WORLD ECONOMIC FORUM

Delivering Climate-Resilient Cities Using a Systems Approach

INSIGHT REPORT

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Future of Cities Reports

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Foreword

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In 2021, Simon Kofe, Tuvalu's foreign minister, gave a speech to the 2021 United Nations Climate Change Conference (COP26) while standing knee-deep in seawater. His powerful action showed us how the climate crisis is not a distant threat, but already a concrete reality – a reality whereby climate change poses an immediate threat to liveability, food security, income and health, and contributes to population displacements.

In this context, piecemeal solutions are ineffective. We need unified and holistic solutions that can deal with the climate crisis in an integrated way, addressing current and future infrastructural needs to make societies and the planet more resilient to devastating climate events. We must also factor in socioeconomic demands – such as those arising from the ongoing COVID-19 pandemic.

We must ensure, at a local and global level, that our commitments are more ambitious and are followed through with immediate action. The application of this to urban planning and policy-making requires a systems approach. Such an approach is based on engaging a system-wide set of stakeholders – the private sector, the public sector and everyday citizens – and working at the intersections of interconnected challenges.

This report focuses on such a systems approach at the urban scale. Cities are responsible for more than 70% of global carbon dioxide emissions, with transport and buildings being among the largest contributors. Cities will also feel the greatest impact from climate change, with 70% of the global population predicted to be living in urban areas by 2050, and 95% of this urban expansion set to take place in the developing world. As such, urban areas should be the focus of innovation, iteration and adaptation. Municipal governments and local stakeholders should capitalize on new opportunities to bring about change and introduce modes of experimentation at a policy level that will reach broader society in rapid and impactful ways, ready to be scaled up. The battle against climate change will be won and lost in cities.

The report outlines case studies that provide in-depth explanation of how net-zero carbon strategies and infrastructure for climate resilience can be developed by involving all stakeholders, from companies and public institutions to the general public. Systems approaches are complex – more connections lead to more complications – yet the successes of cities such as Melbourne, Fukuoka and Helsinki demonstrate that extraordinary rewards can be attained, especially if siloed thinking is dismantled. The solution to a transport query might lie in housing; the unanticipated positive impact of a new park might be felt in a nearby water treatment plant. By pursuing a systems approach, we can bring fresh ideas to fields as diverse as housing, energy, mobility, public and green spaces, water treatment, stormwater management, waste management and many others.

As we see the stark realities of climate change unfolding and affecting lives in areas such as the Pacific Islands, we must accept that climate change is an immediate – not a future – crisis. Our approach must be integrative, at scale, innovative and systematic to deal with today's needs while mitigating risk and planning for future, resilient generations to come.

Executive summary

Adopting a systems approach to urban infrastructure delivery will help cities create more liveable spaces and curb climate change.

More than a thousand cities and local governments joined the United Nations Race to Zero campaign and 33 cities also committed to the Race to Resilience. The window to curb climate change is narrowing, and more aggressive actions are needed to fundamentally change urban systems. A systems approach exploits the links connecting multiple infrastructures, enhances integrated governance and finance, and deepens engagement among diverse stakeholders, thereby maximizing the co-benefits of climate actions.

Recovery from the COVID-19 pandemic poses a unique opportunity to accelerate the adoption of a systems approach to confronting the climate crisis. Despite broad interest, such an approach has not been comprehensively defined, especially in terms of the practicalities of planning and implementing net-zero carbon and climate-resilient urban infrastructure. Drawing on experiences from a wide range of stakeholders, this report outlines a roadmap for cities to take a systems approach to urban infrastructure in service of a green and just recovery.

The main message of each section of the report is summarized below:

What is a systems approach to urban infrastructure delivery?
A systems approach treats the multiple infrastructure sectors that determine the structure and function of cities as components of a larger working system. To address climate change, it builds upon effective sectoral actions, but takes advantage of interconnections and interdependencies among multiple infrastructure sectors. It asserts that treating sectors as parts of a whole system leads to better outcomes than optimizing each sector individually.

Why do we emphasize a systems approach to urban infrastructure delivery?
A systems approach is ideally suited to city-scale actions because cities are both the primary locus of demand and the level at which most infrastructure and services are provided. Such an approach simultaneously addresses multiple goals – in this case seeking to reduce climate change-related risks while maximizing co-benefits for public health and economic growth, among others. As such, a systems approach is well suited to creating liveable cities that improve residents' well-being.

How can cities implement a systems approach?
They can do so by promoting integrative governance structures, encouraging multi-objective planning, supporting legitimate participatory processes involving all relevant stakeholders, and adopting net-zero carbon and climate-resilience targets. Implementing a systems approach would also require comprehensive multilevel governance and deep collaboration among a diversity of social actors, as well as sufficient financial resources from both the public and private sectors.

What are the most serious challenges for cities taking a systems approach?
The challenges of taking a systems approach include: 1) natural resource constraints and legacy infrastructure; 2) lack of technical and political capacity; 3) lack of multi-objective urban planning; 4) limited local regulatory power; 5) weakness of city government in regards to the multilevel governance system; 6) weak collaboration among multiple social actors; 7) limited access to finance and resources; and 8) lack of policy-relevant data and knowledge.

Recommendations
Cities alone will not be able to achieve a systems approach to net-zero carbon, climate-resilient urban infrastructure delivery. Rather, each city must engage with relevant stakeholders from government, business, academia and civil society that interact with the urban value chain. It must also use its hard and soft powers to accelerate action – for instance, by creating working groups to accelerate a green recovery or by declaring a climate emergency. This report provides a five-step action plan to guide cities in adopting a systems approach to urban infrastructure delivery. Recommendations are also provided to help cities transition from the current sectoral approach to a systems approach.

1 Introduction

Cities need to take a systems approach if they are to develop urban infrastructure that will achieve net-zero carbon and climate-resilience goals.

> **Cities are where the climate change battle will be largely won or lost.**
> António Guterres, United Nations Secretary-General

Over 50% of the global population lives in cities,[1] while this value can be as high as 80% when accounting for towns and suburbs.[2] Cities also generate more than 80% of global economic output and more than 70% of global fossil-fuel greenhouse gas (GHG) emissions (Figure 1).[3]

By 2050, cities will increase by an additional 2.5 billion people, mostly in Africa and Asia.[4] Without effective policies supporting the net-zero carbon and climate-resilient transition, global urbanization at this speed and scale is likely to drive a major increase in GHG emissions.

FIGURE 1 **The role of cities in global CO_2 emissions**

High energy use and dense populations – the city is a CO_2 hotspot

1 The main contributing sectors are:

2 Urbanization will continue in the future, and this process will increase emissions…

3 …unless cities take actions to reduce emissions through urban planning, technologies and behavioural changes.

>70%

Altogether, cities account for more than 70% of man-made fossil fuel CO_2 emissions.

Cities' emissions vary depending on land use, energy consumption and a variety of socioeconomic and geographical factors.

343

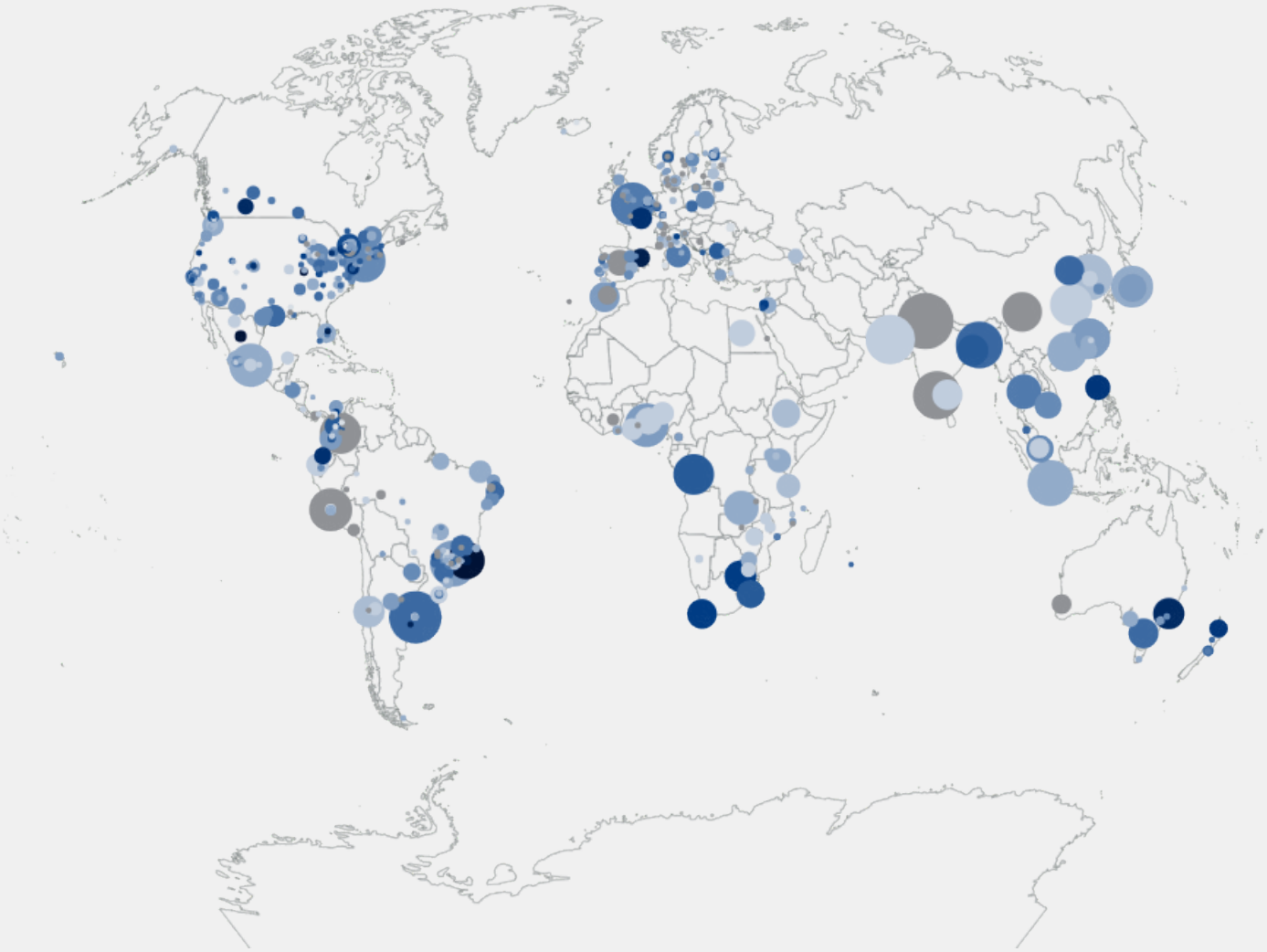
The Global Carbon Project compiled a unique dataset of CO_2 emissions and socioeconomic variables from 343 global cities.

This data will help scientists and policy-markers explain the role of socioeconomic drivers in cities' emissions.

Source: Global Carbon Project, 2019[5]

Cities are also experiencing increasing climate risks (Figure 2), often exacerbated by underinvestment in resilient infrastructure. For example, about 1.5 billion urban dwellers are likely to face exposure to cyclones and earthquakes by 2050, with most contexts relying on infrastructure created under lower risk assumptions.[6] Average annual urban losses from disasters were estimated at about $314 billion globally in 2015 and may rise to $415 billion by 2030.[7] Losses are unevenly distributed among high- and low-income countries. Cities in low-income countries, which will accommodate the majority of new urban residents, face greater climate risks and high economic losses (e.g. disaster-related economic costs account for more than 16% of GDP).[8]

FIGURE 2 **Global cities face various climate change-related risks**



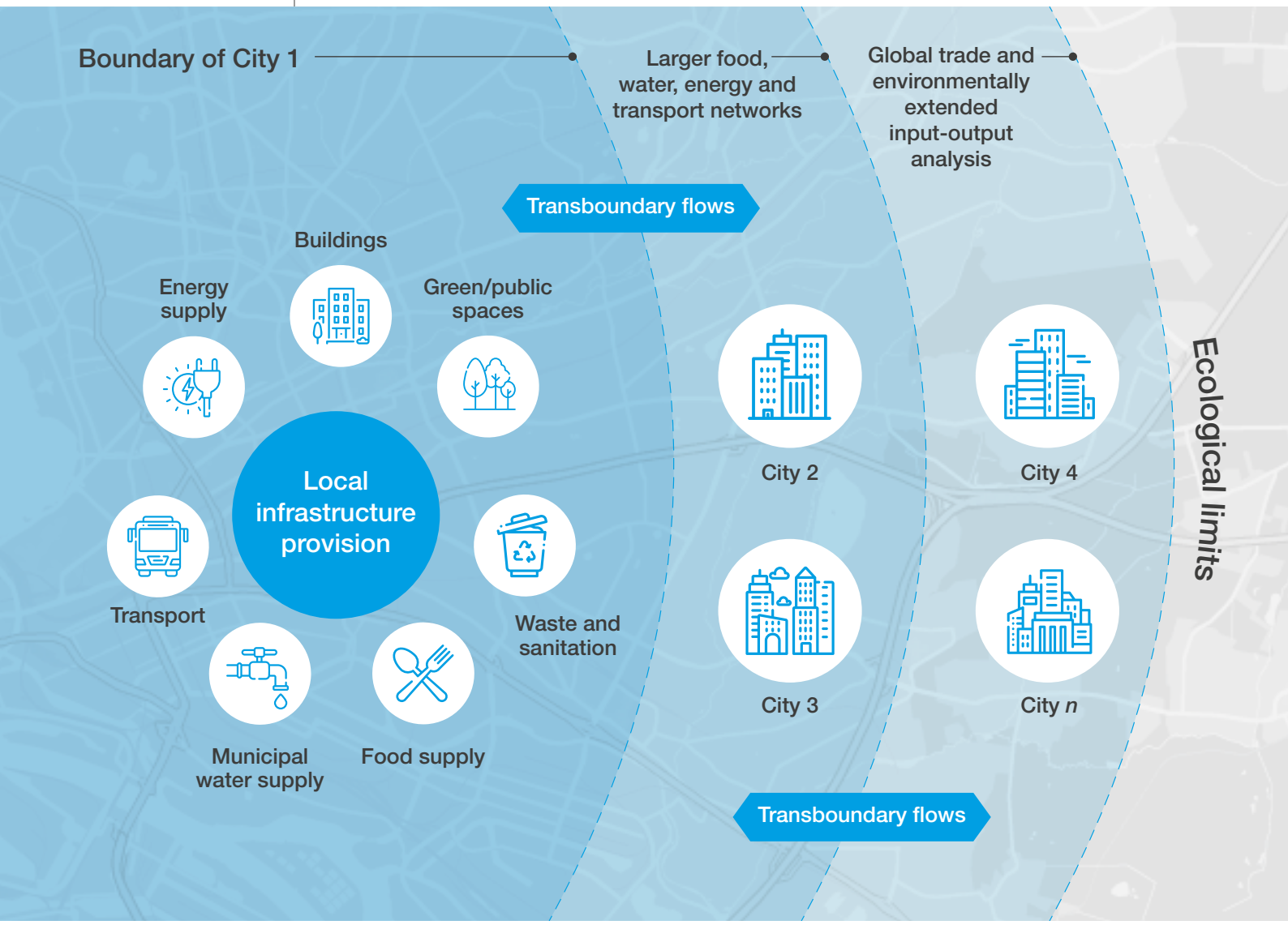
Note: The darker the plot, the higher the hazard score.

Source: CDP, 2021[9]

Urban infrastructure, which includes energy, buildings, transport, water, solid waste management, green infrastructure and digital infrastructure, presents cities with real opportunities to simultaneously reduce GHG emissions and improve climate adaptation.[10,11] About 1,000 cities have already committed either to becoming carbon neutral by 2050, or to generating 100% of their energy from renewable sources.

Somewhere in the region of 350+ cities have declared a climate emergency.[12] These climate and resilience actions by cities depend on complex and interdependent critical infrastructure sectors, which themselves rely on transboundary flows of energy, resources and trade (see the red arrows in Figure 3).[13,14] Meanwhile, climate-resilient cities can also reduce the climate vulnerability of these infrastructure sectors.

FIGURE 3 | **Sustainable urban infrastructure systems framework**



Source: Ramaswami et al., 2016[15]

Historically, urban climate action has tended to focus on individual infrastructure sectors (e.g. improving the energy efficiency of buildings, designating bicycle lanes to promote active travel). In part, this reflects how cities have structured sectoral governance and management to ensure reliability and sufficiency in service provision. However, in the absence of coordinated integration, individual sectoral actions will fall short of the necessary GHG emission or climate change adaptations, in part because they fail to make the most of cross-sectoral opportunities. A systems approach that builds upon and integrates effective sectoral actions is needed to develop urban infrastructure that will achieve net-zero carbon and climate-resilience goals (see Box 1 for a definition adapted from Ramaswami et al., 2016,[16] ACERE, 2018[17] and Ramaswami, 2020[18]).

BOX 1

Definition of a systems approach to deliver net-zero carbon and climate-resilient urban infrastructure

A systems approach takes advantage of the interconnected and interdependent relationships – including reinforcing and balancing feedbacks – among multiple infrastructure sectors (e.g. the close relationship of buildings, mobility and green spaces). Because some infrastructure sectors extend beyond a city's jurisdiction (e.g. transportation, water and energy), a systems approach requires both horizontal and vertical collaboration. It also requires comprehensive engagement with multiple stakeholders to explore new, effective solutions. This approach also aims to maximize multiple benefits (e.g. carbon mitigation, pollution reduction, improving well-being), and reduce potential harms (e.g. deepening social inequality) related to infrastructural services. In this way, a systems approach contributes to sustainable development beyond addressing climate change.

Because the longevity of built environment infrastructure tends to lock in any impacts for decades, the infrastructure built to serve cities over the next 20 years will be critical in determining whether the world is on track to meet its net-zero carbon and climate-resilience goals. Recovery from the global COVID-19 pandemic offers a unique opportunity for cities to effectively address climate change. This report aims to motivate cities to take a systems approach by addressing the following key questions:

- What is a systems approach to urban infrastructure delivery?
- Why do cities need a systems approach to urban infrastructure delivery?
- How can cities implement such a systems approach?
- What have cities learned about the challenges of taking a systems approach to urban infrastructure delivery?

This report provides targeted recommendations to help cities address the complex challenges they face in the wake of COVID-19, and to deliver a healthy, green recovery.

2 What is a systems approach to urban infrastructure delivery?

Creating healthy, productive urban spaces that avoid sprawl, reduce carbon emissions and improve residents' well-being is at the heart of a systems approach.

2.1 Making use of multi-infrastructure linkages

> **Modern infrastructure sectors (e.g. energy, buildings, transportation, water, solid waste and green and digital infrastructure) are interconnected and interdependent. Multiple sectors form complex infrastructure networks that transcend city boundaries.**
>
> Cheryl Benini, Head of Vertical Sales and Partner Development at Siemens Smart Infrastructure

A systems approach applies forward-looking spatial and land use planning to create healthy, productive urban density and avoid sprawl. System-wide planning can incorporate green buildings and streets, low-carbon mobility systems, renewable energy and integrated nature-based solutions.[19] One paradigmatic system-wide approach that has received significant interest during the COVID-19 pandemic is the "15-minute city",[20] in which everything people need to live, work and play is located within 15 minutes of where they reside, thus reducing commuting time and generating efficiencies of agglomeration. This new model draws on existing ideas: for example, the city of Melbourne has long promoted the 20-minute neighbourhood, in which people can meet most of their daily needs, along with safe cycling and local transport options, within a 20-minute walk from home.[21] To achieve these goals, urban planning could take a systems approach, simultaneously managing and evolving multiple infrastructure sectors (see Case study 1). Such an approach offers cities in rapidly urbanizing Africa, South Asia and elsewhere the opportunity to leapfrog stages of development while providing green urban infrastructure that is also more economically viable than traditional models.

CASE STUDY 1

Intensification and transport interventions to combat climate change in Melbourne

Introduction and problem

In 1985, Melbourne, like many other modern cities, had a central business district (CBD) that emptied out at night and over the weekend as the population moved to the low-density suburbs. This model was increasingly inefficient and unsustainable; major urban infrastructure reached peak capacity for only brief periods each day, commuting distances and times were increasing, and prime agricultural land was covered in concrete and asphalt. An alternative approach was needed to increase urban efficiency. The city took advantage of a property market crash in the late 1980s to begin to shift the paradigm.

Solutions

The city developed a two-pronged approach. The Postcode 3000 initiative addressed the depopulated CBD. Facing the problem of the oversupply of new commercial office space, the city promoted the conversion of empty, second-rate office buildings in the centre of the city into residential accommodation. This helped move the CBD towards 24/7 use, thus reducing commuting and the expansion of city boundaries while making more efficient use of existing infrastructure.

The city also worked with the state government to devise a plan for the intensification of the metropolitan area. The study, *Transforming Australian Cities*,[22] showed how Melbourne could double its population without expanding its existing boundaries by building all future residential developments adjacent to existing public transport corridors and nodes. This intensification not only saved land but also generated financial benefits, promoted sustainability and improved social cohesion.

Impact and benefits

Postcode 3000 initiated the idea of converting vacant office buildings into residential apartments, eliminating the loss of embodied energy in those buildings through demolition. The programme also increased density around existing infrastructure, producing a mixed-use CBD by increasing the number of small businesses providing hospitality and retail services. The CBD residential population increased from 685 dwellings in 1982 to more than 41,000 by 2016.

Transforming Australian Cities showed how Melbourne's population could grow from 5 to 10 million over 30 years without any further appropriation of productive farmland, simply by building on just 7.5% of the existing land along road-based transport systems, in activity centres around rail stations and on grey-field (i.e. unused or underused real estate or land) sites. The increase could be achieved with buildings no higher than five to eight storeys, while avoiding all sensitive areas such as heritage buildings and overlays,[23] parks etc. The greatest benefit arising from this approach, apart from a more sustainable city, was the saving in infrastructure costs, measured at US$100 billion for every million people added to the city.

Lessons and experience

Arguably the most important takeaway from these programmes is that cities can adapt to meet the challenges of climate change, liveability and financial efficiency by adopting a systems perspective to explore innovative solutions. *Transforming Australian Cities* showed that major changes can be made to low-density cities by converting small-to-medium building sites to help retain the grain and character of the existing streets – without resorting to mega-projects and high-rise developments. Solutions that address both buildings and transport yield much better results than isolated approaches.

↑ The number of dwellings in the CBD had increased from 685 in 1982 to 41,000 by 2016

Forward-looking land-use planning can create more compact cities, reducing the need to travel and lowering the cost of upgrades to electric systems.

Another good demonstration of the interdependence of multiple infrastructure systems is the coupling of electrification and grid decarbonization with land-use planning. While electrifying mobility, heating and cooling can improve energy efficiency, it can also significantly increase demand. In the case of transportation, adding the charging stations required by private vehicles, enterprise fleet operators and municipal bus operators will require a simultaneous expansion of the power grid. By 2030, more than 55 million chargers consuming at least 525 terawatt-hours per year may exist in buildings alone. This, in turn, would require a substantial new grid infrastructure. However, forward-looking land-use planning can create more compact cities, reducing the need to travel and lowering the cost of upgrades to electric systems. Other city actions, such as the installation of rooftop solar photovoltaic (PV) panels, can further decarbonize the energy supply and likewise limit costs (see Box 2).

Provision of housing is another area in which multiple infrastructure sectors converge. Climate disasters such as wildfires, flooding and winter freezes frequently disrupt infrastructural services. In developing countries, cities experiencing rapid urbanization face the added challenges of upgrading informal settlements while trying to reduce carbon emissions and enhance climate resilience. In responding to these issues, local governments have taken measures ranging from building affordable housing to the temporary provision of post-disaster emergency shelters. In the long run, cross-sectoral engagement, and large-scale public investment in affordable, accessible, net-zero carbon housing are important in addressing shortages and increasing resilience as a component of slum upgrading.[24] Cities can also use their connectivity and interdependence to create novel adaptation solutions (see Box 2).

BOX 2

Innovative cross-sectoral solutions for climate change mitigation and adaptation in Fukuoka, Japan

Fukuoka, Japan, has consistently acted to reduce carbon emissions in its energy sector, initiating new programmes and providing new opportunities to respond to climate change. Two examples stand out:

- **Hydrogen from wastewater treatment plants:** Fukuoka City has collaborated with the private sector to create and manage the world's first fuel station supplying hydrogen generated from biogas produced by wastewater treatment. Sewage flows constantly to wastewater treatment facilities, making it a stable, sustainable and efficient energy resource. It can be used throughout the city to fuel urban development and mobility, and the initiative takes advantage of the city's existing infrastructure. The fuel produced can also be used as a storable energy source for emergency use.
- **Decarbonizing the energy supply and improving climate resilience:** The city has actively installed PV equipment in city-owned public facilities (e.g. elementary schools and community centres), and promotes net-zero energy buildings (i.e. the total amount of energy used is equal to the amount of renewable energy generated on-site) when undertaking large-scale refurbishment of public facilities. Residents receive subsidies for installing solar generation and storage batteries, and for purchasing electric vehicles (EVs) and installing charging facilities. These actions make the city more resilient during natural disasters. For example, electric vehicle batteries can play important roles in evacuation shelters during natural disasters, allowing residents to charge their smartphones and other electronic devices and so keep up to date with essential disaster-related information. Fukuoka City has signed an agreement with three car manufacturers (Nissan, Toyota and Mitsubishi) for the free leasing of EV batteries during disasters.

A systems approach is not limited to physical infrastructure within city boundaries. While most cities do not control their energy grid infrastructure, those that do can shift from centralized to decentralized energy systems, improving the resilience of their energy sources (e.g. the Melbourne Renewable Energy Project[25] discussed in Case study 3). Microgrids offer another option for reducing carbon intensity while also making cities more resilient. Microgrid systems are controlled by advanced digital software, usually include battery storage and renewable power-generating capacity and can be anchored by an industrial plant or a large campus. This can make the overall electricity availability more robust, while also decarbonizing mobility and buildings. District heating and cooling for buildings can further reduce emissions, especially if renewable energy is used and waste heat is recovered. Cities can apply the systems approaches to explore integrated engineering solutions and nature-based solutions.

2.2 Integrated technological and engineering solutions

Technology and engineering solutions are enablers to deliver net-zero carbon, climate-resilient urban infrastructure. For example, building retrofits can reduce carbon emissions by up to 90% in the best-case scenario,[26] and electric vehicles powered by a net-zero carbon grid can result in 75–85% carbon reductions compared to combustion engine vehicles.[27] Yet, even where technology and engineering solutions are available, cities are currently not deploying them at scale. This may be because cities are not fully aware of how they could accelerate technological transitions or due to difficulties in accessing finance. If cities are determined to achieve net-zero carbon and climate-resilience goals, more systemic solutions will be needed.

Digital infrastructure can be of value in forming integrated solutions and engaging multiple stakeholders in the planning and implantation process. It is now possible to develop "virtual twins" at the scale of buildings, districts, cities and even megalopolises. While early projects focused on simple three-dimensional representations, computerized virtual twins now represent city systems and all of their interactions, encompassing not only how a city looks but also how its transport system behaves, how energy is distributed and other factors, providing cities with access to vital information and data. This unprecedented visualization, simulation and information intelligence can facilitate the evaluation of "what if" scenarios in the virtual world before pilot testing in the real world. For example, Virtual Singapore is a dynamic three-dimensional city model and collaborative data platform for experimentation and the creation of forward-thinking city frameworks (see Case study 2).

CASE STUDY 2

Virtual Singapore

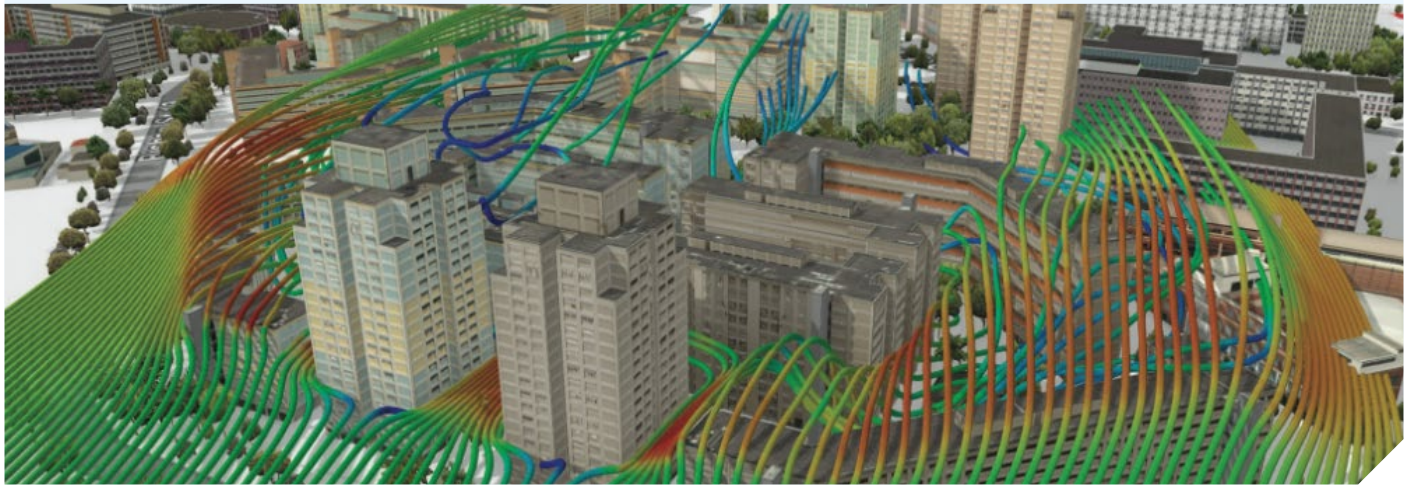
Introduction and problem

Singapore – one of the world's top research and innovation-driven nations – aims to be a forerunner in technological and policy solutions for sustainable development by forming partnerships with research centres, industry and government. It recently announced a Green Plan (SG 2030) to strengthen its efforts to implement its commitments under the UN 2030 Development Agenda. Among its goals are finding solutions to the urban heat island effect, which occurs when land with natural cover is replaced by buildings and infrastructure that absorb heat – this is a crucial challenge for Singapore. Advances in digital technology, such as digital twins, help cities and government authorities develop cost-effective solutions and adopt the right short- and long-term policies to ensure progress towards their sustainable development goals.

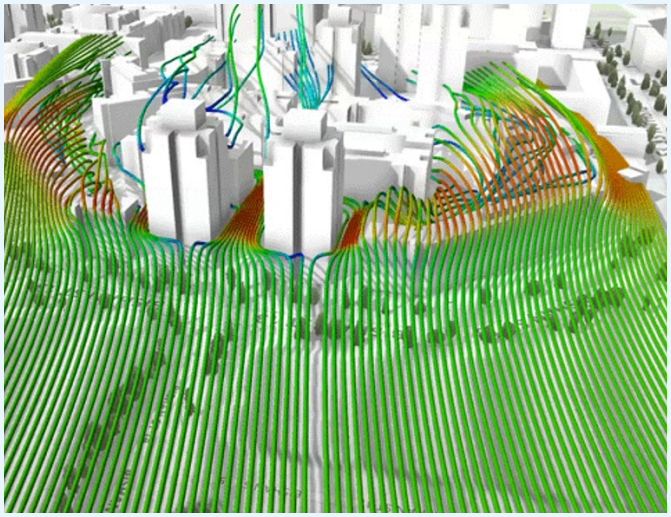
Solutions

The virtual twinning process allows developers to model a car, an aeroplane, a building or an entire city, which can then be subjected to different scenarios to forecast its behaviour. The government worked with Dassault Systèmes to create a virtual twin for Singapore – Virtual Singapore is a dynamic, three-dimensional city model and collaborative data platform for experimenting and creating forward-thinking city frameworks. Through it, the research community can integrate diverse data and develop applications for test-bed concepts. For example, researchers can explore how practical solutions to climate-change impacts affect environmental sustainability. In the case of the urban heat island, city planners can interactively review the effects of climate-responsive strategies in each district and choose the option best suited to each local context. The first two illustrations below demonstrate wind simulation, while the third image demonstrates the solar potential shown in the digital twin platform.

↓ Virtual Singapore – wind simulation



Case study 2 continued



↑ Virtual Singapore – wind simulation

↑ Virtual Singapore – solar potential

The SG Green Plan has also been applied to the challenge of identifying greener ways to commute. Singapore encourages cycling and plans to expand the bicycle network, repurpose roads and implement pedestrianization wherever possible. But these projects are not simple, as they involve various stakeholders from public agencies (e.g. roads, utilities, parks) as well as the private sector. Various scenarios were simulated, accounting for urban planning regulations, to inform potential land and property buy-back schemes. At the same time, new-generation 3D virtual city model was produced to drive citizen engagement.

Impact and benefits

A collaborative model-based platform enables urban planners to design a more comfortable, cooler-temperature living environment for residents. Without having to finance or build a single physical structure, they can create experiences in the virtual world to assess decisions about how best to design, plan, build and monitor the implementation of urban planning activities, such as expanding the cycle network or constructing new buildings and installations.

Lessons and experience

It is not easy for cities to know where to start when mapping out a profoundly transformative, sustainable, inclusive future – especially when there are budget constraints. New, innovative technologies allow cities to bring relevant stakeholders together to envision the impacts of various interventions, thus enabling them to optimize infrastructure and resource allocation while reducing emissions and the city's environmental footprint.

An integrated urban energy system encompassing electrification, electric vehicles and buildings can reduce carbon emissions and improve climate resilience. By allowing the electric grid to use the storage capacity of electric vehicles when they are not in use, the whole electric system can be made more stable. Peaks in demand can be managed using stored energy. And excess production, especially of renewable energy, can be distributed to charge batteries and prepare for future demand, either for mobility or for the grid. Buildings can actively manage energy by installing advanced control systems to drive on- and off-site renewable energy procurement. Cities can analyse building load management to determine where and when energy is pulled from resources, improving consistency and efficiency. Additionally, buildings can maximize local renewable generation (e.g. rooftop solar PV), control storage and shift loads to reduce carbon emissions. They can also generate, store and distribute energy, as in the case of "positive energy" buildings that feed their excess power back to the smart grid. A smart city microgrid can offer capabilities to fortify energy infrastructure in preparation for extreme weather events and power outages in the future.

CASE STUDY 3

Integrated buildings and technology in the face of climate change and COVID-19 in Melbourne

Introduction and problem

Having initiated a city renewal process in 1985, Melbourne had made substantial changes by 2000. In that year, the city began to focus on the impacts of commercial buildings as part of a longer, ongoing urban renewal process. The new programme would adopt different strategies to meet the needs of both existing and new construction.

Solutions

Melbourne decided to build an example of future commercial office buildings: Council House 2 (CH2). It had two main design goals: 1) to meet the highest environmental standards; and 2) to be a healthy building in which to work. Completed in 2006, CH2 achieved both goals. It saved energy through a combination of thermal mass and cool night purges, in which windows were opened during summer nights for cooling. It also uses cogeneration on-site to improve efficiency and lower GHG emissions. To safeguard health, it incorporated a fresh air working environment, in which air is fed into 300mm-deep cavity flooring and released into offices at each workstation. Heat generated by the occupant and their computer rises, drawing up a column of fresh air around them, while hotter air is withdrawn above and vented through the northern facade by a series of wall ducts. These ducts are dark coloured, attracting heat and creating a chimney effect, thus limiting the need for mechanical ventilation. This system contrasts with conventional buildings that blow air from above, circulating it among all occupants before extracting it, again from above.

CH2 showed how new buildings could be built to reduce energy, but a large number of commercial buildings had already been built and, accordingly, Melbourne initiated the 1200 Buildings programme focusing on existing commercial buildings. This programme provided low-interest loans for improving energy and water use efficiency.

One lesson from CH2 was that building-by-building energy systems are probably less effective than solutions covering the whole precinct. Therefore, the Melbourne Renewable Energy Project (MREP) facilitated a power-purchasing agreement for 10 large businesses across Melbourne. To date, two projects have been completed, each generating 110GWh of renewable energy per year.

Impact and benefits

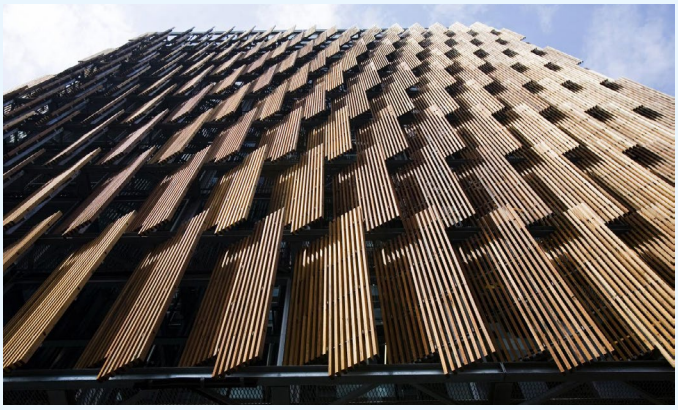
CH2's fresh air system was assessed by the Commonwealth Scientific and Industrial Research Organization (CSIRO) to have reduced absenteeism by 10% and improved productivity. This resulted in $2.4 million saved per year on staffing costs, thus recouping the investments in energy and well-being in five years. CH2, as Australia's first 6-Star Green Star-rated building,[28] inspired more than 600 certified new buildings in Australia. The Green Building Council has assessed that these buildings generate 62% fewer GHG emissions and require 66% less electricity and 51% less potable water (due to water conservation design strategies) than conventional buildings.

Each MREP project is equivalent to providing enough renewable energy to power more than 22,000 Australian households a year, thus reducing GHG pollution by 123,000 tonnes/year – comparable to taking 28,000 cars off the road. MREP allows small businesses to take control of their energy needs and pricing, thus making their operations less carbon-intensive and taheir prices more predictable.

Since 2010, the 1200 Buildings programme has resulted in energy and water efficiency improvements for 540 existing office buildings.

Lessons and experience

When governments set targets and lead by example, they can change the status quo and show the way to a more sustainable future. Cities can systematically evolve urban infrastructure to achieve multiple objectives (e.g. reducing carbon emissions while improving resilience and public health).



↑ CH2 – post-COVID office building of the future
Image credit: City of Melbourne

↑ CH2's fresh-air working environment
Image credit: City of Melbourne

Cities can also move towards net-zero carbon and climate-resilience goals by exploiting water-waste-energy connections via circular economy strategies. Drinking water, wastewater and solid waste are all sources of GHG emissions. By adding redundancy to critical elements of the water supply and deploying sensors to provide real-time information on asset performance and links, cities can improve water reliability at normal times and during periods of stress. Circular economy approaches to waste and wastewater can also support decarbonization efforts – for example, as inputs for waste-to-energy (see Case study 4), waste-to-biogas (e.g. as in Fukuoka, Japan, discussed in Box 2) and sludge-to-biogas power plants.

CASE STUDY 4

Circular economy strategy in water, waste and energy sectors in Granada, Spain

Introduction and problem

Wastewater treatment and reuse in Granada[29] in the Andalusia region of Spain is relatively limited. As of 2020, only 75.3% of the population of Granada has benefited from water treatment (including both plants in operation and those still under construction). This is the lowest rate among all Andalusian provinces, and well below the Andalusian average of 89.7%. Furthermore, only 4.8% of treated wastewater is reused in Andalusia, below the national average of 11.2%. Moving from a linear towards a circular approach of reducing and reusing water can yield positive environmental, economic and social impacts, particularly in water-scarce areas such as Andalusia.

Solutions

In 2015, the local wastewater treatment plant was converted into a bio-factory by the mixed ownership company Emasagra, the municipal water supply and sanitation company of Granada. This enabled increased reuse of water along with increased energy production. The bio-factory represents a step towards circularity through energy generation, water reuse and recovery of waste from the purification process.

According to Emasagra, the principal innovations are:

1. Transitioning from being a major consumer to a producer of energy
2. Reusing treated water, rather than purifying it then returning it to the natural environment
3. Transforming waste into resources, rather than dumping it into landfill

The bio-factory has three main objectives:

1. Reducing the consumption of materials used to treat water (e.g. cellulose, etc.)
2. Achieving zero-waste-to-landfill by recovering all materials with high added value
3. Producing green energy for the plant, both through self-consumption and renewable energy

Impact and benefits

In 2019, the bio-factory almost reached its goal of 100% energy self-sufficiency, with 99% of its waste being recycled, reused or upcycled and turned into economically valuable products. In total, 18.91 million cubic metres of treated water was reused for irrigation and to help maintain the minimum flow of the Genil River. The bio-factory also produced 16,525 metric tonnes of fresh sludge in 2019 – this was reused in direct agricultural applications (85.7%) and for compost (14.3%).

Emasagra's efforts to reduce its GHG emissions have been recognized by the Spanish Ministry for the Ecological Transition and Demographic Challenge, which awarded the company the "Calculate + Reduce + Compensate" label in 2021.

Lessons and experience

The transformation of a wastewater treatment plant into a bio-factory resulted in increased water reuse with zero waste, zero energy and zero CO_2 emissions. The city can build on this experience to further develop its relationships with urban production. From the perspective of the value chain, it can close energy and material loops through a circular economy approach. For example, connecting the bio-factory to urban production can provide surplus energy for city use, generate compost as fertilizer for local food production and consumption, and strengthen urban-rural linkages. In this sense, local government can promote, facilitate and enable the transition from a linear to a circular economy by providing a long-term vision, enabling multistakeholder collaboration and adapting regulation to allow experimentation.

Source: OECD, 2021,[30] OECD, 2020[31]

> **Fostering integrated technological and engineering solutions is a powerful way for cities to directly address climate change challenges. However, their full-scale adoption is still to come and will depend on the ability of city leaders to overcome several challenges:**
>
> – **The acceptability of these solutions by citizens, in particular when living habitats are at stake or perceived as such**
>
> – **The balance between deploying today very innovative technologies for a smaller part of a population or audience versus ensuring a more systemic change that will take longer**
>
> – **The overall costs and benefits over time of these technologies, which often imply investment during the time of an electoral mandate, and an 'off-cycle' payback that may extend over decades**
>
> Simon Huffeteau, Government Coordinator of the Building Energy Efficiency Renovation Plan, Ministries Ecology Energy Territories; Vice-President, Infrastructure & Cities Strategy, Dassault Systèmes (2019–2022)

2.3 Integrated nature-based solutions

Integrated nature-based solutions (NBS) use the natural properties of managed ecosystems to address specific challenges. Incorporating these natural systems in infrastructure planning from the systems perspective provides cities with novel opportunities to limit the impacts of climate change, enhance biodiversity and improve environmental quality while contributing to their economy and social well-being.[32]

Cities are exploring NBS either as an alternative to, or in combination with, traditional grey infrastructure (see Case study 5). NBS tap the potential of ecosystem services to address multiple challenges simultaneously, while providing additional co-benefits that are unavailable from traditional technological approaches such as carbon sequestration,[33] improving air quality and protecting biodiversity. The total economic value of ecosystem services is estimated to be between $125 trillion and $140 trillion per year (more than one-and-a-half times the size of global GDP).[34] Examples of urban NBS include: green roofs and city parks to reduce heat stress; constructed wetlands for wastewater treatment; a variety of interventions to mitigate flooding such as permeable surfaces, vegetation and rain gardens to intercept and absorb stormwater; and city lagoons to store excess run-off. Moreover, the COVID-19 crisis highlighted the importance of accessible green spaces for urban dwellers. Some cities (such as Paris, Montreal, Valencia and Melbourne) have started to expand green spaces in their cities, not only for climate resilience but also for additional open space during the pandemic as well as to gain a direct source of fresh food[35] (see Case study 6).

In coastal areas, urban growth is placing a strain on ecosystems, which puts them at risk of degradation. Given that urban economies often depend on these ecosystems as prime sources of income, cities are starting to prioritize nature, both for coastal protection and as an engine for growth. Engineers are working alongside ecologists to incorporate buffering of ecosystems as protection against sedimentation, flooding and erosion. In some instances, NBS may work better than grey infrastructure, particularly for high-frequency, low-intensity hazards. Initiatives incorporating NBS into integrated coastal management include "living shorelines" in the United States,[36] and "sand nourishment" in the Netherlands. Beira, Mozambique (see Case study 5), demonstrates that cities can also combine grey and green infrastructure to strengthen resilience.

CASE STUDY 5

Bringing together grey and green: strengthening the resilience of Mozambique's coastal cities

Introduction and problem

Mozambique is among the poorest countries in the world, as well as being one of the most vulnerable to rising climate risks. In Beira,[37] the 3.5km (2 mile)-long tidal Chiveve River traverses the central business district as it runs from the fishing port to lower-income neighbourhoods further south-east. The river's ability to mitigate floods has been significantly reduced in recent years. Refuse choked the river, its mangroves and native vegetation were degraded and it was polluted with faecal waste from lower-income neighbourhoods lacking proper sanitation. Government officials and project leaders proposed these issues be addressed through investment in green and other non-structural measures, as well as with conventional grey interventions. This complex mediation aimed to not only enhance the area's climate resilience but also improve citizens' quality of life by providing new recreational and economic opportunities.

Solutions

With resilience-building strategies at the ready, the World Bank and its development partners are providing much-needed finance to mobilize action on the ground. In Beira, the Cities and Climate Change (3CP) project is a collaboration between Germany's KfW bank and the World Bank. It has provided the city with financial and technical assistance to comprehensively strengthen its floodwater management. While this has included conventional grey interventions, such as the replacement of an 11.5km (7 mile) stretch of ageing, colonial-era drainage systems, novel and complementary nature-based solutions have also been introduced.

NBS are part of the second and final phase of 3CP, labelled Green Urban Infrastructure and co-financed by the Strategic Climate Fund's Pilot Program for Climate Resilience ($15.7 million) and KfW ($14.2 million). This funding has provided the resources needed to transform Beira's degraded Chiveve River and surrounding green space into a multifunctional urban park that will enhance local revenue and improve climate resilience.

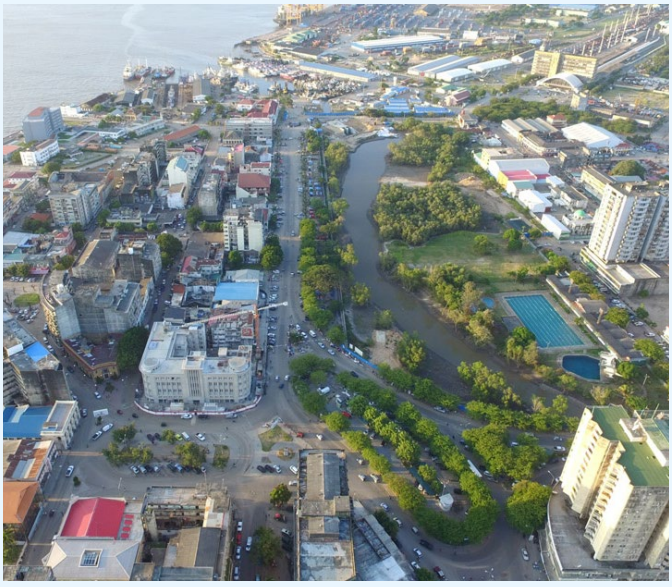
Benefits and impacts

The community-based mangrove restoration, which is the initial phase of this project, has been completed, and the benefits are already visible. The Chiveve is flowing more steadily than before, without refuse and waste, and is providing improved flood protection. Residents also perceive an increase in security in the areas around the park. Soon, residents and visitors alike will be able to enjoy the new amenities and recreational opportunities provided by the park. While more work lies ahead for Beira, the Chiveve River's urban green park and the upgraded stormwater drainage systems are important steps towards creating a more prosperous, resilient city.

Lessons and experience

To ensure that the methodologies and lessons learned from this experience are shared with future actors, the project has used financial support from PROFOR[38] and technical support from the World Bank's Nature-Based Solutions programme[39] to publish several reports on the project, along with assessments of the potential adoption of similar interventions in two other Mozambique cities, Quelimane and Nacala. The project hopes to become a shining example of how coastal cities in Mozambique and beyond can harness the benefits of green and grey infrastructure to meet multiple development goals.

Source: World Bank, 2022[40]



↑ A bird's-eye view of the city of Beira

↑ The envisioned park along the Chiveve River

CASE STUDY 6

An integrated nature-based response to climate change in Melbourne

Background and problem

Melbourne, with 5 million people, is Australia's fastest-growing city. Australia itself is the world's driest continent, and models forecast that a 3°C temperature rise would make most of the continent unliveable. The millennium drought of 2001, which lasted for 12 years, offered a powerful preview of the likely impact of global warming. Reduced rainfall and higher temperatures devastated the city's tree stocks, with up to 48% facing premature death over the next 20 years. In 2017, temperatures in the city reached 47°C, resulting in more than twice as many deaths as in the devastating Black Saturday bush fires of 2009, which claimed 173 lives.

Solutions

Melbourne responded with three highly successful strategies:

- A "Grey to Green" policy to fast-track the conversion of asphalt into widened footpaths and open space to meet the needs of the growing population. This was an obvious measure, with streets making up 80% of the public realm, and addresses both environmental risks (e.g. through increased permeability) and social needs (e.g. by providing space for recreation).
- The "Urban Forest Strategy", which aims to increase canopy cover from 22% to 40% over the next 20 years. Planting 3,000 trees every year in the central city increases species diversity and improves growing conditions and moisture capture.
- The "Total Watermark – City as a Catchment" strategy, complementing the other two measures, to improve permeability and ground water storage. Strategically located stormwater water tanks help capture and control the distribution of rainwater and mitigate overland flows and resultant flooding.

Impact and benefits

The ramped-up Grey to Green programme has seen over 80 hectares (200 acres) of asphalt in the central city repurposed from roads, car parking and other underused infrastructure into open space, bike lanes and widened footpaths. The opportunity, during COVID-19, to further accelerate this programme has resulted in 40 kilometres (25 miles) of new dedicated bike lanes and hundreds of new parklets and cafés with outdoor seating using on-street parking bays.

- The Urban Forest programme was also extended during COVID-19, with 170,000 plants and trees planted to create jobs and accelerate climate change mitigation.
- The Total Watermark: City as a Catchment programme has installed eight strategically located stormwater tanks and added central reservation planted areas to most roads to increase permeability.
- These three strategies, combined, have resulted in reduced carbon emissions, increased permeable surfaces, more street tree plantings, increased area for walking, cycling and public transport, improved health benefits from increased walking and cycling, less flooding, increased soil moisture, improved water quality, a reduction in the amount of drinking water withdrawn from city reservoirs and increased tree species diversity – with a resultant increase in wildlife species. The strategies have also resulted in a higher-quality public realm, leading to improved amenities and greater levels of civic pride and safety within the city.

Lessons and experience

The main takeaway is that ambitious targets can be achieved through small incremental initiatives over time. Recording these small changes was essential to building a body of knowledge to encourage momentum and deliver substantial results, which helps to ensure ongoing political support and the ability to expand programmes.

↑ Before: 9,000m² depot area

↑ After: 5,000m² depot area, new 4,000m² open space, a new visitor centre and a 5ML underground water storage tank

Despite their obvious potential, NBS are infrequently implemented due to a perceived risk of failure and a lack of awareness by federal, state and city governments of their broad co-benefits, including improving public health, reducing pollution, managing climate risks and regenerating urban spaces. Compared with traditional grey infrastructure, NBS may take longer to implement, as ecosystems take time to become established and deliver their full benefits. As NBS are typically less visible, city leaders may be biased towards grey infrastructure solutions as a way of demonstrating action. In addition, the integrated nature of NBS typically requires more collaboration and coordination across a wider group of stakeholders and can challenge long-standing ideas and set practices around urban planning. In short, NBS requires a new mindset. As more cities start to mainstream NBS into their urban planning systems, a systems approach is needed. The key steps are shown in Table 1, and the primary features of successful NBS projects are shown in Figure 4. Philadelphia (Case study 7) shows how cities can adopt such approaches.

TABLE 1 **Key steps to adopting a systems approach that explores nature-based solutions in cities**

Steps	Details
A. Clearly define the challenge	
B. Evaluate whether NBS is the best option	Traditional investments (e.g. grey infrastructure solutions) or hybrid approaches
	Criteria: cost-effectiveness, cultural appropriateness, sustainability, implementation, etc.
C. Define reasonable alternatives for achieving the project objectives	Maximize the total benefits to the city without exceeding its financial and organizational capacities for project delivery and maintenance
D. Establish a baseline for the city's environmental indicators and climate-risk exposure	E.g. precipitation levels, flood risk, temperature extremes, GHG emissions, etc.
E. Establish a baseline of social and economic indicators	E.g. health, occupational status, access to assets, services, natural resources, economic indicators, etc.
F. Conduct technical, environmental, social and financial feasibility and impact assessments, as well as cost-benefit analyses	Identify a preferred solution in a collaboration between the city and relevant stakeholders
G. Develop a prioritized investment programme	Define the measures necessary for implementation (e.g. operations and maintenance) requirements and all necessary complementary actions (e.g. new policy programmes)
H. Quantify and give economic value to projected benefits	Communicate expected outcomes with stakeholders in a meaningful and transparent way
	Assign value to ecosystems services from NBS can generate greater buy-in and support
I. Assess recommendations of market-based mechanisms and business models	Promote opportunities for revenue generation and payment for ecosystem services

> **More cities are starting to consider both standalone and integrated nature-based systems when looking at innovative and systematic ways to address climate change. As these approaches are mainstreamed, it will be critical to consider how to incorporate both eco-benefits and new revenue streams.**
>
> Susan Goeransson, Director, Infrastructure Europe, Sustainable Infrastructure Group, European Bank for Reconstruction and Development (EBRD)

FIGURE 4 **Features of successful nature-based solution projects**

Extensive stakeholder engagement

- Inclusive community engagement throughout all phases of the project
- Examples: awareness campaigns, volunteer programmes, citizen councils, participatory budgeting, co-design activities
- Local organizations: source of local knowledge and expertise
- Facilitate effective design and delivery and promote acceptance, use and a sense of community ownership

Transparency

- Rigorous financial transparency: meet operational and maintenance requirements
- Clarity about full costs, abilities to capture social, environmental, economic and financial benefits
- Identify potential revenue streams and bring more private finance
  - Diverse range of revenue generation options, e.g. payment for ecosystem services, land-value capture schemes or additional side businesses

Flexible and bespoke solutions

- Adapting to local needs – including as they change over time – promotes public support and contributes to making cities more desirable places to live and visit

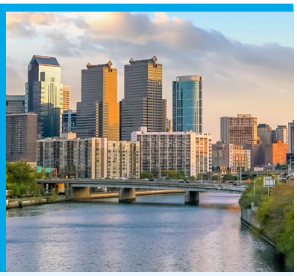
Creation of a dedicated entity

- A dedicated organization is established for the sole purpose of managing project design, delivery or funding
- Such organizations play key roles as focal points for coordination, action and advocacy, and can help generate buy-in from communities and other stakeholders
- Capacity building of the dedicated entity may be advisable

Source: World Economic Forum

CASE STUDY 7

Green City, Clean Waters: the Philadelphia story



Introduction and problem

The US Environmental Protection Agency (EPA) found the city of Philadelphia in violation of the Clean Water Act in 2000, due to a lack of sufficient wastewater treatment and stormwater infrastructure.

Solutions

The Philadelphia Water Department responded with Green City, Clean Waters, a $2.4 billion, 25-year programme. In addition to remediating the combined sewer outflow (CSO) system that services 60% of the city through 3,000 miles (5,000km) of pipeline and building on an earlier watershed protection programme, Green City focuses on installing green infrastructure to reduce high levels of pollution in Philadelphia's rivers, which are the source of drinking water for 1.7 million people living in the city and its immediate surroundings.

The plan incorporates:

- Advanced technology
  - City geographic information system (GIS) base maps updated with real-time monitoring to detect flows and leaks
  - Modelling programmes continually refined to highlight problem areas
- Technical assistance
  - Four planning/management districts established, each with assigned staff
  - Development of stormwater design, management manuals and workshops
- Regulation and enforcement
  - Rules revised for commercial and industrial uses governing run-off
  - Staff added for enforcement/inspections
- Tax policy and other incentives
  - Impermeable surfaces taxed
  - Stormwater credits offered against water charges, and density bonuses provided for green roofs
- Enhanced maintenance
  - Three skimming vessels purchased for removal of water-based debris

Impacts and benefits

Initiated in 2011, Green City aims to meet its goal of reducing pollution by 85% by 2036 through a mix of advanced technology, technical assistance, regulation (including enforcement), tax policy, enhanced maintenance, public and private capital investment at varying scales, and extensive partnerships and community engagement. In its 10th year, the city has surpassed its midcourse goals, despite some setbacks related to the COVID-19 pandemic. Furthermore, Green City has realized several co-benefits beyond environmental improvements, including increases in employment and property values, enhanced health and well-being (especially for low-income communities) and a decline in crime.[41,42] To date, the city has removed 2.7 billion gallons (10.2 billion litres) of polluted water from its rivers. In 2021, despite some slowdowns attributed to the pandemic, the Philadelphia Water Department reported that, in 2020, it had not only surpassed its water pollution targets but had engaged 400,000 city-dwellers of all ages in the process.

Lessons and experience

Public and private capital investment secured the funding for this project. The public sector has invested in public spaces, including streets, trees, tree trenches (also known as vertical rain gardens), bioswales, bioretention basins, cisterns for grey-water reuse, water gardens, open spaces (e.g. parks, school playgrounds, green roofs on public buildings), updated CSO system components, and grants for residential and commercial/industrial green stormwater infrastructure. Meanwhile, the private sector has invested in features that result in direct benefits to businesses (e.g. rain barrels, green roofs, downspout planters). In addition to using resources from both the public and private sectors, the project has also pursued effective partnerships and community engagement. It developed partnerships with city agencies (e.g. parks and recreation, transportation, the education board, sanitation), the private sector and civic groups (e.g. Pennsylvania Horticultural Society, Trust for Public Land, AmeriCorps, United by Blue, Bridgestone Tires, Fairmount Park Conservancy). Additionally, it launched large public education programmes (e.g. in schools, on social media, through community meetings) and created recognition programmes (e.g. the Stormwater Pioneers Award for excellence in design and construction).

National governments can also play a vital role in promoting an enabling environment for cities. In fact, some national governments have started to encourage the use of nature-based solutions. In Norway, for example, national planning guidelines encourage local governments to consider nature-based solutions and ask them to justify the adoption of other engineered methods. The United Kingdom recommends local authorities take into consideration the use of natural flood management through its national planning policy framework.[43]

The roll-out of more NBS projects based on these approaches and principles will generate new and more applicable experiences. This will help with technical aspects of NBS implementation and management, as well as with financing, including how best to capture the benefits of ecosystem services and to identify new revenue streams. This, in turn, will encourage more replicability of solutions, reduce perceived risks and overturn many barriers to implementing and financing NBS.

3

Why do we need a systems approach to urban infrastructure delivery?

A system approach to infrastructure not only makes it easier to take cross-sectoral action and evaluate any impacts holistically, it also aids climate resilience and helps reduce carbon emissions.

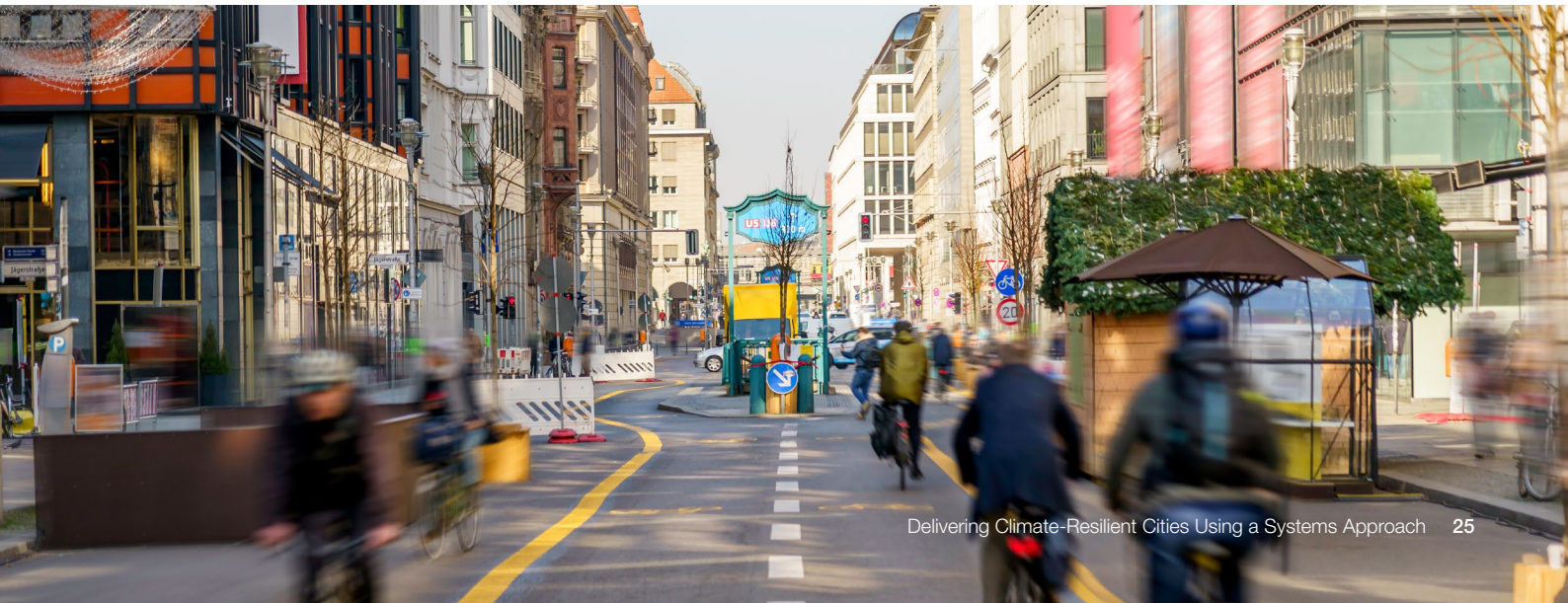
3.1 The unique role of cities in taking a systems approach

> **Cities are the place where 70% of greenhouse gas emissions are produced despite housing 55% of the global population and occupying less than 3% of the global land area. The leadership of mayors and local governments is thus instrumental in devising innovative solutions and urgently scaling up action to put cities on a path of decarbonization and, at the same time, adapting to the impacts of climate change.**
>
> Sameh Wahba, Regional director, Sustainable Development, Europe and Central Asia Region, World Bank; Global Director, Urban, Disaster Risk Management, Resilience and Land Global Practice, World Bank Group (2019–2022)

Urban activities are supported by multiple infrastructural sectors. Cities can shape the demand and use of these infrastructure services through urban planning and policies, but often have limited influence over the supply side of some infrastructure sectors. Even so, given cities' functional and political oversight, their mandate for meeting local needs and their close awareness of issues on the ground, they are the appropriate scale at which to anchor a systems approach to urban infrastructure delivery. This means cities should consider the supply and demand of these multiple infrastructure sectors holistically, identify effective cross-sectoral actions and evaluate multiple impacts at the local and supply-chain levels when improving climate resilience and significantly reducing carbon emissions.

Municipal leaders and city governments need to urgently address multiple infrastructural service delivery sectors to improve climate resiliency and significantly reduce carbon emissions. The expansion of urban areas is expected to outpace population growth by 50% if cities perpetuate existing horizontal spatial patterns.[44] However, cities can reduce such sprawl and harness other benefits through more vertical building.[45] For example, cities could significantly reduce their share of GHG emissions by promoting compact urban form through policies such as: densification and transit-oriented-development, as shown in Melbourne (Case study 1); incorporating nature in the built environment; promoting energy-efficient public transport and active mobility (walking and cycling); encouraging the construction of green buildings and retrofits; developing effective solid waste management systems; and integrating cross-sectoral actions. Changed patterns of spatial mobility and work in the post-pandemic period may drive faster growth in suburban cities than in some global megacities.[46] Suburban cities, taking advantage of this population growth, could use systems approaches to densify their development. Integrating cross-sectoral approaches for climate change mitigation with consideration of co-benefits would ensure delivery of fundamental services while also encouraging considerable global health gains – indeed, economic gains could exceed the estimated investment costs several times over.[47]

Meanwhile, cities can provide greater protection to residents and assets against the impacts of climate change and natural hazards by investing in climate-resilient infrastructure solutions. These range from flood and stormwater drainage systems (both traditional and nature-based), to ensuring effective operation and maintenance of municipal infrastructure, to designing infrastructure using standards that incorporate climate risk. In fact, resilient infrastructure investment in developing countries is expected to result in a net benefit of $4.2 trillion, yielding $4 in benefits for every $1 invested.[48]



Cities can secure important climate co-benefits by improving infrastructure; details are discussed in Section 3.4. For instance, retrofitting substandard housing in cities, converting ageing commercial offices into residential accommodations (see Case study 1) and upgrading slums and informal settlements not only improves liveability and the well-being of the urban poor but also reduces risks from climate disasters – especially flooding. Retrofitting existing housing enhances its resilience, and adopting green building codes and designs improves energy, water and resource efficiency. Scaling up city actions for climate change mitigation and adaptation in the areas within their remit, and in alignment with their devolved responsibilities, is not so obvious from a political economy perspective as the delivery of basic services or job creation. Hence, it is strategic to focus on the co-benefits of climate actions (e.g. health, growth and inclusion) to make them acceptable to the public.

The leadership role of municipal leaders and local governments in climate change mitigation and adaptation inevitably depends on the local decentralization context. Reducing GHG emissions in cities requires action on energy, waste management, buildings, land use and transport systems (linked to the city's compactness or sprawl and existing transport modes). Innovative solutions are needed, and city governments can bring other cities and private-sector actors together to explore new solutions, as demonstrated in the Helsinki Energy Challenge (see Case study 8). However, not all actions in these sectors fall within the remit of municipal leaders. Some are regulated by national or provincial governments, and others are influenced by private entities. Competencies devolved to city authorities often include land-use planning; waste management; municipal buildings (for retrofit and energy efficiency interventions); building regulations (that is, of green and resilient buildings); and, at times, transport (if not under provincial government or the private sector). Furthermore, cities can use their purchasing power, advocacy and incentive programmes to influence transboundary infrastructure services (e.g. buying renewable energy from the electricity grid).

CASE STUDY 8

Helsinki Energy Challenge

Introduction and problem

The city of Helsinki aims to be carbon-neutral by 2035. Today, more than half of the city's heat is produced from coal, so radical new solutions are needed if it is to meet its heat demand and reach its goal. One tempting way forward is through the increased use of biomass. Given that this alternative is not sustainable over the long term, however, especially where forests are not sustainably managed, Helsinki is searching for other solutions. In particular, it launched the Helsinki Energy Challenge[49] in 2020 – a global challenge competition with a prize of €1 million ($1.1 million), to answer the question: How can we decarbonize heating in Helsinki for decades to come using as little biomass as possible?

Solutions

The challenge was a design contest; entries consisted of "master plans" to decarbonize city heating. Proposed plans could include one or more technological or non-technological solution(s). The main requirement was that the proposed solution(s) should significantly contribute to Helsinki's ability to stop using coal by 2029 and accelerate the process of becoming carbon-neutral by 2035.

Helsinki invited other cities to join the discussion and explore new solutions. One main goal was to generate a broad debate on the role of cities as enablers of clean energy solutions. Shortlisted teams were invited to a co-creation phase, during which teams worked together with city officials and other leading stakeholders to further develop their proposals. Following this co-creation process, finalists submitted their proposals for review by an international jury.

Benefits and impacts

Some 252 teams, made up of 1,528 innovators from 35 countries, submitted proposals. Teams included start-ups, technology and energy companies, research institutions and universities. Most teams were international and multidisciplinary, modelling the multistakeholder approach needed to build a sustainable heating system. Many of the teams created during the Helsinki Energy Challenge have continued working together and are building innovative solutions for use by other cities.

Lessons and experience

The Helsinki Energy Challenge has highlighted that there are many approaches to building a carbon-neutral heating system. It also showed that the heating system of the future is resilient and made up of several partial solutions optimized to work together, and that systemic change requires close cooperation throughout industrial and organizational boundaries. The city of Helsinki has now started to build, in cooperation with several stakeholders, a citywide roadmap to carbon-neutral heating that will help it proceed with the results in an innovation-enabling way, so that the upcoming decisions will benefit all stakeholders.

The Helsinki Energy Challenge provided a platform for innovators to co-create the future of urban heating while doing their bit to solve a global issue. The city of Helsinki is now working to share all of its learnings and solutions with other cities around the world.

Source: ThinkGeoenergy, 2020[50]

“ Cities have an important convening role in building coalitions with a wide range of stakeholders, including the private sector and neighbouring municipalities.

Climate action also requires strong commitment from municipal leaders and local governments. Some 65% of 169 United Nations Sustainable Development Goal (SDG) targets would not be achieved without effective local action,[51] reiterating the importance of collective effort among local leaders and governments towards climate-resilient and zero-carbon pathways. Therefore, the UN's Decade of Action for achieving the SDGs aims to embed the necessary transitions in the policies, budgets, institutions and regulatory frameworks of governments, cities and local authorities.[52] The past decade has seen a great increase in the number of municipal leaders committing to such action, with support from global networks such as C40 Cities Climate Leadership Group (C40), the Resilience Cities Network, the Global Covenant of Mayors for Climate and Energy (GCOM), the OECD Champion Mayors Initiative, and Local Governments for Sustainability (ICLEI). The latter has played an important convening role in local government action for climate change and sustainability. Many influential urban initiatives also motivate cities to act. During COP26, it was announced that 1,049 cities and local governments, representing about 722 million people worldwide and more than a quarter of the world's GDP,[53] have joined the UN's Race to Zero campaign.[54] These cities made the pledge to achieve net-zero emissions by 2050 and cut their fair share of global emissions in half by 2030.[55] From these, 33 cities also joined the Race to Resilience[56] campaign. Additionally, initiatives promoting nature-based solutions, such as Nature Positive by 2030 and joining the Edinburgh Declaration,[57] also gain momentum.[58]

Cities also have an important convening role in building coalitions with a wide range of stakeholders, including the private sector and neighbouring municipalities. The private sector is especially critical in filling the huge financing gap as required to make urban infrastructure climate-smart and resilient. This is estimated by the Cities Climate Finance Leadership Alliance (CCFLA) at $4.5 trillion–$5.4 trillion per annum, including a 9–27% premium to make infrastructure resilient.[59] Some infrastructure assets (e.g. power plants, commercial buildings, waste management) are owned by private stakeholders or reside in joint public-private ownership initiatives. It is critical to bring them on board in the transition. Similarly, neighbouring cities within a metropolitan region need to join forces to find integrated transport and service delivery solutions, as well as generate climate change action. They can also partner in creating bankable infrastructure projects with a viable economic scale and risk profile, and then bundle the investment.

If cities fail to deliver high-quality urban infrastructure services, we can expect to see more social and environmental problems, in addition to the failure to address climate change. The COVID-19 pandemic reveals that the way in which infrastructure services are provided can amplify social problems.

3.2 Lessons from COVID-19 on urban infrastructure delivery and climate change response

> **COVID-19 is more than a health crisis; it is a social and economic crisis that has exacerbated long-standing inequities in society.**
>
> Penny Abeywardena, Commissioner for International Affairs, Mayor's Office, City of New York (2014–2022)

All around the world, cities are on the front line of the greatest global challenges, including climate change and the COVID-19 response. The pandemic has accentuated pre-existing infrastructural issues beyond socioeconomic status, such as the lack of digital infrastructure in socially disadvantaged communities. It has revealed more than it has changed.

The impact of COVID-19 has forced city governments to rethink infrastructure such as public spaces, buildings, transport services and digital access – and the ways to encourage equity in the provision of these essential services. For example, New York City is committing $17 billion to capital projects, including affordable housing, green spaces and parks, street safety, digital infrastructure, school expansions and coastal resiliency projects.[60] These capital projects are guided by the principles of reducing GHG emissions and maximizing resiliency in response to climate change.[61] Another example is Melbourne's focus on commercial buildings to combat climate change and improve health. Melbourne (Case study 3) demonstrated that commercial buildings could achieve high environmental standards through energy and health codes (e.g. with consistent fresh air flow), in addition to traditional-energy retrofits and renewable energy use. What Melbourne is doing also fits into the World Economic Forum *Framework for the Future of Real Estate*, which prioritizes liveability, sustainability, resilience and affordability in a post-COVID world.[62]

COVID-19 has accelerated the need to find green and sustainable solutions that also address other infrastructure development targets. For example, social segregation in cities is an ongoing crisis, but COVID-19 has cast the problem into stark relief. Yet, although infrastructure tools to address segregation have been applied in some cities for years, COVID-19 has not brought significant widespread change. Cities have to address the need to combine holistic evaluation and quick delivery, since neither is naturally present in city infrastructure planning. Scaleable programmes such as the delivery of urban forests, as in the city of Melbourne, can easily be introduced into cities at all stages of maturity.

As with COVID-19, climate change also poses higher risks to lower-income neighbourhoods and communities of socially disadvantaged groups that have historically faced disinvestment. These communities are more prone to flooding, have a higher heat index and suffer a dearth of parks and green spaces.[63] In developing countries across the globe, up to 70% of the urban population lacks access to core services and infrastructure, relying instead on informal and unpredictable alternatives for water, sanitation, energy and transport.[64] Today, nearly 600 low-lying coastal cities face projected sea level rises of at least 0.5m (20in) by 2050, putting 800 million people at risk of coastal flooding, storm surges and energy disruptions. The projected reduction in access to freshwater could affect 650 million people in 500 cities worldwide by 2050, even as the demand for water is expected to increase by 55% because of population growth and increased temperatures.[65]

If we are to learn from the COVID-19 pandemic, climate actions should focus not only on single targets but also on holistic leadership and systemic change that positively affects society as a whole. Beyond single targets, it is crucial for cities to commit to the wider goals and reach of the SDGs. They can then build an approach to urban infrastructure that addresses equity and community-building from a wider perspective, while maintaining crucial climate and sustainable development targets. Since 2018, many cities across the globe have adopted a place-based approach to the SDGs. In practice, cities have gone beyond the SDG compliance agenda, using it as a policy tool to rethink from the ground up the way they plan, budget, invest, shape and implement policies, and how they engage stakeholders. For example, the city of New York has created the Voluntary Local Review (VLR) process to localize the SDGs. The VLR is a tool that can guide strategy and resource allocation, accelerate international cooperation and share methodologies and learned lessons for a better urban future. Many cities around the world have joined the city of New York and signed up to the VLR process, including Helsinki (Case study 9), Bristol, Kitakyushu and others.

CASE STUDY 9

From agenda to action – implementing the UN Agenda 2030 Sustainable Development Goals in Helsinki

Introduction and problem

Much of the implementation of the 2030 Agenda's Sustainable Development Goals (SDGs) is carried out at the local and regional level. Helsinki[66] was one of the first cities to commit to the Voluntary Local Review (VLR) of the SDGs in 2019. In Helsinki, as in every city, there is still much to do to achieve the SDGs, especially in regards to ecological sustainability. In addition, COVID-19 has put a strain on all of Helsinki's residents, highlighting inequalities and increasing polarization among various groups.

Solutions

Helsinki aims to be a pioneer in the local implementation of global responsibilities. The city's goals for the VLR process were to illustrate the successes (and possible failures) of its strategies in relation to the SDGs, produce understandable, transparent information about its sustainable development and spark dialogue within the global community.

Helsinki's first VLR report focused mainly on the city's strategy and primary projects. The second report, issued in 2021, covers all of the SDGs and expands the focus to the entire government. The aim was to describe and assess the goals from the city's perspective.

Impact and benefits

The VLR model has strengthened cooperation between the UN and national and city governments. In Helsinki, the intention is to adopt recommendations efficiently within the city. During the second VLR reporting period, SDG coordination was improved and more closely linked to the city's overarching strategy. Its second VLR includes an electronic platform for 54 SDG indicators, and dozens of practical examples of actions. Constant monitoring and learning are needed to assess the effects of such change in sustainability thinking and determine what it means for Helsinki in both the short and the long term.

Lessons and experience

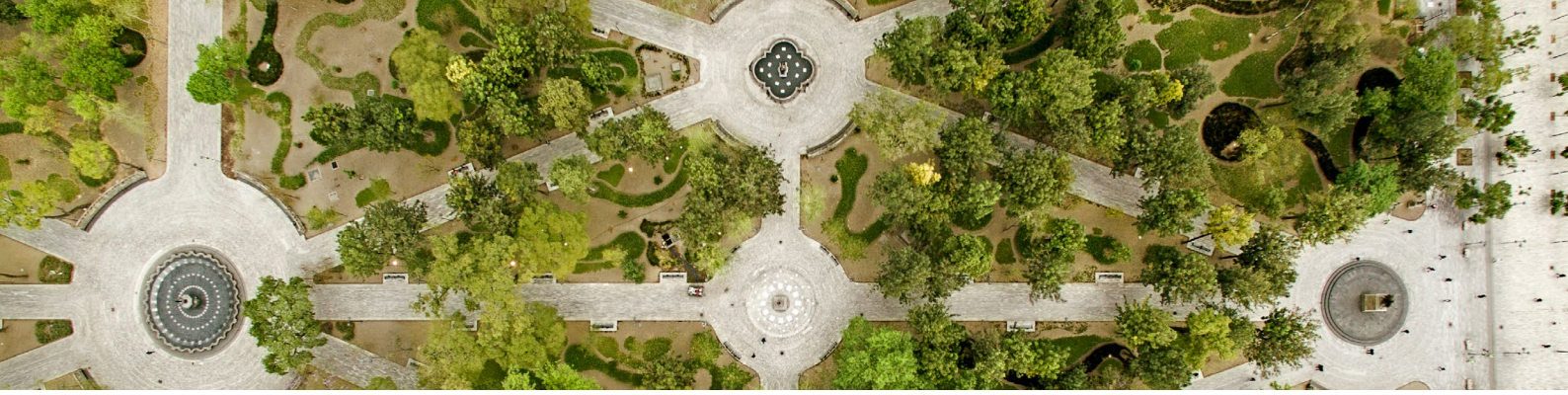
The VLR model has helped Helsinki to develop its operational structures and thereby deliver sustainable development solutions successfully at city-scale. The city actively communicates the results to stakeholders and inhabitants to raise consciousness of the importance of the SDGs in its day-to-day operations. This, in turn, enables it to explore new ways to put the goals into practice.

Helsinki is working to build recognition of the role of cities in key international forums and networks to enable them to participate in setting future agendas and goals – not just implementing existing recommendations.

Source: City of Helsinki, 2021[67]

Cities are leading actors in taking on these challenges at local scale, with innovative approaches based on evidence and public accountability. Since the outbreak of COVID-19, cooperation between and within cities has accelerated considerably. Such cooperation has been an asset for local management of the pandemic; examples include the C40 Green and Just Recovery task force and other efforts by United Cities and Local Governments (UCLG), the Urban 20 (U20), the OECD Champion Mayors and ICLEI among others. Likewise, collective urban action as driven by C40, ICLEI and others is vital to advancing the more ambitious climate targets of the Paris Agreement on a local basis.

Cities could lead on these efforts to accelerate economic recovery, enhance social equality and secure a sustainable and resilient future. The SDGs provide a unique framework for cities to adopt a systems approach, and to help manage trade-offs between competing priorities and objectives while driving a green and inclusive recovery.



3.3 Systems approach to urban infrastructure delivery post-COVID: challenges and opportunities

> **With climate change and income inequality looming issues, calls for the planning and developing of impactful investments to address their effects are emerging.**
>
> Eugenie L. Birch, Nussdorf Professor and Co-Director, Penn Institute for Urban Research, University of Pennsylvania

The pandemic has saddled city governments with significant revenue losses – often ranging from 15% to 25% – while also increasing expenditures for healthcare and social services.[68] Diminishing revenues have raised concerns about the future of city infrastructure and sustainable urban development. For example, across the US, lower-income neighbourhoods and communities of colour have historically faced disinvestment, and are now finding that the devastating effects of neglect by federal, state and local government are being magnified by the pandemic and climate change. In addition, cities rely heavily on federal and state government transfers, which have been reduced due to the increased debt burden that those institutions have had to bear from the COVID-19 pandemic.

Cities offer a unique opportunity to reduce carbon emissions – by up to 90% – while delivering significant economic returns, based on currently available technologies and practices in buildings, transport, materials efficiency and waste.[69] Moreover, well-designed infrastructure investment can benefit local well-being, especially through cleaner air and less congestion. Such investment can also address increasing climate-related risks, while delivering opportunities for local economic development. A C40 study highlights that a green and just recovery could create more than 50 million jobs by 2025, reduce air pollution by as much as 29% and prevent more than 270,000 premature deaths in the course of the next decade.[70] A systems approach to designing urban infrastructure would help cities fulfil their many remits.

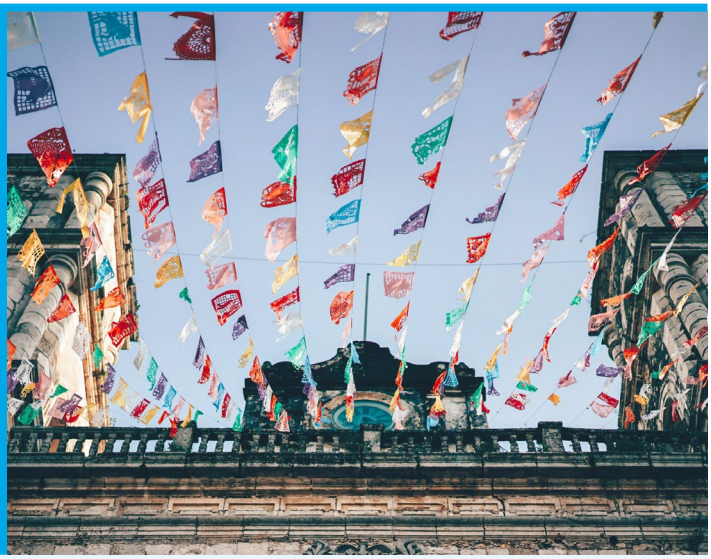
Prior to the pandemic, the Coalition for Urban Transitions (CUT) commissioned an analysis of the potential effects of urban-focused green investments, finding that such investments could generate 87 million jobs by 2030 and an additional 45 million jobs by 2050, while allowing energy and material savings of $24 trillion.[71] In a subsequent study, CUT asserted that the core strength of cities would persist over time, despite difficulties arising from the pandemic – such as large numbers of people working remotely, leaving offices and associated retail spaces vacant and a sharp decrease in public transport use.

Stimulus packages and financing approaches focusing on climate-resilient and net-zero carbon infrastructure are slowly appearing worldwide. For example, Germany's €130 billion ($132 billion) programme targets electric vehicles, public transport and green buildings; Korea's $62 billion programme focuses on a digital new deal and green new deal to eliminate coal and support renewable energy and job training; and the European Green Deal promises to raise more than $100 billion for its Just Transition Mechanism (JTM) to support conversion from carbon-intensive to low-carbon installations.[72] Elsewhere, green bonds have grown exponentially, from $15 billion in 2013 to $465 billion in 2020.[73] Some cities, e.g. Mexico City (Case study 10), have issued green bonds to finance sustainable infrastructure projects. When a project involves more than one infrastructure sector, investment is expected to be higher.

Most stimulus packages have yet to recognize the opportunities afforded by cities. As of February 2021, only 14% of the G20, plus 10 other major economies, had focused on cities, and only 27% of the stimulus packages were green.[74] This position may soon change, with the European Commission seeking to deliver 100 climate-neutral and smart cities by 2030 and requiring that all EU cities have committed to this path by 2050.[75]

CASE STUDY 10

Mexico City leads subnational issuance of green and sustainable bonds in Latin America



Introduction and problem

Cities are frequently constrained by their ability to access capital markets. Even where legal and regulatory frameworks do not prevent it, risk or political considerations can limit the level of subnational lending. As the most populous city in North America, Mexico City's infrastructure needs – e.g. water, drainage, transportation – are significant, with its most recent public works investment plan estimated at around $3 billion. Mexico City finances these needs, among others, through fixed-term interest debt security instruments, such as bonds.

Green and sustainable themed bonds specifically earmark proceeds to support climate and environmental projects, and in the case of sustainable bonds, require a positive social outcome. Cities with supporting credit ratings have issued municipal bonds to finance public projects for decades, but green bond markets emerged only relatively recently – in 2013, in Massachusetts. In Latin America, Mexico City was the first city to pursue this course, issuing green bonds to finance the city's climate action programme.

Solutions

Mexico City issued its first green bond on the Mexican stock market in December 2016, with a value of 1 billion Mexican pesos (around $50 million), for a term of five years at 6.2% interest. It was issued to finance projects in energy-efficient lighting, transport upgrades and water infrastructure. High demand meant that the bond was "oversubscribed" by two-and-a-half times. In November 2017, Mexico City issued a new, sustainable bond for 2 billion Mexican pesos (approximately $100 million), for a term of 10.5 years at 7.6% interest.

This bond finances social and environmental projects linked to basic services, renewables and energy efficiency, sustainable transport, pollution prevention and water adaptation and conservation. To guarantee the effectiveness of these bonds, internationally certified independent experts (Carbon Trust Mexico) have systematically provided second opinions consistent with the Green Bond Principles (GBP). They also periodically collect data on agreed indicators and produce and publish reports.

Impact and benefits

A sustained and growing demand for bonds of this type could: 1) enable public-sector institutions to tap into capital markets and mobilize private-sector investments towards green investments, supporting a more sustainable and resilient recovery and transformation strategy; 2) increase transparency in the management and allocation of income and the final destination of public investments, thus reducing perceived governance risks; and 3) help cities meet commitments under the Paris Agreement (climate resilience and low carbon development) and SDG agendas.

Lessons and experience

Specialized thematic bonds can help cities holistically identify and prioritize investments from both public and private actors to address environmental and climate change elements. In Latin America, the issuance of green bonds has been dominated by three countries (Brazil, Mexico and Chile) and three issuers (non-financial corporates, sovereigns and development banks). But subnational entities hold untold potential to scale up investment in green projects and inclusive recovery through green and sustainable bonds.

Within the federal and national policy realm, countries can undertake three critical reforms that will have positive effects on action for climate change and economic growth:

1. Fiscal efforts: eliminate fossil-fuel subsidies, provide incentives for private-sector investment in renewable energy and green technology, and reward green investments via intergovernmental fiscal transfers.[76]

2. Governance changes: establish a federal/national urban policy, with a comprehensive strategy that recognizes and supports a system of prosperous and inclusive cities.

3. Financial improvements: develop dependable revenue streams and channels for cities to access finance from federal/national and multilateral financial institutions.

With a supportive enabling environment, cities can accelerate the adoption of a systems approach to infrastructure investment that prioritizes their specific needs. They can set their own priorities to enable green investment and support programmes in energy, public transport and active travel, buildings, waste, water and compact urban planning. In a nutshell, cities play a critical role in the net-zero carbon and climate-resilience agenda.

3.4 Co-benefits of net-zero carbon and climate-resilient actions

Beyond net-zero carbon and climate resilience, a systems approach to urban infrastructure delivery offers multiple co-benefits for other societal goals.

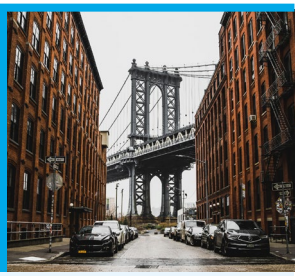
José Siri, Urban Health Consultant, World Health Organization; Senior Science Lead – Cities, Urbanization & Health for Our Planet Our Health Programme, The Wellcome Trust (2019–2021)

Net-zero carbon, climate-resilient infrastructure, designed and delivered through a systems approach, can directly benefit people's health, well-being and livelihoods and the environment. Through these multiple co-benefits, it offers significant economic efficiencies – critical under any circumstances, but more so in the wake of COVID-19. In the coming years, local governments face revenue decreases of 15–25% or more due to shortfalls from property and income taxes, public transport and parking fees, tourism, remittances and other sources.[77,78]

Net-zero carbon, climate-resilient urban infrastructure has wide-ranging, direct health benefits. For example, decarbonized energy production and low-carbon transport reduce the harmful air pollutants that stem from the burning of fossil fuels, recently linked to one in five global deaths.[79] The most important transport-related health gains come from systems that encourage walking, cycling and use of public transport, which reduce sedentarism and traffic accidents while promoting better mental health. However, significant emissions reductions and health improvements can be achieved by simply shifting to cleaner vehicles.[80] Energy-efficient housing and other buildings can protect health by improving heating in cold seasons, while reducing exposure to outdoor air pollution (see Case study 1), though care must be taken to limit exposure to indoor pollutants. In warm contexts, architectural principles for passive cooling can protect against extreme heat. Net-zero carbon, climate-resilient infrastructure itself emits less heat, reducing urban heat island effects. Nature-based solutions can likewise mitigate against heat and flood exposure, conserve water and provide a range of direct health benefits such as space for physical recreation, social gatherings and psychological restoration. In Cape Town, for example, the city is removing invasive plants as a targeted nature-based solution for increasing water supply and restoring local ecological systems, thereby securing green spaces for public use.[81] Cities should strive to identify and implement opportunities to take advantage of the co-benefits to ensure that infrastructure is net-zero, climate-resilient, and health- and nature-positive.

CASE STUDY 11

Co-benefits of the New York City Retrofit Accelerator



Introduction and problem

New York City has committed to achieving carbon neutrality by 2050 in line with Paris Agreement goals to limit global warming to 1.5°C. Buildings account for nearly 70% of NYC's GHG emissions, making building energy efficiency critical to meeting the city's climate goals. The burning of fossil fuels in buildings for heat and hot water also contributes to air pollution that causes health problems, particularly in children and older people. Addressing the large buildings sector using smart, equity-driven programmes can also improve health outcomes, especially for historically marginalized communities.

Solutions

NYC Mayor's Office established the Retrofit Accelerator programme in 2012 to offer free, personalized advisory services that help streamline the process of pursuing building energy efficiency improvements and clean energy projects. The programme's efficiency advisers work directly with building owners and managers to provide free one-on-one guidance throughout the entire retrofit process. Core services include:

- Identifying customized retrofits
- Procuring and managing contractors
- Monitoring progress for quality assurance
- Reducing out-of-pocket costs through connection to incentives and financing

The resulting projects span a broad range of measures aimed at supporting efficiency and the green economy, including high-efficiency lighting, windows, insulation, boilers, energy management systems and solar panels. The programme is open to properties of more than 25,000 square feet (2,300 square metres), as well as to all affordable housing projects[82] regardless of size, to ensure benefits to historically marginalized communities.

Impact and benefits

The Retrofit Accelerator reduces building operational costs and utility bills, while cutting the city's air pollution emissions. The programme supported nearly 8,300 projects on energy efficiency, water conservation and clean energy in its first four years – exceeding its stated goals. These projects included the conversion of approximately 50 million square feet (4.6 million square metres) of building space to cleaner fuels, and the reduction of pollution by 7.71 metric tonnes of particulate matter (PM2.5) and 56,087 metric tonnes of CO_2e each year. They also yielded economic benefits by supporting upgrades to affordable housing and by reducing utility costs for low-income residents. The table below summarizes the multiple benefits of the NYC Accelerator.

Number of projects converted	Total square feet	$PM_{2.5}$ avoided	$PM_{2.5}$ avoided per building	$PM_{2.5}$ reduction
544	~50,000,000	7.71 (metric tonnes/year) (final)	0.014 metric tonnes/year, 1.44 kg/year	~25% (from 2014 baseline)
		CO_2E avoided	CO_2E avoided per building	CO_2E reduction
		56,087 ($MtCO_2E$/year) (final)	103.10 $MtCO_2E$/year	~15% (from 2014 baseline)

Note: $MtCO_2E$ = metric tonnes of carbon dioxide equivalents.

Lessons and experience

Key methodologies helped drive the success of the Retrofit Accelerator, including:

- Coordinating with the buildings sector to design and implement important aspects of the programme, ensuring that the resources developed fill actual needs
- Partnering with utilities and other government agencies on programme design to exploit potential avenues of collaboration, such as on state-run pilots and new utility business models
- Targeting outreach to focus on the specific projects or technologies that are most relevant to each building, rather than presenting all of the potential retrofit options
- Building on existing relationships with building operators, securing buy-in from large property managers and partnering with building networks and stakeholders to connect decision-makers to resources
- Conducting consistent, coordinated and regular customer engagement through multiple channels, including public events, community meetings, news articles and social media

“ Urban density creates economies of agglomeration, reduces commuting times and supports social capital. New infrastructure projects, or retrofits of existing infrastructure, can create significant employment opportunities while also driving economic gains.

The direct benefits of net-zero carbon, climate-resilient infrastructure extends to social and economic well-being. For example, urban density is supported by well-designed transport systems in tandem with effective urban planning. Urban density creates economies of agglomeration, reduces commuting times and supports social capital. New infrastructure projects, or retrofits of existing infrastructure, can create significant employment opportunities while also driving economic gains. The OECD and others have identified infrastructure investment as vital to post-COVID job creation and economic recovery.[83] Critically, green infrastructure projects have been shown to lead to a higher rate of job creation than fossil-fuel projects.[84] One study found that spending on renewable technologies created 75 jobs per $10 million, versus just 27 for fossil-fuel spending.[85] A UK report highlights that tens of thousands of good jobs could be created through coordinated, net-zero-aligned investment in six main areas: energy efficiency in buildings; natural capital projects; active travel equipment and infrastructure (such as bicycles and cycle lanes); renewable power generation and distribution; electric vehicle production and charging infrastructure; and carbon capture, utilization and storage (CCUS), along with hydrogen production.[86]

Local environments can also benefit from net-zero carbon and climate-resilient infrastructure. Greater energy efficiency – achievable through the use of renewables, building automation systems, energy generation from waste or channelling of waste heat to area heating systems – means lower short-term impacts on local ecosystems. The city of Copenhagen, for example, meets most of its heating needs with waste heat from electricity production.[87] Nature-based solutions such as green and blue urban spaces (i.e. spaces covered by vegetation and water bodies, such as urban forests, wetlands and lakes), green walls and roofs, and coastal habitat restoration can directly protect biodiversity while also providing a range of climate-relevant services such as flood management, food security, microclimate regulation and carbon capture.[88]

Net-zero carbon and climate-resilient infrastructure can also play a vital role in local resilience. For example, distributed energy sources (e.g. rooftop solar PV panels) can ensure power is available during weather-driven disasters – particularly important for health facilities in the developing world. Advanced water-leak detection systems can help to manage storm risks, reduce waste and boost the sustainability of critical water resources. Building design and operation can incorporate principles of passive survivability (i.e. buildings maintain critical life-support conditions when they lose power or water).[89] Modern building automation systems, which already sustain comfort, safety and energy efficiency, can incorporate resilience principles in order to effectively accommodate change along multiple dimensions.[90]

By incorporating the true costs or benefits of health and ecological impacts, an explicit co-benefits strategy can change the economic calculus on net-zero carbon and climate-resilient infrastructure. According to the World Health Organization (WHO),[91] “the value of health gains from climate action would be approximately double the cost of mitigation policies at global level”, and some locations would see even greater benefit-cost ratios. In the face of significant post-COVID financial shortfalls and increased costs, cities can no longer afford to ignore these potential gains. Moreover, a focus on green infrastructure can be a highly visible stimulus for broader awareness and acceptance of sustainability principles in society at large. Incorporating co-benefits into decision-making brings a new arsenal into play for policy-makers seeking to convince their constituents and other stakeholders of the need for net-zero carbon and climate-resilient infrastructure. While local priorities will vary, the moral imperatives surrounding the preservation and promotion of health, equity, livelihood and the environment constitute powerful arguments for a greener future.

4 How to implement a systems approach to urban infrastructure delivery

City-led actions have been critical in integrating climate and resilience objectives into urban infrastructure planning.

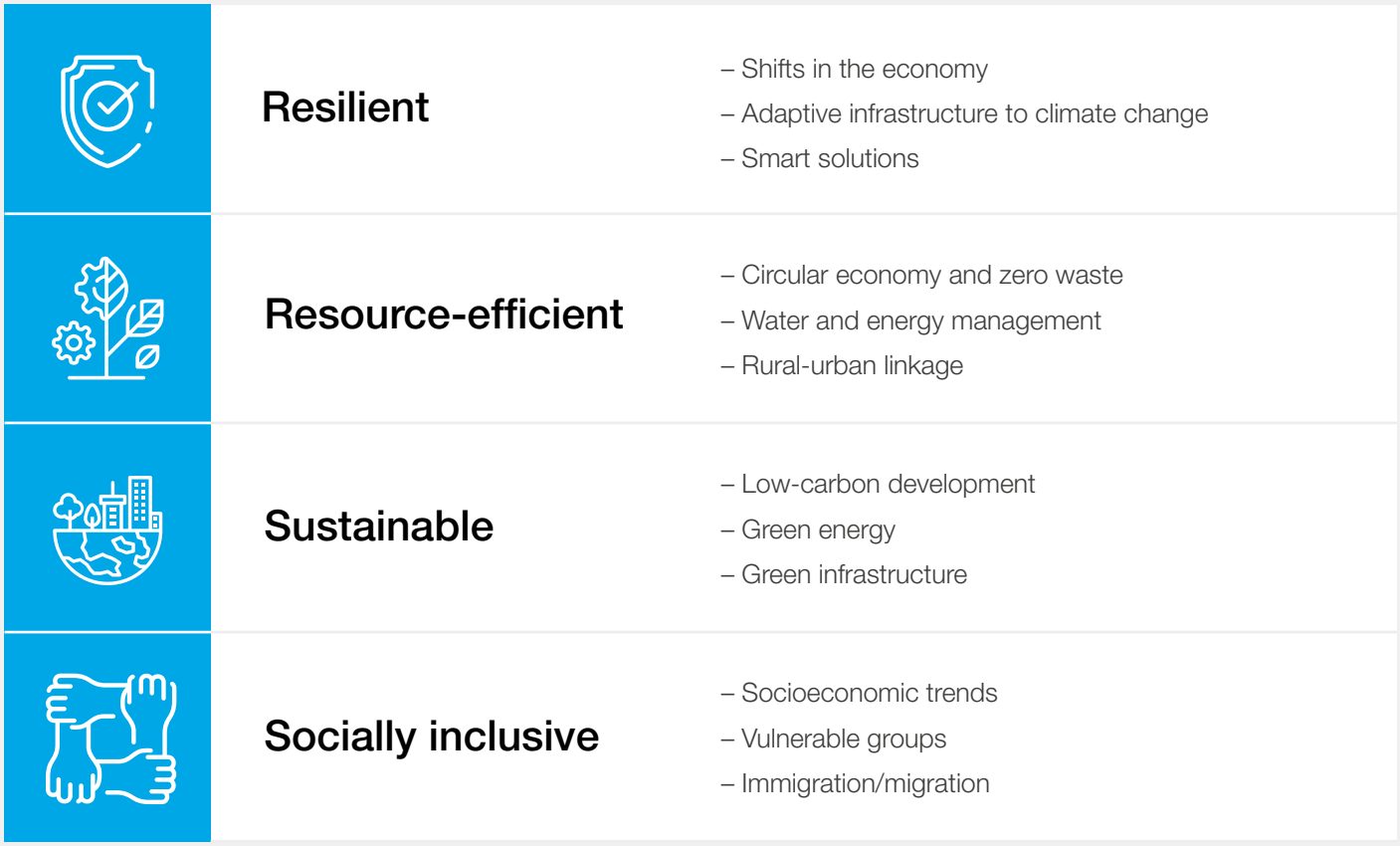
4.1 Multi-infrastructure planning and cross-sectoral policies

Effective climate and resilience action in cities, by its very nature, will require an integrated and place-based policy approach, rather than a fragmented and sector-based approach. While cities are at the heart of the action, diverse actors should interact and play their respective roles in a systematic approach.

Aziza Akhmouch, Head of Division, Cities, Urban Policies and Sustainable Development, Centre for Entrepreneurship, SMEs, Regions and Cities, OECD

In addressing climate and resilience challenges, cities can implement participatory, tailored strategies to promote local economic development and social cohesion. They can also choose public investments that create the most jobs.[92] In Kenya, the Sustainable Urban Economic Development Programme supports municipalities in designing urban economic plans, which enable county-level governments to identify climate-resilient value chain and infrastructure opportunities for future urban development. The planning process applies four main principles (resilient, resource-efficient, sustainable and socially inclusive), which enable local government officials to assess the priorities for development of different projects (Figure 5). Similarly, the city of Bristol, UK, recognizing that urgent action was needed to address the climate and ecological crises, created multistakeholder processes to engage city partners and enable the city to become carbon neutral by 2030 (see Case study 12).

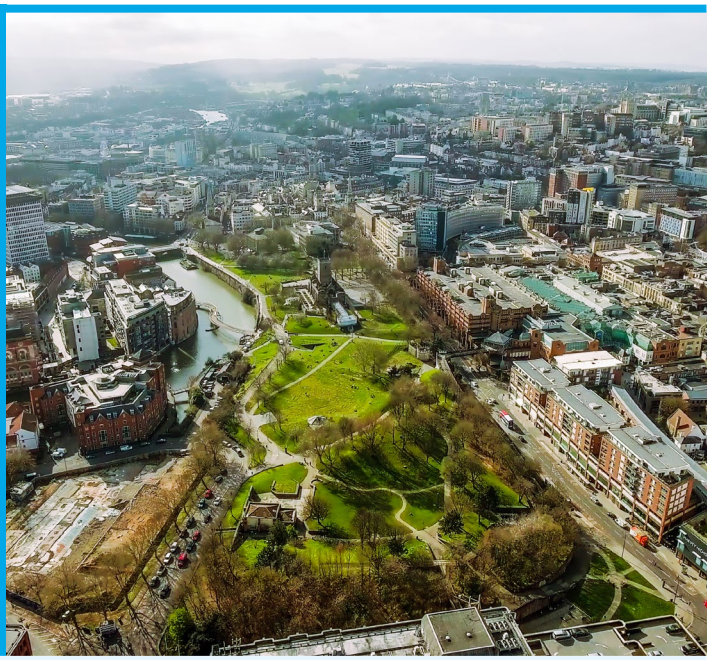
FIGURE 5 **Key principles of the Sustainable Urban Economic Development Programme**



Source: Sustainable Urban Economic Development Programme[93]

CASE STUDY 12

One City approach to climate and ecological emergencies in Bristol, UK



Introduction and problem
In 2018 and 2020, respectively, Bristol declared climate and ecological emergencies, setting an ambitious goal of becoming carbon neutral by 2030 and beginning to collaborate on strategies that would stimulate partners in the city to align their actions and resources.

Bristol City Council had already worked hard to mitigate its climate impacts, reducing corporate emissions by 84% and overall city emissions by 39% between 2005 and 2018. However, the Intergovernmental Panel on Climate Change (IPCC) Special Report (Global Warming of 1.5 ºC) and the International Union for Conservation of Nature (IUCN) ecological report calling for a halt to species decline by 2030 spurred the city to greater action.

Solutions
In 2018, the city's councillors and Mayor Marvin Rees declared a climate emergency and set a goal of achieving carbon neutrality by 2030. Bristol was the first city in the UK to take such action, which sparked a wave of similar declarations by local authorities across the country.

Recognizing that Bristol City Council alone could not deliver the scale and pace of change needed to achieve this goal, the mayor called for the implementation of a "One City" approach. Developed in 2016, this brought a range of local partners together to formulate a joint plan to tackle the biggest challenges facing the city. It involved a small central secretariat consisting of the city office and seven thematic boards – including an environment board co-chaired by the mayor.

The One City Environment Board commissioned the city's climate strategy, and later, in 2020, its ecological strategy. It is now working with the other six One City boards and leading city partners on the implementation of sibling strategies.

Planning and community engagement
Both strategies enlisted city partners and UN stakeholders to shape, draft and approve the approaches, with extensive public engagement on climate and ecological issues. In 2021, Bristol held its first-ever Citizens' Assembly, with a focus on climate change, and gathered recommendations to which the city office and council could respond.

Benefits and impact
The One City approach has enabled a wide range of stakeholder input and brought about a collective commitment to the resultant goals, objectives and actions. A range of delivery structures are now being developed to turn the strategies into concrete action with benefits for the city's residents.

Lessons and experience
The challenges and opportunities facing ambitious city action on climate change and ecology are too great and too complex for a single organization to manage. The One City approach has enabled Bristol to harness the expertise, perspectives and agency of a range of partners in a way that a single municipal strategy would not have allowed.

Local governments inherently take a place-based approach and thus have been actively pursuing cross-sectoral strategies and policies in recent years. Examples include transport-oriented development and urban redevelopment (see Case study 1), eco-industrial parks, waste-to-energy strategies and urban farming. For instance, Fukuoka, Japan, and neighbouring cities collaborated to build a power plant fuelled by biomass waste as an economically viable and sustainable cross-sectoral alternative to traditional power generation. Likewise, in responding to the COVID-19 crisis, cities are rethinking the organization of public spaces to enable clean and active mobility, taking into account the long-term impact of remote working.[94] Examples include permanently closing roads (e.g. Seattle), creating additional space for bicycles and pedestrians (e.g. Bogota, Dublin, Medellín, Milan and Seoul) and reserving public spaces and car parks for shared or electric vehicles (e.g. Madrid and Paris).[95] A vital lesson from these innovative experiments is that urban transport infrastructure is being seen as part of an integrated urban system (e.g. public spaces, housing, health) and not just as an individual sector.

The 'three S' framework adopts a strategy that is coherent, integrated and effective; targets policy action at the appropriate scale; and engages stakeholders in co-designing, co-implementing and co-monitoring urban policy.

A "three S" framework is developed to guide policy-makers in multi-infrastructure planning and promote cross-sectoral policies as part of a systems approach.[96] This framework adopts a **strategy** that is coherent, integrated and effective; targets policy action at the appropriate **scale**; and engages **stakeholders** in co-designing, co-implementing and co-monitoring urban policy.[97]

Effective implementation of **strategies** in the 3S framework requires innovative policy and financial instruments. Pricing mechanisms (e.g. taxes, fees and charges on carbon and other negative environmental externalities), put into place as a component of holistic policy objectives such as carbon neutrality or the circular economy, offer significant potential to affect consumer behaviour. Such mechanisms can make urban infrastructure investment more effective, while also providing funding to cities.[98] However, since they may also deepen economic divisions (e.g. tax credits for buying electric vehicles generally benefit high-income households), their design should consider the impacts on social inequality. Developing financial instruments that cities can access directly by promoting green and just urban investment is particularly important in the context of COVID-19 recovery.[99]

Since urban infrastructure planning can extend beyond city boundaries, the **scale** of a strategy must be properly set to ensure its effectiveness and provide an accurate baseline. A "functional urban area" approach should also support interdependencies and cooperation between urban and rural areas.[100] An example of comprehensive planning and collaborative governance at the metropolitan scale is the Helsinki-Uusimaa Regional Programme 2.0 in Finland, covering the metropolitan area of Helsinki.[101] To set up and implement the target of carbon neutrality by 2035, municipalities in the region have taken a complementary approach, using their comparative advantages to reduce emissions and increase sequestration.

The importance of the role of national urban policies in guiding and supporting integrated urban planning while also addressing the climate emergency is being increasingly recognized.[102] For example, Costa Rica's National Urban Development Policy 2018–2030 addresses climate change and other environmental factors in a cross-sectoral fashion. Risk-sensitive land-use policies are another important strategy as they serve as an anchor to connect different sectoral policies and guide urban infrastructure and development away from risk-prone areas.[103] In the Netherlands, the 2019 National Strategy on Spatial Planning and the Environment highlights the increasing importance of a climate-resilient, water-robust built environment, accompanied by sufficient open green and blue infrastructure to mitigate heat stress and store water. In addition to providing well-defined narratives, the strategy also recognizes the role of regions in shaping the built environment in an integrated way and allows regions and cities to make the necessary decisions to achieve this. Colombia has also developed a national policy to guide the management of climate change in urban areas (see Case study 13).

Engaging diverse **stakeholders** is essential to informing, designing, implementing and monitoring these strategies to ensure that they achieve better outcomes. See section 4.2 for further details.

CASE STUDY 13

National climate change policy in Colombia: guidelines for the management of climate change in urban areas

Introduction and problem

In 2017, Colombia ratified the Paris Agreement, committing to reduce emissions by 20% below the business-as-usual scenario by 2030. Several related national strategies and initiatives have also been developed, including the National Climate Change Policy, Colombian Low Carbon Development Strategy, the National Plan for Disaster Risk Management and the National Strategy for Climate Financing. Among the main challenges to achieving Colombia's climate goals is localizing actions, taking such national policies and strategies as a roadmap. As in many countries, the majority of Colombian cities' urban households are concentrated in areas at risk from floods, droughts and rising sea levels, while the cities themselves generate a large share of transport and waste emissions. As such, they are key actors in adaptation to climate change and the reduction of GHG emissions.

Solutions

In 2018, the Government of Colombia passed Law 1931 to establish guidelines for the management of climate change. This is intended to consolidate and harmonize the various policies, processes, institutions, strategies and mechanisms that had previously been used to encourage climate action. Uniquely, the law recognizes the importance of cities as sites for climate action. According to Law 1931, the National Climate Change Policy pursues low-carbon and climate-resilient urban development through eight lines of action:

1. Provide urban infrastructure resilient to floods and rising sea levels
2. Reduce climate risk due to urban water shortages
3. Provide efficient public transport systems
4. Encourage constant reductions in the generation of solid and liquid waste
5. Encourage residential and non-residential energy efficiency
6. Reduce flood exposure and transport emissions through controlled urban expansion
7. Promote conservation of local ecological systems
8. Generate scientific knowledge to quantify the capture of CO_2

Colombian municipalities are encouraged to apply a spatial lens, identifying areas of the city where the development of human settlements is not viable and directing urban expansion towards places that do not place urban residents or ecosystems at risk. In addition, to support implementation of climate change mitigation and adaptation actions in Colombian cities, the Ministry of Environment and Sustainable Development created a "roundtable of cities and climate change".

Impacts and benefits

In 2020, Colombia submitted its updated nationally determined contribution (NDC) to the Paris Agreement, reinforcing its commitment to urgent climate action, and aligning itself much more closely with its objective of achieving carbon neutrality by 2050. The new 2020 commitment entails a 51% reduction in emissions by 2030, compared with projections under the previous NDC. The new NDC includes many climate actions in cities, such as efforts to expand existing Bus Rapid Transit (BRT) systems, electrify bus fleets and increase cycling. A prime entry point is Colombia's Active Transport and Travel Demand Management programme (called NAMA TAnDem), which seeks to increase the share of trips made by bicycle to over 5% in all Colombian cities by 2030. Combined with measures to increase cycling during the COVID-19 pandemic, the NDC offers a perfect opportunity to increase ambition. So far, Colombia's new NDC is one of the most ambitious in the region of Latin America and the Caribbean. The roundtable has established the foundations of the National Strategy for Cities and Climate Change, prioritizing and selecting indicators and identifying financial instruments for the implementation of low-emissions development initiatives in Colombian cities.

Lessons and experience

The Colombia experience demonstrates the importance of integrating national climate policies into urban ordinances and plans, including municipal development plans, land management plans and others. Cities are vital actors in the adaptation to climate change and the reduction of GHGs. National commitment and legal action are critical, and the full cooperation and leadership of cities will ensure crucial impacts from better urban planning and more active participation of citizens.

4.2 Deepening multistakeholder engagement

A systems approach would require comprehensive engagement among diverse stakeholders, working together to build capacity, redesign urban infrastructure and set clear targets. Critical stakeholders include residents, infrastructure operators, city governments, national and regional policy-makers, academia, NGOs, civil society and the private sector.[104] Involving those disproportionately affected by climate change – including women, elderly people, people with disabilities, young people, migrants and minorities – is a must. Reaching out to academia and wider civil society could ensure that strategies are informed by the latest knowledge and fully reflect the need of citizens. Enlisting the private sector (e.g. property developers, infrastructure and service providers, urban planners, institutional investors and the financial sector) can help harness the potential of technological, social, public-sector and civic innovation. The importance of engaging such stakeholders in infrastructure policies has been addressed in many prior reports.[105,106,107] Building upon existing knowledge, Table 2 summarizes the critical roles and values of leading stakeholders in a systems approach to urban infrastructure policy development.

TABLE 2 **Critical roles and values of stakeholders**

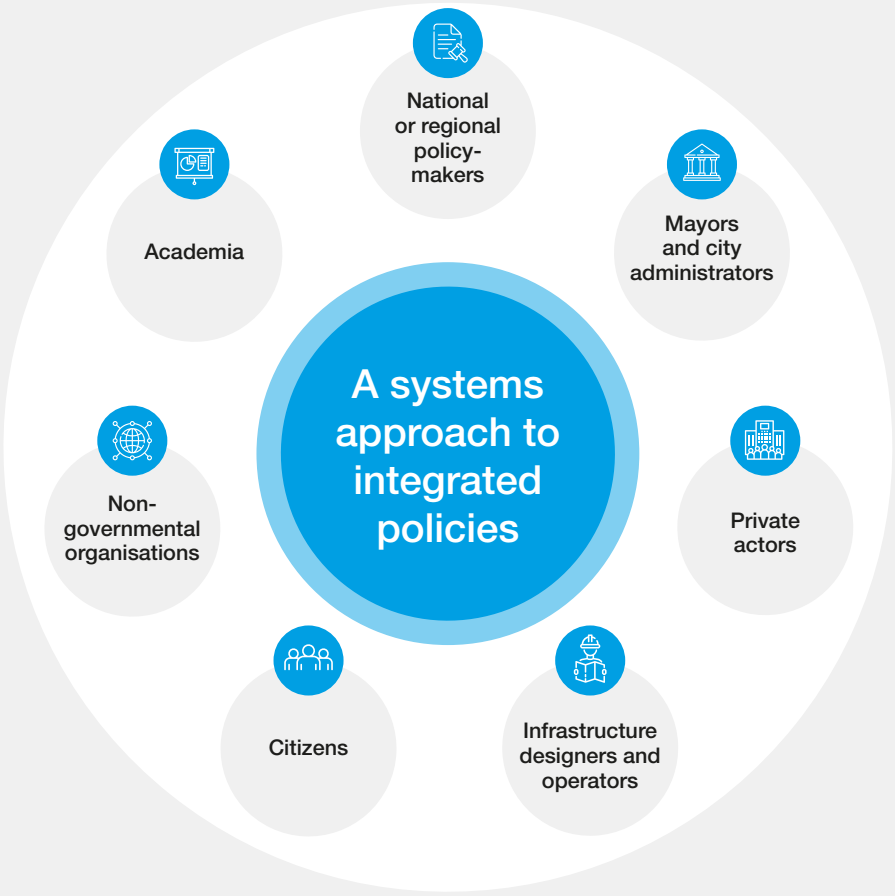
Stakeholders	Role and value to infrastructure policies
Residents	Resident demands for high-quality infrastructure and services are the core of any infrastructure policy. Engaging residents also helps identify problems with current infrastructure.
Infrastructure operators	Infrastructure operators (e.g. utilities) provide services, often through public contracts, and need to drive investment to meet climate change challenges.
City governments	City governments regulate infrastructure planning and delivery and/or provide infrastructure and services, either directly or through community-owned utilities and companies. For private-sector delivery, the city is typically the counterparty to the concession or public-private partnership (PPP) arrangement.
Regional and national policy-makers	Regional and national policy-makers set regulations (including tariffs), and license infrastructure providers (e.g. the electricity grid, regional transportation networks). They can enhance coordination through effective leadership in addressing climate change mitigation and adaptation.
Private sector	The private sector includes infrastructure users and providers, so incorporating their input can help to identify problems and improvements. Additionally, the private sector can finance infrastructure development in markets where enabling policies encourage private investment and protect investors' rights.
Academia	Academia generates basic knowledge to improve the design and delivery of infrastructure and services. Innovative transdisciplinary research design can integrate academia with public-, private- or civic-sector actors, providing real-time evidence to guide implementation.
Non-governmental organizations	Non-governmental organizations can conduct effective outreach to communities, bringing in the perspectives of citizens to help shape decision-making.

Source: Adapted from World Economic Forum, 2021,[108] Ramaswami et al., 2012,[109] World Economic Forum, 2017[110]

In general, deciding which stakeholders are critical depends on the specific cross-sectoral policies and actions under consideration. Adopting a systems approach to urban infrastructure delivery depends on first identifying these key stakeholders, and then developing an engagement plan – given the importance of creating buy-in and a shared vision. Six key dimensions of effective stakeholder engagement[111] are shown in Figure 6. New governance structures may be needed for such a systemic, multistakeholder approach. For example, cities may need to support and legitimize a key point person, or unit with sufficient authority, to act as a leader and convener in addressing climate issues and equitable infrastructure transitions. Cities can also establish steering committees incorporating city staff, utilities, relevant NGOs, academia, the private sector, other key municipal players and technical experts to collect and analyse data. Having such comprehensive engagement in place in the initial stages of any project or urban planning process ensures the early integration of critical inputs from key stakeholders.

FIGURE 6 **Multiple stakeholders shaping integrated policies using a systems approach (left) and the features of successful stakeholder engagement (right)**

Key stakeholders shaping integrated policies using a systems approach



Effective stakeholder engagement
Builds trust among key stakeholders
Facilitates cooperative problem identification and mutual understanding
Uses well-defined pilot programmes to test innovative solutions with key stakeholders
Incorporates knowledge producers, including academic institutions and NGOs, in generating innovative solutions
Fosters scale-up through effective regulation at city, regional and national scales
Sources financing for green infrastructure development through the public and private sectors

Source: Adapted from World Economic Forum, 2021,[112] Ramaswami et al., 2012,[113] World Economic Forum, 2017[114]

One example of effective stakeholder engagement is in Freetown, Sierra Leone, where the city council has created a climate action plan that addresses climate adaptation and mitigation, and is committed to strengthening the city's resilience, halving GHG emissions by 2030 and becoming carbon neutral by 2050. Freetown focuses on integrating all stakeholders during planning and problem identification. It emphasizes the involvement of residents to create ownership and trust, which ultimately ensures the sustainability of climate actions (see Case study 14).

CASE STUDY 14

Freetown climate action planning

Introduction and problem

In the context of climate change, cities are as vulnerable as they are powerful. While GHG emissions are comparatively low in Freetown,[115] the effects of climate change are already visible, and particularly affect its most vulnerable residents. Hence, the city aims not only to halve GHG emissions by 2030 and become carbon neutral by 2050, but also to strengthen resilience. The Freetown Climate Action Plan was designed to meet these commitments.

Solutions

Freetown City Council (FCC) frames its climate action plan as a combined approach to adaptation and mitigation (see the image below). It is intended not only to identify future actions and pathways, but also to highlight existing innovative efforts that encompass priority sectors of the city's (subnational) transformation agenda, while also contributing to the national government's efforts.

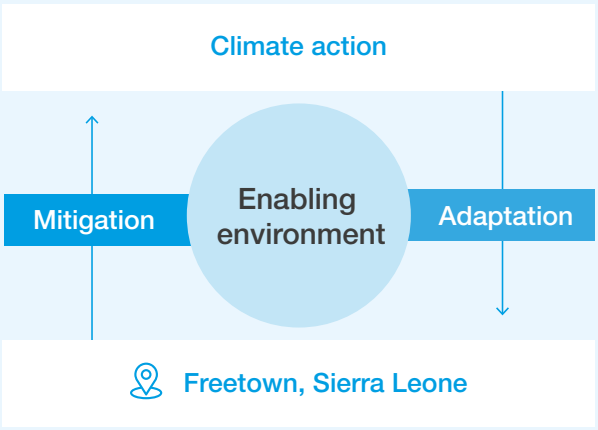
Impacts and benefits

FCC's approach to adaptation and mitigation is data-driven, evidence- and science-based, and iterative. On the mitigation side, it focuses strongly on low-carbon development in the energy, waste and transport sectors. FCC recently developed its first GHG inventory based on the Global Protocol for Community-Scale Greenhouse Gas Inventories. Freetown regularly consults relevant stakeholders to inform and steer policies, programmes and projects in the most impactful direction. For example, given that almost a third of Freetown's GHG emissions stem from transport, the city council is exploring green urban mobility solutions, such as the development of a cable car system. In the waste sector, recycling is a major concern, and involves, for example, cooperation with youth-led waste management micro-enterprises. Facilities will be created within FCC's seven solid-waste transfer stations (currently under construction), allowing for the sorting of plastic for onward supply to a privately operated recycling plant. On the adaptation side, FCC is focusing on nature-based solutions, such as the widely publicized #FreetownTheTreeTown campaign, which aims to plant 1 million trees by 2022. Planting trees has multiple beneficial effects: it reduces the risks of climate hazards such as landslides, while simultaneously cooling the city and absorbing GHG emissions.[116]

Lessons and experience

It is important to FCC not only that climate action is framed as a combined, evidence-based approach to adaptation and mitigation throughout various sectors, addressing the city's most pressing climate-related risks and hazards, but also that it be guided by the principles of policy inclusivity and collaboration across a wide range of stakeholders. In Freetown, all approaches involve multiple stakeholders, including the ministries, departments and agencies of the national government, civil society, the private sector, NGOs and international development partners. More specifically, FCC emphasizes the integration of all stakeholders at the point of planning and problem identification, with a strong focus on the inclusion of the city's residents to create ownership and trust, and ultimately to contribute to the sustainability of climate actions.[117]

Freetown adopted a combined approach for climate change mitigation and adaptation



It is important to recognize that some green policies may unintentionally exacerbate inequalities (e.g. federal subsidies to electric cars that can be afforded only by the comparatively wealthy in the US). Involving multiple social actors in cross-sectoral solutions can help address these problems and optimize multiple benefits. This improves the effectiveness of green policies, and encourages buy-in and participation in the green transition.

4.3 Enhancing multilevel governance

> **Nationally determined contributions (NDCs) embody the targets established by each country that signed the Paris Agreement to domestically reduce emissions and adapt to the impacts of climate change. Localizing these targets beyond broad sectoral commitments requires the collective effort of multiple actors, especially cities**
>
> Tatiana Gallego-Lizon, Urban Expert

The fiscal responsibilities of city governments vary enormously across geographies and political systems, yet the important role played by cities in the design and implementation of climate change mitigation and adaptation agendas is beyond question. For example, cities are critical to enabling solutions for: energy use and efficiency; transport – including reduced commutes, non-motorized mobility (e.g. walking and cycling) and switching to low-carbon fuels; waste management and the circular economy; construction and the built environment. Cities can also play central, strategic roles in adaptation and resilience in the context of: spatial and urban planning (e.g. the establishment of green belts or natural buffers in coastal areas); flood and erosion control; and the protection, restoration and expansion of natural systems through urban features such as parks and water bodies.

Responding to these complex and interconnected challenges demands a closer look at both the institutional coordination and the coherence of sectoral policies. Moreover, in many countries, city authorities lack service and regulatory competencies, making multilevel governance arrangements necessary. Horizontal and vertical coordination among different levels of government is essential to accelerating the pace of climate action adoption.

Horizontal coordination

A systems approach to urban infrastructure delivery requires stronger coordination across sectors and administrations. The integration of climate-related solutions is constrained by outdated laws and policy frameworks, and gaps and overlaps in institutional mandates. In some countries – such as Mexico[118] or the Philippines – inter-ministerial climate change commissions have been established as lead policy-making bodies at the national level, and tasked with independently coordinating, monitoring and evaluating climate change responses. Such commissions provide a venue for developing cross-cutting instruments, incorporating cohesive climate actions into individual sectoral policies and programmes and, in some cases, coordinating resource mobilization. Unfortunately, many remain weak or unempowered despite their mandate – unable to balance competing interests, prioritize the most urgent actions or effectively coordinate across levels of government. The Lake Victoria Water Supply and Sanitation project (Case study 15) shows that horizontal collaboration between countries and international organizations can deliver urban infrastructure effectively, in cases where cities alone might have difficulty providing such services.

CASE STUDY 15

Multilevel governance and financing: the Lake Victoria Water Supply and Sanitation Project in East Africa

Introduction and problem

Around 45 million people live in the Lake Victoria Basin (LVB) area, which has an estimated population density of 300 people per square kilometre (0.38 square mile). The majority of inhabitants (more than 80%) make their living from agriculture or fishing. The growing urban population in this densely packed environment has resulted in unsustainable levels of resource use and waste generation – with most of the waste draining into the lake. This has had significant negative impacts on natural systems in the area.

Solutions

The Lake Victoria Water Supply and Sanitation Program (LVWATSAN)[119] was initiated to mitigate pollution by improving the sustainable water supply and sanitation infrastructure in 15 secondary towns within the Lake Victoria Basin. Five national governments of the East African Community (EAC) together formed the LVB Commission as a coordinating body, which then negotiated funding opportunities with development partners. UN-Habitat identified priority issues in the largest cities on the lake, including serious and increasing gaps in sanitation, waste management and access to safe drinking water. These efforts used financial support from institutions such as the World Bank, the African Development Bank (AfDB), the French Development Bank, the European Investment Bank (EIB) and the Government of the Netherlands, among others.

Phase I of the project was launched in 2004, and introduced:

- A public-private partnership approach for planning and decision-making on town-waste management issues, drawing membership from leading town institutions and agencies
- Tailor-made waste-collection equipment and technology, e.g. optimized for narrow-street collection services. A simple portable machine, the Vacutug, was used as a low-cost faecal sludge extraction option
- Development of controlled waste disposal sites

Impacts and benefits

- 1,190 water connections and 423.4km (263 miles) of new water pipes
- Capacity-building for hygiene and sanitation, including training of 2,562 peers and facilitators – of whom 50% were women
- 16 new boreholes in Tanzania and Uganda, to provide enhanced access to clean water for domestic use
- Reconstruction of five wastewater treatment plants in Kenya and Tanzania, with an additional 14 in construction in other programme towns
- Public access to water through 20 public water fountains
- Prioritization of public health and hygiene in partner states, with 88 public toilets constructed

Lessons and experience

- Regionalism and cooperation increase the bargaining power of city governments when negotiating funding support from multilateral development partners and institutions. In isolation, city governments usually lack the requisite collateral needed for bankable investments
- Governments should take the lead in attracting investments and bear the related reporting obligations. This puts city authorities under close scrutiny with respect to their performance on set targets
- Countries involved in the cooperative mechanism succeed together, regardless of their individual economic strengths or weaknesses (e.g. Burundi, the weakest economically of the five EAC countries, was exempted from co-financing projects in phase I)

Source: Covenant of Mayors in Sub-Saharan Africa, 2020[120]

At the subnational level, horizontal coordination is an even greater challenge when adopting a systems approach to infrastructure delivery. In metropolitan areas, infrastructure typically crosses municipal boundaries, requiring goals and actions relating to, for example, transportation, land use or waste services, to be managed across administrations. Just as importantly, transboundary issues – such as infectious disease transmission (as seen during the COVID-19 pandemic), air quality (itself linked to COVID-19 vulnerability) and flood/watershed management – call for highly coordinated actions across local or regional boundaries. Coordination is often limited by political and economic pressures, competition and fragmentation. Yet intra- and inter-institutional articulation has been successfully achieved in cities such as Quito, Ecuador (through its Climate Change Metropolitan Committee), New York City, USA (whose comprehensive PlanNYC strategic plan [2007] and subsequent OneNYC [2015] oriented the city for growth in a climate-resilient manner through coordination of all of its sectors)[121] and Portland (where citywide street improvements have improved transport services and increased ridership). Indeed, a range of innovative cross-sectoral programmes – such as Bloomberg's Cities Climate Challenge, or C40's Building Energy 2020 Programme – have been pivotal for cities to quickly implement and scale emission reduction solutions at the metropolitan level.

Vertical integration

The design and implementation of international climate-change commitments, particularly nationally determined contributions (NDCs), has frequently been top-down and centralized. In many instances subnational governments have independently developed their own strategies for lowering emissions,[122] resulting in weak alignment with national policy frameworks. Actions that could help establish common ground include the adoption of international GHG accounting standards and inventory methods, the enrolment of cities in certification and award schemes and the development of green procurement criteria. These actions have important cost and capacity implications. Box 3 lists the requirements for a successful approach to climate change implemetation.

BOX 3 **Requirements for a successful approach to climate change implementation**

1. Participatory goal-setting, with contributions from all relevant actors
2. Interconnected planning and processes for cascading or consolidated target-setting
3. Integrated progress-tracking, measuring and verification protocols at multiple levels of government
4. Coherent and harmonized reporting

A successful approach, in turn, requires joint identification by governments of suitable incentives for vertical collaboration and the development of integrated data management systems capable of steering decision-making.

Even in countries with decentralized governance structures, such as Colombia or Indonesia, ensuring the effectiveness of local climate change action plans remains challenging. National and subnational efforts should build capacities for incorporating clear, trackable links to climate change targets into their investment plans and facilitate their implementation. Capacity-building is also needed within local governments and among professional networks and guild associations, which, in many cases, are entrusted with plan preparation. International and regional climate groups, along with city platforms, can provide paths for building capacity and exchanging knowledge. In some instances, they may also sponsor programmes (e.g. the Green Climate Fund's Readiness Programme).

Links across urban, rural and protected area strategies

“ Rural and protected areas play a vital role in reducing the vulnerability of built-up areas. Long-term urban resilience depends on preserving these areas and identifying the services they provide.

Finally, city adaptation strategies cannot be dissociated from the surrounding environment. Rural and protected areas play a vital role in reducing the vulnerability of built-up areas. Long-term urban resilience depends on preserving these areas and identifying the services they provide – including coastal protection, land conservation, flood management and purification, and storage of water resources through watershed management. Indeed, valuation and monetization of ecosystem services is essential. Moreover, continuous encroachment on natural habitats is at the heart of many recent public health outbreaks. Comprehensive regional strategies are needed that simultaneously consider human and biodiversity needs and explicitly identify and manage trade-offs. However, rural-urban associations are rarely addressed in city adaptation plans. Against this background, regional planning may offer a complementary framework to steer land use and infrastructure development while managing externalities in larger areas.

4.4 Public and private financing

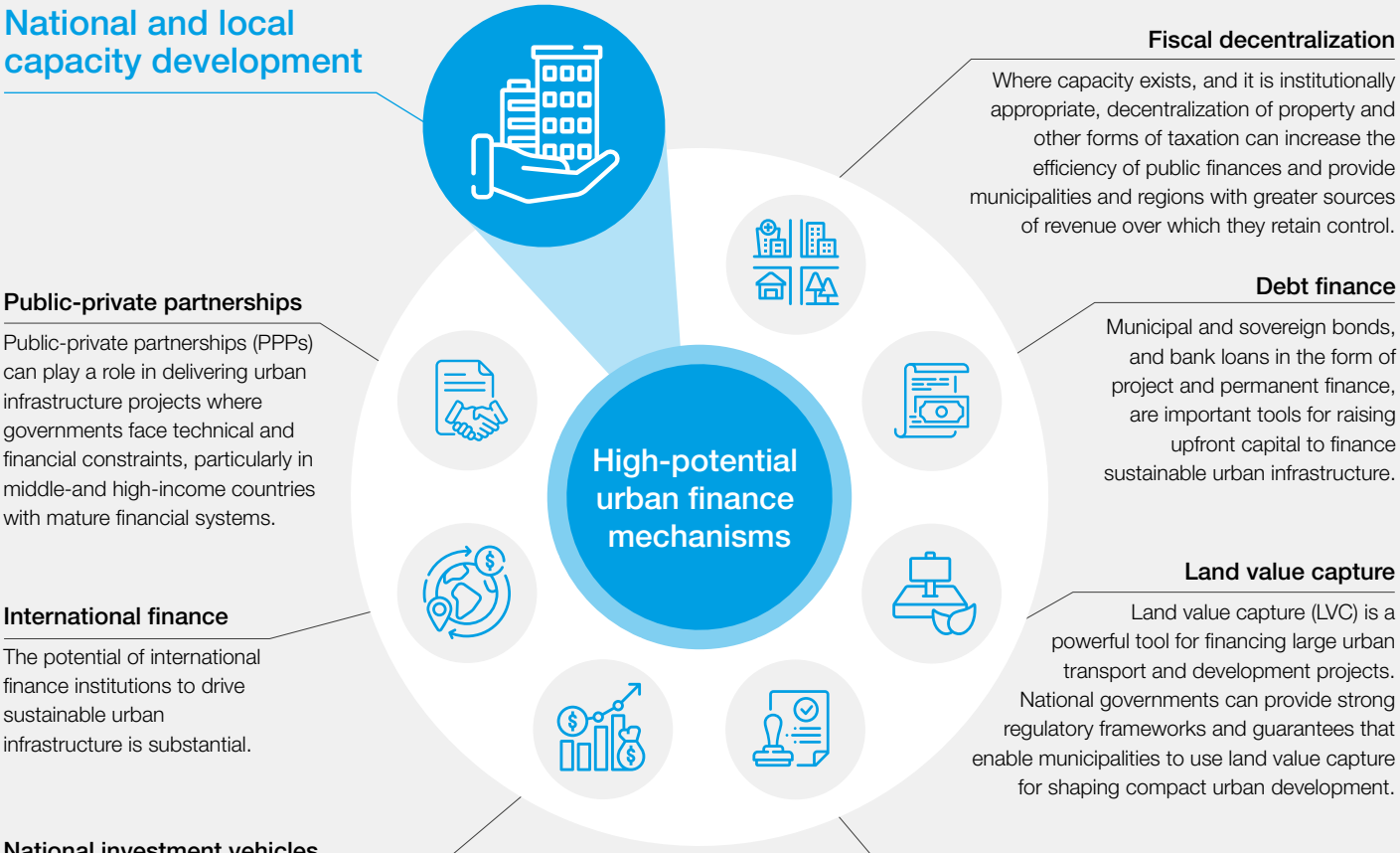
Cities face numerous challenges in accessing finance for climate infrastructure investments. This is exacerbated in the current pandemic environment as cities face the dual impact of both falling revenue and rising costs. Moreover, net-zero carbon and climate-resilient urban infrastructure typically tends to be capital-intensive, and may have higher upfront costs than business-as-usual alternatives. Despite delivering long-term economic, environmental and social benefits, in the context of short-term planning/political horizons and tighter budgets, climate investments sometimes struggle to attract needed finance.

Mauricio Rodas, Mayor of Quito (2014-2019); Visiting Scholar, University of Pennsylvania

While a variety of financing mechanisms are potentially available to cities (see Figure 7), most are chained to sovereign debt and creditworthiness and highly politicized, significantly delaying needed investments. While some cities have begun to modernize their urban policy frameworks, build capacity for developing "bankable" climate infrastructure projects and incorporate sustainable development planning, much more needs to be done – especially for projects involving multiple infrastructure sectors. A transformation is needed in the financial ecosystem; in particular, local capacity needs to be strengthened to finance and execute projects, allowing cities to take a systems approach to urban infrastructure delivery.

Existing financial mechanisms do not offer cities affordable financing for net-zero carbon, climate-resilient infrastructure. City networks have recognized the urgent need to increase the available financing, and there have been noteworthy advances. However, the infrastructure financing gap continues to grow. According to the Global Infrastructure Hub, approximately $15 trillion will need to be invested in infrastructure worldwide by 2040. Assuming 70% of this to be in urban areas, or to serve mostly urban dwellers, cities need investments of ~$550 billion per year.[123] Thus, even if the available capital increases, the financial architecture for climate change mitigation and adaptation must evolve to expand its sources, enable direct access for cities (i.e. without national governments as intermediaries) and reduce transaction costs for local governments.

FIGURE 7 | **Urban finance mechanisms**



Source: Floater et al., 2017[124]

Public financing plays a crucial role in using private investment for net-zero carbon, climate-resilient infrastructure. It is even more crucial in developing countries, where 60–65% of infrastructure projects are financed by public resources, compared with 40% in advanced economies.[125] At the national level, national development banks (NDBs) and funds provide credit (or a mix of grants and loans) to local governments and other institutions investing in local infrastructure. Besides providing credit at below-market prices, their goal is to improve the effectiveness of local investment, build capacity and set the stage for independent city credit systems. Although this model has worked in some countries, a lack of institutional capacity and financial reliability has often prevented cities from accessing these resources. As with the challenges cities face regarding sovereign guarantees, the strong link to national governments has made borrowing from NDBs and funds highly politicized. To close the financing gap, national and regional policies governing a city's creditworthiness should be revised to enable cities to access various financial resources directly (for more details, see the forthcoming World Economic Forum report, *Rethinking City Revenue and Finance*[126]).

Cities can also access financing from local government funding agencies (LGFAs), which are jointly owned by member cities and local governments, and whose primary mission is to pool their borrowing needs and issue bonds in capital markets. This model is thriving in the Netherlands and Scandinavia, but has had very limited acceptance elsewhere.[127] LGFAs advocate to build local creditworthiness, help create local markets and increase transparency in local decision-making.

There is growing interest in stakeholder capitalism, given the need to create long-term benefits for all stakeholders. This provides cities with a unique opportunity. One of the legacies of the COVID-19 pandemic is a shift in focus towards sustainable

When assessing whether a project can be delivered more efficiently by the private sector, cities need to be able to conduct robust value-for-money analysis and ensure monitoring systems are in place for key performance indicators.

investments. According to the *Financial Times*, $38 billion was invested in environmental, social and governance (ESG) funds in the first half of 2020, which topped $100 billion in total assets for the first time.[128] Although, historically, ESG factors have influenced city risk ratings, a greater focus on ESG principles in city financial planning also results in new opportunities.

For example, cities can ensure that project preparation and due diligence for all investments consider ESG factors, using public consultation in the design phase. Cities can also disclose the ESG impacts of their investments when seeking finance, in addition to the financial returns. The readiness of a project for financial investment can be demonstrated through analysis of environmental and social externalities, including the potential effects on biodiversity, gender and vulnerable and marginalized communities, and not just financial metrics. This should resonate with investors, who often argue that one of the challenges of financing urban climate infrastructure is not the lack of finance, but the lack of well-prepared projects.

Sustainable bond issues (e.g. green, social and sustainability bonds) are trending upwards, reaching $650 billion in 2021 (an increase of 32% over the previous year).[129] This suggests investors see them as alluring market options. Nevertheless, local governments encounter strict regulation on borrowing rights and creditworthiness, which is a prerequisite for private funding. Moreover, issuing a green bond can be challenging given strict use of proceeds requirements. Cities, no matter their ability to issue bonds, that incorporate ESG principles into their overall financial plans will benefit from the increased focus of investors on sustainable value creation and climate action. Indeed, several existing programmes are designed to help cities in this type of planning, including EBRD Green City Action Planning, C40 Climate Action Planning and World Bank's City Resilience Program, among others. In short, cities with strong planning and transparent disclosure policies will have an advantage both in raising finance and in using their soft power to attract much-needed private-sector investment.

In addition to cities seeking funding, the insurance industry is actively exploring approaches to investing in infrastructure projects that improve urban resilience and manage climate risks.[130] Urban areas are increasingly influenced by climate disasters, resulting in tremendous social and economic losses. Investment to improve urban climate resilience should reduce these losses. The insurance industry is gathering cases from cities to assess the value of investment in risk management to prevent urban disasters.[131]

Increased interest in sustainable investment also benefits cities looking at public-private partnership (PPP) models to finance climate-resilient infrastructure. However, in many countries, PPP regulatory frameworks are complex and, at times, conflict with existing legislation, which adds to investor perception of risks. A comprehensive benchmark analysis is necessary to develop policy recommendations and legal reforms in this field. When assessing whether a project can be delivered more efficiently by the private sector, cities need to be able to conduct robust value-for-money analysis and ensure monitoring systems are in place for key performance indicators.

Investments alone are not sufficient to achieve cities' net-zero and climate-resilient goals.[132] To deliver a transformation, greater results will come from investments integrated with strategic planning and climate policy measures, which themselves incorporate ESG principles and strong stakeholder engagement. Cities can identify critical investments while also providing an appropriate enabling environment for net-zero carbon and climate-resilient investments. Only in this way can cities shape a paradigm shift in climate action.

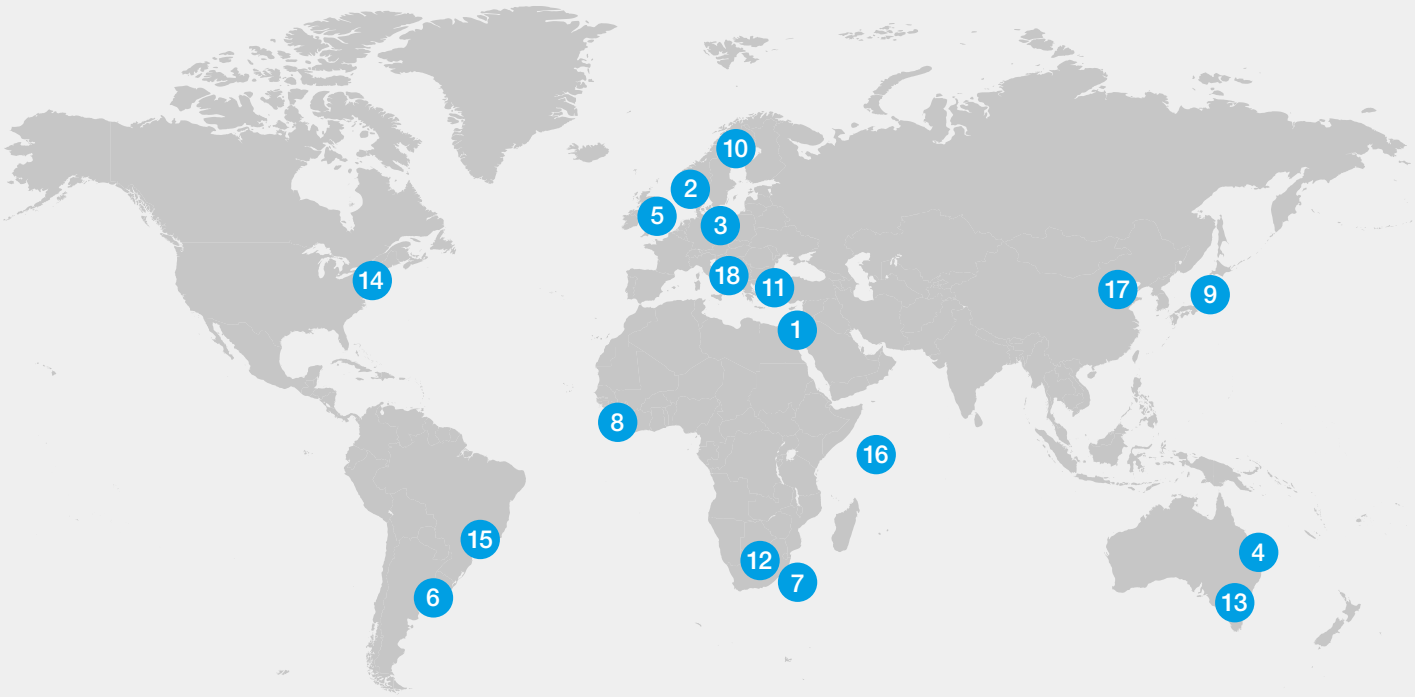
5 Systems approach to urban infrastructure delivery: city perspectives

Eighteen cities responded to the survey conducted for this paper on the challenges they face in implementing a systems approach.

A city survey was conducted for this paper on the challenges faced by city governments in implementing a systems approach to net-zero carbon, climate-resilient urban infrastructure delivery. Eighteen cities worldwide responded (see Figure 8).

Respondent cities include small and megacities in developing and developed nations. Table 3 presents the main challenges that these cities face in implementing a systems approach to delivering net-zero carbon, climate-resilient urban infrastructure.

FIGURE 8 **Map showing cities that responded to the city survey**



1 Amman
2 Amsterdam
3 Berlin
4 Brisbane
5 Bristol
6 Buenos Aires
7 Durban
8 Freetown
9 Fukuoka
10 Helsinki
11 Izmir
12 Johannesburg
13 Melbourne
14 New York
15 Rio de Janeiro
16 Victoria
17 Tianjin
18 Tirana

TABLE 3 **Challenges faced by city governments in moving towards a systems approach**

Category of challenges	Details	Quotes from city survey responses
Infrastructure upgrade and natural constraints	– Local resource endowment and ecological conditions – Infrastructure conditions, e.g. legacy infrastructure	"Currently, at the street level, more public space is allocated to driving and parking cars than walking and cycling, even though the number of people walking and cycling is far greater."
City governments' capacity	– Lack of leadership, clear strategies and coordination of multiple projects – Working individually instead of collaboratively throughout departments – Need to build capacity and enhance professional skills and expertise – Long-term strategies can be disrupted by the political cycle in cities – Lack of political will to prioritize climate issues	"Strategies, plans and investment often fluctuate based on election cycles, and are driven by the party in power, rather than by a long-term view of communities' needs. This results in infrastructure being developed that is insufficient to meet long-term demand or fully respond to climate risks over time."

TABLE 3 | **Challenges faced by city governments in moving towards a systems approach (continued)**

Category of challenges	Details	Quotes from city survey responses
Multi-objective urban planning	– Lack of multi-objective planning to harmonize different priorities, which leaves them as competing interests – Lack of climate action planning in city plan-making	"For a developing city, more urgent development and social needs can eclipse climate actions, so the city has incorporated a process of addressing such needs through its climate change programme. This has helped substantially in garnering the political support needed for top-down driven action."
Local regulatory power	– Limited regulatory power – Legislative obstacles to deter the private sector – Bureaucratic obstacles in the implementation of projects – Local governments do not have authority over transboundary infrastructure and supply chains, e.g. electricity grid	"(The city encounters) legislative obstacles and restrictions for renewable energy investments."
City government in the multilevel governance system	– Relying on high-level governments, e.g. national leadership and international support – Lack of alignment between local and higher-level governments' agendas – Lack of a holistic approach and common direction due to fragmented governance	"(There is a) high reliance on foreign consultancy, which means that most efforts and money are spent on technical assistance that rarely remains in the city and may not be followed up."
Collaboration across multiple social actors	– Private sector may lack incentives to act – Difficult to change residents' behaviour or overcome their distrust of new technology – Difficult to introduce a shared vision when working with multiple organizations – Lack of effective approaches to conduct multistakeholder engagement	"Lack of formalized and/or institutionalized stakeholder engagement processes to engage and align actors from various sectors on an overarching goal." "Bringing informal settlement leaders into climate change governance processes is essential to understand what the solutions are, and to implement actions."
Finance and resources	– Limited funding is transferred from national and subnational governments, especially for long-term projects – No effective approaches to access external funding – No comprehensive and holistic investment mechanisms for innovative and systemic solutions	"Transition to low-carbon practices is more challenging for poorer countries, which have fewer possibilities to implement proper financial incentives." "(We need to) create a more coherent and holistic finance and investment landscape for innovative solutions."
Data and knowledge	– Lack of data to localize challenges, establish the baseline and track progress/performance – Lack of knowledge supporting decision-making, e.g. using the latest research and know-how in the city or exploring innovative local solutions – Lack of approaches to scaling up pilot programmes to become permanent long-term strategies – Limited understanding of long-term impacts of reprioritizing resources away from climate change mitigation and adaptation work during the pandemic	"[It is difficult to create] data and AI capabilities fast enough to integrate systemic transformations to infrastructure planning, etc."

While city contexts vary, the challenges they face in adopting a systems approach to delivering net-zero carbon, climate-resilient urban infrastructure may be similar. The next section will provide specific recommendations for tackling these challenges in cities around the world.

6 Conclusion and recommendations

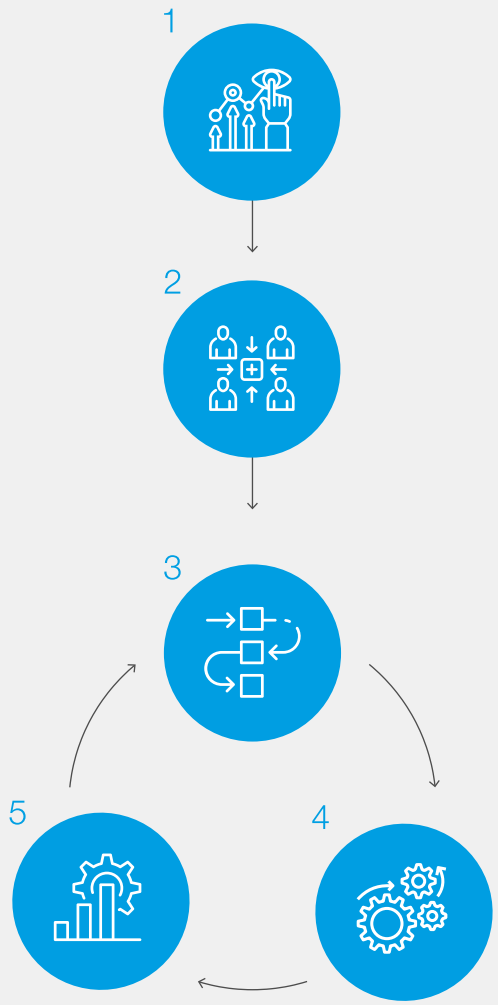
Cities often encounter similar issues when adopting a systems approach to the delivery of urban infrastructure and there are valuable lessons to be learned from others.

According to the IPCC, we have 12 years left to control rising global temperatures if we are to remain within 1.5°C.[133] GHGs associated with cities account for more than 75% of anthropogenic GHGs globally.[134] Cities should take urgent action to protect their citizens from the worst outcomes of climate change, and transition rapidly toward a net zero carbon, climate-resilient future. However, a business-as-usual approach focusing on the delivery of individual infrastructure projects is no longer sufficient; cities should instead adopt a systems approach.

Such an approach is based on the idea that the system is more than the sum of its individual sectors.[135] It takes advantage of the interconnected and interdependent relationships among multiple infrastructure sectors (e.g. buildings, mobility and green space). As some infrastructure sectors extend beyond a city's jurisdiction (e.g. transportation, water and energy), a systems approach requires horizontal and vertical collaboration throughout government departments. It also requires comprehensive engagement with multiple stakeholders to identify innovative solutions and overcome barriers to delivery. This approach maximizes the co-benefits (e.g. air pollution reduction, improved health and well-being, and job creation), and can contribute to a green and just recovery.

Cities cannot implement a systems approach to net-zero carbon, climate-resilient urban infrastructure delivery alone. For example, cities have limited control over the electricity grid and waste management infrastructure, which are often provided by another level of government or the private sector. A systems approach requires engagement with multiple stakeholders from government, business, academia and civil society that interact with the urban value chain. Below is a five-step action plan (Figure 9) to guide cities seeking to adopt a systems approach.

FIGURE 9 **The five-step action plan to guide cities seeking to adopt a systems approach**



1 **Leadership and vision**

2 **Stakeholders and community engagement**

3 **Integrative process**
- Identify baseline and set targets
- Localize best practices and maximize existing infrastructure use
- Identify projects for quick wins

4 **Implementation**
- Establish partnerships to accelerate urban infrastructure financing

5 **Build capacity**
- Enhance internal expertise
- Seek external technical assistance

Source: World Economic Forum

> Cities can prioritize actions that could generate quick wins and provide learnings for future actions.

In this action plan, (1) *leadership and vision* and (2) *stakeholders and community engagement* provide the foundations for the following three interlinked elements: (3) *integrative process*; (4) *implementation*; and (5) *building capacity*. The details of the five-step action plan are provided below.

1) Leadership and vision: Cities need to show leadership and be aware of the climate emergency. They can move towards a more integrated, cooperative model and work to create a shared vision, collaborating with all levels of government, business, civil society and academia. To enable this, cities can make use of existing working groups or create locally appropriate working groups to ensure a whole-of-government and multistakeholder engagement. Once the working groups are created, they can decide what to prioritize, then align their net-zero carbon and climate-resilient strategies with national and regional strategies and convene civil society and the private sector to advise on how they can act and work to provide an enabling policy environment.

2) Stakeholders and community engagement: The working groups can convene key multistakeholders, including multilevel government, the private sector, civil society and academia. This will ensure the development of coherent policies and regulations. It will also help to identify innovative urban infrastructure solutions, assist project preparation and financing, and ensure outcomes that meet the needs of citizens while being socially and environmentally responsible. Cities can also build awareness and support citizens through the development and implementation of a citizen communication and engagement strategy. This will enable citizen consultation, deliberation and participation in decision-making and resource allocation through a consensus-based approach.

3) Integrative process: This entails three main steps. First, cities can identify their baseline and set targets. Second, they can localize the most effective solutions and maximize existing infrastructure use. Third, they can identify projects for quick wins based on the above two steps. The details of each step are provided below.

- **Identify baseline and set targets:** Cities can better understand their baseline by evaluating multiple infrastructural services, developing a GHG emissions inventory and assessing exposure to multiple climate risks. They can use both internal and external expertise to assist in the development of the baseline, using working groups to support and act as an advisory board. They can also liaise with working groups to set a target year for achieving net-zero carbon – by 2050 at the latest – and an interim target of at least 50% of these emissions by 2030. In addition, cities can bring about a step change in their ambition for climate resilience, convening with working groups to set a target year for strengthening the resilience of vulnerable communities in the city – by 2030 at the latest.

- **Localize effective solutions and maximize existing infrastructure use**: Cities can review international best practices, and invest in innovative urban infrastructure solutions that are net-zero carbon, resilient, scaleable, replicable and capable of adoption in their city's context. Before employing new urban infrastructure solutions to meet their net-zero carbon, climate-resilience goals, however, cities can review any spare capacity in their existing urban infrastructure systems to determine what they can unleash through making use of existing, underused resources. They can also cut out their peak use (e.g. in electricity generation, water supply and transport), as upwards of 20% of capacity sits idle much of the time, ready to cope with peak demands.[136]

- **Identify projects for quick wins:** Cities can prioritize actions that could generate quick wins and provide learnings for future actions. This may include the deployment of small-scale infrastructure solutions for climate change adaptation that could have a significant impact on an urban area, from creating cycle lanes to planting trees.[137] Cities need to assess the primary benefits of these actions (e.g. emissions reduction, increased resilience, etc.) and their co-benefits (e.g. health improvements, air pollution reductions, better public services, etc.).

4) Implementation: This step requires the establishment of partnerships to accelerate urban infrastructure financing. Cities can engage infrastructure designers, providers and operators, investors and financiers in the planning process to make the most of innovative financing solutions. Guided by the working groups, this can create a united vision, build trust and integrity and identify innovative ways of financing for a mutually beneficial partnership. The working groups can assist the city in promoting urban infrastructure projects by analysing the economic and social benefits.

5) Build capacity: Cities can enhance their internal expertise on climate change and resilience, along with urban infrastructure planning, financing and operations and maintenance. To design urban infrastructure projects that have the structure and risk profile to attract investment, cities can seek technical assistance from multilateral development banks (MDBs), development agencies and the private sector. The working groups can assist cities to develop a series of programmes to ensure that a basic understanding of climate change resides within all city government departments.

Table 4 provides a pathway for cities transitioning to a systems approach to deliver net-zero carbon, climate-resilient urban infrastructure.

TABLE 4 **Enabling factors for cities transitioning to a systems approach**

Category of challenges	Details
Leadership and vision	– **Create climate and resilience working groups:** develop a shared vision to deliver net-zero carbon, climate-resilient urban infrastructure – **Join city networks:** share challenges and solutions with other cities around the world, and make use of the technical assistance and support that these networks provide
Multistakeholder engagement	– **Diversify climate and resilience working groups:** involve leaders throughout the urban value chain, including multiple levels of government, business, civil society and academia – **Implement a multistakeholder city engagement strategy:** learn from all relevant urban actors, including communities and end users – **Adopt a collaborative working relationship:** actively engage multiple levels of government to ensure policy alignment – **Use the expertise of academia:** build policy-relevant databases and ensure that the latest scientific research and innovation are reflected in knowledge outputs – **Use private-sector experience:** consolidate knowledge of potential financing risks and scenarios associated with net-zero carbon, climate-resilient urban infrastructure – **Use civil society skills and networks:** partner with civil society actors as facilitators, educators, conveners, innovators, service providers, advocates and implementation partners, making interventions more effective and outcomes more socially feasible – **Engage citizens, community groups and NGOs:** develop mutual confidence and ensure that solutions are more sustainable and human-centric, transparently communicating project impacts, interdependencies, pay-offs (whether positive or negative) and outcomes[138]
Technical and political capacity	– **Hire staff with expertise:** ensure that all city administration departments have expertise in climate resilience and net-zero carbon urban infrastructure and planning – **Provide training programmes:** educate city officials and elected political representatives on climate and resilience action, urban infrastructure planning, cross-sector synergies, financing, implementation and operation – **Make use of external technical assistance:** use inputs from multilateral development banks (MDBs), development agencies and national infrastructure banks to develop capacity and prepare net-zero carbon, climate-resilient urban infrastructure projects with the risk profile and structure to attract investment
Localized solutions	– **Evaluate challenges:** understand the climate challenges faced by city governments – **Build databases:** establish a baseline and map the evolution of critical factors (e.g. GHG inventory, climate risks and infrastructure services) over time – **Set progressive overall targets:** aim to deliver net-zero carbon (no later than 2050) and climate resilience (no later than 2030), and set interim targets (e.g. reducing emissions by 50% by 2030), with progress evaluated annually – **Create an enabling platform:** use expertise to solve local problems – **Identify multi-objective and multi-infrastructure solutions:** look for opportunities to deliver systemic solutions and wider co-benefits

TABLE 4 | Enabling factors for cities transitioning to a systems approach (continued)

Category of challenges	Details
Project pipeline and action prioritization	– **Build and prioritize a pipeline of projects:** map a policy and action pathway – **Implement quick-win projects:** build momentum and learn from implementation – **Use pilot programmes to test innovative systemic solutions:** map systems and barriers – **Monitor, iterate, scale and replicate solutions:** learn by doing – **Amend policy frameworks:** be flexible and act on evidence
Financial resources	– **Engage key stakeholders at the beginning of the planning process:** include financiers, investors, MDBs, development agencies and national infrastructure banks, among others – **Take advantage of technical assistance:** identify and employ technical opportunities from key stakeholders (See Multistakeholder engagement section in this table) – **Re-evaluate and reform intergovernmental transfers:** ensure that funds are going where they are needed – **Introduce finance training programmes for city officials:** increase capacity for managing public, private and blended finance in cities – **Increase own-source revenue mobilization:** employ authorities to collect sales taxes, property taxes and fees in a progressive manner – **Rationalize expenditures:** prioritize expenditures according to the needs of communities and leading stakeholders – **Manage and exploit land and property assets:** increase property taxes as an own-source revenue – **Tackle issues of debt and contingent liability:** mainstream solutions to debt and contingent liability plans into financial planning (e.g. set up a rainy day fund) – **Design an enabling regulatory environment at national and subnational levels:** establish creditworthiness

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