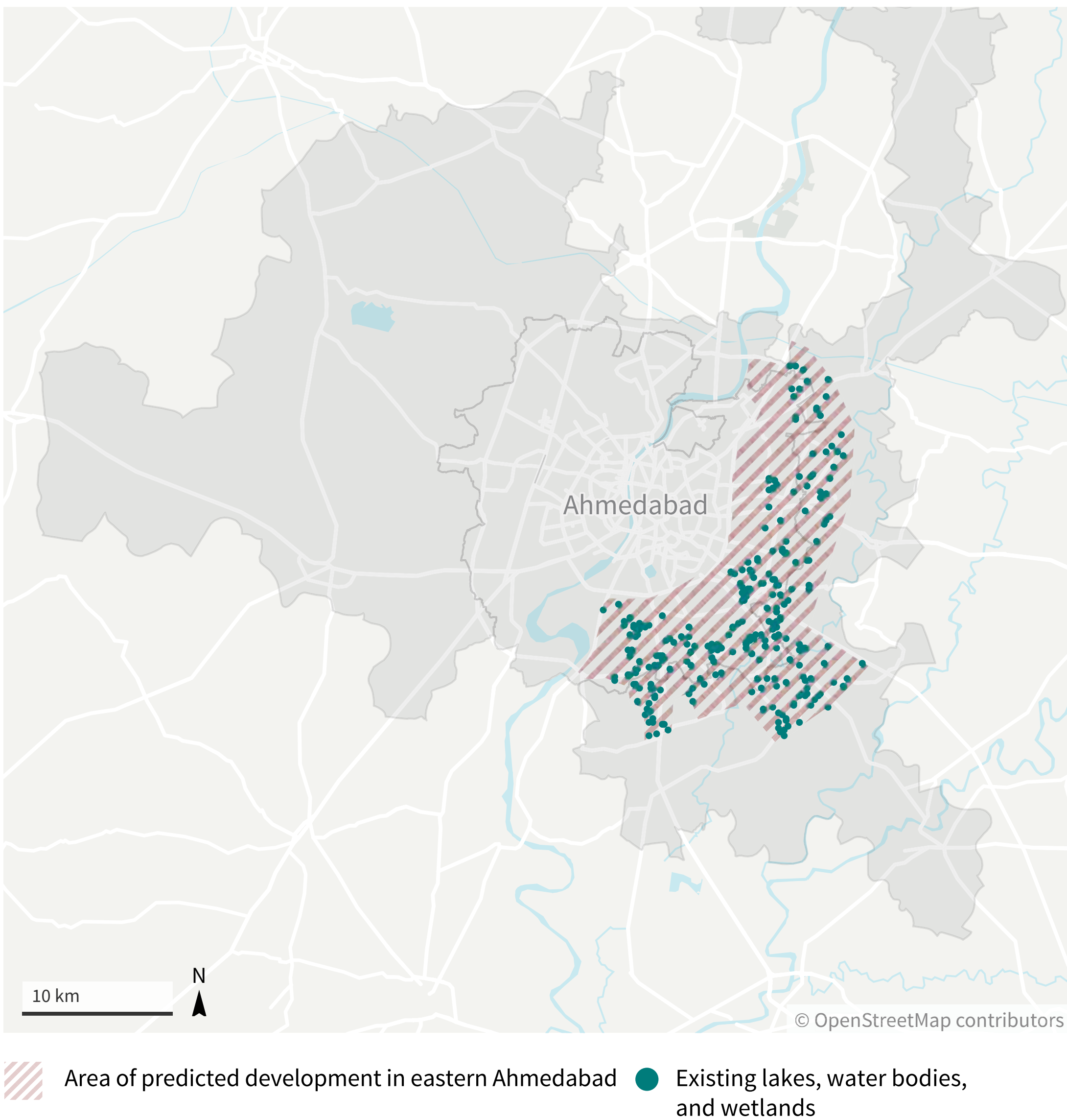
xiv Groundwater recharge is the addition of water to an aquifer by the infiltration of water from the surface (for example, stormwater) through the ground.

Ahmedabad

Ahmedabad has a hot, semiarid climate. It experiences a monsoon season, where an average of 78 cm (31 inches) of rain falls between June and September and very little rain falls the rest of the year.[130] This brief, intense period of rainfall often causes significant flooding in the city. For example, on July 11, 2022, over 11.5 cm (4.5 inches) of rainfall fell in under three hours — Ahmedabad's highest one-day rainfall in July in the past five years.[131] The flooding submerged cars, inundated homes and businesses, and created sinkholes.[132] Capturing and infiltrating rainfall during the brief monsoon season is key to reducing flooding in Ahmedabad, and the city has many existing lakes that can be used for this purpose (Exhibit 16).

Exhibit 16

Existing water bodies in Ahmedabad's eastern expansion zone



Meeting the housing and development needs of a growing population in eastern Ahmedabad would require 94 square kilometers, which is approximately 40% of the pink shaded area. Gray borders and shading indicate the boundaries of the city proper and greater metropolitan region.

Source: RMI; Google Earth Pro; AUDA 2021 Zoning[133]

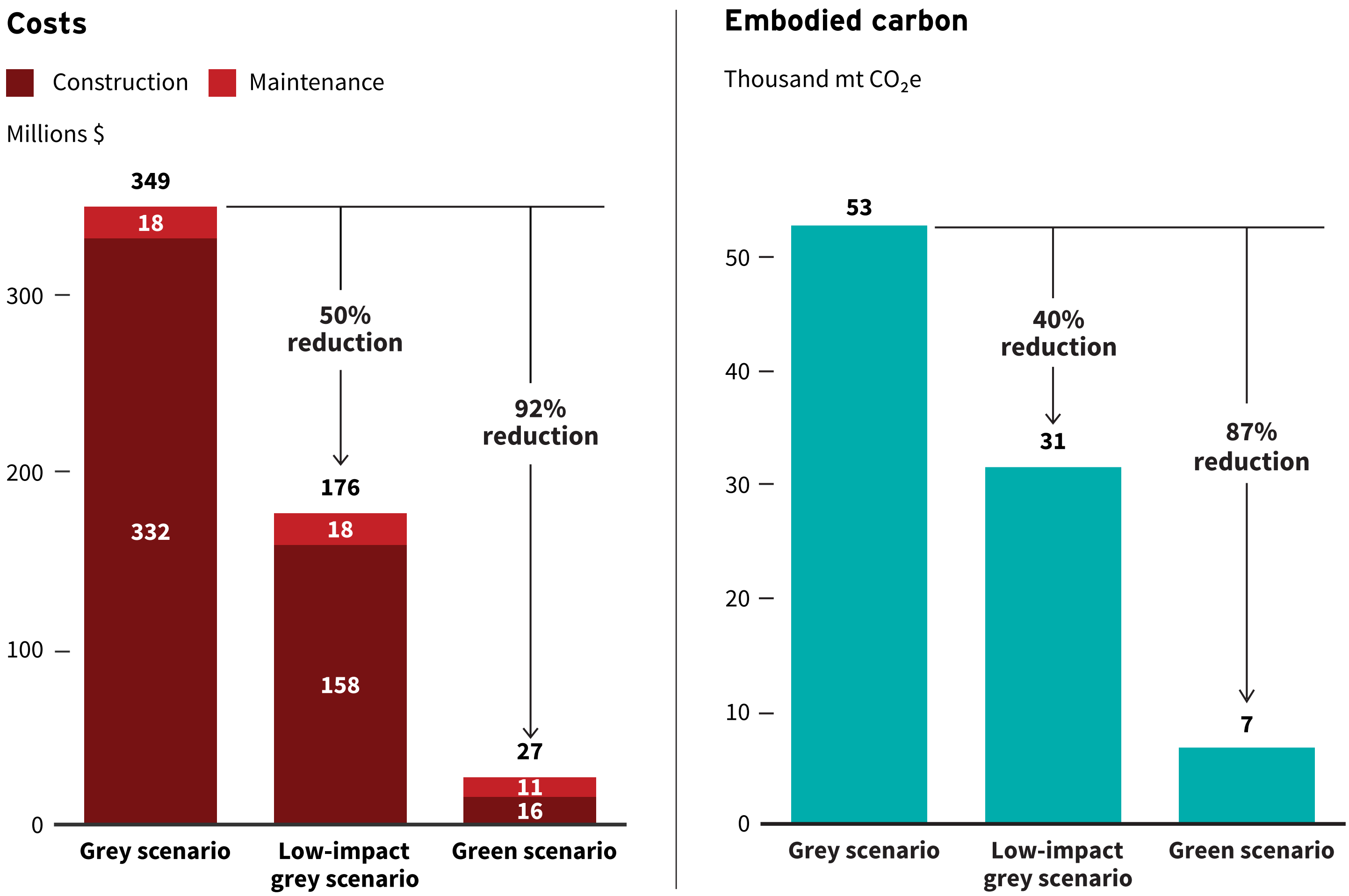
Ahmedabad is the fifth-largest city in India, with 8.3 million people in 2019 and an anticipated 12.4 million by 2050 in its metropolitan area (an annual growth rate of 1.5%).[134] The city is dense and fast-growing, with an average of 10,500 people per square kilometer (27,200 people per square mile — approximately the same density as New York City) and little undeveloped space in its urban core.[135] Ahmedabad is densifying as it grows, but it still needs to expand beyond its current borders. Our modeling focused on a 94 square-kilometer area east of the city (which represents approximately 20% of Ahmedabad's total new growth area) that is beginning to develop.

Flooding in Ahmedabad. Source: Photo (left) by Amarjeetarc via Wikimedia, licensed under CC BY-SA 4.0; photo (right) reproduced by permission from NDSAP of the Government of India by Ministry of Home Affairs via Wikimedia.

In Ahmedabad, our results demonstrate that proactive conservation and development of green infrastructure in newly developing areas can capture intense monsoon rainfall more sustainably and cost-effectively than grey alternatives.

Exhibit 17 summarizes our findings. As a baseline, the high-impact grey scenario (concrete-lined lakes) would cost $349 million by 2050 and result in 52,700 mt CO_2e of embodied carbon. Taking a green approach to preserving or enlarging 83 lakes instead of building new concrete basins can achieve a 92% reduction in costs and an 87% reduction in emissions, all while handling the same volume of stormwater runoff. Under this scenario, the city could avoid 46,000 mt CO_2e in cumulative embodied carbon through 2050 and save over $323 million.[136] The low-impact grey approach (rock-lined lakes) would save $173 million in cost and 21,000 mt CO_2e (a 40% savings) compared with high-impact grey infrastructure.

Exhibit 17 **Using nature to manage stormwater in Ahmedabad's eastern expansion zone — projected costs and embodied carbon under three scenarios, 2050**



Grey scenario includes concrete-lined lakes. Low-impact grey scenario includes lakes lined with rock and wire mesh. Green scenario includes preserved natural lakes. All scenarios assume maintaining 15% green cover in the eastern expansion zone. Maintenance emissions are minimal in comparison to construction. This excludes rehabilitation (material replacement) emissions.

Source: RMI

Houston

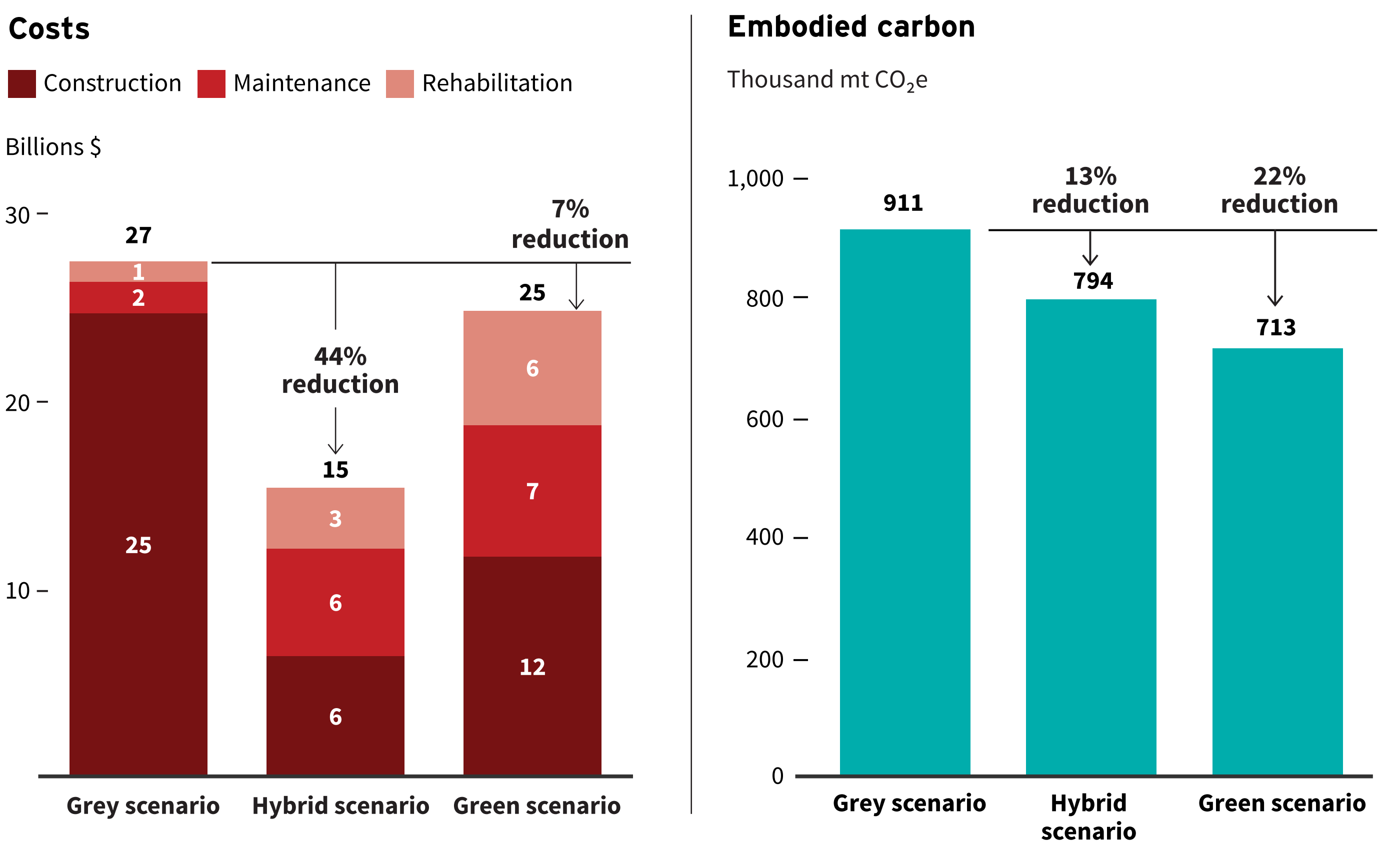
Houston is the fourth-largest city in the United States, with a population of 2.3 million and a projected 2050 population of 3.3 million (an annual growth rate of about 1.1%).[137] Houston's population density is 1,350 people per square kilometer (3,500 people per square mile), almost 90% less dense than Ahmedabad.[138] Currently, the city has 18% tree canopy cover.[139]

Houston has a humid subtropical climate, experiencing year-round rainfall.[140] It also faces extreme weather events and hurricanes — in 2017, Hurricane Harvey brought over 127 cm (50 inches) of rain in a few days, flooding more than 300,000 homes.[141] Houston is known as the Bayou City, named for its marshy, slow-moving rivers called bayous. Historically, vast prairies and bayou channels successfully captured rainfall and conveyed excess runoff to the Gulf of Mexico. Today, flooding is common due to widespread development and often compounds downstream. This, plus Houston's very flat topography, make stormwater management difficult.[142] Unlike Ahmedabad, which has the opportunity today to get ahead of its growth, Houston must, for the most part, work with its existing urban form.

Reductions in Costs

In Houston, the green infrastructure scenario is a distributed system of rain gardens, infiltration trenches, and small grassy parks. The hybrid infrastructure scenario is a combination of green features and small concrete features, and the grey infrastructure scenario consists of large concrete detention basins and tanks. Compared with the grey scenario, the green scenario saves $2.6 billion in construction and maintenance costs, a savings of 10% over 30 years. Green infrastructure would cost $24.7 billion compared with $27.5 billion for traditional grey infrastructure (Exhibit 18). The green scenario requires about half the initial construction costs as the grey scenario but requires more maintenance and rehabilitation costs over time. While the green scenario requires more area to capture the same amount of runoff — 19.2 square kilometers through 2050 compared with 6.4 square kilometers for the grey scenario — the cost per area is substantially less, $1.3 billion per square kilometer compared with $4.3 billion per square kilometer for the grey scenario. The area used in the green scenario also provides community amenities and other benefits.

Exhibit 18 Managing stormwater across Houston's built-up area — projected costs and embodied carbon under three scenarios, 2050



Grey scenario includes large concrete detention basins, retention basins, and storage tanks. Hybrid includes rain gardens, small detention basins, infiltration trenches, and sand filters. Green includes rain gardens. Includes lifecycle construction, maintenance, and rehabilitation (replacement) costs (left). Maintenance emissions are minimal in comparison to construction (right).

Source: RMI analysis, CLASIC[143]

The hybrid scenario has the highest cost savings. This scenario costs $12.1 billion less in construction and maintenance than the grey scenario, a savings of 44% over 30 years. We found that hybrid infrastructure would cost $15.4 billion. The hybrid scenario also requires more area than the grey scenario — 17.6 square kilometers through 2050 — for a cost per area of $875 million per square kilometer.

Reductions in Embodied Carbon

The green scenario has the highest carbon savings potential, avoiding 199,000 mt CO_2e in cumulative embodied carbon through 2050, a 22% savings compared with the grey scenario (equal to the carbon emissions from nearly 39,000 homes' electricity use for one year[144]). The hybrid scenario could save 116,000 mt CO_2e, or 13%, in embodied carbon by 2050 compared with the grey scenario. For additional embodied carbon savings, Houston can use less emissions-intensive materials. Although not considered in our model, low-carbon concrete is a complementary strategy to reduce embodied carbon that construction companies are already using in projects.

Reductions in Runoff and Pollutants and Increases in Infiltration

Compared with grey infrastructure, green features retain 4.8 cm (1.9 in) more potential runoff, for a 10% decrease in runoff, and increase annual infiltration by 3.6 cm (1.4 in), a 5% increase. Hybrid features retain 3.3 cm (1.3 in) more runoff, for a 7% decrease in runoff, and allow for 2.5 cm (1 in) more infiltration, a 4% increase. Since Houston is projected to experience high water stress by 2030, all rainfall captured and converted into groundwater recharge is crucial.[145]

Additional Benefits

The green scenario also creates economic, environmental, and social co-benefits that grey infrastructure does not. For our Houston analysis, we used a hydrological modeling tool that also estimates co-benefits; it showed that the green scenario creates four times the economic co-benefits, five times the environmental co-benefits, and over three times the social co-benefits of the grey scenario.[146]

Insights

Stormwater management requires tailored approaches based on city growth curves.

Ahmedabad's projected rapid expansion into previously undeveloped areas provides a unique opportunity to get ahead of growth and protect existing natural features like lakes and wetlands. In doing so, Ahmedabad can manage flooding and increase resilience at a lower cost and with lower embodied carbon.

Houston's low density allows for infill of many smaller stormwater management features. Analyzing Houston's existing landscape can identify the best locations for different types of small features. Adding green features, especially in low-value impervious areas like existing parking lots or vacant lots, reduces runoff and provides amenities for the community. Additionally, hybrid features like infiltration trenches and grassy sunken parks can be located where green features are not preferred or feasible, and in the case of small parks, can function as recreation during dry periods.

Green infrastructure investment should prioritize historically disadvantaged, low-income neighborhoods, which are often the most flood-prone.

In majority Black and Latino neighborhoods in northeast Houston, frequent flooding currently impedes mobility for people traveling to work and for senior citizens.[147] Houston neighborhoods with the highest social vulnerability — reflective of factors like poverty, lack of vehicle access, ethnicity, and age — were also the most damaged by flooding during Hurricane Harvey in 2017.[148] As Houston builds more green and hybrid stormwater management features, the city can reduce embodied carbon, costs, and flooding and directly improve residents' safety and quality of life, especially in these more vulnerable neighborhoods.

Minor street flooding near Houston (left). Severe flooding after Hurricane Harvey in August 2017 (right). Photo by SC National Guard, online image, Flickr

In Ahmedabad, informal low-income settlements often establish in low-lying areas, which means the lowest-income residents are more likely to be exposed to flooding from monsoon rain events. As the city grows, it can be intentional about preserving low-lying natural areas and lakes for stormwater management and simultaneously preventing communities from settling where they will repeatedly face extreme flooding.

Transportation — Energy, Carbon, and Cost Savings

Street trees can support existing walking, biking, and public transit use and encourage further “mode shift” away from private vehicle use. This effect of street trees on driving choices, especially for short trips in activity-dense urban areas, has not been well studied. Our analysis of Austin and Curitiba supports the idea that street trees can reduce private vehicle use, VKT, and transportation emissions. Exhibit 19 summarizes our results from modeling the addition of street trees to key streets and transit stops.

Exhibit 19

Modeled natural features supported reduced car use in Austin and Curitiba, lowering household transportation costs and improving citywide health outcomes

	Austin	Curitiba
Annual vehicle kilometers traveled reduction by 2050	43 million km (0.4%)	16 million km (0.2%)
Individual household transportation cost savings	\$2,500–\$4,250 (21%–35%)	\$700 (7%)
Citywide health cost savings through 2050	\$1.5 billion	\$1.1 billion

Percent values in parentheses reflect shares of current-day baselines. Results for Austin reflect modeling trees along streets and in the areas around transit stops; results for Curitiba reflect street trees only.

Source: RMI

Austin aims to lower car use from 70% of 2020 commute trips to 50% by 2039, planning for biking, walking, and transit to increase from 10% to 25%.[149] Holding other variables (including walkability score, zoning type, transit frequency, and population density and income) constant, we observed a 4% reduction in car use between otherwise similar shaded and unshaded Austin streets and two fewer car trips per day between otherwise similar shaded and unshaded transit catchment areas.[xv] Our research indicates that increasing tree canopy cover to 40% in under-shaded areas across Austin could decrease annual VKT by 31 million km in 2035 (0.3% of Austin’s 2019 VKT) and by 43 million km in 2050 (0.4% of 2019 VKT).[150]

xv A transit catchment area is the total area within a 0.8 km radius of a transit stop, representing the “last mile” trip from the transit stop to a rider’s destination.

This would reduce emissions by 3,700 mt CO_2e in 2035 and 3,500 mt CO_2e in 2050 (approximately 0.1% of Austin's transportation emissions in 2017) — even after accounting for increased adoption of EVs and a cleaner electric grid to charge them.[151]

Unshaded (Woodrow Avenue, left) and shaded (South 5th Street, right) streets in Austin. Source: Google Earth, 30o33', -97o73' (left) and -30o26', -97o76' (right), accessed August 15, 2022

In Curitiba in 2016, 45% of residents used public transit, 20% walked, 5% cycled, and 22% used personal vehicles.[152] However, Curitiba has recently experienced challenges maintaining its high bus ridership and active transportation, and car use is increasing.[153] The city intends to reverse this trend by reducing wait times and commute duration by providing more frequent bus service.[154] Urban nature can also help with these goals. Holding other variables constant, we observed a 5% reduction in car use between pairs of otherwise similar shaded and unshaded Curitiba streets. We found that increasing tree canopy cover to

40% on under-shaded streets across Curitiba could reduce annual VKT by 15 million km in 2035 (0.2% of Curitiba's 2021 VKT) and by 16 million km in 2050 (0.2% of 2021 VKT).[155] Curitiba would reduce emissions by 1,100 mt CO_2e in 2035 and 500 mt CO_2e in 2050 (0.05% and 0.02% of its 2021 transportation emissions).[156]

While these overall emission reductions may be small, reduced car usage also immensely improves a community's health, financial savings, and subjective well-being.[157] In Austin, the 2035 and 2050 VKT reductions are equivalent to taking 990 and 4,200 cars off the road for the entire year.[158] Decreased air pollution saves the community $550,000–$698,000 in reduced mortality. Lower VKT also reduces the risk of traffic crashes, avoiding four to six deaths and injuries annually through fewer vehicle collisions with pedestrians (translating to $4.2 million–$5.8 million in value annually). In addition, a typical Austin household that reduces its car use can save $2,500–$4,300 per year (21%–35% of 2022 average household transportation costs in Austin), depending on whether they switch to public transit or biking and walking.[159]

In Curitiba, the 2035 and 2050 VKT reductions are equivalent to removing 1,800 and 2,000 cars from the road for a year, saving $265,000 or more in annual health costs from decreased pollution.[160] A reduction in car use also prevents two pedestrian deaths or injuries annually from collisions, a value of $2 million annually. Furthermore, a Curitiba household switching from driving to biking or walking could save $700 per year (7% of 2017 average household transportation costs).[161]

Tree-shaded streets in Curitiba (left) and in Austin (right). Source: Alfribeiro via iStock (left) and Compass (right)

Street trees also increase heat safety for residents who rely on biking, walking, or taking the bus regardless of shading. These residents face health risks to reach essential destinations, especially in hot and humid environments. Reducing heat exposure is crucial for community resilience, and addressing tree cover inequities along transportation corridors can decrease health disparities.

Street trees will not singlehandedly eliminate transportation emissions, but they can reinforce existing transportation mode shift strategies. For street trees to successfully encourage mode shift, less shaded areas must already be primed to reduce car use by having high-quality bicycle lanes, sidewalks, and frequent transit service. These locations must also be close to areas of employment, education, and recreation. In Curitiba, 45 streets (160 km total) already meet these criteria, as do 150 streets (290 km) and 1,765 transit stops in Austin. These streets and transit stops served as the basis for our modeling and present a major opportunity for the self-reinforcing community mode shift behaviors.

For all cities wanting to reduce car use and bolster or maintain high usage of bicycling, walking, and public transit, street trees are an effective, targeted strategy to help meet climate goals and improve community health.

To achieve all benefits from street trees outlined above, Austin needs to plant about 150,800 trees: 9,300 on the under-shaded streets and 141,500 in under-shaded catchment areas. Austin's cumulative 2035–2050 health benefits and transportation savings from street trees are $1.5 billion, far outweighing the $26 million to plant and maintain the trees. Curitiba needs to plant about 16,800 trees on the 45 under-shaded streets. Consequently, Curitiba's 2035–2050 health benefits and transportation savings would total $1.1 billion, much greater than the $2.8 million in planting and maintenance costs. For all cities wanting to reduce car use and bolster or maintain high usage of bicycling, walking, and public transit, street trees are an effective, targeted strategy to help meet climate goals and improve community health.

Austin

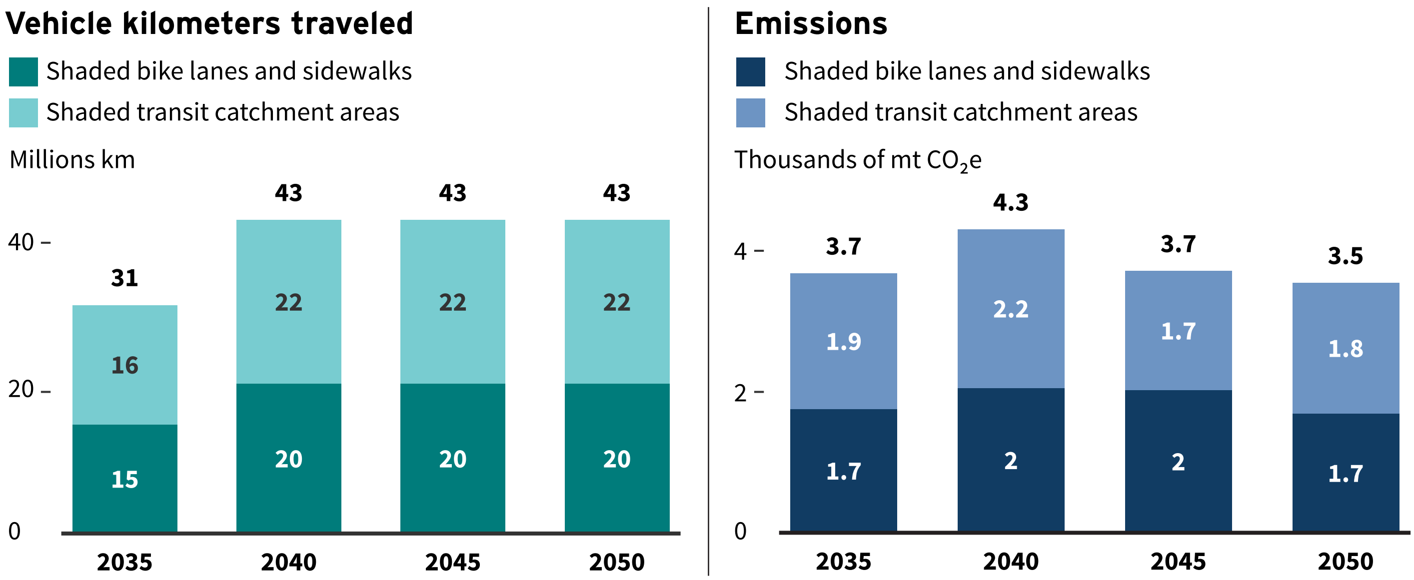
Austin has relatively high car use, which could further increase due to its booming population (a 21% increase from 2010 to 2020, the second-fastest in the state of Texas).[162] However, the city aims to accommodate this growth with more support for public transit and active transportation users, including ongoing development of several large infrastructure projects. Street trees can support the success of these projects, especially to address rising temperatures in Austin's humid climate, which affect both the city's active mode share objectives and residents' health. The average temperature in the city has been increasing by 0.22°C (0.4°F) per decade since 1938, with a projected increase of 2.7°C–5.5°C (5°C–10°F) by the end of this century.[163]

Austin aims to reduce private car use from 70% of current trips to 50% by 2039.[164] The city also aims to increase residents' non-car trips (public transit, biking, walking, carpooling, and trips avoided through remote work) from 20% today to 50% by 2030, and is already utilizing street trees in this effort.[165] The city's Great Streets Development Program explicitly prioritizes active transportation over private vehicles downtown, requiring features like street trees, benches, and bike racks, and ensuring sidewalk space is increased to create a cohesive and comfortable environment.[166]

Reduction in Private Car Mode Share, VKT, and Associated Emissions

We observed a 4% reduction in car mode share between pairs of otherwise similar shaded and unshaded streets in Austin, supporting the city's goals to reduce private vehicle usage. We also observed two fewer car trips per day in shaded catchment areas versus unshaded ones from increased bus boarding. Increasing tree canopy cover to 40% on the 150 Austin streets and inside the 1,765 catchment areas could reduce VKT by 31 million km in 2035 (0.3% of total 2019 citywide VKT) and 43 million km in 2050 (0.4% of total 2019 citywide VKT), as seen in Exhibit 20.[167] For reference, the 150 Austin streets make up 5% of Austin's overall street length, and the 1,765 catchment areas contain 74% of all Austin bus stops.[168]

Exhibit 20 **Modeled added street trees in Austin — annual reduction of VKT and emissions, 2035–2050, relative to a business-as-usual scenario**



Source: RMI

In 2035, 2040, and 2050, Austin's newly shaded corridors and shaded catchment areas are likely to be fairly equally responsible for VKT reduction. More private car trips are avoided per kilometer of shaded street than per square kilometer of shaded catchment area, since Austin's public transit usage is relatively low. However, the high number of applicable catchment areas means the overall VKT reduction is similar for both analyses. As Austin continues investing in public transit infrastructure, concurrent tree planting means transit use from shaded catchment areas will only increase as future commuters feel more comfortable over their entire trip.

Avoided VKT corresponds to a transportation emissions reduction of 3,700 mt CO_2e in 2035 and 3,500 mt CO_2e in 2050. Emissions savings ultimately decrease from both a higher share of EVs (reducing on-road emissions from ICE cars) and a cleaner electricity grid (reducing emissions associated with EV charging). Austin's projected population growth, which is expected to slow after 2040, influences the potential VKT reduction.[169] Lastly, we expect mature tree canopy in the under-shaded areas by 2035 if trees are planted now, although they will deliver benefits to the community in the interim, too.

Reduction in Electricity and Fossil Fuel Consumption

Avoiding use of both EVs and ICE vehicles reduces electricity demand and gasoline consumption. Electricity demand could decrease by 1,000–1,400 MWh in 2035 (the range reflecting EV uptake), equivalent to 0.1% of Austin's projected 2035 EV demand.[170] By 2050, 2,600–5,500 MWh of EV electricity demand could be avoided (0.2% of Austin's projected 2050 EV demand).[171] Gasoline consumption from remaining ICE vehicles would decrease by 1.4 million–1.55 million liters (370,000–410,000 gallons) in 2035 (0.06% of Austin's 2035 projected gasoline demand) and 490,000–1.5 million liters (130,000–400,000 gallons) in 2050 (depending on remaining ICE vehicle stock).[172]

Economic and Health Co-Benefits

Street trees in Austin provide $1.5 billion in health benefits and $260 million in transportation savings through 2050, far outweighing the $26 million required for initial planting and annual maintenance ($5.5 million and $715,000, respectively).

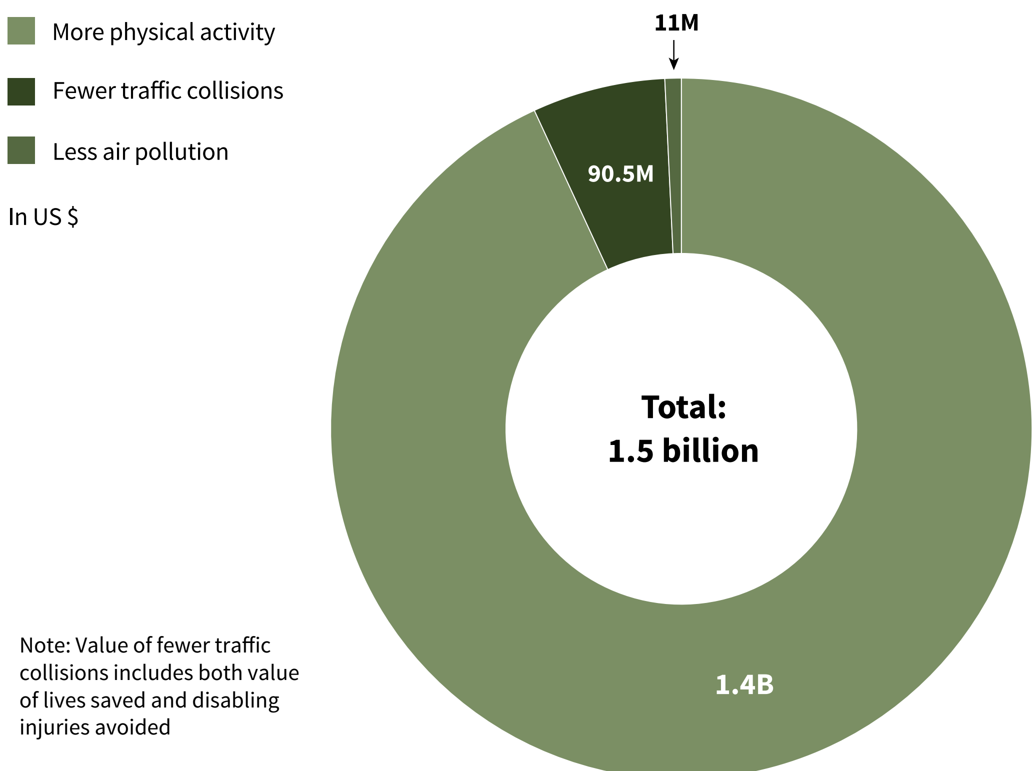
Austin households that switch from driving to biking, walking, and public transit can reduce their transportation expenses. A household that shifts one car round trip every day to cycling or walking could save up to $4,250 each year (35% of 2022 average household transportation costs in Austin[173]). Households shifting one car round trip every day to public transit would need to pay for fares, but could still see annual savings up to $2,530 (21% of 2022 average household transportation costs in Austin).[174]

Lower-income residents could see the largest reduction in transportation cost burdens. Furthermore, communities characterized by high levels of poverty, low levels of formal education, and immigrant or non-White populations use public transit more frequently and are disproportionately exposed to higher temperatures.[175] For these residents, who are already driving less often, street trees can make commuting safer and more comfortable, regardless of any potential transportation savings.

Exhibit 21 shows the health benefits in detail. To achieve these substantial benefits and the transportation savings, Austin would need to plant 9,300 trees along the 150 streets and 142,000 trees within catchment areas to reach 40% tree canopy cover.

Exhibit 21

Modeled added street trees in Austin — cumulative value of lives saved by source, 2035–2050



Note: Value of fewer traffic collisions includes both value of lives saved and disabling injuries avoided

Source: RMI

A recent study independently determined that Austin would require a similar number of trees (149,000) to eliminate disparities in tree cover across neighborhoods.[176] While Austin has high average citywide tree cover (36%),[177] the 20% difference in canopy cover between Austin's high-income and low-income neighborhoods is the widest gap among large US cities.[178] Street trees can lower air and surface temperatures. In 2020, the City of Austin proposed a tree-planting initiative to increase canopy cover in under-shaded locations, where temperatures are generally higher, like lower-income neighborhoods in east Austin. From 2015 to 2020, 60% of tree planting occurred in these areas. Going forward, Austin plans to continue prioritizing tree planting and maintenance in these areas.[179]

Planting street trees to reduce VKT can reduce the risk of injury or death from traffic collisions, improve community health through greater physical activity, and reduce air pollution. The VKT reduction from added street trees could prevent a combined four to six pedestrian deaths or serious injuries annually through 2050, translating to $4.2 million–$5.8 million in value annually.[180] As residents bike and walk more frequently, the additional physical activity would reduce mortality, translating to $65 million–$89 million in value annually. Increased biking and walking on shaded streets deliver more active health benefits than increased bus use in shaded catchment areas. Finally, planting street trees to reduce VKT on Austin's streets and catchment areas would translate to $550,000–$698,000 annually in avoided pollution-related mortality.

Curitiba

Curitiba has robust public transit ridership and high active transportation rates; the city's historical investment in public transit and active transportation provides an excellent template to accommodate growth. However, the share of car trips is increasing. Population growth pushed development beyond areas served by public transportation, and many middle-class users stopped using buses as fares rose and travel times increased.[181] Curitiba now has Brazil's highest car ownership rate, with 1.8 residents per car, and faces similar challenges to Austin from population growth (its population grew by almost five times from 2007 to 2017).[182]

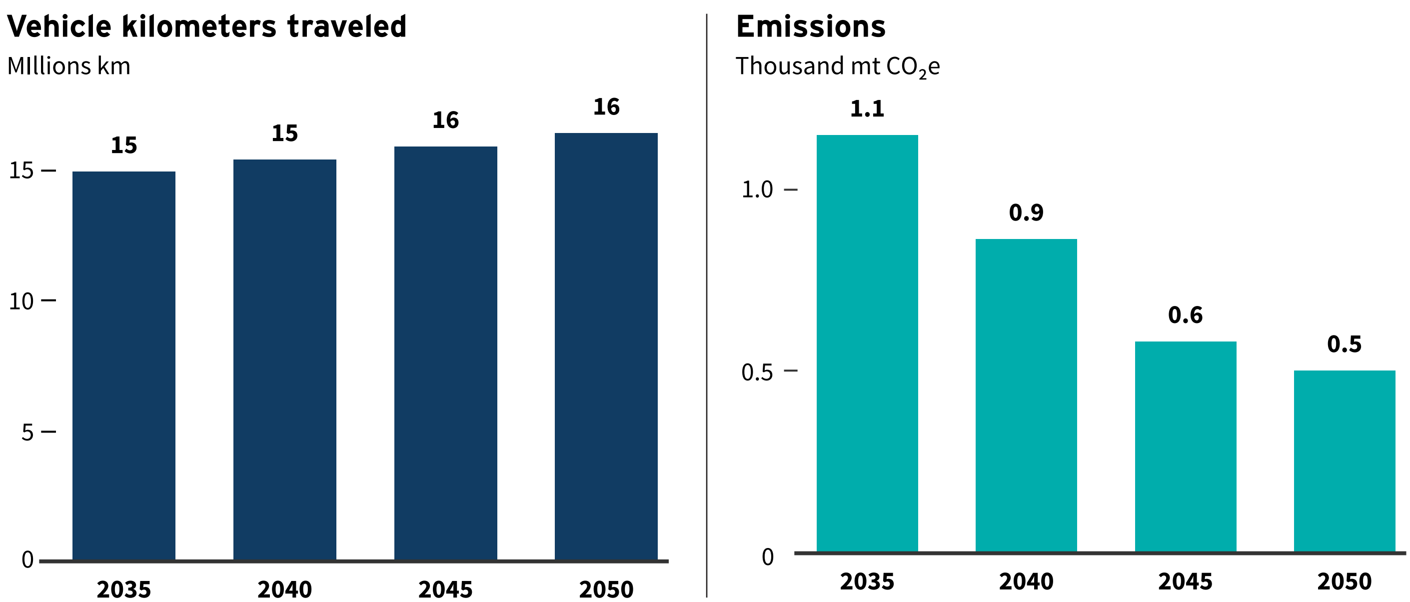
Curitiba's Bus Rapid Transit system connects residents to destinations throughout the city, and pedestrian streets provide safe and convenient commuting routes, but additional investment is crucial to maintain high usage. Source: Marcio Silva via iStock (left) and tupungato via iStock (right)

Curitiba's bus rapid transit network, developed in the 1970s, is internationally recognized and has been replicated in more than 150 cities worldwide.[183] By 2018, the city had also constructed 200 km of bike lanes and, in its 2019 Cycling Plan, committed to reach 400 km by 2025.[184] The city has recently partnered with the New Development Bank for more improvements to the bus rapid transit system in an effort to increase weekday ridership by 5%.[xvi,185]

Reduction in Private Car Mode Share, VKT, and Associated Emissions

We observed a 5% reduction in car mode share between pairs of otherwise similar shaded and unshaded streets in Curitiba, indicating that street trees could help maintain high bus use and active transportation and avoid future attrition during population growth. Increasing tree canopy cover to 40% on 45 Curitiba streets (totaling 160 kilometers) could reduce VKT by 15 million km in 2035 and 16 million km in 2050, relative to business as usual (Exhibit 22).[186] This VKT reduction corresponds to approximately 0.2% of all automobile VKT in Curitiba in 2021 and is equivalent to taking 1,800 cars off the road in 2035 and 2,000 in 2050.[187]

Exhibit 22 **Modeled added street trees in Curitiba — annual reduction of VKT and emissions, 2035–2050, relative to a business-as-usual scenario**



Source: RMI

Avoided VKT is split between ICE vehicles and EVs based on projections of electric vehicle growth through 2050. While we did not study shading in Curitiba's transit catchment areas because of limited data availability, we expect that adding street trees in these areas could have an even greater impact than in Austin because Curitiba's bus mode share is at least five times higher than Austin's. Achieving 40% canopy cover on both streets and catchment areas in Curitiba would conservatively contribute equal reductions in

xvi The New Development Bank was established in 2015 by Brazil, Russia, India, China, and South Africa, and is open to United Nations members.

Adding trees along these 45 streets could reduce Curitiba's household transportation costs by $29 million for 2035–2050. Street trees also create $1.1 billion in health benefits for residents through 2050, yet require only $2.8 million in cumulative planting and annual maintenance.

VKT (as in Austin), doubling Curitiba's potential VKT reduction. Exhibit 22 only shows estimated VKT and emission reductions from increased tree cover on Curitiba streets.

In 2035, reducing VKT by 15 million km would reduce transportation emissions by 1,140 mt CO_2e (0.05% of Curitiba's transportation emissions in 2021[188]), from both on-road emissions and power grid emissions. Unlike Austin, Curitiba's population is projected to increase through 2050, but avoided emissions are still tempered by more EVs and more renewable power. The 2050 VKT reduction (16 million km) corresponds to 500 mt CO_2e of avoided emissions. While adding trees on the 45 streets reduces 2050 emissions by only 0.02% of Curitiba's 2021 transportation emissions, street trees still help Curitiba both achieve full carbon neutrality by 2050 and deliver energy, economic, and health benefits to residents.[189]

Reduction in Electricity and Fossil Fuel Consumption

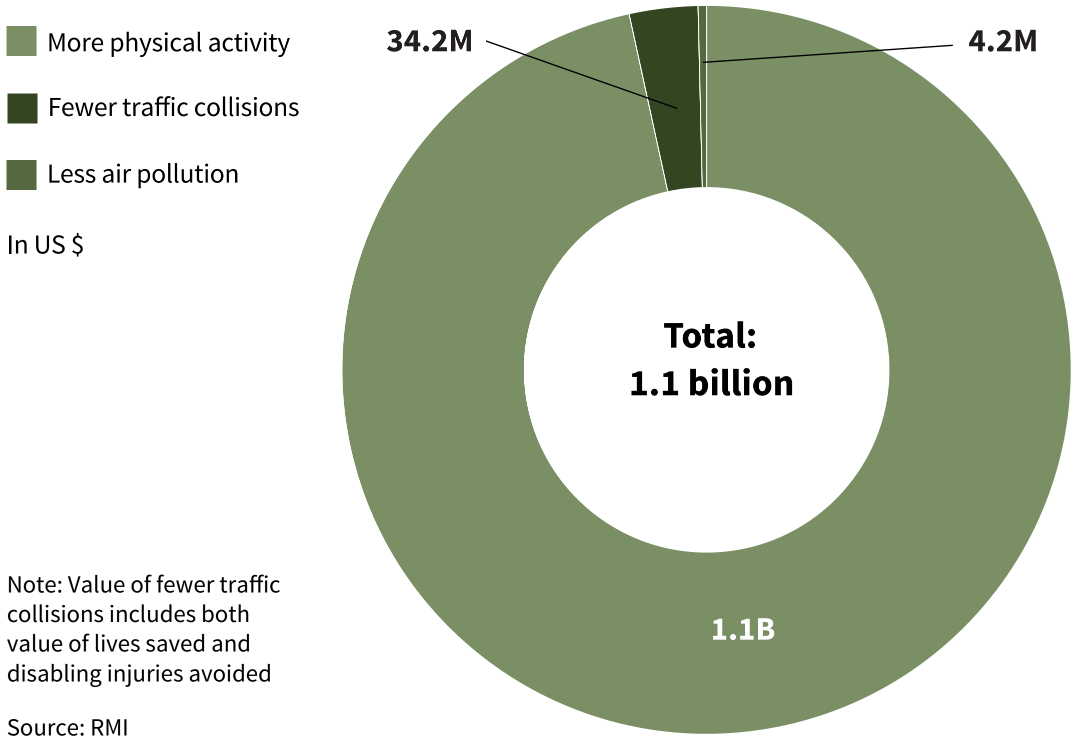
Avoiding use of both EVs and ICE vehicles results in avoided fossil fuel consumption and electricity demand. The 2035 VKT reduction from ICE vehicles corresponds to 420,000–490,000 liters (110,000–130,000 gallons) of gasoline (approximately 0.05% of Curitiba's projected 2035 fuel demand).[190] As in Austin, the range depends on two projections for EV adoption.[191] By 2050, as more residents own EVs, annual fossil fuel savings drop to 170,000–220,000 liters (46,000–59,000 gallons). Avoided electricity demand is additional to fossil fuel saved, with 25–28 MWh (0.04% of Curitiba's projected 2035 EV demand) avoided in 2035 and 44–46 MWh (0.03% of Curitiba's projected 2050 EV demand) avoided in 2050.[192] Curitiba's avoided EV demand is much smaller than Austin's due to the lower numbers of current and projected EVs.

Economic and Health Co-benefits

Street trees in Curitiba provide tremendous value compared with their cost, and Curitiba only needs to plant 16,800 trees to achieve 40% canopy cover on the primed streets, or those streets with high-quality bicycle lanes, sidewalks, and frequent transit service that are close to areas of employment, education, and recreation. Adding trees along these 45 streets could reduce Curitiba's household transportation costs by $29 million for 2035–2050. Street trees also create $1.1 billion in health benefits for residents through 2050, yet require only $2.8 million in cumulative planting and annual maintenance ($612,000 in initial capital and $78,900 in annual maintenance). Exhibit 23 shows the health benefits in detail.

Exhibit 23

Modeled added street trees in Curitiba — cumulative value of lives saved by source, 2035–2050



Note: Value of fewer traffic collisions includes both value of lives saved and disabling injuries avoided

Source: RMI

Street trees can also help Curitiba achieve its Vision Zero goals to eliminate pedestrian deaths from vehicles.[193] The VKT reduction would avoid a combination of two deaths or injuries every year because of fewer vehicle collisions with pedestrians, translating to $2 million in value annually. Reduced mortality from greater physical activity would be worth $65 million to $71 million annually, too.[194] Curitiba residents would also experience improved air quality from reduced VKT worth $265,000–$267,000 each year from 2035 through 2050. Finally, households that shift to active transportation would benefit from reduced transportation costs. Like in Austin, each individual household's savings would depend on how often they use an alternative to driving. A household that shifts one round trip daily from driving to bicycling or walking for a year could save $700 (7% of 2017 average household transportation costs in Curitiba).[195] Lower-income residents in Curitiba could experience reduced economic burden to travel to employment and other destinations, if they are not already using active transportation.

Insights

Further research can strengthen the relationship between street features, including street trees, and transportation mode shift.

In conjunction with existing research and household survey data, our findings suggest that street trees can help cities reduce private vehicle use. A separate analysis determined that microscale features like sidewalks, benches, and street trees are likely to have a statistically significant impact on reducing VKT by 13%.[196] Of respondents to a survey in Phoenix, Arizona, USA, 73% said they would walk more frequently to nearby shops if the connecting paths had a comfortable level of tree shading.[197] Our observations are limited in scope and we did not determine statistical significance; with limited data availability, we focused on intensive analysis of a few locations. We intend to provide conservative estimates and insights into street trees' reduction of car use and thereby encourage further research.

Street trees can encourage transportation mode shift even more in cities with drier climates, and cities with snowier climates can see improvements, too.

Austin and Curitiba's high ambient humidity reduces trees' thermal cooling effects, yet in both cities we still observed reduced car use in higher-canopy areas. Less humid cities could experience an even greater increase in pedestrian comfort and mode shift due to street trees — for example, Phoenix plans to create 100 shaded "Cool Corridors" by 2030.[198] Colder cities can also benefit from street trees. Cities that still prioritize pedestrian and bicyclist comfort in winter, like northern European cities and Boulder, Colorado, address the two most important factors for users: frequent maintenance during snow season, often even before streets are plowed for cars, and protected infrastructure for biking and walking.[199]

Developing and Scaling Innovative Financing Solutions

Urban nature already provides substantial value, but more investment is urgently needed to unlock its full potential. Mobilizing this investment requires public and private actors to scale up their efforts and to work together to develop new funding and financing models.

Public finance has a foundational role in supporting urban nature, and a growing number of local governments are branching out beyond budgetary spending to use fiscal levers, like tax increment financing (TIF), and policy levers, like zoning requirements, to deploy urban nature. But local and national governments and development finance institutions need to use all the tools at their disposal, including those that attract private investment.

Governments should not have to bear all of urban nature's costs given the benefits that accrue to private businesses, utilities, property insurers, healthcare payers, and the public generally. The private sector is starting to approach urban nature as an opportunity, showing more interest in, for example, public–private partnerships and carbon credits from cities. But progress has not matched the need or potential. This chapter explores some of the financing options that are ready to scale up now and some that merit more attention, as well as ways to involve a range of private sector actors.

How to Align Public Sector Budgeting with Urban Nature's Value

Most financial support for nature globally comes from local, regional, and national governments. The role of governments makes sense given that many of urban nature's benefits are public goods. But the small fraction of their budgets that cities devote to nature is incommensurate with its value.[200] Local governments have a responsibility to protect, support, and maintain infrastructure and public space, and nature is part of that responsibility. All too often, though, cities treat nature as one of the most discretionary parts of their discretionary budgets.

However, cities may actually be overspending when they *don't* use green infrastructure by default. For example, our stormwater management analysis shows the cost savings that green and hybrid infrastructure provide compared to grey infrastructure. This points to the importance of a "green first" approach to policy and infrastructure: identifying where natural solutions will work before turning to concrete and steel, and budgeting accordingly.

In addition to providing sufficient dedicated spending for nature, cities can also lower the cost of deploying urban nature by integrating it with other priority budget items or projects or taking advantage of key policy and development trigger points (e.g., planning new development, initiating city planning processes, revising or eliminating exclusionary zoning, initiating major infrastructure projects).[201] For example, major infrastructure capital improvement projects offer an opportunity to use green elements instead of grey where possible (reducing up-front costs) and to add green elements (at a fraction of total project costs).[202] In addition to lowering the cost of urban nature investments, this approach integrates nature into well-funded projects, and the potential scale of these investments could be much larger than what the city would fund for a nature-only project. Strong policy support would still be important to ensure urban nature doesn't get cut from projects, for example in a street redesign when planned elements are competing for space.

Finally, cities need to raise revenue and access private finance. Significant responsibility for investment lies with the private sector, but a strong demand signal from cities can spur progress. Building relationships with impact investors, real estate developers, and companies with meaningful climate pledges will pave the way for public–private partnerships and new resource streams.

As critical funders of local governments, regional and federal governments need to step up as well. They can increase funding available to cities, stand up and capitalize green banks with dedicated products for supporting urban nature, and provide capacity building and technical assistance to local governments working to access national or international resources. Local governments are often highly resource-constrained, making it even harder for them to explore new approaches and activities. When regional and national governments provide monetary and technical support, it can help cities overcome institutional inertia.

The other existing source that needs to scale up is support from bilateral and domestic development finance institutions, multilateral development banks, and other international financial institutions. These entities are particularly well-suited to finance urban nature because they:

- Combine subject-matter expertise and financial expertise.
- Provide technical assistance and capacity building.
- Can blend public and private finance.
- Can provide a variety instruments.
- Have different levels of risk tolerance.

While sustainable development and climate action are a focus of these institutions, the resources they are dedicating to urban nature are very limited, and not all major multilateral development banks include support for nature in their urban programs. Even for all nature globally, public international funders provide only 2% of finance, compared with 16% for climate finance overall.[203] If more development finance institutions and multilateral development banks could marshal their tremendous assets for urban nature, we could see a range of possible solutions in action.

One positive example comes from the European Investment Bank's Natural Capital Financing Facility. The facility was created to finance ecosystem-based projects, including green infrastructure and nature for resilience, and provide project preparation support and monitoring.[xvii] In 2018, the European Investment Bank provided the City of Athens, Greece, with a €55 million framework loan for resilient urban renewal and development. Part of this package was a €5 million loan from the Natural Capital Financing Facility to incorporate nature into its public spaces and connect green spaces with green corridors.[204] This example

xvii The Natural Capital Financing Facility will be replaced by EU Invest.

shows how packaging financing for nature as part of a larger program can enable a city to use revenue from the whole development project to pay back the investment on urban nature elements that might not generate sufficient revenue on their own.

Athens is planning some of its greening along the route of an ancient aqueduct and on Mount Lycabettus. Source: George E. Koronaios via **Wikimedia**

Policy incentives to spur developers

Real estate developers are a major beneficiary of urban growth and rising land and property values; how they choose to develop their land can either help or hinder a city's goals. Cities can use requirements or incentives to shift some costs and implementation responsibilities to developers and landowners, for example by requiring development to include nature or by imposing a fee on developers who want to avoid the mandate.

Washington, D.C., for example, uses a "green area ratio" approach for most new buildings and major renovations. This "sets integrated environmental requirements for landscape elements and site design that contribute to the reduction of stormwater runoff, the improvement of air quality, and the mitigation of the urban heat island effect." Landscape elements must meet conditions like tree height, diameter, and planting depth, and cannot include invasive species.[205] Green-area-ratio requirements should specify what features are eligible and provide supporting technical guidance to ensure high-quality natural features and to avoid a perverse incentive to plant, for example, fast-growing invasive species.

In Toronto, Canada, new development has to set aside part of the property as dedicated parkland. If the property is too small to accommodate a park, the developer purchases off-site property and conveys it to the city, or the city requires a payment to the parks department.[206]

Beyond Budgets: Innovative Financing Solutions

There is a growing number of business and financing models for urban nature, illustrating how local governments are going beyond traditional spending or public finance to raise revenue and attract co-financing.[xviii]

The options described below are examples of emerging solutions we think are most promising, for both raising government revenue and shifting the investment cost burden of urban nature. Not all of these approaches are completely novel, but none of them have yet achieved widespread adoption for urban nature. Several require conditions that might not be present in all cities, like widespread property insurance, planned development, and enforcement of zoning regulation and codes. And because investors still perceive urban nature as higher risk than grey solutions, even when they are more cost-effective, we need to do more work on education and producing robust valuations.[207]

One actor absent from the list below is philanthropy, which has had a key role in supporting urban nature. Although philanthropic funding may not be a sustainable path to scale, grants allow innovation in a way that commercial finance may not. And philanthropies can be trusted intermediaries between cities, investors, and technical experts.

Tax Increment Financing

Many cities already use tax increment financing (TIF), typically to subsidize infrastructure or development like sewer and water upgrades, transportation upgrades, new construction, and brownfield remediation and development. Through TIF, the city makes an improvement in a defined TIF zone, and the incremental increase in property taxes resulting from increased property values in that zone can then go toward additional projects or maintenance. TIF also offers significant potential for cities to acquire land for parks, add street trees and stormwater infrastructure to streets, revitalize existing green and blue spaces, and more.[208] Chicago has used revenue from TIF districts to subsidize green roofs on commercial buildings and to fund a landmark complete street redesign, including trees and green stormwater infrastructure.[209] It is critical, though, that cities using TIF also implement anti-displacement measures to avoid displacing long-time residents and small-business owners as property values rise in TIF zones.

Aggregating Urban Nature Projects

Developers could aggregate urban nature projects or include nature as a component of a larger project portfolio to strengthen the business case and make urban nature projects bankable in a way that they would not be individually. The IGNITION effort in Greater Manchester, United Kingdom, assessed many sites for green stormwater management projects and then identified the subset of sites (as an aggregated project) where reduced wastewater charges and flood risk would recoup capital expenditures.[210]

xviii This chapter highlights a few promising financing approaches, but many more exist. For further reading and examples, see United Nations Environment Programme **ANNEX II: Financing Nature-based Solutions for Smart, Sustainable and Resilient Cities**; UNaLab **Business Models & Financing Strategies**; IGNITION **investment toolkits**; **The Nature Based Solutions Business Model Canvas**; The NATURVATION **Business Model Catalogue for Urban NBS**; and NATURVATION **Key Stepping Stones**.

“Rate-Basing” Urban Nature

In some regulatory environments, the rate base (the value of the utility’s assets) helps determine the utility’s revenue requirement; regulators could include urban nature in the rate base. Including trees, green stormwater infrastructure, and other natural assets would provide an incentive for electric and water utilities to add these features on their properties and potentially even on private property on which they have easements. In turn, electric utilities would have lower peak demand, and water utilities would have fewer sewer overflows, less need for new grey infrastructure, and more groundwater recharge.

Property Insurance

As climate change impacts result in more claims, insurers and reinsurers face higher costs that they have to pass on to customers as higher premiums. Insurance companies can act at the customer and product levels, providing discounted products or incentives for customers who take action to protect themselves from climate impacts. For example, the Dutch insurer Interpolis, concerned about flood risk, ran a marketing campaign to increase green roof adoption.[211] This approach could be more effective at the municipal level as a way to spur local governments to use urban nature to make their properties more climate resilient. But insurers could have even more impact by supporting governments directly, in effect subsidizing governments to take actions from which insurers will benefit. Relatedly, insurers both need data, to model future property impacts, and can be useful providers of data and risk analysis to local governments. Partnerships between cities (and others that can provide data, like local universities) and insurers could facilitate exchange of this information.

Healthcare Payers

Nature’s enormous health benefits could avoid significant healthcare costs and improve health equity. Given how healthcare payers (including public- and private-sector insurers and integrated managed-care systems) would benefit from fewer heat-related illnesses and better physical and mental health, they have an interest in ensuring access to green space and heat mitigation, especially for vulnerable populations. Business models could range from healthcare payers campaigning for greater investment in urban nature (like the property insurance company described above) to actively co-investing in it. This is not something we have found examples of, so it is a topic that could benefit from further exploration.

Beyond Carbon Credits to a Multidimensional Product

Interest is growing in urban trees as a source of voluntary carbon credits. In 2022, the climate fintech company Regen Network bought all 31,000 metric tons of city forest credits available in the United States for over $1 million. That’s a price of $34–$45 per metric ton, compared with less than $10 per ton for most forest carbon credits globally.[212] Freetown, Sierra Leone, is funding its tree-planting campaign partially by selling tokens for new trees to companies.[213]

But urban trees provide many benefits beyond carbon sequestration that could be incorporated into a “beyond carbon” product. Companies looking to fulfill their corporate social responsibility goals and invest in their communities would appreciate their energy and carbon savings, biodiversity, resilience, equity, health, and social benefits as well — many of which would be absent or diminished in a traditional forest credit. (Mitigating the urban heat island effect and enhancing the health of a concentrated population, for example, are benefits that are specific to urban nature.) City Forest Credits uses this approach to connect interested funders, like Microsoft, with potential projects, which it assesses for impact on human health, equity, and the environment.[214]

Advance Market Commitments

In advance market commitments, buyers commit to purchasing a specified quantity or set of products or services, conforming to a set of predetermined specifications, at a predetermined price, thereby creating a market for solutions that may not have reached maturity.[215] Urban nature lends itself to advance market commitments because the costs of the absence of nature are not reflected in the market and the number and capacity of high quality "suppliers" is limited. Buyers could be either local governments (committing to buying solutions from companies when they're developed) or the private sector (committing to purchasing carbon credits or "beyond carbon" products).

Messages for Key Actors

Cities are already branching out in how they finance nature, but they cannot and should not carry the full burden. The global community needs to recognize the value and importance of urban nature, partner with cities on developing and testing innovative solutions, scale up support, improve valuation, and provide technical assistance. In so doing, local governments, the private sector, and urban nature technical experts and providers can form an ecosystem of urban nature finance, accelerating innovation, solutions, and implementation. Key messages for some of the actors in this ecosystem are summarized below.

- **General:** Urban nature needs more investment globally. Because nature provides value to so many beneficiaries, local governments should not bear all costs. Governments, development finance institutions, investors, and other private sector actors can work together to develop new innovative financing solutions, create new markets, and capture additional value.

- **Local governments:** Cities should scale up their budgeting for urban nature commensurate with the value it provides. Integrating urban nature into comprehensive plans, climate action plans, and other policy priorities can ensure sufficient attention to nature while lowering its marginal costs. Cities can also use policy and fiscal instruments to raise revenue for nature and can partner with the private sector.

- **Development finance institutions:** These entities need to prioritize and increase support for urban nature as part of their focus on climate and sustainable development. They should work with local governments to develop fit-for-purpose financing mechanisms and attract private investment. They also have an important role in helping local governments and the private sector build capacity related to urban nature finance.

- **Private investors:** Private-sector actors need to recognize that they are beneficiaries of urban nature's value and that they should define return on investment more broadly. Partnering with local governments will build the understanding necessary for new market opportunities.

Seizing Urban Nature's Opportunity

Adding more than 2 billion people to the world's cities in fewer than 30 years is a daunting prospect. Over 1 billion people already live in informal settlements, with hundreds of millions more living in subpar housing or lacking access to electricity or clean water. Air pollution exceeds World Health Organization limits in 98% of cities in low- and middle-income countries.[216] Nearly 1,000 cities, home to 1.6 billion people, will face regular extreme heat in the 2050s (compared with 200 million people exposed today). And over 500 cities will face a major decrease in freshwater availability over the next 30 years.[217]

Given these challenges, can we really justify prioritizing nature in our growing cities? The answer is that we can't afford *not* to.

We can only realize the vision of "just, safe, healthy, accessible, affordable, resilient and sustainable cities" with nature woven prominently into our urban fabric.[218] Holding the natural world apart from our built environment ignores how these systems interact with one another — and prevents us from taking advantage of nature's myriad benefits.

These false dichotomies — nature versus people or city versus wilderness — echo a broader failure of imagination. When we view the natural world as separate from us, we become detached from the responsibility we have for it — a mental model that has led us directly to our current climate and biodiversity crises.

> *"What would our economy look like if it fully valued all forms of capital, including human and natural capital? What if our economy were organized not around the lifeless abstractions of neoclassical economics and accountancy but around the biological realities of nature?"*
>
> **— AMORY LOVINS, PAWL HAWKEN, AND L. HUNTER LOVINS, *NATURAL CAPITALISM***

More people are experiencing the effects of climate change and recognizing that the economy and society are a subset of the ecosystem. That understanding now needs to extend to the people designing, leading, and implementing policy for urban areas.

Our modeling in six cities estimated urban nature's carbon- and energy-savings potential. If your city is interested in finding out the energy, embodied carbon, and VKT reductions it could achieve, contact the report authors.

Chicago's Lincoln Park Zoo transformed a constructed pond and its surroundings into an ecological park known as the Nature Boardwalk with native plantings.

This report offers recommendations for the different actors in the urban nature ecosystem. We offer one more concrete next step here — one that RMI is actively working on in partnership with the Cool Coalition, Sustainable Energy for All, the UN Environment Programme, World Resources Institute, and WWF. This partnership is working to launch the "Nature for Cool Cities Challenge" as a way to drive exponentially more investment in urban nature by bringing together actors in a structured way that builds understanding and confidence in these solutions. Using a "challenge" model, local governments would commit to specific investment levels, policies, and implementation practices related to urban nature in exchange for matching funds, technical assistance, and partnership opportunities with development finance institutions, philanthropy, and the private sector (including financial institutions, real estate developers, insurers, and carbon credit buyers).[xix] We invite local governments, financiers, and other organizations to join us in shaping this effort to drive scalable, replicable investment and implementation.

With increasing global attention to biodiversity and our planetary life-support systems, we need to raise their prominence in the context of cities, the places that are home to most of humanity.

xix Recent examples include the Global Cooling Prize, the Million Cool Roofs Challenge, and the Global LEAP Awards.

Endnotes

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RMI Innovation Center
22830 Two Rivers Road
Basalt, CO 81621

www.rmi.org