

Financing Climate Futures

# Financing a Resilient Urban Future

A Policy Brief on World Bank and Global Experience on Financing Climate-Resilient Urban Infrastructure



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A Policy Brief on World Bank and Global Experience on Financing Climate-Resilient Urban Infrastructure Standard Disclaimer:

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# **Abbreviations**

- ADB Asian Development Bank
- AFD Agence Française de Développement
- CDIA Cities Development Initiative in Asia
- **CEPAC** Certificate of Potential Additional
  - Construction
  - CIF Climate Investment Funds
  - CRP City Resilience Program (World Bank)
  - CSO combined sewer overflow
  - GCF Green Climate Fund
- GDPc gross domestic product (city)
  - GEF Global Environment Facility
  - **DFI** development finance institution
- DFID Department for International Development (U.K.)
  - **DR** demand response
- EDF Electricité de France
- **EFT** ecological fiscal transfer
- ERB Energy Resilience Bank (N.J.)
- FPL Florida Power & Light Company
- GCF Green Climate Fund
- GEF Global Environment Facility
- GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
- GW gigawatt
- **IDB** Inter-American Development Bank
- IEA International Energy Agency

- JICA Japan International Cooperation Agency
- KWh kilowatt-hour
- LDCF Least Developed Countries Fund
- LVC land value capture
- MDB multilateral development bank MW megawatt
- orr N. 10
- NCFF Natural Capital Financing Facility
- NGO nongovernmental organization
- **ODA** official development assistance
- OECD Organisation for Economic Cooperation and Development
- $\ensuremath{\mathsf{0\&M}}$  operations and management
- **PES** payment for ecosystem services
- **PPCR** Pilot Program for Climate Resilience
  - **PPI** Private Participation in Infrastructure
- **PPP** public-private partnership
- RATP Régie Autonome des Transports Parisiens
- **ROI** return on investment
- SCCF Special Climate Change Fund
- SDG Sustainable Development Goal
- **TEPCO** Tokyo Electric Power Company
  - **TNC** The Nature Conservancy
  - TWh terawatt-hour
- UNEP United Nations Environment Programme

# **OVERVIEW**

As urbanization trends become more prominent globally, a variety of questions arise about how cities will develop physically, demographically, economically, and technologically. Each dimension has profound implications for the type and scale of infrastructure needed to facilitate-or manage-these changes.

Climate change and the push to deliver on the United Nations' global Sustainable Development Goals (SDGs) raise the ante on all of these issues. For example, climate change may accelerate the growth rates of some cities as subsistence farmers and pastoralists in rural areas lose their livelihoods because of drought and are forced to move to areas where other livelihood opportunities are more promising (Rigaud et al. 2018). In other cities, climate impacts may ultimately shrink the amount of land available for habitation or affect the viability of economic activity on that land (Hallegatte et al. 2013). Aging infrastructure systems may be especially prone to damage as temperature levels rise, extreme weather events grow in severity, and higher sea levels and storm surges become more problematic, overwhelming the design capacity of these systems.

The cost of the direct physical impacts of climate change may be matched or exceeded by the indirect economic losses suffered if essential infrastructure systems and supply chains are forced offline for many weeks or months (Noy and Patel 2014). Both types of impacts could have dramatic effects on a city's ability to bounce back following a climate-related disaster (Goldstein 2018).

Acknowledging these possibilities, mayors and local policy makers are increasingly focusing

on these issues, as are national governments worried about the threats to their primary economic engine. Local climate action plans are emerging that-as best they can given the many uncertainties about what the future may hold-reflect the latest climate science and circumstances such as local geography, level and type of economic activity, demographic trends, policy-making capabilities, political will, and legacy investments in infrastructure systems. The science and circumstances profoundly affect what climate resilience strategies or investments are viable.

In many cities in the global South, the problem is even more complex because cities already facing an infrastructure deficit must also grapple with the growing demand for infrastructure services sufficient to accommodate their burgeoning populations. This problem is particularly acute in Sub-Saharan Africa and South Asia. Layering climate change on top of this situation only adds to the challenge as cities weigh strategies to ensure that the investments made today do not quickly become tomorrow's damaged or stranded assets. Failing to invest in urban resilience can also reverse hard-fought development gains and send millions of urban residents back into poverty (Santos and Leitmann 2015).

Where will the resources come from to pay for any climate-related repairs or these new or replacement climate-resilient urban infrastructure systems? The cost may be immense, with some estimates placing the current sustainable infrastructure financing gap at more than US\$1 trillion a year (Bhattacharya et al. 2016).

# About this policy brief

This policy brief was developed as part of the Financing Climate Futures initiative, a joint effort of the Organisation for Economic Co-operation and Development (OECD), United Nations Environment Programme (UNEP), and the World Bank, with the support of the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety. The initiative emerged in response to the invitation by the G20 Hamburg Climate and Energy Action Plan for Growth for "the OECD, UNEP, and the World Bank to compile ongoing public and private activities within the G20 for making financial flows consistent with the Paris goals and, building on this, to analyze potential opportunities for strengthening these efforts and present this analysis in 2018."

This brief complements the longer *Financing Climate Futures: Rethinking Infrastructure* report prepared by OECD and another analysis prepared by UN Environment, both of which will be released in late 2018.

The analysis described here examines issues related to the funding and financing of three core urban infrastructure systems: water, transport, and energy. These systems are essential to sustaining local public health, economic productivity, and quality of life. These systems are also critical during times of crisis, facilitating the movement of people out of harm's way and supporting recovery once the emergency has ended.

This brief draws on World Bank experience and data sets and a desktop review of the academic and grey literature on these topics. It does not present new research on the topic, seeking instead to bring existing information together in new and different ways. Specifically, it seeks to answer the question of what funding and financing instruments may be available to local governments and infrastructure system operators in cities around the world, and how these instruments link back to the climate challenges these governments and operators may face. Because the answer is heavily dependent on local circumstances, this brief offers some commentary on the potential relevance of these instruments to different contexts. However, because the World Bank primarily engages with governments, this analysis does not delve into the roles different types of private financing instruments may play in the financial package for a specific investment project (such as subordinated debt or equity investment).

This policy brief is organized as follows. Chapter 1 describes how urban infrastructure costs are traditionally funded or financed in cities around the world, as well as the recent trends in this area. Chapter 2 distills the growing literature on how climate change may affect urban infrastructure systems, what solutions local authorities and infrastructure system operators may need to consider to address these challenges, and how these solutions link back to capital or operating cost implications. Chapter 3, the heart of the analysis, looks in greater detail at the relevance of the specific policy, funding, and financing mechanisms currently available in each sector, highlighting specific city examples where possible. The brief concludes with some final thoughts on the issues that local governments, infrastructure system operators, national governments, and development finance institutions may wish to consider going forward.

# Terminology and scope of the brief

In this policy brief, the default choice is use of the term climate resilience wherever possible when describing activities directed at reducing the future impact (or system vulnerabilities) of climate change-related risks. In several instances, however, the terms adaptation or climate adaptation appear. Use of these terms is deliberate, so that the text accurately reflects the author's choice of terms in research or publications cited in this brief. The term *climate* adaptation is also commonly used by multilateral development banks (MDBs) to report climate co-benefits, and some of the global climate funds also prefer this term. For consistency's sake, their lead is followed to ensure that their conclusions or results are not misrepresented.

As for the scope of this policy brief, it does not seek to capture or discuss the totality of the World Bank's experience on all facets of urban resilience, including economic, social, and technological resilience. This topic has received growing research and programmatic attention in recent years, and it has been explored at length in other publications by the World Bank and other institutions (see, for example, Rodin 2014 and Santos and Leitmann 2015). The World Bank has been particularly active in this area. Its 2015 flagship report Investing in Urban Resilience detailed a myriad of technical assistance, analytic work, and financing mechanisms addressing different aspects of this issue (Santos and Leitmann 2015).

This brief also does not seek to develop a new definition of what constitutes spending on climate-resilient urban infrastructure. Each of the data sets reported on here uses its own definitions and methods. For example, Georgeson et al. (2016) aggregated data on what they characterized as the "make and mend" economy. They looked at 10 specific sectors of the economy and then quantified spending on specific activities thought to have a relationship to adaptation and resilience to climate change. The leading MDBs employ a process-based approach, seeking to distinguish between a regular development project and one that provides climate adaptation co-benefits. To qualify as the latter, a project must include design elements responsive to future (and locally appropriate) climate change impacts. Moreover, for accounting purposes

only the incremental costs associated with the design elements that make a project climate responsive qualify as adaptation-related finance. Because of the limited scope of this policy brief, the approach employed by each researcher or institution is simply accepted as a given, and the cost or spending levels as they have defined them are reported.

Finally, in this brief use of the term *infrastructure* is necessarily broad, encompassing forms that are both "green" (natural/ecosystem-based) and "grey."

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# 1.

# FINANCING CLIMATE-RESILIENT URBAN INFRASTRUCTURE: SOME BASIC CONCEPTS

Several aspects of urban infrastructure systems fundamentally shape the financing conversation. The first is the overarching enabling environment, market structure, and system design parameters established by government at the national<sup>1</sup> or local level. The decisions made at this level affect who operates these systems, whether a competitive marketplace is in place for infrastructure services delivery, and how these services are priced. Important decisions are also made on the extent to which a national government makes intergovernmental cash transfers available to support local infrastructure systems, thereby supplementing any system revenues, and how or whether government shoulders any of the risk borne by the system operator for climate-related disasters.

The second aspect is the basic difference between a local authority's capital expense budget, covering expenditures for goods and services whose benefits extend beyond one year, and its operating expense budget, covering the expenditures needed for day-to-day operations, including maintenance (Venkateswaren 2014). This temporal difference is important because the impacts of climate change may increase the maintenance requirements for assets of the urban infrastructure system. Failure to undertake repairs in a timely manner could result in far greater expenditures down the line, shifting the burden from operating budget to capital budget (McKinsey 2013).

Third is the difference between a local authority's overall spending levels and the capital and operating budgets linked to specific infrastructure systems. The point here is that a city is a "system of systems" (Gardner 2016) and-especially when speaking about financing considerations-system-specific circumstances matter. For example, a city may have a municipally managed department for roads and highways on which use is freely permitted. In the same city, however, the electricity supply may be owned and operated by a private utility. Access is limited to those paying for the service, and few government resources are available for either operating or capital expenditures. The management team at each utility likely views the financing landscape for their respective operations in starkly different terms.

Table 1.1 illuminates the elements that funding and financing landscape might include. It presents 12 basic types of funding sources that local authorities or infrastructure system operators may conceivably tap to pay for operations or system upgrades. Sources include those over

<sup>1.</sup> For simplicity's sake, the term *national government* is treated as a proxy for all supralocal government bodies, including state or regional authorities. The goal here is to differentiate a government entity with primary political and administrative responsibility for a specific city (referred to here as a local government or local authority) from other tiers of government responsible for multiple cities.

which local government may have some leverage such as intergovernmental cash transfers, taxes, user fees/tariffs, fines/penalties, official development assistance (ODA), government-issued debt, and the creation of some type of public-private partnership. Funding sources potentially of use but generally outside of local government control include dedicated climate funds, philanthropic resources, private debt or equity investments, risk finance and insurance payouts, and central government transfers determined by formulas.

Type of source	Description	Comments
Intergovernmental cash transfers	• Cash transfers of tax revenues or other resources from central government to local authorities for general or specific use	The importance of these transfers in local budgets is gener- ally linked to the level of fiscal decentralization authorized by a national government. Depending on restrictions imposed by the provider, cash transfers can be used equally for operating or capital expendi- tures. The size of the cash transfer is generally based on some formula or methodology and can be vulnerable to political differences between providing and receiving institutions. The timing of the transfer is a key concern because delays in receipt can make it difficult for a city or system operator to meet payroll or other costs. Heavy reliance on these transfers can also lead to delays in emergency response or post disaster recovery because recipients have limited control over the timing or conditions governing release of the transfers.
Taxes	<ul> <li>May include:</li> <li>General tax revenues (such as property, sales, and income tax)</li> <li>Targeted environmental or location-specific taxes or surcharges linked to access to infrastructure services or other amenities</li> </ul>	Taxation powers at the local level are typically tightly con- trolled and regulated by national government. Targeted taxes that seek to internalize the cost of negative externalities are commonly used to support public goods, including capital expenditures on environment-focused infra- structure. Revenues can be used for either operating or capital expendi- tures.
Land value capture	• A mechanism to allow a government to capture some of the development value impact of policy and zoning changes or amenity and infrastruc- ture improvements in a designated area	Typically targeted at the location-specific beneficiaries of a policy or zoning change or other capital investments. Can be structured as a tax (linked to existing property taxes) or as an auctionable development right. Generally used to support new capital investments.
User fees/tariffs	• Directed at the users of a good or service (such as the per unit charges for electricity or water usage; rider- ship fees for public transport)	Fees/tariffs are usually tightly regulated, balancing equity and cost recovery goals. One benefit is that they can be adjust- ed relatively quickly and deliver immediate sources of new revenue compared with other financing sources that may be available only once a year or on a one-off basis. Can be used for either operating or capital expenditures.
Fines/penalties redirected for other use	<ul> <li>Financial penalties for violation of environmental quality standards or other rules</li> </ul>	Generally considered to be an unstable revenue source. Presumes that a system exists to monitor and levy these fines. Alternatively, penalties may arise from legal proceedings assessing damages for rule violations.

Table 1.1 Financial sources potentially availab	le to support urban infrastructure projects
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Type of source	Description	Comments			
Official development assistance (ODA)	May include: Grants or subsidies Market rate investment project financ- ing (loans) or development policy Loans Concessional rate investment project financing (loans) or development policy loans Pay-for-results loans De-risking instruments (guarantees)	From multilateral and bilateral sources. Generally linked to a framing agreement laying out goals for how resources are to be used. Often comes with an emphasis on environmental and social safeguards designed to protect people and ecosystems. Depending on a country's development status, these funds may or may not include discounted (concessional) rates to ensure affordability. May take the form of loans to support capital investments or projects or loans to support policy, regulatory, or institution- al changes. May take the form of a direct loan or a credit guarantee aimed at improving the attractiveness of a project to private investors.			
Government-issued debt	May include: General obligation bonds Special-purpose bonds Green bonds (for dedicated environ- mental purpose)	Requires basic creditworthiness and an enabling environment that allow a city or system operator to issue bonds. Because of the transaction costs of issuing a bond, they are usually used to finance large capital projects.			
Other private finance	May include: Investment in public debt (general or project-specific) Equity stake investment in specific projects Investment in infrastructure system operators operating under a pub- lic-private partnership (PPP) or other operating authority	Classes of investors have different appetites for these types of investments based on return on investment (ROI), investment liquidity, and investment tenure. Some investors also make sectoral investments for asset diversification purposes. Typically used for capital investment projects.			
PPPs	Build-operate contracts between government and private contractor	Can take multiple forms, often with a focus on how contracts can be structured to require the private contractor to bring additional resources to maintain or upgrade the infrastruc- ture system. Can also be structured so risks to system integrity are shared by government and contractor, thereby providing the contractor with a greater incentive to ensure the system is properly maintained or protected against risks (including climate change)			
Dedicated climate funds	May include: Loans/grants from Global Environ- ment Facility (GEF), Green Climate Fund (GCF), Climate Investment Funds (CIF), or country- or re- gion-specific funds Carbon markets or other mar- ket-based climate instruments	May involve entitlement window with guaranteed resource flow to individual countries based on fixed parameters. Also includes project-based applications under certain funding windows. Access to carbon-focused climate funds is linked to the mitiga- tion outcome achieved, but if done properly projects can also be structured to deliver climate adaptation co-benefits. Can be used for either operating or capital investment costs.			
Philanthropic resources	May include: Grants or subsidies Social impact investments	Typically involves small grants. Resources are more commonly available for technical studies, project preparation, and capaci- ty building than for capital investments. Social impact investments are typically made in companies or projects with the intention of generating both a financial and a social or environmental return. Often structured to generate a below-market (concessional) financial return on investment.			

Type of source	Description	Comments
Insurance payouts (used to repair or replace damaged system assets)	May include: Private risk or catastrophe insurance National or regional parametric risk facilities	Can have a high cost ratio but may nonetheless be preferred by governments and system operators facing strict borrowing constraints who will not be able to borrow to finance repairs if damages occur; if borrowing is too slow to allow for a rapid response to system outages; or if insurance brings other advantages such as speed, predictability, transparency, and discipline in how resources are used.
		Parametric risk facilities vary in terms of whose resources are at risk in terms of payout (private investors or development aid/donor resources) and the nature of the triggering event or action. Speed of payout is a concern, as is clarity on what qualifies as a triggering event.
		Typically used to replace revenues (for operating capital) or for replacement or upgrade of capital stock.

The amount of resources potentially available from each of these funding sources varies profoundly across countries. For example, a comparison of eight large cities in OECD countries found that intergovernmental cash transfers ranged from a low of 6 percent in one city's budget to 69 percent in another's. However, six of the eight cities in the study receive less than a third of their annual budget from these transfers, with the majority of the difference made up from own-source revenues, including various types of property taxes, sales taxes, and other fees (Slack 2017).

By contrast, cities in developing countries are generally far more dependent on intergovernmental transfers. One study looking at local government resources in Tanzania found that ownsource revenues make up just 7 percent of total revenues in Tanzanian cities, with cash transfers covering the remaining 93 percent (Masaki 2018). Bahl's 2017 study looking at the finances of 10 large Asian and Pacific Rim cities (including Bangkok, Beijing, Jakarta, Kolkata, and Saigon) similarly found that intergovernmental transfers are a "major" revenue source for most of these cities and that their ability to establish different types of local taxes is greatly proscribed by central government.

A principal reason intergovernmental transfers dominate the fiscal picture of many developing countries cities is the general lack of capacity within local government, where there are frequently too few trained tax assessors, revenue collectors, and effective enforcement mechanisms. Even if the national government allows a local government to impose specific types of taxes or fees, it may have difficulty delivering on the full revenue potential of these funding instruments (Venugopal and Yilmaz 2010).

In many countries, official development assistance is another critical part of the financing picture, particularly for large capital investment projects. Sources of funds may be global or regional multilateral development institutions such as the World Bank, Asian Development Bank (ADB), or Inter-American Development Bank (IDB) or bilateral development finance institutions such as the Japan International Cooperation Agency (JICA), Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), Agence Française de Développement (AFD), and the United Kingdom's Department for International Development (DFID). The parameters governing funding are formally negotiated and codified in a multiyear agreement. These resources typically cover a wide range of development goals, with the level of attention paid to climate change mitigation and climate adaptation varying across countries.

Depending on the ODA source and how funding is structured, monies may flow separately to a specific city or project or pass through as part of a larger intergovernmental transfer allocation. Before development support can be allocated to an urban infrastructure project, the project must generally receive the endorsement of the national finance ministry as it is often the official interlocutor of ODA relationships. Some development finance institutions (DFIs) do have direct urban access financing windows, including AFD. How much this influenced the fact that 51 percent of AFD's climate-focused lending in 2014 had an urban focus (CCFLA 2015) is unclear.

To enhance the level of own-source resources, ODA, and private capital available for urban-scale projects, cities are increasingly focusing on capacity building, city (or system) creditworthiness, and project preparation support initiatives. The goal is to address the inability of a city or infrastructure system operator to attract certain types of financing or to learn more about how to bundle available own-source and ODA resources in ways that strategically mobilize other resources. The notion of leverage emerged from the Addis Ababa development finance conference in 2015, when the leading MDBs agreed to enhance the use of concessional resources to crowd in other sources of finance (Joint Ministerial Committee 2015). The World Bank's vision of how to deliver on this pledge is known as Maximizing Finance for Development.<sup>2</sup> The Bank is also preparing to release a new policy note exploring how to prioritize the use of concessional public finance to maximize the climate impact and crowd in additional private financing sources on climate-related projects (World Bank, forthcoming).

The World Bank (2015a) and C40 Cities (2016) have each launched city creditworthiness initiatives that seek to remedy low-capacity levels within city government by educating local government leaders about the fundamentals of creditworthiness and municipal finance. These fundamentals include revenue management and enhancement; expenditure control and asset maintenance; capital investment planning; debt management; and financing options. Research by the World Bank estimates that only 20 percent of the 500 largest cities in developing countries are considered creditworthy (Kuzio and Lypiridis 2018). The Bank provides a preliminary self-assessment tool<sup>3</sup> that allows users to develop a customized action plan of specific institutional reforms, capacity building, and other measures that improve their creditworthiness and their ability to plan, finance, and deliver infrastructure services. The difficult and sometimes slow work then lies ahead as cities begin to make the needed changes revealed by the assessment process. To date, more than 600 officials from more than 300 cities in 60 countries have participated in World Bank-led workshops on this topic. The Bank is currently in the process of revamping these activities, so they better align with follow-up technical assistance work.

Another important global trend is the creation of project preparation facilities aimed at turning ideas about infrastructure upgrades or system expansion into investable projects. Facility staff work with the project proponent to improve the project description or design, carry out detailed feasibility studies, determine the structure of the deal and identify potential investors, and undertake other project development tasks that most investors consider preconditions (USAID 2017). Project preparation facilities supportive of urban climate projects have been established by C40 Cities (2018); the Inter-American Development Bank (2018); and the Global Urbis program of the European Union, European Investment Bank, European Bank for Reconstruction and Development, and Global Covenant of Mayors (Global Covenant of Mayors 2017).

The Cities Development Initiative in Asia (CDIA) is one of the oldest project preparation facilities. It has engaged 143 medium-size cities in 18 Asian countries over the last 11 years. Supported by Austria, France, Germany, Sweden, and Switzerland, and managed by the Asian Development Bank, CDIA has helped 71 cities with pro-

<sup>2.</sup> For more information, see http://www.worldbank.org/en/about/partners/maximizing-finance-for-development.

<sup>3.</sup> See http://www.citycred.org.

ject preparation studies that ultimately yielded US\$7.7 billion in project support. CDIA conducts infrastructure investment prioritization assessments and project preparation studies, and it provides capacity development support. The initiative seeks to ensure that each urban infrastructure investment has positive impacts in at least two out of three priority areas: poverty reduction, environmental governance, and climate change mitigation or climate change resilience. To date, 13 percent of CDIA's project preparatory studies have focused on climate change resilience, often in connection with flood and drainage infrastructure. CDIA has been co-managed by ADB and GIZ, but as of 2019 it will continue as an ADB-managed multidonor trust fund.<sup>4</sup>

The World Bank's new urban infrastructure project preparation facility is integrated into its City Resilience Program (CRP), a multifaceted initiative that seeks to help local officials shift away from the traditional sector-specific approaches toward projects and programs that improve a city's resilience in a more holistic manner.<sup>5</sup> CRP engages in three distinct phases of work: (1) a comprehensive needs assessment looking at the institutional, technical, and financial barriers to infrastructure system investments in a city; (2) a rapid capital assessment that gives an initial indication of a city's (or system operator's) readiness to access specific types of capital finance instruments used by the private sector and development finance institutions; and (3) once the specific policy interventions and investment plans are defined, expert advisory support (including legal and financial services, transaction structuring, and capital markets experts) to tackle private capital mobilization, PPP arrangements, and loan structuring and syndication. If necessary, assistance is also made available on hedging, de-risking, and credit enhancement financing instruments.

Photo 1.1 Financial Solutions for City Resilience Workshop, Bangkok, July 2018.



Photo credit: Stephen Hammer.

The CRP initiative was launched in 2017 and is currently working with 45 local government teams in 20 countries. Engagement is launched by holding week-long intensive workshops involving government teams, sector experts, and project financing advisers. (photo 1.1) With sufficient funding, the World Bank expects to bring on 40–50 new cities each year, with a major emphasis on knowledge sharing across cities. The Bank also expects to use these workshops and technical assistance efforts to leverage resources from other initiatives at the World Bank linked to infrastructure adaptation.<sup>6</sup>

<sup>4.</sup> http://cdia.asia/.

<sup>5.</sup> For more information, see http://www.worldbank.org/en/topic/disasterriskmanagement/brief/city-resilience-program.

<sup>6.</sup> See Santos and Leitmann (2015) for a full listing of these instruments.

# 2

# THE IMPACTS OF CLIMATE CHANGE ON URBAN INFRASTRUCTURE AND HOW TO ADDRESS THEM

## **Overview**

The previous chapter focused on the mechanisms that local authorities and infrastructure system operators could access to support spending on climate resilience. This chapter provides a glimpse into the impacts of climate change and the possible solutions driving local funding needs.

For the purposes of this policy brief, the major impacts of climate change affecting urban infrastructure are divided into three basic types: (1) temperature increase and drought, (2) other extreme weather events, and (3) sea level rise and storm surge. Each of these impacts has the potential to damage urban water, transport, and energy infrastructure, affecting the physical integrity of system assets and the level or quality of service that could be provided by these assets. In some instances, the impacts of climate change could alter the level or timing of demand placed on infrastructure systems. For example, rising heat levels could increase the overall level and demand for energy, or floodwaters could overwhelm the storage or throughput capacity of water system assets.

Climate change could have positive impacts as well, such as operating cost savings and lower repair costs for utilities. For example, milder winters could reduce the level of asset damage associated with snow or freezing temperatures. Whether the overall operation cost impacts are positive or negative depends on the circumstances in each city. The discussion of impacts that follows is indicative and does not seek to fully replicate the many excellent studies that explore these impacts at great depth-see, for example, Ebinger and Vandyke (2015); Ebinger and Vergara (2011); and Rosenzweig et al. (2011, 2018). The appendix to this brief provides more detail about the impacts described here.

#### Impacts of temperature increase and drought on operations and operating and capital budgets

With each passing year, rising temperatures are becoming more commonplace in cities around the world, straining infrastructure systems as cities struggle to cope with the heat (Rosenzweig, 2018). In urban water systems, higher temperature and drought can affect the level of water supply available and degrade water quality. Temperature rise can also increase rates of evaporation, thereby increasing the demand for water for landscape irrigation and human consumption and exacerbating the competition for water resources.

In the transport sector, higher temperatures can buckle road surfaces and railway tracks and change the freezing and thawing conditions affecting roadways and subsurface rails during winter months, affecting their durability and quality. Passengers may be forced to endure higher temperatures both above and below ground while waiting for transport services to arrive, potentially affecting their willingness to use these systems. In the energy sector, impacts may take several forms. Energy demand is likely to be affected in many cities as rising temperatures interact with growing wealth and rising population levels, driving up the demand for air-conditioning and refrigeration technology. According to the International Energy Agency (IEA), the energy demand for cooling is expected to triple globally by 2050 over the current levels (IEA 2018). China has already experienced tremendous increases in its cooling-related load, jumping from 6.6 terawatt-hours (TWh) in 1990 to more than 450 TWh in 2016, a 68-fold increase. The amount of generation capacity required to satisfy the growing peak demand is potentially massive.

High levels of energy demand can tax transmission and distribution systems beyond their original design limits, leading to equipment failure. Drought can also reduce the volume of water available to cool thermal power plants and lessen energy output from hydro facilities, leading to brownouts or blackouts. Higher temperatures can lengthen the growing season for vegetation, thereby increasing the amount of material that could fall and damage power distribution lines during wind and rainstorms.

In each of these cases, utilities may incur capital costs for additional supply and storage capacity for water and energy resources. System operators may also face operating revenue losses as system generation output and usage levels are affected. Depending on the locale, the overall operational and maintenance costs may increase for municipalities as they seek to repair damaged roads, rail lines, and power distribution networks. In some instances, cooling water intake or effluent pipes will have to be relocated, and power transmission and distribution systems may need to be upgraded to meet more rigorous performance standards.

#### Impacts of extreme weather events and storms on operations and operating and capital budgets

Because of climate change, storms and other extreme weather events may become more frequent and severe. For all system types, the flooding, high winds, and lightning strikes associated with storms can badly damage physical infrastructure assets. Downed trees, tree limbs, and wires can block roadways, undermine the structural stability of facilities, and damage equipment. For water systems, intense rainfall events will increase sediment loads in waterways and reservoirs, leading to increased siltation of water storage facilities and reducing overall storage capacity. Higher rainfall volumes can also overwhelm cities with combined sewer overflow systems, resulting in the release of raw sewage into local waterways. Fuel stocks staged near power plants may be destroyed by floodwaters or rendered unusable.

Extreme weather events typically result in higher operating costs for cleanup, repair, and replacement of assets. In addition, utilities knocked offline may experience a loss in operating revenue, and insurance costs may rise because of a payout. For energy systems, capital investments in flood barriers or berms may be required, or assets may have to be moved out of flood zones altogether. Meanwhile, water storage capacity may have to be expanded to handle future floodwaters and rainfall.

# Impacts of sea level rise and storm surge on operations and operating and capital budgets

Sea level rise and storm surge also pose threats to physical infrastructure. Floodwaters and storm surge can undermine the structural stability of roads, rail networks, and bridges. They also can damage vehicles, transmission poles, and underground substations, among other assets. Saltwater encroachment can contaminate surface and groundwater supply sources.

Beyond the repair and replacement costs of damaged infrastructure as sea levels rise, cities may no longer be able to rely on gravity to discharge combined sewer overflow and wastewater effluent, increasing pumping costs. Energy assets in coastal areas may have to be replaced with saltwater-resistant alternatives or relocated to higher elevations to avoid sea level rise and storm surge. Transmission and distribution assets may also have to be hardened or placed underground to prevent damage during extreme weather events.

#### Potential positive impacts of climate change on operations and operating and capital budgets

The impacts of climate change will generally be adverse, but there may be some cost reductions in certain cities. For example, warmer temperatures may reduce the incidence of burst water distribution pipes in winter, or lower snow and ice levels may result in less damage to road surfaces, rail tracks, or above-ground power distribution lines. Whether overall operating cost impacts are positive or negative depends on the circumstances in each city.

#### Climate change impacts outside urban areas

Climate change-related system impacts may occur directly within a city, or they may occur remotely where power is generated or water is stored before it is consumed in the city. For power generation or transmission assets that feed into but are located outside of the purview of a local energy system owner or operator, the direct costs will be immediately borne by that entity. Customers in the city may nonetheless feel the pinch as prices rise to cover the cost of any system repairs or changes needed to harden the system against climate change impacts. Depending on locale and historic investments or agreements, urban water customers may be affected by climate change impacts at the point of supply that are quite different from those impacts experienced in the city itself.

# Taking action: Changing the management practices and operations of infrastructure system to enhance climate resilience

Local authorities and infrastructure system operators can mitigate the higher capital and operating expenditures arising from the impacts of climate change by implementing management practices and operational changes that reduce hazards to physical infrastructure. Data-informed forward planning can lessen climate risks and defray future replacement and recovery costs for water, transport, and energy systems.

#### System management practices

Changes in system management practices are essential to mainstream climate change action into the planning and maintenance activities of an infrastructure system operator. For example, some local authorities and infrastructure utilities are educating their general staff about climate change issues and integrating responsibility for specific climate resilience tasks into individual staff or teamwork program agreements. Such steps expand the capacity of individuals within the operation, create the mandate for staff to systematically take this issue into account, and then establish oversight mechanisms that maintain an organizational focus on these issues over time. In Rio de Janeiro, for example, the city's latest climate adaptation plan specifically highlights the need to define institutional focal points, assign responsibilities across different departments, train professionals within local government, and create incentives and fundraising mechanisms to allow the placement of scientific and technical professionals within specific departments (Rio de Janeiro 2016).

Analytically, many cities and utilities are undertaking climate risk and system needs assessments as a first step, seeing this as a road map for directing efforts going forward (Asian Development Bank 2013; World Bank 2015b). The results inform changes in system monitoring and maintenance protocols, as well as conversations about future system design changes. Many water industry groups and consultants have developed guidance on how to carry out these assessments, including how to manage uncertainty about the localized nature and severity of the impacts (GWOPA, UN Habitat 2016; Hulsmann et al. 2015; USEPA 2018). One point that inevitably arises in these risk assessment conversations is the central role of facility siting in minimizing or exacerbating climate risks. For obvious reasons, water facilities are often located adjacent to local waterways, leaving them vulnerable to flooding. As system upgrades are considered, however, a climate proofing strategy may involve relocation of these facilities to other parcels of land where the flood risk is lower.

Many public works departments and system operators are launching initiatives to improve their oversight of climate resilience efforts. PG&E, the largest private investor-owned utility in California, has recruited its own in-house science team to regularly review relevant climate science studies and integrate that information into the company's risk assessment process (PG&E 2016). In Hong Kong, local officials have set up a working group to monitor the implementation status of recommendations arising from a climate assessment of its transport system (UITP 2016).

To the extent necessary, climate considerations also should be integrated into procurement practices, especially for equipment that has a long lifespan. In London, Transport for London (2015) invested in a Comprehensive Flood Risk Review that covers all assets and all causes of flooding, emphasizing impacts related to loss of service. As part of this assessment, Transport for London is prioritizing key assets and assigning a "tolerability of safety risk" factor to these facilities. The World Bank has begun to embrace improved asset management practices as a systematic part of its work with transport clients, arguing that mainstreaming climate change into siting, operations, maintenance, and system planning activities will ultimately deliver a payback over the long term that is many times the size of this upfront investment. One study looking at this issue in the Pacific Islands concluded that "every dollar of routine maintenance that is deferred will end up costing US\$5 in repairs, or ultimately US\$25 in rehabilitation or replacement as the asset declines overtime" (Pacific Infrastructure Advisory Centre 2013).

One after-the-fact strategy potentially of use to utilities or system operators is the adoption of catastrophe bonds (also called cat bonds) to serve as an insurance instrument to cover losses from climate-related disasters. The New York Metropolitan Transportation Authority was the first transit agency to pursue such an instrument, procuring a US\$200 million catastrophe bond in 2013 to cover losses specifically arising from storm surge (see box 2.1) A second catastrophe bond was issued in 2017 valued at US\$125 million. The bond pays out if there is a storm surge event that exceeds certain threshold levels at one of two tidal gauge locations in New York Harbor (Artemis 2013).

#### Box 2.1 New York MTA cat bond

In 2012 the storm surge from Hurricane Sandy inflicted damage totaling nearly US\$5 billion on New York's Metropolitan Transportation Authority (MTA), the largest transportation network in North America (Mortimer 2013). In preparation for more frequent and severer weather events, in 2013 the MTA sought the first-ever storm surge-focused catastrophe bond worth US\$200 million. The bond, named MetroCat Re Ltd., was issued by First Mutual Transportation Assurance Company (FMTAC) the MTA's traditional insurance provider.

The bond is triggered on the basis of storm surge heights at two tidal gauges in New York Harbor managed by the National Oceanic and Atmospheric Administration and the U.S. Geological Survey (Kenealy 2013). In a pre-sale report, the rating agency Standard & Poor's demonstrated through modeling how the two tidal gauges selected by the MTA were those most closely correlated with the MTA's exposure at different subway and transit tunnels. The MetroCat was structured with no sliding scale of loss, so that FMTAC would receive 100 percent of the outstanding principal if a loss payment were triggered. Standard & Poor's rated the MetroCat bond at BB- and priced it with an interest rate of 4.5 percent (Burne and Mann 2013).

In May 2017, the MTA and FMTAC issued a second cat bond, structured by Swiss Re Capital Markets and Goldman Sachs, for US\$125 million. In addition to storm surge, the bond will be triggered by parametric factors associated with earthquake risks over a three-year term. The bond was eventually priced with an interest rate of 3.7 percent.

One area in which system operators may wish to expand efforts is data collection linked to local weather and climate conditions. Because of the tremendous uncertainty over how conditions will change in the coming decades, utilities can better inform future planning efforts by compiling locally accurate data on system needs under different weather conditions. Flood hazard maps are being scrutinized to determine which system assets are most at risk and how flood zones may change because of sea level rise or more extreme rainfall events. Some national transport ministries have begun to revise their construction protocols to better take changing conditions into account. For example, Canada, Denmark, New Zealand, the Republic of Korea, and the United Kingdom have begun changing drainage standards and structures and modifying road construction protocols to handle higher volumes of water (Filosa 2015). To support this planning work and to ensure timely access to information in the run-up to and during extreme weather events, many system operators are purchasing bespoke information or working with weather forecasting firms or agencies to tailor the type of information that is publicly available.

#### System operational changes

System operators can take several steps before, during, and after climate-related events to ensure that operations are less likely to be affected or recover quickly if the impacts of climate change do slow or stop system services. One step is pricing system services to promote conservation and efficient water and energy use, which in turn affects the amount of resources a utility must supply or treat. As the impacts of climate change become more prominent, the role of pricing may become even more important as a means of cutting demand and reducing the need for costly new supply sources. A key challenge, however, is how to structure the tariff so it does not price low-income users out of the market, making it impossible for them to afford access to even basic system services.

Other operational activities that can be carried out before climate change-related events are managing vegetation (to prevent limbs from falling on roadways and power lines), clearing trash from drainage systems, and reducing commercial water losses. These activities may have to be pursued more aggressively in the future. Rigorous adherence to an equipment maintenance schedule can also ensure the longevity of mission-critical equipment. Operational changes that increase systemwide climate resilience start with improved maintenance practices because of the revenue and operating cost implications and the link to supply adequacy issues that may arise in the future. In the immediate run-up to a climate-related storm event, system operators could install flood barriers near energy stations or water facility entrances, cover ventilation grates, and move rolling stock to elevations where they are less at risk. As an option of last resort, operators could remove particularly critical and hard to replace equipment just before a storm arrives. In New York in the 24-hour period before Hurricane Sandy hit the city, the subway system had crews remove critical (and hard to replace) control and signal systems that were particularly vulnerable, reducing the eventual downtime in the system from three weeks to one (Kolitz 2017).

A change in operating practice specific to the energy sector is the use of demand response (DR) programs that pay customers to cut demand when requested by the system operator. Payment levels can vary, based on the amount of demand reduction and how far in advance the customer notifies the system operator it is willing to take this action. Demand response programs have proven highly effective in many developed countries but are less prominent in developing countries because they lack the enabling environment. DR programs typically require the presence of third-party firms or entities that will install the equipment needed to enable the customer response, monitor the change in energy use, and manage payments from the system operator. One exception is India, where the pilot demand response programs established over the last several years have successfully reduced the demand for electricity by nearly 50 megawatts (MW) during critical demand periods (Sarkar et al. 2016).

During and after extreme weather events, equipment substitution may be required. In the transport sector, buses could offer routing flexibility when subsurface or surface rail networks are flooded or otherwise shut down. Public communication after extreme weather events is also critical to ensure that the public and local businesses have the information they need about road closures, transit options, water quality, and energy supply. Stockpiling key equipment can allow repairs to made quickly following such an event. For example, Paris's Régie Autonome des Transports Parisiens (RATP) and many other transport system operators now stockpile sand (for sandbagging operations), pumps, or other mission-critical equipment that may be damaged in a climate event, allowing workers to repair any problems without excessive delay (RATP 2018). Timely system repairs of damaged rail or road surfaces, bridges, water facilities, and power generation assets are important because of both the short- term revenue impacts on the system operator and the longer-term economic impacts on the region, affecting the tax base on which local system operations may partially depend.

# Taking action: Changing urban infrastructure system design to enhance climate resilience

Management or operational changes will help mainstream climate change into existing operations. However, because many cities will likely grow in the coming decades or need to replace certain system assets, new design principles or features that clearly account for climate change impacts will be required. Some of these will apply to the physical design of the system, whereas others will emphasize geographic considerations to minimize exposure risks. Because of important sectoral differences, this section breaks the discussion out by infrastructure type.

#### Water systems

Urban water systems have three major components: water supply, wastewater treatment, and stormwater management. These systems reflect local demand, geography, proximity to supply sources and the quality of those sources, any historic agreements granting the city access rights to supply sources, zoning rules affecting lot size, and system design decisions about the service reach and structure of the "formal" water supply and wastewater treatment system.<sup>7</sup>

Land use planning is an important starting point for efforts to influence water system needs in a city. Allowing development to expand into flood-prone areas means a city virtually guarantees it will be obliged to grapple with sea level rise or stormwater management problems long into the future. By contrast, land use strategies that create "green" infrastructure, including parks and other open spaces that double as short-term stormwater retention ponds, can reduce the size requirements and cost of "grey" (manmade) infrastructure that local authorities or system operators are obliged to build and maintain. China has been particularly active in promoting the use of green infrastructure in 30 of its cities (see box 2.2).

Using their control over construction practices and permits, local authorities can influence systemwide needs through a parcel-specific focus. For example, many cities promote the use of green roofs or on-site storage cisterns to manage stormwater runoff from individual parcels of land. In heavy downpours, these systems serve as a buffer and lessen (or eliminate) a parcel's demands on the formal stormwater management system. Rules that limit the extent of allowable impermeable surfaces on a given parcel have a similar impact. Barcelona has gone so far as to estimate the total potential green roof space capacity in the city (65 hectares), although as of 2013 only 3.5 hectares of green roofs could be found in Barcelona. In the Barcelona Green Infrastructure and Biodiversity Plan 2020, the city committed to increasing this number in each of the city's 10 districts (Ajuntament de Barcelona 2013). From a system operator's perspective, a key virtue of such rules is that they effectively transfer some stormwater management costs directly to individual property owners relieving the cost burden on the communal system.

<sup>7.</sup> In some cities, service levels differ geographically, with decisions frequently driven by the expense of extending service networks to less densely populated areas. In such areas, property owners may be expected to rely on their own groundwater supply or manage wastewater on-site via septic tank systems. This discussion primarily focuses on the formal infrastructure-intensive systems available in cities.

#### Box 2.2 China's US\$300 billion "sponge cities"

China is investing nearly US\$300 billion (1.9 trillion yuan) through 2020 to create 30 "sponge city" projects in Beijing, Shanghai, Shenzhen, Wuhan, and other areas. Sponge city projects are an approach to flood management that utilizes blue-green infrastructure such as permeable pavement, rain gardens as catchment basins, and wetlands to buffer against floodwater (Ohshita and Johnson 2017). Many cities in arid areas of northern China have struggled to provide adequate sewerage systems as road networks and urban developments have rapidly expanded (Garfield 2017). In recent years, major storms in the region have damaged infrastructure and caused flooding and loss of life. By 2030, China aims to install sponge city projects in 80 percent of urban areas across the country and reuse at least 70 percent of rainwater (Roxburgh 2017).

In Shenzhen, a city of 20 million, the local government is partnering with The Nature Conservancy(TNC) and Glocal, a local nongovernmental organization, to create a sponge city demonstration project at an apartment building (Standaert 2018). The project will outfit the building with a potted plant system that absorbs water and gutter systems to capture excess rainwater in large tanks. The city is seeking to scale up the project to cover 50 percent or more of its buildings to reduce localized flooding, cut urban heating costs, and decrease canyon-effect air pollution.

As of November 2017, China provided cities with US\$12 billion for sponge projects. The central government provides funds for 15–20 percent of the costs (Biswas and Hartley 2017). The remainder of the costs is shouldered by local governments and private developers. TNC is looking into how financing structures in other cities outside China can be used in China. Environmental impact bonds are a possibility (Standaert 2018). However, in the Chinese context this debt-financing instrument may not be necessary because government-led initiatives can often be expanded and implemented quickly. For now, state-owned enterprises are likely to remain the main source of funding for sponge city projects.

> Several strategies are available to increase the robustness of local water systems. Manmade or natural berms or barrier walls can help protect water storage and wastewater treatment facilities from flooding events and sea level rise. Some cities may need to increase the capacity of their stormwater diversion systems because, with the spread of impermeable surfaces and the growing intensity of storm events, systems once sufficient are now undersized due to the increased runoff levels. A different issue arises in cities that have combined sewer overflow (CSO) systems that process storm runoff through the wastewater treatment system. The design of these systems allows large volumes of storm water to overwhelm a system, pushing untreated sewage into local waterways. In the future, system operators may wish to separate these stormwater and wastewater systems lest contamination concerns become a recurring problem, possibly in violation of local water quality standards. At water supply storage facilities, system capacity may need to be revisited to allow cities to better withstand extended drought conditions or to ensure that when water volumes are too great be

cause of extreme weather events, the structural integrity of the storage facility is not at risk.

Some cities may need to explore new water supply options in the coming decades. Identifying new sources of water is a challenge in an era in which freshwater sources are subject to long-standing water rights agreements. New storage facilities (sometime doubling as hydropower plants) are discussed, but they are generally not something undertaken by local water system operators because of the cost, land use required, and the siting and permitting challenges in areas outside of their geographic control. Many system operators believe desalination plants are a promising new supply source. Growth rates for new installations are estimated at 7–9 percent a year in the Middle East and North Africa region alone (Voutchkov 2016). These systems have high associated energy costs, however, because of the energy intensity of the desalination process. To the extent that these facilities are powered by fossil fuel sources, cities may find themselves exacerbating the climate problem these facilities are helping to solve.

#### Transport systems

Transport systems in cities usually comprise various types of roads, sidewalks, bike lanes, highways, bridges, and tunnels; mass transport systems either above or below ground; marine and rail systems; intermodal freight facilities; and airports. Not only essential to daily life and the economic vitality of a city, the transport sector also plays a key role in facilitating an emergency response to natural disasters. However, transport systems and road networks are highly vulnerable to the impacts of climate change and generate high asset and well-being losses when damaged.

System operators and the relevant local planning bodies must therefore work closely to integrate long-term climate information into local planning processes. Steps in this approach can include mapping hazards, identifying highly vulnerable assets, and understanding the potential risk of asset failure. For example, in Can Tho, Vietnam, the World Bank team working with the local people's committee on a comprehensive resilience strategy discussed how the placement of a new bridge could drive development into either the low-lying parts of the city or those at a higher elevation (World Bank 2014). Bridge placement had obvious implications for the construction cost of the bridge, but longer-term implications were the potential repair costs for any road networks that might ultimately be constructed in low-lying areas of the city.

When climate risks do exist, it may be necessary to invest in system upgrades that protect the system from these risks. Investments will vary by system type: building expansion joints into rail networks, redesigning subway entrances to be more flood-resistant, elevating road surfaces or train tracks in areas likely to flood more frequently in the future, and elevating system-critical equipment. System operators may also acknowledge that it is not possible to fully protect against some climate change-related events, and so they must seek equipment or system design features less prone to damage during these events or less costly to repair or replace (World Bank 2017).

#### Energy systems

Energy system operators have long taken weather into account when designing and operating their systems. Hot days drive up the demand for energy for air-conditioning, and attention turns to determining where the power will be sourced from and whether the load borne by different segments of the local grid will exceed its design capacity.

This short-term focus does not necessarily mesh with a system's long-term needs, however, particularly if demand changes and climate risks result in a significant departure from current patterns. The World Bank's energy and climate teams recently collaborated with power transmission system operators in Bangladesh (Box 2.3) and the eastern Caribbean to develop new ways to weave long-term climate change projections into their regular demand forecasting and system upgrade planning (World Bank 2017a). The push for electric vehicles as an industrialization or climate change mitigation strategy may also have to be factored into local power system planning processes. Electric vehicles change overall load levels and the timing of the load, and they require the installation of charging stations across the local distribution grid, including locations originally designed for much lower load levels.<sup>8</sup>

Demand forecasting work is also essential in identifying the need for new or expanded power generation capacity in a city. To the extent that some generation sources may be less reliable in the future-for example, because elevated water temperatures in rivers used by power plants for cooling purposes force these facilities offline, or because drought cuts the output potential of hydro facilities-there may be a need to expand the level of transmission capacity feeding power

<sup>8.</sup> The World Bank is currently in the process of developing guidance for government and power system operators on issues associated with the shift toward electric mobility. The report will be released in December 2018.

#### Box 2.3 Building climate resilience into power system planning in Bangladesh

Bangladesh is one of the world's most vulnerable countries to climate change. Home to over 161 million people, it faces frequent rolling blackouts due to inadequate power generation. In April 2017, Bangladesh had 13,179 MW of electrical generating capacity, or less than 400 kilowatt-hours (kWh) per capita, of which three-fourths comes from domestic gas extracted from onshore gas fields. As a result, Bangladesh has one of the lowest generating capacities in the world.

In 2014 Bangladesh announced an ambitious program to develop the nation's power system by increasing capacity by an additional 10 GW by 2019 and achieving 100 percent electrification by 2021 at a cost of approximately US\$35 billion. The centerpiece of the program is a power system master plan dating from 2010 that weighs options to increase capacity to about 57 gigawatts (GW) by 2041. Recognizing the need for low-cost electricity, the 2010 version of the master plan adopted a least-cost planning methodology that was carried over to the 2015 iteration of the plan. The least-cost planning analyses in 2010 and 2015 were led by the consulting division of Tokyo Electric Power Company (TEPCO) and funded by the Japan International Cooperation Agency. This analysis suggested a shift in the generation mix from natural gas to coal in recognition of the declining amount of natural gas available domestically and the low price of coal.

Bangladesh's power system master plans of 2005, 2010, and 2015 reflect three separate analyses undertaken over an 11-year span. While comprehensive, the plans for domestic generationfailed to fully account for important climate change-related risks, including flooding (which damages or forces power stations offline) and extreme heat waves (which drive up demand for cooling).

Working with the government, the World Bank's energy and climate teams recently reran the analysis, taking these climate change impacts into account. The new analysis found that standard least-cost planning methods underestimate capital costs by US\$3 billion over 25 years if Bangladesh omits the costs of protecting against floods. Moreover, the analysis identified the need to prioritize locations for new power plant development based on their flood risk profiles. For countries like Bangladesh in which most power plant sites are at high risk for flooding, a climate-aware plan that considers flood risk and alternative generation technologies (including renewables) can save US\$0.2–3.3 billion during the planning period. The implications of this analysis are global and represent a first attempt to explicitly integrate climate risks in the models that underpin power system planning.

Source: Based on World Bank (2017a).

into a city or expand existing (or construct new) generation facilities in or near the city less vulnerable to these climate risks.

During flooding, storm surge, extreme weather, or heat events, system "hardening" strategies that move critical equipment out of harm's way may prove helpful (see box 2.4). Steps could include elevating electric transformers or substations above flood levels, adding air-cooling capacity at power stations to supplement or replace water-cooled systems, or burying transmission and distribution wires to limit their vulnerability to wind damage. System operators may also wish to explore what steps they can pursue to achieve redundancy in the system, allowing it to better withstand (or rebound from) climate-related damage. In New Orleans, which was hard-hit by Hurricane Katrina in 2005, the local utility partnered with the U.S. Department of Energy to explore the role that microgrids can play in maintaining critical infrastructure during storm-induced outages. Facilities were identified in areas less prone to inundation that could serve as potential system hosts. This information is feeding into planning efforts for a "resilience district" in the city (Meub 2018). Towns in the Philippines are similarly piloting solar-powered microgrids as a hedge against brownouts and storm-induced outages (*Philippine Star* 2018).

#### Box 2.4 Florida Power & Light Company hardens system against storm outages

Florida Power & Light Company (FPL) has invested nearly US\$3 billion since 2006 in hardening and stormproofing its electric network (Nehamas and Dalhlberg 2018). To handle stronger winds of up to 150 miles per hour, FPL has replaced wooden poles that no longer meet certain wind loading and strength criteria with steel and concrete poles. The utility has also increased the size of distribution lines to protect the system from lightning and shortened the span between poles to better withstand severe weather. Strengthened power lines have been shown to perform 40 percent better than nonhardened power lines, and they have allowed FPL to improve service reliability by 25 percent over the last five years (Pounds 2017). By the end of 2016, FPL had hardened over 600 main power lines in key areas that service more than 700 critical facilities, including police and fire stations, hospitals, and other emergency service centers. In addition to the physical strengthening of its system, FPL has installed over 4.8 million smart home meters and 36,000 smart grid devices in its poles and wires (Fischbach 2016). This smart grid technology allows FPL to monitor and assess the health of the power system, as well as restore power quickly when outages occur.

In the aftermath of Hurricane Matthew in September 2016, the Florida Public Service Committee allowed FPL to collect a US\$3.36 monthly surcharge per customer over 12 months to pay for storm cleanup and upgrades (Turner 2017). After Hurricane Irma swept through South Florida in late 2017, FPL then sought to levy a US\$4 monthly surcharge through 2018 and a US\$5.50 monthly surcharge into 2020. However, following reform of the federal tax system in December 2017, the utility decided to use the federal tax savings to offset Hurricane Irma restoration costs and avoid a general base rate increase until 2022 (Neal 2018).

In March 2018, in the aftermath of Hurricane Irma, FPL announced a pilot program to put utility lines underground. FPL will seek approval from the state regulator to pilot several locations within its 35-county service territory. During Hurricane Irma, only 19 percent of underground main lines lost power, compared with 69 percent of hardened overhead power lines and 82 percent of nonhardened overhead power lines (Pounds 2018). FPL plans to pay 25 percent of the cost of placing power lines underground, with cities and developers covering the remaining amount. It aims to have 60 percent of its distribution system hardened or placed underground by the end of 2018 and the entire system underground by 2024 (Keefer 2018).

# 3

# TRENDS AND INNOVATIONS IN URBAN INFRASTRUCTURE FINANCING

### **Overview**

Limited information is available on the current sector-specific, climate-resilient infrastructure spending in cities. Climate change impact studies that estimate the spending required over a certain period to upgrade a specific infrastructure system are accessible, as well as anecdotal information detailing how much was spent to repair and upgrade a specific system after a major catastrophe. However, the academic and grey literature are noticeably silent on the current overall level of climate resilience spending in cities around the world.

#### Figure 3.1 Percentage of local "Adaptation Economy" spending on urban infrastructure climate adaptation initiatives (by subsector) in 10 global megacities



Source: Based on Georgeson et al. (2016).

Georgeson et al. (2016) are a notable exception. They use proprietary data sets and methods to estimate public and private spending on climate adaptation upgrades in 10 global megacities (Addis Ababa, Beijing, Jakarta, Lagos, London, Mexico City, Mumbai, New York, Paris, and São Paulo) for the period 2014-15. The authors reach two key conclusions. First, climate adaptation spending, or what the authors call the "adaptation economy," is currently just a tiny fraction of a city's gross domestic product (GDPc), ranging from 0.14 to 0.33 percent. In percentage terms, the figures are generally quite consistent by city type (developed, emerging, developing), with few exceptions. This remains the case when the focus is narrowed to urban water, transport, and energy systems. There is little variation between countries across the water transport, and energy sectors (see figure 3.1).

The picture changes, however, if the focus is on aggregate spending levels because there are material differences in the total level of climate adaptation spending between different city types, ranging from £15 million in Addis Ababa to £1.624 billion in New York over the 2014-15 period. The authors conclude that spending appears linked to protection of the stocks of capital more prevalent in developed cities, such as comprehensive energy and transport systems supporting "high-consumption, high-comfort lifestyles." Figure 3.2 isolates total climate adaptation spending by urban infrastructure sector across each of the 10 cities covered by the Georgeson et al. study. In another comparative analysis, Lee and Kim (2018) look at planned and actual spending on climate adaptation projects in six metropolitan cities in Korea. The study does not contextualize climate adaptation spending as a part of the overall spending of a city, but it does illuminate key adaptation priorities across these cities, such as a heavy emphasis on sewer system upgrades to handle increased stormwater volumes, investments in the development of new water resources, and investments to preserve water quality.

Neither of these studies provides insights into the origin of the resources used to support these investments, including intergovernmental transfers. As noted earlier, sources of funds vary widely by city, depending on the larger political and national authorizing environment, creditworthiness considerations, and the local government's institutional and administrative capacity.

The balance of this chapter explores the current global experience with the use of different funding and financing instruments over which local governments or infrastructure system operators may have some control. It makes no presumption Figure 3.2 Total climate adaptation spending by urban infrastructure sector in 10 global megacities, 2014–15



Source: Extrapolated from Georgeson et al. (2016).

about the applicability of these instruments to a city or infrastructure system context. Municipal government officials or infrastructure system operators must assess that situation based on local circumstances. Moreover, each instrument may have more or less relevance, depending on the type of cost burden being targeted (for example, changes in operating and maintenance costs resulting from climate change impacts versus

#### Box 3.1 Policy and investment decision making under uncertainty

Cities and infrastructure system operators are increasingly employing sophisticated methods to assess climate risks that may affect operations or the physical integrity of their system and basing operations and maintenance and investment decisions on the results. Climate change introduces deep uncertainty to this process: uncertainty about how much carbon dioxide emissions will grow over the time; how the climate system will respond to different aggregate emission levels; and how those system responses will manifest themselves at the local level, interacting with other natural and social systems.

The World Bank is working on sector-specific guidance to support improved decision making under uncertainty. This guidance seeks to identify robust decisions (that is, those that satisfy multiple objectives in different plausible futures and over multiple time frames), evaluate the trade-offs among options, and identify actions that reduce the vulnerability of future investments. Central to many of these approaches are discussions between climate experts and key system stakeholders on current and future priorities and monitoring systems that assess risk throughout the life of a project so solutions can be adjusted over time to respond to this new information. Guidance also typically includes a blend of preventive actions and reactive solutions. To date, World Bank teams have developed guidance for the water supply sector, flood risk management projects, hydropower facilities, and road network projects.

This work is relevant to the funding and financing discussion in this chapter because it influences the amount of resources needed by a city or system operator over time. However, so far little work has been done on linking the uncertainty discussion with the type of funding and financing instruments employed by a local authority or infrastructure system operator.

Source: Based on Hallegatte (2012, 2017).

the cost of financing major system upgrades or replacements that make the system more climate-resilient).

The majority of the instruments discussed here can be used for anticipatory investments-that is, design and construction spending aimed at avoiding or minimizing damage caused by climate change. Less attention is focused on recovery or reconstruction instruments that help address after-the-fact climate-related damage costs.

## **Policy control powers**

Because many local governments have power over land use and zoning, they are able to influence what occurs on a given parcel of land. Land use rules are important because they can preclude or minimize development in areas vulnerable to climate hazards, thereby keeping expensive infrastructure investments out of harm's way. Building codes specifying what building practices are allowed or required are another closely related set of powers sometimes delegated to local authorities.

Both sets of powers are relevant to climate-resilient infrastructure because they also allow local authorities to place the investment onus directly on the property owner. This is particularly true for new parcel development or major redevelopment projects because it can be difficult to force longtime property owners to undertake the retrofitting needed to meet new codes or requirements developed with enhanced climate resilience in mind. For example, as noted in chapter 2 some local authorities are taking steps to reduce stormwater management operating costs by imposing land use policies requiring or incentivizing the use of more permeable surfaces on a given a parcel of land. These measures help shift a portion of the cost burden away from system operators and onto individual property owners. The city of San Jose, California, has such requirements that vary according to parcel size. Property owners developing vacant land or redeveloping an existing plot of land must attempt to minimize the amount of impervious surfaces, manage roof and driveway runoff on-site, and construct driveways

or parking areas using permeable surfaces (City of San Jose 2011). In Can Tho, Vietnam, the World Bank's City Resilience Program is helping the local people's committee plan a major land redevelopment project, building in requirements that bidders incorporate an enhanced stormwater and floodwater management system into their design (World Bank 2018a).

Local authorities interested in pursuing these strategies must recognize that their effectiveness is ultimately linked to the quality of any enforcement efforts. Cities with limited enforcement capacity or a legacy of corruption related to regulatory enforcement may see few impacts or behavioral changes in the absence of a robust enforcement regime.

## Taxes

Many local authorities support the development and maintenance of urban infrastructure systems with general tax revenues directly under their control. These revenues may derive from local property taxes, sales or income taxes, permit fees, and other revenue sources. In general, local authorities or infrastructure system operators must be authorized by the national government to levy these taxes.

This also holds true for targeted taxes, which can be another important source of funding. The key difference between targeted taxes and general taxes is that targeted taxes are specifically aimed at the users or beneficiaries of a specific infrastructure system. In the United States, for example, more than 1,300 government jurisdictions or water authorities impose some type of stormwater fee to help pay for local stormwater control measures. These fees can be based on a fixed rate per parcel or on the extent of impermeable surfaces (such as roofs, driveways, or other paved areas) covering a parcel (Milne 2015). For example, in the Seattle region of the United States there is a US\$0.129 property tax levy per US\$1,000 of assessed property value. The tax raises US\$55 million a year, with the proceeds used to support levee improvements, flood barrier construction, and other efforts aimed at protecting roads, power systems, and water and wastewater infrastructure.<sup>9</sup> The underlying reason for these taxes is clear-one study estimates an acre of pavement generates 10–20 times the runoff from an acre of grass (Frazer 2005). The tax thus serves as both a usage charge and an incentive for the property owner to take steps to reduce runoff levels.

In Mexico City, the incentive goes in the other direction: the local government offers a 10 percent property tax reduction for new and existing buildings that install green roofs (C40 Cities 2015). The subsidy policy has been quite effective. The city is currently Latin America's leader in green roofs, accounting for nearly 22,000 square meters of green space on local rooftops (Maxwell 2015). In North Rhine–Westphalia, Germany, the combination of a surface water drainage charge and subsidies resulted in a significant increase in green roof and water reuse system installations, and more than 6 million square meters of land was disconnected from the local stormwater system between 1996 and 2004 (Bennett 2011).

Some jurisdictions are beginning to consider dedicated taxes specifically linked to climate resilience as a way of increasing the level of funding available for climate projects. In the nine-county San Francisco Bay area in California, 70 percent of voters supported a 2016 ballot measure self-imposing an annual US\$12 tax per property in each county over the next 20 years. The measure will raise US\$25 million a year (and US\$500 million over the life of the measure). Among other uses, funds will be available to support habitat restoration and green infrastructure along the bay aimed at providing flood and storm surge protection (San Francisco Bay Restore 2016).

In the transport sector, fuel taxes have long been used by national governments to pay for highway development and maintenance. Some local authorities are now seeking to impose their own localized version of this tax, targeting different fuels sold within the city limits. In the United States, voters in Portland, Oregon, authorized in 2016 a tax of US\$0.10 per gallon of all fuel sold in the city. The revenue will be used for street repair, sidewalk construction, creation of safer corridors for bicycles, intersection safety, and high crash corridor safety improvements (City of Portland 2016). Chicago (2018) imposes a tax of US\$0.05 per gallon on fuel sold in the city. The revenue is ring-fenced to pay back transport-related bonds issued by the city (City of Chicago Debt Management and Investor Relations 2018). When crafting fuel taxes, it is especially important to pay attention to how the tax is constructed. Because many fuel taxes are imposed on a per-gallon-sold basis, the amount of funds raised may respond to changes in driving habits or an increase in the fuel efficiency of vehicles driven in that jurisdiction. Both changes could reduce the revenue flow. As a result, some countries have moved to impose vehicle-miles-traveled taxes on certain types of vehicles such as heavy trucks (Kim 2016).

In the energy sector, Boulder, Colorado, is one of the first cities in the United States to impose a local tax on electricity use. The revenue collected supports energy efficiency initiatives, public education, and energy audits. Differential rates are charged based on the type of user (residential users, US\$0.0049 per kilowatt-hour; commercial users, US\$0.0009 per kilowatt-hour; industrial users, US\$0.0003 per kilowatt-hour). The tax costs the average residential user US\$21 a year, commercial user US\$94 a year, and industrial user US\$9,600 a year, generating roughly US\$1.8 million a year for climate-related initiatives (City of Boulder 2018). To date, this spending does not appear to include climate resilience initiatives for the energy system, but that is not precluded should Boulder decide to pursue this approach.

## Land value capture

Land value capture (LVC) is a public financing method whereby governments trigger an increase in land or property value because of a regulatory decision (such as a change in development rights) or an investment in infrastructure or an amenity. The government seeks to

<sup>9.</sup> See http://kingcountyfloodcontrol.org/.

capitalize on this increase in value by selling the properties benefiting from the investment or by identifying a proxy for this land value increase (such as the assessed value of the land) and then collecting additional taxes, betterment charges, or other assessments to pay for or help offset any of the original investment costs (Suzuki et al. 2015). LVC is well known in transit circles because increases in land value are associated with the creation of a new transport hub or corridor.

The use of LVC to support climate resilience investments is a newer notion, predicated on the idea that an infrastructure investment that makes a neighborhood less prone to flooding or a climate-related power outage might enhance its value compared with other areas of the city. For example, there is already some evidence that areas less prone to flooding in Florida's Miami-Dade County enjoy a "nuisance" premium over other areas around the city in terms of pricing (Keenan, Hill, and Gumber 2018). To date, however, there has been no attempt to pursue an LVC strategy that explicitly seeks to capitalize on this differential.

There may also be other ways to structure LVC approaches so they support investments in climate resilience. In São Paulo, for example, the local authority identified a section of the city it wished to see redeveloped, and then it issued bonds (known as Certificates of Potential Additional Construction, or CEPACs) for auction to developers to allow them to build at height or density levels not allowed under current zoning rules. Under the arrangement, over the last 10 years São Paulo has received roughly US\$2.2 billion for use in supporting essential infrastructure and housing in those same neighborhoods (Blanco et al. 2017). There are no restrictions in how these funds are to be utilized. meaning some or all of the funds raised could be devoted to climate resilience investments.

### Insurance

This use of catastrophe bonds (cat bonds) for sector-specific climate resilience activities is a relatively new phenomenon that complements the traditional insurance coverage employed by infrastructure utilities. Unlike the green and environmental bonds discussed below, the proceeds from cat bond sales are not made immediately available to support preemptive climate resilience investments. Rather, the proceeds are held in an investment account for the entire bond term. If there is no triggering event, investors get their money back at maturity, just like a regular bond. If a qualifying triggering event occurs, however, investors lose their principal and the money is released to the sponsor of the bond. Cat bonds hold appeal to the sponsor (such as a transit system or energy utility) because they are treated as insurance products, not municipal bonds, which means the sponsor only pays the premiums, not the entire bond principal. This is advantageous to the sponsor because it means debt limits or impacts on its credit rating need not be a concern (ReFocus Partners 2017).

In recent years, the New York Metropolitan Transportation Authority issued cat bonds for US\$200 million and for US\$125 million. The U.S. national rail system, Amtrak, also issued a cat bond valued at US\$275 million (Insurance Journal 2015). To date, the urban energy sector has made limited use of these instruments. In 2003 and 2011, Electricité de France (EDF) pioneered the use of two parametric insurance cat bonds to protect against windstorm damage to its national transmission network. The goal was to obtain a source of risk capital that would pay out quickly after a triggering event and to secure risk transfer for an area of ECF's operation that was previously uninsured. These bonds were not repeated after the 2011 bonds matured (Artemis 2017), and it appears that similar cat bonds have not been issued by EDF or any other large electric utility since then.

## **User fees**

Depending on the type of infrastructure system in question, user fees or tariffs are often assessed as a means of supporting partial or full recovery of a system's operations and maintenance (O&M) costs. The amount of cost recovery achieved is generally a political or regulatory issue because the need for resources to cover O&M costs, or any necessary capital upgrades, must be balanced against the risk of pricing customers out of the

		Percentage of water utilities whose average tariffs appear to be			Percentage of electricity utilities whos average tariffs appear to be			
		Too low to cover basic O&M	Enough to cover most 0&M	Enough for 0&M and partial capital	Too low to cover basic O&M	Enough to cover most 0&M	Enough for O&M and partial capital	
Global		39	30	30	15	44	41	
rel	High income	8	42	50	0	17	83	
ne lev	Upper-middle income	39	22	39	0	71	29	
incor	Lower-middle income	37	41	22	27	50	23	
By	Lower income	89	9	3	31	44	25	
	OECD	6	43	51	0	17	83	
	Latin America and Caribbean	13	39	48	0	47	53	
5	Middle East and North Africa	58	25	17	-	-	-	
r regio	East Asia and Pacific	53	32	16	29	65	6	
B	Europe and Central Asia	100	0	0	31	38	31	
	South Asia	100	0	0	33	67	0	
	Sub-Saharan Africa	-	-	-	29	71	0	

#### Table 3.1 Utility cost recovery rates based on sector, income level, and region

Source: Komives et al. 2005.

*Note:* OECD = Organisation for Economic Co-operation and Development; 0&M = operations and maintenance.

market. Especially in many parts of the developing world, user fees are subsidized to ensure that low-income households can maintain access to these services.

To the extent that system operators can impose new road or bridge tolls or increase the cost of existing tolls or electricity or water charges, they can help address some of the rising cost burden they are likely to face from climate change. System operators cannot get too far ahead of their customers' ability to pay, however, which potentially limits the use of these fees as a cost recovery tool. This problem is already emerging in many parts of the world where user fees for essential services are so low that they do not even cover basic O&M costs. According to a 2005 World Bank assessment of cost recovery levels in the water and electricity sectors around the world, the problem is particularly acute in South Asia and Sub-Saharan Africa (Komives et al. 2005)-see table 3.1.

Utilities whose rates are set by a regulatory agency may also face difficulty if the staff of these agencies are not certain how to assess valid climate-related expenditures. In California, the state Public Utilities Commission recently established a rulemaking process related to spending on climate change adaptation (California Public Utilities Commission 2018). It will ultimately help determine what climate-related expenditures are considered deserving of cost recovery.

# Payments for ecosystem services

Payments for ecosystem services (PES) are a financial instrument in which the users of ecosystem services (for example, parks or open spaces that provide recreational or temporary flood control benefits or the cooling or air quality benefits of urban forest cover) compensate the providers of these services. Users of ecosystem services can include individuals, communities, businesses, or governments acting on behalf of their citizens. A PES scheme essentially rewards land and other natural resource managers for access to "green infrastructure" that otherwise would not be available at these levels in the absence of such payments. As a result, PES indirectly puts a price on ecosystem services that had previously not been compensated, such as climate adaptation benefits.

PES schemes must be carefully designed to not undermine existing stewardship efforts. Many land or resource managers may already be subject to regulation and do properly undertake measures to protect and enhance ecosystem services.

PES schemes can be most efficiently applied in situations in which

- Specific land or resource management actions have the potential to increase the supply of a particular service.
- There is a clear demand for the service in question, and the provision of the service is financially valuable to potential buyers.
- It is clear whose actions have the capacity to increase or enhance the supply.

PES schemes come in a variety of forms that can include both public and private actors. Although some PES programs include contracts between consumers and suppliers and ecosystem services, many programs continue to be funded by governments and involve intermediaries such as NGOs. A majority of schemes have focused on carbon sequestration and storage, biodiversity conservation, and water quality protection. An important feature of PES schemes is that they can be developed and operated at various levels of scale: international, national, catchment, and local (neighborhood). New York City has one of the most well-known urban programs, targeting investments and payments in rural areas 100 miles north of the city that are adjacent to the city's massive water supply system. The payments ensure proper management of woodlands, prevent erosion, and minimize pollutant runoff into the city's reservoirs (Hu 2018).

## **Ecological fiscal transfers**

A closely related instrument is an ecological fiscal transfer (EFT), a form of cash transfer from a national government to a local or regional government aimed at promoting biodiversity conservation and ecosystem services that can support adaptation goals. Through EFTs, local and state actors can be compensated by the national government for creating or maintaining certain types of ecosystem services. Recipients are required to meet conditions to use the funds and to show accountability in the process. These conditions include clear objectives, an allocation method for the funds, measurable targets, and an auditing and evaluation system. A successful fiscal transfer instrument must include (1) revenue adequacy-to ensure sufficient resources for the transfers; (2) equity-so that transfers vary according to local fiscal needs and capacity; (3) transparency and stability-to allow local governments to prepare a budget that forecasts total revenue from the transfers; and (4) capacity building-to help local organizations and firms take over once the program has been completed.

EFTs have been used in Brazil, China, India, South Africa, and the United States. In Brazil, ecological fiscal transfers have been used by the central government since the 1990s. Some Brazilian states rely on the ICMS (Imposto sobre Circulação de Mercadorias e Serviços) Ecológico, a value added tax on goods and services. Municipalities with conservation or protected areas receive 5 percent of the revenue from the ICMS, and those with larger protected areas receive a greater share of the revenue. The mechanism provides local Brazilian governments with financial incentives to prioritize conservation efforts (Cassola 2010; Rowcroft and Black 2017).

# Official development assistance

Official development assistance (ODA) is a traditional source of funding for water, transport, and energy systems in most developing countries. In 2014 the OECD's Development Assistance Committee published summary data detailing bilateral support for urban climate change adaptation. Collectively, these commitments made up 8 percent of total bilateral adaptation-related aid for the period 2010-12, averaging US\$720 million a year. Seventy-two percent of this support was in the form of loans-a far higher percentage than most adaptation-related aid. The emphasis on loans likely reflected the fact that 84 percent of urban adaptation-related support targets cities in middle-income countries, which tend to be less eligible for grants. Thirty-seven percent of the funds supported transport and storage climate adaptation initiatives, and another 18 percent funded water supply and sanitation climate adaptation initiatives. Ten cities-eight of which are in Asian countries-account for 77 percent of the bilateral commitments, reflecting the strong geographic focus of the five donors (European Union, Germany, France, Japan, and Korea) responsible for 97 percent of urban climate adaptation-related aid during this period (OECD DAC 2014).

In the latest OECD ODA tracking report (2013–15), an average of US\$13.69 billion in development assistance was directed at the water and sanitation sector each year, split between grants and loans. The urban fraction of this amount is unclear, although OECD did note that US\$9.2 billion in development aid was committed to "large" water supply and sanitation systems in 2015 (OECD 2018a). During the same time, ODA averaging US\$9 billion a year was allotted to transport projects. Again, the urban fraction of this total is unclear, as is the proportion of funding allotted to climate adaptation.

Energy systems are traditionally one of the largest areas of ODA support in developing countries. Between 2013 and 2015, donors committed an average of US\$27.2 billion to enhancing system access, system reliability, the development of clean power sources, and improved management practices (OECD 2018b). Data that break this down into projects targeting urban systems or climate adaptation are not available.

Data provided by the multilateral development banks (MDBs) provides additional insights into how ODA is supporting climate adaptation projects in the water, transport, and energy sectors. Table 3.2 breaks down investments by the reporting categories most closely linked to

	а	b	С	d = a + b + c	е	f=d÷e	g	h = e ÷ g
	Spending o	n climate adapt categories	tation, targeted			Water +		Water + transport + energy
Year	Water and wastewa- ter sys- tems (US\$, millions)	Energy, transport, and other built envi- ronment infrastruc- ture (US\$, millions)	Coastal and riverine infrastructure, including built flood protec- tion infrastruc- ture (US\$, millions)	Subtotal (US\$, millions)	Total MDB climate adapta- tion fi- nance, all categories (US\$, millions)	transport + energy + coastal flooding in- frastructure as % of total MDB climate adaptation finance	Total MDB climate finance, all climate mitigation + adapta- tion (US\$, millions)	+ coastal flooding infra- structure adaptation as % of total MDB climate finance
2014	541	1,147	847	2,535	5,069	50%	28,345	9%
2015	1,362	1,230	589	3,181	5,024	63%	25,096	13%
2016	1,129	1,093	973	3,195	6,224	51%	27,441	12%
2017	2,600	1,938	88	4,626	7,352	63%	35,219	13%

#### Table 3.2 Climate adaptation finance per year, multilateral development banks (MDBs)

Source: IDB et al. 2014, 2015, 2016, 2017.

the three infrastructure categories of interest here. One thing clearly stands out. Although energy, transport, and water and flood protection investments dominate the MDBs' annual spending on climate adaptation (over 50 percent in each of the years reported here) as a percentage of the overall climate finance spending by the various MDBs, climate adaptation spending on urban infrastructure has been relatively small. This percentage may reflect the high spending levels on mitigation projects, the spending levels on other nonurban infrastructure projects, or the methodology used by MDBs to track climate adaptation spending, which limits credit for adaptation finance to the incremental cost of making a project better address climate risks (IDB et al. 2017). The World Bank (2018c) recently announced it had increased its investments in adaptation in fiscal 2018, with 49 percent of its climate finance supporting adaptation efforts, compared with an average of 42 percent during fiscal 2015–17. Other MDBs have also committed to exploring ways to increase their level of support for adaptation projects (AfDB, 2017).

Because of the way MDB data are currently collected, no systematic information is available to break down this information into urban versus nonurban figures. One report published by the City Climate Finance Leadership Alliance (CCF-LA 2015) did include self-reported figures for several MDBs-including the World Bank Group and other bilateral aid institutions for a single calendar year, but the methods used by the different institutions were not consistent, nor did the report divide the figures into climate adaptation investments and mitigation investments.

A separate point is the type of ODA mechanism employed. Development policy financing involves resources that support policy reform or institution- and capacity-building projects. Funds are made available to clients upon completion of a set of policy or institutional actions or changes agreed upon in advance between the funder and the recipient. For urban infrastructure projects, qualifying actions might include land use changes that help minimize the climate risks to essential urban infrastructure and building codes that promote increased climate resilience.

## **Global climate funds**

All three urban infrastructure sectors have benefited from global climate funds set up by international bodies over the last 20 years. However, compared with the potential market needs noted earlier, the allocation of resources to urban infrastructure projects is relatively small and the geographic reach is limited. Based on a World Bank team assessment of information available on each fund's portfolio, it appears that across the four global climate funds discussed here, an estimated US\$1.94 billion has been allocated to climate adaptation support for water, transport, and energy infrastructure projects, leveraging an additional US\$4.1 billion in public and private co-financing. By far the lion's share of these resources-roughly 61 percent-have focused on climate adaptation upgrades in the water sector, with the balance split among the other sectors (see table 3.3).

The Pilot Program for Climate Resilience (PPCR), one of the Climate Investment Funds (CIF), has invested US\$103 million in seven countries in projects on climate resilience in the water sector. Because of the design of these projects, it is difficult to determine what proportion of these funds is strictly urban in nature. Another US\$89 million from the PPCR supports transport-related climate resilience projects in seven countries, but again the urban fraction of this total is not clear. The energy sector has received much PPCR support to date, although an allocation of US\$11 million to one project in Tajikistan includes energy sector resilience to climate change. Across the three sectors, the US\$203 million in PPCR funds has leveraged US\$661 million in co-financing from government and private sources.10

It is still early day to see definitive trends in Green Climate Fund (GCF) support for urban

10. All figures based on communication with Jose Andreu, Climate Investment Funds team, July 2018.

Table 2.2 Allocation of global	climate funde to water operav	and transport projects
Table 5.5 Allocation of global	cumate runus to water, energy,	, and transport projects

			Se	ector					
	w	ater	Trai	nsport	En	iergy	т	otal	Additional
Fund	No. of projects	Allocation (US\$, millions)	No. of projects	Allocation (US\$, millions)	No. of projects	Allocation (US\$, millions)	No. of projects	Allocation, (US\$, millions)	leveraged (US\$, millions)
Pilot Program for Climate Resilience (CIF-PPCR)	7 <sup>a</sup>	\$103.3	7 <sup>a</sup>	\$88.8	1	\$11.0	12	\$203.0	\$661.5
Green Climate Fund (GCF)	19 <sup>b</sup>	\$1010.8	6 <sup>b</sup>	\$273.3	6	\$362.4	29	\$1,646.5	\$2,828.1
Least Developed Countries Fund [LDCF] and Special Climate Change Fund [SCCF]	9 <sup>c</sup>	\$41.4	2 <sup>c</sup>	\$4.3	1°	\$1.4	9	\$47.1	\$611.9
Adaptation Fund	6 <sup>d</sup>	\$27.7	3 <sup>d</sup>	\$13.5			6	\$41.2	
Total		\$1,183.2		\$379.9		\$374.8		\$1,937.8	\$4,101.5

Source: World Bank.

Note: CIF = Climate Investment Funds.

a. Three projects include both water and transport elements.

b. One project includes both water and transport elements. Four projects include both energy, water, and transport elements.

c. Two projects include both transport and water elements, while one project includes energy and transport elements.

d. Three projects include both water and transport elements. One water project also includes housing and EWS (economically weaker section) elements, which have been excluded from the dollar total.

infrastructure climate adaptation projects. Of the three sectors, water has been the biggest recipient of GCF climate adaptation funds to date-six urban and rural projects are receiving approximately US\$1011 million. GCF resources on these projects are blended with an additional US\$950 million from government and private sources.<sup>11</sup>

Two GCF transport projects have been approved thus far, one on the island of Nauru in Micronesia (a grant of US\$27 million that leverages additional co-financing of US\$38 million) and a multisector project in Bangladesh that supports mainstreaming of climate and disaster risk in the water and transport sectors (a US\$40 million grant that leverages US\$40 million in additional project co-financing).<sup>12</sup> The GCF has also supported energy system climate adaptation in Tajikistan (US\$50 million in loans and grants to support increased hydro sector adaptation, leveraging an additional US\$83 million in government and private sector resources). A second GCF project supporting the development of new hydro resources in the Solomon Islands has also been approved

<sup>11.</sup> Based on communication with GCF team, World Bank, July 2018. Covers projects approved by the GCF Board through B21, October 2018.

<sup>12.</sup> Based on communication with GCF team, World Bank, July 2018. Covers projects approved by the GCF Board through B21, October 2018.

(US\$86 million in GCF loans and grants, leveraging US\$148 million in additional resources).

The Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF), two funds managed by the Global Environment Facility (GEF), have issued grants to urban infrastructure projects. A World Bank team assessment of LDCF and SCCF project-level data produced estimates that nine projects specifically target urban infrastructure systems, emphasizing flood protection measures, including some based on ecosystem-based approaches; upgrades to water supply systems; and other measures. Across the three infrastructure sectors, nine grants worth US\$41.4 million support water system upgrades in seven countries and two regions, and two grants valued at US\$4.3 million promote enhanced climate adaptation in transport systems. A single project in Malawi includes elements promoting enhanced energy system adaptation valued at approximately US\$1.4 million. Collectively, these LDCF and SCCF grants are estimated to leverage an additional US\$573 million in project co-financing from public and private sources.

The Adaptation Fund has allocated US\$28 million in support of six urban water projectsgenerally focused on flooding protection-in seven countries in Latin America, East Asia, and Africa. Three of these projects also include transport climate adaptation elements, which are estimated to total US\$14 million across four countries.<sup>13</sup> No co-financing has been reported on these projects.

These data are clearly an incomplete portrait of the total climate funds available to support urban infrastructure projects because other national and philanthropic funds are available. Moreover, because of the ways in which the funds highlighted here operate, municipal governments or infrastructure system operators will rarely enjoy direct access to these funds as requests must be approved by and channeled through the sovereign focal point to each fund. Other funds may be structured to allow direct subnational access. Municipal governments and infrastructure system operators should learn how these resources work in their country.

## **Public-private partnerships**

A public-private partnership (PPP) is a contractual relationship between a government entity and a private party to provide a public asset or service. PPPs typically involve very costly projects, and they call for private sector engagement in a project or service over an extended period. Governments generally pursue PPPs to contain cost; to limit the risks associated with delays in the delivery of a project; to establish budgetary certainty over an extended time frame; and to extend their capacity for infrastructure development, maintenance, or service delivery (World Bank 2018b). PPPs can also be effective at mobilizing recent technologies and using updated knowledge to improve operation of the system and provide discipline in the construction phase of a project to prevent cost overruns. Governments may also turn to PPPs to facilitate greater access to finance beyond that available to government itself.

The World Bank's PPP database<sup>14</sup> contains information on thousands of projects worldwide, including more than 1,400 projects dating back to 1984 which are clearly labeled as being sponsored by local governments. (see table 3.4). Seventy-eight percent of these projects are in East Asia (of which three-fourths are in China), and 14 percent are in Latin America and the Caribbean. Water and sewerage projects (including water treatment and water supply and delivery) and energy projects (primarily focused on elec-

<sup>13.</sup> Based on communication with Adaptation Fund, November 2018.

<sup>14.</sup> The World Bank's Private Participation in Infrastructure (PPI) database contains information on more than 8,000 infrastructure projects dating back to 1984. The database contains 50 data fields per project record, including country, infrastructure services provided, and type of private participation, based on publicly available information. It is one of the most comprehensive data sets of its kind globally. See http://ppi.worldbank.org.

Primary sector	East Asia and Pacific	Europe and Central Asia	Latin America and Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa	Total
Energy	491	12	1	2	15	5	526
Transport	79	5	46	3	7		140
Water and sewerage	528	42	149		9	9	737
Total	1,098	59	196	5	31	14	1,403

Table 3.4 Urban public-private partnership projects by region

Source: World Bank analysis of World Bank's Private Participation in Infrastructure (PPI) database as of August 22, 2018.

tricity generation and natural gas distribution) dominate the project list. In the transport sector, road projects make up half the total, and port facilities are responsible for most of the balance. The database contains information on just 11 local rail projects, covering both light rail and freight

The database does not include detailed information about each project, so it is not clear how many of these projects have some elements in either their design or service delivery requirements specifically emphasizing climate risk reduction.

Other research indicates it is unlikely that many PPPs specifically address climate risks in the way they should (World Bank Group/PPIAF 2016). As a contractual relationship, this is somewhat surprising because PPPs typically provide tremendous clarity on responsibilities and risk allocation (financial, market, political, legal, and operational) related to the project (Independent Evaluation Group 2015). The impacts of climate change can threaten the revenue model on which a project is based or hurt a provider's ability to meet the service delivery or quality requirements built into the contract. Thus it would make sense that more PPPs formally account for climate change as a factor affecting the design and implementation of a project.

Guidance provided by many national governments to help government entities interested in establishing a PPP typically contain no direct references to climate change. Many do require that PPP contracts account for unforeseen risks under a force majeure clause, which includes "Acts of God" such as extreme weather events. The guidance typically does not explain how to define such situations in terms of type, frequency, or intensity, which leaves a lot of room for interpretation and legal challenges. The burden of developing such definitions, and assigning responsibility for managing any risk, thus falls on the contracting parties (World Bank Group/ PPIAF 2016). In the United Kingdom, however, by law weather and climate events are never included in force majeure clauses, leaving the management of climate up to the private investor. In Japan, some PPPs define the nature hazard component of force majeure, but this is more the exception than the rule.

In Canada, climate change was taken into account in a PPP supporting the construction and operation of a bridge connecting New Brunswick and Prince Edward Island. Designed, built, financed, and operated by a private consortium, the design guidance called for a structure one meter higher than what was considered currently necessary to account for any future rise in sea level (Agrawala and Fankhauser 2008).

The World Bank has developed guidance on strategies that parties entering into a PPP contract may wish to consider to ensure climate change is taken into account (World Bank Group/PPIAF 2016). Parties should

- Retain the ability to modify a project through its term so they can take into account new scientific or technical information that could help improve the system's ability to adapt to changing climate conditions.
- Impose technical standards or a "fitness for purpose" warranty that require the private party to ensure that the infrastructure can meet its in-

tended function over an extended time frame, thereby giving the private partner the incentive to take long-term climate risks into account.

• Conduct a revenue analysis that takes climate change into account, and then employ the relevant financing instruments (such as index-based weather derivatives, catastro-

# **Box 3.2** Supporting green infrastructure in European cities: The Natural Capital Financing Facility

Funded by the European Investment Bank and the European Union's LIFE Programme, the Natural Capital Financing Facility (NCFF) is a €100-120 million revolving fund that supports projects promoting biodiversity and nature-based climate adaptation. Support takes the form of project loans and equity investments of between €2 and €15 million during the pilot phase running through 2021, as well as project preparation, implementation, and monitoring grants of up to €1 million. The NCFF finances up to 75 percent of total project costs for direct debt financing subject to the €15 million cap. Equity investments are capped at 33 percent of the total project value (European Investment Bank 2018).

The NCFF provides support for businesses engaged in sustainable forestry, agriculture, aquaculture, ecotourism, and biodiversity offsets that go beyond regulatory requirements. In urban areas, the NCFF provides funding for so-called green and blue infrastructure, including the creation of green corridors, green roofs, green walls, ecosystem-based rainwater collection and reuse schemes, flood protection, and erosion control. Projects must be located in EU-28 countries. Government agencies and private businesses are eligible to apply for support.

Athens, Greece, is the first urban recipient of support from the NCFF. It obtained €5 million to better integrate green and blue infrastructure elements into the redesign of streets, squares, and open public spaces. The projects will be designed to align with the climate impacts identified in the Athens Resilience Strategy, including reducing the urban heat island, lowering the potential for flash flooding, and increasing the connectivity of green spaces (and thus the habitat for fauna). The exact of mix of projects will be determined via a co-creation process with citizens and other relevant stakeholders.

The funds are earmarked as part of a larger €55 million project in Athens aimed at upgrading the city's infrastructure and improving energy efficiency in public buildings. Athens pursued funds from the NCFF as part of the larger financing deal in part because the project comes with a technical assistance grant supporting the planning, scoping, feasibility, design, and permitting process for both the main infrastructure and the integrated nature-based systems. phe risk insurance or risk-deferred drawdown options, or other sovereign insurance schemes) to protect revenue streams if key system assets are damaged or forced offline.

• Differentiate climate risks from "Acts of God," thereby clarifying the circumstances under which a contractor's failure to perform would be accommodated.

# Dedicated financing facilities and "green banks"

Housed at a development finance institution or established as a freestanding entity, financing facilities that support the preparation and financing of climate-related investments have been around for many years. Facilities that narrowly focus on urban projects or urban infrastructure climate resilience are, however, a relatively new idea. A virtue of narrowly focused facilities is that staff can quickly build expertise in specific markets, regulatory structures, financing instruments, and technology.

In the climate resilience sphere, the European Investment Bank and the European Commission have collaborated on creating a dedicated financing facility that will promote the use of "green infrastructure" to help address both increases in ambient temperatures and flooding problems in cities. Grants, loans, and equity investments in climate resilience projects and businesses are available during the pilot phase of the program (European Investment Bank 2018)–see box 3.2. In the United States, the New Jersey Energy Resilience Bank was created in 2013 to address problems that arose with critical energy infrastructure during Hurricane Sandy. Capitalized with a US\$200 million grant from the U.S. government, the Energy Resilience Bank provides low-interest loans and grants to hospital and water treatment facilities to support upgrades that should protect them against power outages in future storms (Johnson 2014, 2016)-see box 3.3.

In other parts of the world, green banks are being established to serve roughly the same purpose as dedicated financing facilities. To date, the primary focus of these facilities has been to support energy efficiency and low carbon development through the provision of concessional loans, risk guarantees, and equity investments in projects. According to OECD (2017), green banks have been established on a national scale (Australia, Japan, Malaysia, Switzerland, United Kingdom), state level (California, Connecticut, Hawaii, New Jersey, New York, Rhode Island-all in the United States), county level (Montgomery County, Maryland, United States), and city level (Masdar, United Arab Emirates). Washington, D.C., also recently approved the creation of a green bank to serve the city. It is currently awaiting congressional approval (DC.gov 2018).

One important question facing these entities is where to find the funds needed to capitalize their programs. As noted earlier, the New Jersey Energy Resilience Bank was capitalized with disaster relief funds from the U.S. government after Hurricane Sandy. In other countries, green banks have been capitalized through government appropriations, carbon tax or emissions trading scheme revenues, utility bill surcharges, and bond issuances and loans (OECD 2017).

### Bonds

Municipalities and infrastructure system operators allowed by sovereign authorities to issue debt can tap private investors for support for capital projects. In many countries in more advanced economies, debt in the form of bonds is a traditional source of financing for infrastructure systems, often with user fees or other system revenues ring-fenced to pay back the bond.

Bond markets have seen many different types of innovations in recent years. For example, in addition to their regular bond issuances, Washington, D.C.'s water and sewer agency recently issued the country's first environmental impact bond, which pays investors a higher rate of return if key environmental objectives are achieved (or charges them a premium if they are not achieved.) The bond's US\$25 million in proceeds will be used for the installation of

#### Box 3.3 New Jersey Energy Resilience Bank

In 2013 the U.S. state of New Jersey established the New Jersey Energy Resilience Bank (ERB) to minimize the impacts of major power outages in the state and strengthen resilience by offering financing support for distributed energy systems at critical facilities (such as hospitals, long-term care facilities, and wastewater treatment plants) affected by major disasters (New Jersey Board of Public Utilities 2014). The ERB, the first bank of its kind in the United States, was created in response to power disruptions in much of the state during Hurricane Sandy. In the aftermath of the hurricane, the storm surge left more than 90 wastewater treatment plants offline and forced the evacuation of two hospitals after the electricity failed.

The ERB was established with a US\$200 million grant from the U.S. government as part of its postdisaster aid program. The bank seeks to leverage public and private capital to fund energy projects that provide clean, reliable sources of energy (Tweed 2014). The ERB provides critical facilities with low-interest loans and grants that allow them to remain online using distributed energy technologies when traditional sources are offline (Johnson 2016). Applicable technologies may include combined heat and power plants, fuel cells, and solar panels with off-grid inverters and battery storage.

ERB funding targets the nine counties most damaged by Hurricane Sandy (Johnson 2014). As of July 2018, the ERB had approved 11 projects and disbursed over US\$65 million to a range of entities, including seven hospitals. The hospitals have also received additional loans from PSE&G, the largest electric utility in the state, to supplement ERB's financing. Two other facilities receiving ERB funds are the Bergen County Utility Authority (US\$27 million) and the South Monmouth Regional Sewerage Authority (US\$2.5 million). Both facilities lost power for a prolonged period in the aftermath of Hurricane Sandy (Choose NJ 2016).

The ERB has not yet been replenished for another round of financing, although additional federal money may be forthcoming to allow it to continue operations.<sup>a</sup>

a. Bruce Ciellela, Managing Director, N.J. Energy Resilience Bank, personal communication, July 12, 2018.

green infrastructure to absorb and slow surges of storm water around the city during heavy rains, thereby reducing the frequency and volume of combined sewer overflows that contaminate local rivers. Under the provisions of the bond, if the level of runoff is reduced by at least 41 percent compared to the baseline level, the agency will pay investors a bonus of US\$3.3 million. But if at the end of a designated period runoff levels are reduced by less than 18.6 percent compared to the baseline level, investors will make a "risk share payoff" to DC Water of US\$3.3 million (Goldman Sachs 2016).

Although it has yet to be issued, one bond issuance likely to garner attention in the next year is the US\$400 million "Miami Forever" general obligation bond, approved by voters in 2017. Nearly half (US\$192 million) of the bond proceeds are to be dedicated to flood prevention and sea level rise mitigation projects around the city. Projects will be chosen via a process involving extensive public input (Miami Forever 2017).

Green bonds are another way in which cities and infrastructure system operators can combine climate and capital-raising goals. Focused specifically on supporting investments in green physical assets (such as solar panels, public transport system upgrades, or water system improvements), green bonds appeal to investors seeking to align their investing with certain types of environmental or social outcomes, including climate adaptation. Green bonds are more complicated than general obligation or revenue bonds issued by a city because use of the funds is limited to agreed-upon asset types or classes. Green bonds also require some type of review process to ensure that funds are spent appropriately or deliver certain outcomes.

The global interest in green bonds has grown dramatically over the last decade, with total issuance hitting US\$161 billion in 2017 (Climate Bonds Initiative 2018b). Issuers include companies, national governments, development institutions, and cities (which have raised US\$17 billion to date). City-focused green bond have been issued almost entirely in developed countries, however, because creditworthiness challenges and sovereign prohibitions on municipal bond issuance continue to limit these opportunities in most developing country cities. As of October 2018, Johannesburg and Cape Town, South Africa, were the only two cities in a developing country to issue green bonds directly (Oliver 2016).

Following historic trends, the clear majority of green bond revenues raised in 2017 supported renewable energy projects (33 percent), low carbon and energy-efficient buildings (29 percent), and clean transportation (15 percent). Sixteen percent of funds supported "sustainable water management" and "adaptation" (Climate Bonds Initiative 2018a). Limited data are available on how many of these funds supported urban projects in either developed or developing countries.

Because of the tremendous increase in the number of cities developing climate resilience strategies as part of their climate action plan, Standard & Poors expects to see growing interest in municipal green or climate-aligned bonds that support local climate resilience projects (S&P Global Ratings 2018). However, it is important to acknowledge the risks that overindebted local authorities pose for the national governments of both developed and developing countries. If local governments are unable to make payments on debts, state or national governments are generally obliged to cover the shortfall. Governments must therefore proceed with caution and establish systems to ensure that cities granted the ability to assume debt do not overextend themselves.

One way of easing an extensive debt burden is through a "debt-for-climate swap" (or "debt-fornature" swap) in which a bilateral or multilateral agreement reduces a developing a country's debt stock in exchange for a commitment from the debtor to invest in national climate adaptation or mitigation programs. This voluntary transaction cancels some level of debt of the recipient country or city, allowing the savings from the reduced debt to be invested in conservation projects or climate-related expenditures. Donors might include the governments of developed countries, private foundations, international conservation organizations, and commercial banks. For example, in early 2018 The Nature Conservancy purchased \$15.2 million in outstanding debt from the Seychelles and mobilized an additional \$5 million in grants from several foundations, the UN Development Programme, and the Global Environment Facility. The Seychelles then cut its debt service by US\$2 million a year, and these resources have now been diverted directly into the newly established Seychelles Conservation and Climate Adaptation Trust (UNDP 2017).

# **4** KEY TAKEAWAYS

This policy brief highlights some of the new operating conditions that cities and infrastructure system operators may be forced to grapple with in the coming decades because of climate change. The nature and timing of these changing conditions, their severity, and their impact on local system operating and capital expense budgets will vary by locale. If one layers in other factors-uncertainty about other market and system pressures such as population growth; changes in technology, consumer tastes, and economic circumstances; and the need to overcome legacy underinvestment in these systems-then local authorities and system operators may face unprecedented challenges and massive costs as they try to keep their cities thriving economic engines and desirable places to live.

Exploring strategies for covering these costs has been the primary emphasis of this policy brief. The options available in one city may look quite different in another, reflecting varying market, regulatory, and policy circumstances. Even within the same city, the funding and financing picture may be significantly different across infrastructure systems. The value of each type of strategy in terms of scale and timing of resources is critical, and whether funds can cover increased operating expenses or capital investments only is an important factor for decision makers to weigh.

Several key takeaways deserve further consideration by local and national government officials and the larger climate and development finance community:

- · Circumstances in developing countries are profoundly different from those in developed countries. Fiscal instrument mechanisms that are commonplace or have proved successful in developed cities may not be easily replicated in cities with drastically different economic, financial, and political contexts. These differentiating circumstances fundamentally affect what cities in developing countries can accomplish. Funding for adaptation measures, in particular, can be addressed only to the extent that fundamental aspects of city financing are fixed. Action in some areas may be more fruitful than in others. For example, in a developing country lacking an adequate municipal credit market a donor-funded economic fiscal transfer to improve climate resilience would be more feasible than developing a green or municipal catastrophe bond.
- The national government plays an important role because it creates the essential operating conditions for its cities, including whether local authorities and infrastructure system operators can issue bonds, impose taxes, and enter into PPPs. A national government also has a say in how official development assistance is used and whether urban infrastructure projects are given priority in the use of these funds. There are many valid reasons why a national government may want to keep a tight rein on these decisions, rather than devolving decisionmaking powers to a local authority. One reason may be political considerations or concerns about whether it will ultimately be forced to cover debt incurred by these local authorities. A key question going forward

is whether or when sovereigns should revisit these restrictions of authority. This notion of improved vertical policy alignment between national and local government was at the center of a call to action by the Global Covenant of Mayors (2017) and others at the December 2017 One Planet Summit in Paris. And this issue will likely remain a prominent one for local authorities seeking to actively engage in climate resilience matters.

- Local authorities and infrastructure system operators need to look hard at the capacity or policy levers currently under their control and use them strategically to tackle current and future climate challenges. Most important is a local authority's ability to use its policy authority to shape development in ways that essential urban infrastructure remains out of harm's way. Meanwhile, when complemented by a strong enforcement regime, land use controls can be exercised to force property owners to shoulder more of the burden of the impacts of climate change such as minimizing runoff into communal stormwater management systems. Land use control powers may also imply the ability to pursue land value capture strategies. In São Paulo, additional development rights are serving as a source of significant new revenue. LVC strategies that seek to capitalize on climate resilience upgrades have yet to prove their viability, although this is an area that deserves attention going forward.
- Another capability that local governments and infrastructure system operators control is the use of comprehensive asset management strategies. Covering infrastructure system siting and design considerations, maintenance and monitoring practices, and contingency planning, asset management affects all the new resources local authorities and infrastructure system operators will ultimately need for capital investment or operations and maintenance purposes in the coming decades.
- ODA will likely remain a resource of outsized importance in developing countries. The growing level of ODA that simultaneously delivers climate co-benefits is an important trend,

although how much this trend will continue over the coming decades is an open question. Within the World Bank Group, the recent capital increase by the International Development Association (IDA) and International Bank for Reconstruction and Development (IBRD) expands the overall lending volume available to clients over time. Even if the proportion of projects delivering climate co-benefits remains relatively stable, that still means the availability of more money for urban infrastructure climate adaptation projects. Prioritization of urban infrastructure is a matter that must be raised jointly by both national government and development partners as part of their framing agreement discussions.

- The creation of taxes dedicated to climate resilience is still a new phenomenon, although there is a long track record of user fees that have a climate link, meaning there are many implementation models from which to learn. Assuming local authorities are authorized to establish such taxes, who get taxed, on what basis, and how the funds will be used are questions that policy makers must identify from the outset. Using the example of a per gallon fuel tax, local authorities pondering the stability of the revenue stream must think carefully about how the tax is designed and whether changes in technology or behavior could ultimately influence the level of tax receipts.
- The use of different types of bonds to support longterm capital upgrades is a well-worn strategy in many cities around the world, but basic creditworthiness considerations limit their use in much of the developing world. The growing interest in green bonds is noteworthy, although to date few of the funds raised have specifically been used for climate resilience investments. Whether this subsector is an area of potential growth is something that should be explored more fully because buyers may be looking for quantifiable outcomes more easily achieved by investments in mitigation.
- Sector-focused catastrophe bonds (cat bonds) may be an important new product line complementing the traditional insurance schemes. In New York

and France, transit and energy system operators have used cat bonds as part of their disaster insurance strategy. Similar opportunities may exist in many cities targeting infrastructure systems. The scarcity of these issuances deserves further exploration so that it becomes clearer whether it is simply an awareness problem, whether there are problems in terms of the bond buyer appetite, or whether it is a matter of who has the authority to issue these bonds.

- Dedicated green banks and climate resilience finance facilities will become broadly relevant only if the question of how they are capitalized is resolved. Growing global interest in these targeted financing mechanisms is a promising sign, but they are primarily a phenomenon in more advanced economies. Solving the funding problem is a prerequisite to their growth.
- Dedicated global climate funds are helpful, but they have a limited reach in view of the scale and diversity of global demand. The current funding patterns may also reflect the priorities of those establishing the funds versus those formally submitting the requests (typically at the sovereign/ministerial level). Urban infrastructure projects must compete with priority investments in other climate-affected sectors, including agriculture, rural water supply projects, and health. These funds can nonetheless prove helpful in the capacity building and institutional strengthening support they provide governments. This benefit is often overlooked if the focus is strictly on how

much money these sources bring into government coffers.

Perhaps the most significant innovation with the potential to transform climate resilience for urban infrastructure is the growing role that technical assistance initiatives and project preparation facilities are playing in helping governments improve their access to public and private financing. The Cities Development Initiative in Asia and the World Bank's City Resilience Program are the largest technical assistance programs of their type, working in dozens of cities simultaneously to help government teams take raw ideas and refine them into project proposals capable of attracting support from the World Bank, other development finance institutions, global climate funds, and the private sector. The CRP draws heavily on private sector expertise to help cities structure deals in ways that use ownsource resources and development aid to maximize the amount of private investment in these projects. Another important feature of CRP and similar initiatives is the direct feedback given local government officials and infrastructure system operators about any deficiencies in both individual proposals and the larger policy, regulatory, and operating environment in a city, all of which can entice or make investors hesitant to invest funds there. Remedving these problems can take some time, but the combination of blunt talk by private sector experts and supportive capacity building initiatives managed by the World Bank and others holds promise as a way of helping cities scale up their investments on climate and other essential development priorities.

# **Appendix**

# Impacts of climate change on urban infrastructure: Water, transport, and energy systems

# Impacts of climate change on urban water supply, treatment, and stormwater management systems

### Temperature increase and drought

System component	Infrastructure or system impact	Potential budget impacts
Water supply	Higher temperatures can affect amount and nature of precip- itation (that is, rain versus snow), thereby affecting level and timing of water supply availability.	Capital cost for additional supply sources or storage capacity.
	Higher temperatures can lead to degradation of water quality from concentration of contaminants as evaporation occurs or through enhanced growth of algae, microbes, or invasive species. Can also result in loss of foliage in areas adjacent to reservoirs or other supply feeders, resulting in increased turbidity of water or siltation lessening capacity of the stor- age facility.	Higher operating costs for additional water supply pretreatment. Capital cost for dredging of storage facility(s).
	Higher temperatures can result in higher rates of evaporation in surface water storage facilities.	Capital cost for relocation of intake pipes feeding water system.
Water demand	Higher temperatures can result in higher rates of evapo- transpiration, increasing demand for landscape irrigation or human consumption. May require additional storage capacity or physical reduction of water loss (through leakage) to deal with heightened demand or involve higher pumping costs to extract supply from deeper groundwater levels. Coastal cities may choose to pursue use of desalination plants as a supply option.	Higher operating costs such as energy cost associated with higher rates of water pumping and distribution. Capital cost for network rehabilitation or construction of new or expanded storage or desalination facilities.
	Higher temperatures can raise competition for water re- sources, particularly from power plants dependent on rivers for cooling water supply.	Potential revenue loss from lower operat- ing levels at water-cooled power stations. Capital cost for shift to air-cooled systems at power plants.

### Extreme weather events and storms

System component	Infrastructure or system impact	Potential budget impacts
Water supply	More extreme weather events can overwhelm capacity of storage facilities, creating safety hazards in both the imme-diate vicinity and downstream.	Capital cost for expanded storage capacity or enhancements of the structural integrity of storage facilities.
	More frequent and intense rainfall events will increase sedi- ment, nutrient, and pathogen/pollutant loads in waterways and reservoirs because of flooding.	Higher operating costs for additional water supply pretreatment.
	Intense rainfall events can lead to increased siltation of water storage facilities.	Higher operating costs for additional dredging at storage facilities;
		capital cost of expanded storage system capacity.
Wastewater treatment	Intense rainfall events can overwhelm systems in cities with combined sewer overflow (CSO-systems that combine wastewater and storm water runoff), leading to release of raw sewage into local waterways.	Capital cost for CSO system redesign or de- velopment of stormwater and wastewater retention systems that reduce likelihood of raw sewage release into local waterways.

#### Sea level rise

System component	Infrastructure or system impact	Budget impacts
Water supply	Higher potential for saltwater encroachment in surface and groundwater supply sources.	Capital cost for barriers or berms or devel- opment of alternative supply sources.
Wastewater treatment	Higher likelihood of flooding of sewers and wastewater treatment plants in coastal cities, with reduced ability to rely on gravity to discharge CSO and wastewater treatment facility effluent.	Higher operating cost for pumping of wastewater treatment facility effluent; capital cost for barriers or berms or relo- cation of treatment facilities.

# Impacts of climate change on urban transport systems

## Temperature increase

System type	Infrastructure impact	Budget impacts
Roads, bridges, tunnels	Damage and rutting of road surface as it softens from high heat.	Higher operating and repair costs.
	Change in freeze and thaw conditions during winter months, affecting pothole incidence or other road surface damage.	Affects operating and repair costs.
	Change in incidence and severity of snow and ice during winter months.	Change in road maintenance costs (more or less salt needed, number of snowplows and plow operators required, etc.), depending on incidence and severity of storms.
Rail bridges and tunnels	Potential buckling of rail as it heats up during extreme heat event.	Higher operating and repair costs.
	Subsurface rail systems may experience elevated heat levels, with potential dis- comfort and health impacts on riders.	Higher capital and operating costs for space cooling.
Marine	Incidence of ice-blocked waterways may diminish in severity and frequency.	Budget impact unclear, as previously impassable waterways may now become more regularly usable in winter months, with knock-on operating cost and revenue impacts.

### Increased incidence of extreme weather events and storms

System type	Infrastructure impact	Budget impacts
Roads, bridges, tunnels	Downed trees, limbs, and wires block roadways.	Higher operating and cleanup costs.
	Water and waves can undermine structural sta- bility of roadways or bridges, eroding subsurface or portion of roadway itself. Flooded tunnels may experience structural damage.	Higher operating and repair costs; possible capital replacement of certain road segments.
	Damage to vehicles, fleets, and equipment from flooding or debris.	Higher capital replacement costs.
	Damage to linked systems (such as street lighting along roadways, lighting in tunnels).	Higher repair costs; possible capital replacement costs.
	Damage to overhead lines for surface transport from downed limbs, trees, and strong winds.	Higher operating and repair costs; possible capital replacement of certain line segments.
Rail bridges and tunnels	Downed trees, limbs, and wires block roadways.	Higher operating and cleanup costs.
	Water and waves can undermine structural stabil- ity of tracks or rail bridges, eroding subsurface or portion of track surface itself.	Higher operating and repair costs; possible capital replacement of certain road segments.
	Damage to vehicles, fleet, and equipment.	Higher capital replacement costs
	Water and waves can damage or destroy sub- surface transit stations, track and tunnels, and electrical and control systems.	Higher operating and repair costs; possible capital replacement of certain tunnel segments or stations.
Marine	Damage or destruction of facilities, fueling facili- ties, and power systems by floodwaters.	Higher operating and repair costs; possible capital replacement of certain tunnel segments or stations.
	Damage to inventory staged at or near port facility.	Potential loss of operating revenue and elevated insurance costs.
	Difficulty berthing ships because of higher eleva- tion of ship (compared with normal water level).	Higher operating costs.

## Sea level rise and storm surge

System type	Infrastructure impact	Budget impacts
Roads, bridges, tunnels	Water and waves can undermine structural stability of road- way or bridges, eroding subsurface or portion of roadway itself.	Higher operating and repair costs; possible capital replacement of certain road seg- ments.
	Damage to linked systems (such as street or tunnel lighting).	Higher repair costs; possible capital replacement costs.
	Damage to vehicles, fleet, and equipment.	Higher capital replacement costs
Rail bridges and tunnels	Surface railzwater and waves can undermine structural sta- bility of roadway or bridges, eroding subsurface or portion of roadway itself.	Higher operating and repair costs; possible capital replacement of certain road seg- ments.
	Damage to vehicles, fleet, and equipment.	Higher capital replacement costs.
	Water and waves can damage or destroy subsurface transit stations, track and tunnels, and electrical and control systems.	Higher operating and repair costs; possible capital replacement of certain tunnel seg- ments or stations.

System type	Infrastructure impact	Budget impacts
	Damage or destruction of facilities, fueling facilities, and power systems by floodwaters.	Higher operating and repair costs; possible capital replacement of certain tunnel seg- ments or stations.
Marine	Damage to inventory staged at or near port facility.	Potential loss of operating revenue and elevated insurance costs.
	Difficulty berthing ships because of higher elevation of ship (compared with normal water level).	Higher operating costs.
	Potential reduced need for dredging because of higher water level.	Lower operating costs.

# Impacts of climate change on urban energy systems

System element	Infrastructure impact	Budget impacts
Power or district heating and cool- ing assets	High heat or drought can warm or reduce the available volume of cooling waters used to exhaust waste heat from thermal power plants or district heating and cooling plants, forcing shutdown or reduced output from the facility.	Revenue loss; potential penalties for violating regulator-imposed temperature standards in waterways where power plants exhaust their waste heat; potential capital cost for installation of air-cooling system (as alternative to water-cooled system design).
	Climate change–induced changes in cloud cover or wind patterns may affect system generation output of solar photovoltaic or wind power facilities.	Change in operating revenues.
	Drought can lead to lessening or loss of hydro facili- ty output.	Loss of operating revenues; capital cost of constructing larger retention facilities to ensure adequate water supply to feed hydro plant during dry season.
Transmission and distribution assets	Carrying capacity of transmission and distribution lines decrease as ambient temperatures increase, leading to potential failure of the line as it reaches its design limits.	Higher repair and maintenance costs; higher capital cost to upgrade these lines or install redundant capacity to share the power load burden.
	High heat can cause system failure of transformers or other equipment at power generation facility.	Higher repair and maintenance costs; capital investment in equipment that can operate under higher temperature conditions.
	Rising temperatures may lengthen growing season, leading to tree growth encroaching on power distribution lines, putting them at risk of damage or failure.	Higher operating cost (tree-trimming operations).
Energy demand	During periods of high heat, power demand (generally linked to high rates of air-conditioning use) on individual distribution lines, transformers, and substations may exceed the available capacity, leading to power system failure.	Higher repair and maintenance costs; higher capital cost to upgrade these assets to accommodate higher load levels or install redundant capacity to share the power distri- bution burden.
	Rising temperature drives elevated demand for air-condi- tioning and refrigeration use, increasing need for expand- ed peak supply availability and overall system capacity.	Higher capital cost for construction of addi- tional generation capacity.

### Temperature increase/drought

### Extreme weather events and storms

System element	Infrastructure impact	Budget impacts
Power or district heating and cool- ing assets	Damage to assets from flooding, high winds, hail, or lightning strikes.	Higher repair and maintenance costs; may require capital invest- ment in flood barriers and berms or relocation of these assets out of flood zone.
	Damage or loss of fuel stocks (for example, coal stockpiles flooded, no longer usable for power generation).	Higher operating costs for replacement of fuel stocks; may require capital investment in flood barriers or berms or relocation of these assets out of flood zone.
Transmission and distribution (T&D) assets	Damage to overhead lines from downed limbs, trees, and strong winds.	Higher operating/repair costs; may involve capital investment in more robust T&D towers and poles or undergrounding of certain line segments.
	Underground wiring, substations, and other system assets may be affected by floodwaters.	Higher repair and maintenance costs; may require replacement or relocation of select system assets to locations above elevation of flood zone.

# Sea level rise and storm surge

System element	Infrastructure impact	Budget impacts
Power or district heating and cool- ing assets	Damage to assets from flooding.	Higher repair and maintenance costs; may require capital invest- ment in flood barriers or berms or relocation of these assets out of flood zone.
	Damage or loss of fuel stocks (for example, coal stockpiles flooded, no longer usable for power generation).	Higher operating costs for replacement of fuel stocks; may require capital investment in flood barriers or berms or relocation of these assets out of flood zone.
Transmission and distribution assets	Damage to T&D towers and poles from storm surge.	Higher operating and repair costs; may involve capital invest- ment in more robust T&D towers and poles or undergrounding of certain line segments.
	Underground substations or other system assets may be affected by floodwaters.	Higher repair and maintenance costs; may require replacement with saltwater-resistant assets or relocation of select system assets to locations above elevation of potential sea level rise or storm surge.

# References

- ADB (Asian Development Bank). 2013. Increasing Climate Change Resilience of Urban Water Infrastructure: Based on a Case Study from Wuhan City, People's Republic of China. Mandaluyong, Philippines: ADB.
- AfDB (African Development Bank). 2018. One Planet Summit - Joint IDFC-MDB Statement - Together Major Development Finance Institutions Align Financial Flows with the Paris Agreement. Abidjan, Cote d'Ivoire: AfDB.
- Agrawala, Shardul, and Samuel Fankhauser, eds. 2008. Economic Aspects of Adaptation to Climate Change: Costs, Benefits, and Policy Instruments. Paris: Organisation for Economic Co-operation and Development.
- Ajuntament de Barcelona. 2013. Barcelona Green Infrastructure and Biodiversity Plan 2020. http:// ajuntament.barcelona.cat/ecologiaurbana/ sites/default/files/Barcelona%20green%20 infrastructure%20and%20biodiversity%20 plan%202020.pdf.
- Artemis. 2013. "First Storm Surge Catastrophe Bond, MetroCat Re Ltd. 2013-1, Launches." July 15. http:// www.artemis.bm/blog/2013/07/15/first-stormsurge-catastrophe-bond-metrocat-re-ltd-2013-1launches/.
- —. 2017. "Multi-billion Dollar Electric Grid Risks Need Risk Transfer: Swiss Re." July 25. http:// www.artemis.bm/blog/2017/07/25/multi-billiondollar-electric-grid-risks-need-risk-transferswiss-re/.
- Bahl, Roy. 2017. Metropolitan City Finances in Asia and the Pacific Region: Issues, Problems, and Reform Options. Bangkok: United Nations Economic and Social Commission for Asia and the Pacific.
- Bennett, Oliver. 2011. Surface Water Drainage Tax (Rain Tax). London: U.K. Parliament.
- Bhattacharya, A., J. P. Meltzer, J. Oppenheim,
  Z. Qureshi, and N. Stern. 2016. Delivering on Sustainable Infrastructure for Better Development and Better Climate. Washington, DC: Brookings Institution, New Climate Economy, and Grantham Institute for Climate Change and the Environment.
- Biswas, Asit K., and Kris Hartley. 2017. "Tackling the Challenges of Sponge Cities." *China Daily*, September 26.
- Blanco, Andres G., Nancy Moreno, David Vetter, and Marcia Vetter. 2017. The Potential of Land Value Capture for Financing Urban Projects: Methodological Considerations and Case Studies. Washington, DC: Inter-American Development Bank.
- Burne, Katy, and Ted Mann. 2013. "MTA Sells Storm Bond." *Wall Street Journal*, July 31.
- C40 Cities. 2015. Green Building City Market Briefs: Mexico City. https://www.c40.org/researches/ c40-usgbc-and-wgbc-green-building-city-marketbrief-compendium.

- -----. 2016. Good Practice Guide: Creditworthiness. http://www.citiesclimatefinance.org/2016/03/c40good-practice-guide-creditworthiness/.
- ------. 2018. C40 Cities Finance Facility. https://www.c40cff.org/.
- California Public Utilities Commission. 2018. "Order Instituting Rulemaking to Consider Strategies and Guidance for Climate Change Adaptation." Rulemaking 18-04-19. Issued May 7.
- Cassola, Rodrigo. 2010. TEEB Case: Financing Conservation Through Ecological Fiscal Transfers in Brazil. http://img.teebweb.org/wp-content/ uploads/2013/01/Financing-conservationthrough-ecologicalfiscal-transfers-in-Brazil.pdf.
- CCFLA (Cities Climate Finance Leadership Alliance). 2015. State of City Climate Finance 2015. New York: CCFLA.
- Choose NJ. 2016. "EDA Advances Two Projects for Energy Resilience Bank Funding." July 14.
- City of Boulder. 2018. "Climate Action Tax." https:// bouldercolorado.gov/climate/climate-action-plancap-tax.
- City of Chicago. 2018. "Department of Finance, Revenue, Tax List, Vehicle Fuel Tax (7577)." https:// www.cityofchicago.org/city/en/depts/fin/supp\_ info/revenue/tax\_list/vehicle\_fuel\_tax.html.
- City of Chicago Debt Management and Investor Relations. 2018. "Chicago Motor Fuel Tax Bonds." https://www.cityofchicagoinvestors.com/ motorfuelbonds/financial-documents/i1399.
- City of Portland. 2016. "Charter, Code and Policies, City of Portland, Chapter 17.105 Motor Vehicle Fuel Tax." https://www.portlandoregon.gov/ citycode/71044.
- City of San Jose. 2011. "Council Policy: Post-Construction Urban Runoff Management, Policy #6-29." https://www.sanjoseca.gov/ DocumentCenter/View/3891.
- Climate Bonds Initiative. 2018a. "Green Bonds Highlights 2017." https://www.climatebonds.net/ files/reports/cbi-green-bonds-highlights-2017.pdf.
- DC.gov. 2018. "DC Green Bank." Department of Energy and Environment, District of Columbia, Washington, DC. https://doee.dc.gov/greenbank.
- Ebinger, Jane, and Nancy Vandyke. 2015. *Moving* toward Climate-Resilient Transport. Washington, DC: World Bank.
- Ebinger, Jane, and Walter Vergara. 2011. Climate Impacts on Energy Systems: Key Issues for Energy Sector Adaptation. Washington, DC: World Bank. European Investment Bank. 2018. Natural Capital Financing Facility. http://www.eib.org/en/ products/blending/ncff/index.htm.

- Filosa, G. 2015. International Practices on Climate Adaptation in Transportation: Findings from a Virtual Review. Washington, DC: U.S. Department of Transportation.
- Fischbach, Amy. 2016. "FPL Hardens System against Storm Outages," *T&D World Magazine*, June 20.
- Frazer, Lance. 2005. "Paving Paradise: The Peril of Impervious Surfaces." *Environmental Health Perspectives* 113 (7).
- Gardner, Gary. 2016. "The City: A System of Systems." In Worldwatch Institute, *State of the World: Can a City Be Sustainable?* Washington, DC: Worldwatch Institute.
- Garfield, Leanna. 2017. "China Is Building 30 'Sponge Cities' that Aim to Soak Up Floodwater and Prevent Disaster." *Business Insider*, November 10.
- Georgeson, Lucien, Mark Maslin, Martyn Poessinouw, and Steve Howard. 2016. "Adaptation Responses to Climate Change Differ between Global Megacities." Nature Climate Change (6).
- Global Covenant of Mayors. 2017. "The Global Covenant of Mayors Announces 3 New Initiatives and Partnerships to Support Local Climate Action at One Planet Summit." Press release. https:// www.globalcovenantofmayors.org/wp-content/ uploads/2017/12/GCoM-Release-12.12.2017-FINAL. pdf.
- Goldman Sachs. 2016. "Fact Sheet: DC Water Environmental Impact Bond." http://www. goldmansachs.com/media-relations/pressreleases/current/dc-water-environmentalimpact-bond-fact-sheet.pdf.
- Goldstein, Matthew. 2018. "Puerto Rico's Positive Business Slogans Can't Keep the Lights On." New York Times, March 5.
- GWOPA (Global Water Operators Partnership Alliance), UN Habitat. 2016. A Tool for Coastal and Small Island State Water Utilities to Assess and Manage Climate Change Risk. Nairobi: UN Habitat.
- Hallegatte, Stephane, Colin Green, R. J. Nicholls, and J. Corfee-Morlot. 2013. "Future Flood Losses in Major Coastal Cities." *Nature Climate Change* 3: 802–6.
- Hallegatte, Stephane, Ankur Shah, Robert Lempert, Casey Brown, and Stuart Gill. 2012. "Investment Decision Making under Deep Uncertainty: Application to Climate Change." Policy Research Working Paper 6193, World Bank, Washington, DC.
- Hallegatte, Stephane, Adrian Vogt-Schilb, Mook Bangalore, and Julie Rozenberg. 2017. Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. Washington, DC: World Bank.
- Hu, Winnie. 2018. "Billion-Dollar Investment to Protect the 'Champagne of Drinking Water." New York Times, A19.
- Hulsmann, A., G. Grutzmacher, G. van den Berg, W. Rauch, A. L. Jensen, V. Popovych, M. Rosario, et al., eds. 2015. Climate Change, Water Supply and Sanitation: Risk Assessment, Management, Mitigation and Reduction. London: International Water Association.

- IDB (Inter-American Development Bank); EBRD (European Bank for Reconstruction and Development); World Bank; AfDB (African Development Bank); IDB Invest; ADB (Asian Development Bank); EIB (European Investment Bank); and IsDB (Islamic Development Bank).
  2017. Joint Report on Multilateral Development Banks' Climate Finance. Washington, DC: IDB.
- IDB (Inter-American Development Bank); World Bank; EBRD (European Bank for Reconstruction and Development); EIB (European Investment Bank); IIC (Inter-American Investment Corporation); AfDB (African Development Bank); and ADB (Asian Development Bank). 2016. Joint Report on Multilateral Development Banks' Climate Finance. Washington, DC: IDB.
- IDB (Inter-American Development Bank); World Bank; EIB (European Investment Bank); EBRD (European Bank for Reconstruction and Development); ADB (Asian Development Bank); and AfDB (African Development Bank). 2015. Joint Report on Multilateral Development Banks' Climate Finance. Washington, DC: IDB.
- IDB (Inter-American Development Bank); World Bank; IFC (International Finance Corporation);
  EIB (European Investment Bank); EBRD (European Bank for Reconstruction and Development);
  ADB (Asian Development Bank); and AfDB (African Development Bank). 2014. Joint Report on Multilateral Development Banks' Climate Finance. Washington, DC: IDB.
- Independent Evaluation Group. 2015. World Bank Group Support to Public-Private Partnerships: Lessons from Experience in Client Countries FY02-12. Washington, DC: World Bank.
- Insurance Journal. 2015. "Amtrak Sponsors \$275m Cat Bond for Northeast Storm Surge, Wind, Quake." https://www.insurancejournal.com/news/ east/2015/10/14/385087.htm.
- Inter-American Development Bank. 2018. "Project Preparation Facilities." https://www.iadb.org/en/ node/712.
- International Energy Agency. 2018. The Future of Cooling: Opportunities for Energy Efficient Air Conditioning. Paris: OECD/IEA.
- Johnson, Tom. 2014. "State Targets \$65m for Country's First Energy Resiliency Bank." *NJ Spotlight*, September 3.
- 2016. "NJ Energy Resilience Bank Getting Ready for Second Round of Withdrawals," NJ Spotlight, September 29.
- Joint Ministerial Committee of the Boards of Governors of the Bank and the Fund on the Transfer of Real Resources to Developing Countries. 2015. From Billions to Trillions: Transforming Development Finance: Post-2015 Financing for Development: Multilateral Development Finance. Prepared jointly by African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, European Investment Bank, Inter-American Development Bank, International Monetary Fund, and the World Bank Group, April 2.

Keefer, D. W. 2018. "This Utility Is Heading Underground to Protect against Storm Damage." Energy Central, Aurora, CO. https://www. energycentral.com/c/cc/utility-headingunderground-protect-against-storm-damage.

Keenan, Jesse M., Thomas Hill, and Anurag Gumber. 2018. "Climate Gentrification: From Theory to Empiricism in Miami-Dade County, Florida." Environmental Research Letter 13: 054001.

Kenealy, Bill. 2013. "New York's MTA Buys \$200 Million Cat Bond to Avoid Storm Surge Losses." Business Insurance, October 11.

Kim, Julie. 2016. Handbook of Urban Infrastructure Finance. Montreal: New Cities Foundation.

Kolitz, Daniel. 2017. "The NYC Subway Is Still Getting Ready for the Next Hurricane Sandy." *Gizmodo*, August 1.

Komives, Kristin, Vivien Foster, Jonathan Halpern, and Quentin Wodon. 2005. *Water, Electricity and the Poor. Who Benefits from Utility Subsidies?* Washington, DC: World Bank.

Kuzio, Michael, and Charis Lypiridis. 2018. New Perspectives on Results-Based Blended Finance for Cities: Innovative Finance Solutions for Climate Smart Infrastructure. Washington, DC: Global Partnership on Output-Based Aid/World Bank Group.

Lee, Jae-Seung, and Jeong Won Kim. 2018. "Assessing Strategies for Urban Climate Change Adaptation: The Case of Six Metropolitan Cities in South Korea." Sustainability (10) 2065.

Masaki, Takaaki. 2018. "The Impact of Intergovernmental Transfers on Local Revenue Generation in Sub-Saharan Africa: Evidence from Tanzania." World Development (106): 173–86.

Maxwell, Amanda. 2015. "Latin America Green News." NRDC, May 11. https://www.nrdc.org/experts/ amanda-maxwell/latin-america-green-newsgreen-roofs-mexico-green-grid-uruguay-greentax.

McKinsey. 2013. Infrastructure Productivity: How to Save \$1 Trillion a Year. New York: McKinsey.

Meub, Kristen. 2018. How Microgrids Could Boost Resilience in New Orleans. Albuquerque, NM: Sandia National Laboratory, May 24. http:// www.sandia.gov/news/publications/labnews/ articles/2018/25-05/microgrids.html.

Miami Forever. 2017. "Miami Forever Bond." https:// www.miamiforever.org/.

Milne, Janet. 2015. "Storms Ahead: Climate Change Adaptation: Calls for Resilient Funding." Vermont Law Review 39 (819).

Mortimer, Sarah. 2013. "New York's MTA to Sell \$125 Million 'Catastrophe' Bond." *Reuters*, July 15.

Neal, David. 2018. "That Hurricane Irma Cleanup Surcharge Coming to Your FPL Bill? It's Been Turned Off." *Miami Herald*, January 17.

Nehamas, Nicholas, and Nancy Dahlberg. 2018. "FPL Spent \$3 Billion Preparing for a Storm. So Why Did Irma Knock Out the Lights?" *Miami Herald*, May 2. New Jersey Board of Public Utilities. 2014. New Jersey Energy Resilience Bank Grant and Loan Financing Program Guide. October 14. https://www. adaptationclearinghouse.org/resources/newjersey-energy-resilience-bank-grant-and-loanfinancing-program-guide.html.

Noy, Ilan, and Pooja Patel. 2014. "Floods and Spillovers: Households after the 2011 Great Flood in Thailand." Working Paper Series 3609, School of Economics and Finance, Victoria University of Wellington.

OECD (Organisation for Economic Co-operation and Development). 2017. "Green Investment Banks: Innovative Public Financial Institutions Scaling Up Private, Low-Carbon Investment Policy Reform." OECD Environment Policy Paper No. 06, Paris, January.

----. 2018a. "Detailed Aid Statistics: Official Bilateral Commitments by Sector." OECD International Development Statistics (database). https://doi. org/10.1787/data-00073-en.

—. 2018b. "Energy-Related Aid Data at a Glance." http://www.oecd.org/dac/stats/energyrelatedaiddataataglance.htm.

OECD DAC (Organisation for Economic Co-operation and Development Development Assistance Committee). 2014. "OECD DAC Statistics: Aid to Urban Climate Change Adaptation." https:// www.oecd.org/dac/environment-development/ Urban%20Adaptation%20Flyer.pdf.

Ohshita, Stephanie, and Kate Johnson. 2017. "Resilient Urban Energy: Making City Systems Energy Efficient, Low Carbon and Resilient in a Changing Climate." European Council for an Energy Efficient Economy. https://www.eceee.org/ library/conference\_proceedings/eceee\_Summer\_ Studies/2017/3-local-action/resilient-urbanenergy-making-city-systems-energy-efficientlow-carbon-and-resilient-in-a-changing-climate/.

Oliver, Padraig. 2016. "Green Bonds for Cities: A Strategic Guide for City-Level Policymakers in Developing Countries." Climate-KIC/South Pole Group/ICLEI/Climate Bonds Initiative. https:// climatepolicyinitiative.org/publication/greenbonds-guide-city-policymakers-developingcountries/.

Pacific Infrastructure Advisory Centre. 2013. Infrastructure Maintenance in the Pacific: Challenging the Build-Neglect-Rebuild Paradigm. Sydney, Australia: Pacific Region Infrastructure Facility.

PG&E (Pacific Gas and Electric Company). 2016. Climate Change Vulnerability Assessment. http://www.pgecurrents.com/wp-content/ uploads/2016/02/PGE\_climate\_resilience.pdf.

Philippine Star. 2018. "No More Blackouts in Mindoro Town." March 18. https://www.philstar.com/ nation/2018/03/18/1797800/no-more-blackoutsmindoro-town.

Pounds, Marcia. 2017. "FPL spent \$2.78B on Grid Upgrades, But Customers Doubt They Got Their Money's Worth." *Sun Sentinel*, December 3. ——. 2018. "FPL Seeks Pilot Program to Test Underground Powerlines," Sun Sentinel, March 1.

- RATP (Régie Autonome des Transports Parisiens). 2018. "When the Seine Floods: How We Protect the RATP Network." https://www.ratp.fr/en/ decouvrir/coulisses/au-quotidien-traduire/whenseine-floods-how-we-protect-ratp-network.
- ReFocus Partners. 2017. A Guide for Public-Sector Resilience Bond Sponsorship. http://www. refocuspartners.com/wp-content/uploads/pdf/ RE.bound-Program-Report-September-2017.pdf.
- Rigaud, Kanta Kumari, Alex de Sherbinin, Bryan Jones, Jonas Bergmann, Viviane Clement, Kayly Ober, Jacob Schewe, et al. 2018. *Groundswell: Preparing for Internal Climate Migration.* Washington, DC: World Bank.
- Rio de Janeiro. 2016. Climate Change Adaptation Strategy for the City of Rio de Janeiro. Rio de Janeiro: Rio de Janeiro Prefeitura, Center for Integrated Studies on Climate Change and the Environment -Centro Clima/COPPE/UFRJ.
- Rodin, Judith 2014. The Resilience Dividend: Being Strong in a World Where Things Go Wrong. New York: Public Affairs.
- Rosenzweig, Cynthia, William Solecki, Stephen Hammer, and Shagun Mehrotra, eds. 2011. Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network. Cambridge, U.K.: Cambridge University Press.
- Rosenzweig, Cynthia, William Solecki, Patricia Romero-Lankao, Shagun Mehrotra, Shobhakar Dhakal, and Somayya Ali Ibrahim, eds. 2018. Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network. Cambridge, U.K.: Cambridge University Press.
- Rowcroft, Petrina, and Jennifer Black. 2017. Toolkit of Measures for Managing Environmental Externalities in Urban Areas. Washington, DC: World Bank.
- Roxburgh, Helen. 2017. "China's 'Sponge Cities' Are Turning Streets Green to Combat Flooding." *The Guardian*, December 27.
- San Francisco Bay Restore. 2016. "Ballot Measure Summary: San Francisco Bay Clean Water, Pollution Prevention, and Habitat Restoration Program." http://sfbayrestore.org/docs/ BallotMeasure Language.pdf.
- Santos, Valerie-Joy, and Josef Leitmann. 2015. Investing in Urban Resilience: Protecting and Promoting Development in a Changing World. Washington, DC: World Bank/GFDRR.
- Sarkar, A., N. Mukhi, P. S. Padmanaban, A. Kumar, K. Kumar, M. Bansal, and S. Ganta. 2016. Utility Scale DSM Opportunities and Business Models in India. Washington, DC: World Bank.
- Slack, Enid. 2017. How Much Local Fiscal Autonomy Do Cities Have? A Comparison of Eight Cities around the World. Toronto: Institute on Municipal Finance and Governance, Munk School of Global Affairs, University of Toronto.

- Standaert, Michael. 2018. "Sponge Cities: China's \$300 Billion Investment Plan for Green Stormwater Infrastructure." *Impact Alpha*, May 7.
- S&P Global Ratings. 2018. 2018 U.S. Municipal Green Bond and Resiliency Outlook. New York: Standard & Poors.
- Suzuki, Hiroaki, Murakami Jin, Hong Yu-Hung, and Beth Tamayose. 2015. Financing Transit-Oriented Development with Land Values: Adapting Land Value Capture in Developing Countries. Washington, DC: World Bank.
- Transport for London. 2015. Providing Transport Services Resilient to Extreme Weather and Climate Change 2015: Update Report Following Last Report to Government in 2011. London: Transport for London.
- Turner, Jim. 2017. "FPL customers to Pay for Costs of Responding to Hurricane Matthew." *Miami Herald,* February 8.
- Tweed, Katherine. 2014. "New Jersey Launches \$200M Energy Resilience Bank for Microgrids and Distributed Generation." Green Tech Media, July 24.
- UITP (International Association of Public Transport). 2016. Urban Rail, Climate Change, and Resilience: A Joint Report by the Metro Committee, the Light Rail Committee and the Regional and Suburban Railways Committee. Brussels: UITP.
- UNDP (United Nations Development Programme). 2017. Debt for Nature Swaps. http://www.undp.org/ content/sdfinance/en/home/solutions/debt-fornature-swaps.html.
- USAID (U.S. Agency for International Development). 2017. Project Preparation Facilities Toolbox. Power Africa Program, USAID, Washington, DC. https://2012-2017.usaid.gov/sites/default/files/ documents/1860/PPF%20Toolbox%20REVISED.pdf.
- USEPA (U.S. Environmental Protection Agency). 2018. Tools to Assess Risks to Water Utilities from Extreme Weather. https://www.epa.gov/crwu/tools-assessrisks-water-utilities-extreme-weather.
- Venkateswaran, Rama Krishnan. 2014. "Municipal Financial Management." In Municipal Finances: A Handbook for Local Governments, edited by Catherine Farvacque-Vitkovic and Mihaly Kopanyi, chap. 3. Washington, DC: World Bank.
- Venugopal, V., and S. Yilmaz. 2010. "Decentralization in Tanzania: An Assessment of Local Discretion and Accountability." *Public Administration and Development* 30: 215–31.
- Voutchkov, Nikolay. 2016. "Desalination–Past, Present and Future." International Water Association, London. http://www.iwa-network.org/ desalination-past-present-future/.
- World Bank. 2014. Cân Thơ, Vietnam–Enhancing Urban Resilience. CityStrength Initiative. Washington, DC: World Bank.
  - —. 2015a. "Creditworthiness Academy Provides Financial Management Training to Uganda's Urban Government Representatives." http://www. worldbank.org/en/news/feature/2015/05/13/ creditworthiness-academy-provides-financialmanagement-training-to-ugandas-urbangovernment-representatives.

—. 2015b. Lesotho Water Security and Climate Change Assessment. Washington, DC: World Bank.

—. 2017a. Building Climate Resilience into Power System Planning: The Case of Bangladesh. Washington, DC: World Bank.

—. 2017b. Climate and Disaster Resilient Transport in Small Island Developing States: A Call for Action. Global Facility for Disaster Reduction and Recovery.

—. 2018a. City Resilience Program: City-Level Capital Investment Planning and Transaction Identification: Cần Thơ, Vietnam Inception Report. Washington, DC: World Bank, June 20.

----. 2018b. "What Are Public Private Partnerships?" Public Private Partnership Legal Resource Center. https://ppp.worldbank.org/public-privatepartnership/. -----. 2018c. "World Bank Group Exceeds Its Climate Finance Target with Record Year." Press release, July 19. https://www.worldbank.org/en/news/ press-release/2018/07/19/world-bank-groupexceeds-its-climate-finance-target-withrecord-year.

——. Forthcoming. Disciplined Use of Concessionality to Maximize Its Contribution to Climate Change Action. A Guiding Framework. World Bank Climate Change Group. Washington, DC: World Bank.

World Bank Group/PPIAF (Public-Private Infrastructure Advisory Facility). 2016. Emerging Trends in Mainstreaming Climate Resilience in Large Scale, Multi-Sector Infrastructure PPPs. Washington, DC: World Bank.



# Financing Climate Futures

Governments recognise that scaling up and shifting financial flows to low-emission and resilient infrastructure investments is critical to deliver on climate and sustainable development goals. Efforts to align financial flows with climate objectives remain incremental and fail to deliver the radical transformation needed. The OECD, UN Environment and the World Bank Group, with the support of the German Ministry of Environment, Nature Conservation and Nuclear Safety, have joined forces under a new initiative – *Financing Climate Futures: Rethinking Infrastructure* – that provides a roadmap to help countries make the transformations in their infrastructure, investment and finance systems that are needed to make financial flows consistent with a pathway towards a low-emission, resilient future.

For more information on Financing Climate Futures: Rethinking Infrastructure visit: oe.cd/climate-futures

# FINANCING A RESILIENT URBAN FUTURE: A Policy Brief on World Bank and Global Experience on Financing Climate-Resilient Urban Infrastructure

In the coming decades, climate change will force cities to grapple with new operating conditions to construct and maintain key urban infrastructure. Strategies for covering the costs of climate-resilient upgrades will vary by locale, reflecting differing market, regulatory, and policy circumstances. This policy brief draws on World Bank experience and datasets and a desktop review of academic and grey literature on financing three core urban infrastructure systems - water, transport, and energy. It seeks to answer the guestion of what funding and financing instruments may be available to local governments and infrastructure system operators in different cities around the world, and how these link back to the climate challenges they may face. This brief was developed as part of the Financing Climate Futures initiative, a joint effort of OECD, UN Environment, and the World Bank Group, with the support of the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU).

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