OVERVIEW

Making cities *green, resilient,* and *inclusive* in a changing climate

THRIVING

Megha Mukim
Mark Roberts
Editors

WORLD BANK GROUP

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This booklet contains the overview, as well as a list of contents, from *Thriving: Making Cities Green, Resilient, and Inclusive in a Changing Climate*

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Foreword

The past 50 years have seen both a quadrupling of global urban population and a rapidly changing climate, with rising surface temperatures and sea levels and increasing frequency of extreme weather events. Fast-growing cities—which offer a range of opportunities—can give rise to a wide variety of stresses, especially if their urbanization is not well-managed. An unpredictable and fast-changing climate compounds these underlying stresses. The impacts of climate change–related shocks on cities may be significant; for many households, they can be devastating. Cities, both small and large, in less-developed countries suffer disproportionately when confronted by extreme hot and dry weather events, as well as by tropical cyclones.

Using data from across 10,000 cities globally, this report asks four important questions. How green, resilient, and inclusive are cities today? How does climate change affect cities and people in cities? How does the growth of cities impact the climate and, more generally, the environment? And finally, what policies will help make cities greener, more resilient, and more inclusive?

Climate change is also a symptom of a larger problem—the erosion of natural capital, to which poorly managed urbanization contributes. This erosion contributes, in turn, to dangerously poor air quality in many cities, detrimental competition for water between urban and rural areas, unnecessary loss of fertile agricultural land, deforestation, and loss of biodiversity. These trends are playing themselves out against a backdrop of high and rising levels of inequality in many cities globally and stalled progress in the worldwide fight against extreme poverty. These trends both interact with and reinforce climate change–related stressors to affect the greenness, resilience, and inclusiveness of urban development.

This report provides a compass to help policy makers—both local and national—meet their objectives to make cities greener, more resilient, and more inclusive. It outlines what policy instruments are available; who wields these instruments; and how policy choices could be tailored, prioritized, and sequenced for effective implementation.

Policy makers can draw on five broad sets of policy instruments that constitute the "five I's": information, incentives, insurance, integration, and investments. Early warning information can help save lives, property, and infrastructure. Accurate information that reflects risks can help governments, individuals, and businesses make better decisions. Incentives are needed to motivate people and businesses to act on the available information and take account of the impacts of their own decisions on the environment and on others. Insurance can help minimize the financial impact of disasters, complementing adaptation strategies. Integration within cities, to which well-implemented planning is key, is good for the poor and good for budgets, helping minimize unnecessary sprawl and bringing people closer to jobs and opportunities. Integration across cities—through measures that help promote the movement of people, goods, and services—can have a dampening effect on shocks and stresses. Finally, investments can be used to anticipate, prevent, and respond to shocks, as well as to retrofit buildings and infrastructure in response to stresses.

It is well known that cities are "engines of growth" at both the local and national levels. However, less is known about how urban development and climate change are interacting, and this flagship report makes an important contribution to our collective understanding of cities and climate change. I firmly believe that the insights from this report will provide valuable guidance for the World Bank Group as we collaborate with partners and clients to help cities not only survive but also thrive in the face of the perils of climate change.

Action now is possible, action now is necessary and urgent, and action now is where we should focus our efforts.

Juergen Voegele
Vice President for Sustainable Development
The World Bank Group

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OVERVIEW

Introduction

For at least 50 years, the view that human activity has spurred the world's warming has been supported by scientific evidence, the weight of which is now beyond dispute (Benton 1970; IPCC 2021; Madden and Ramanathan 1980).[1] Globally during this time, the number of people living in cities has almost quadrupled[2] and the Earth's surface temperature has climbed by nearly 1.2 degrees Celsius above its preindustrial levels.[3] This warming has been associated with an increased frequency of extreme hot, dry, and wet events across cities worldwide.[4] Global sea-level rise has also increased the risk of flooding for many coastal cities.

Because of the prosperity they have helped generate, cities have been an important cause of this climate change (Kahn 2010).[5] At the same time, this prosperity has helped make cities more resilient to climate change–related shocks and stressors. Cities have also become increasingly vocal advocates of climate action;[6] however, in the race between climate change and climate action, climate change retains a commanding lead. Cities in high- and upper-middle-income countries, which account for the bulk of global urban carbon dioxide (CO_2) emissions, are not moving quickly enough toward net zero. Similarly, although their current contributions to climate change may be small, cities in lower-income countries are not acting fast enough to moderate their emissions trajectories. These trajectories, if left unchecked, will eventually offset any reductions in global emissions made by cities in higher-income countries. Poorly managed urbanization also contributes to an even larger problem—the more general erosion of natural capital.[7] This erosion takes the form not only of polluted skies but also of contaminated water bodies, destroyed natural habitats, and the loss of both plant and animal species.[8]

In addition to not acting quickly enough to mitigate climate change, cities, especially those in low- and lower-middle-income countries, are also not adapting quickly enough to its challenges. The residents of cities in lower- and even in higher-income countries may see climate change as a secondary concern, especially when pitted against poverty, inequality, and a lack of access to markets and services—problems that for some people and some cities have worsened over time. As illustrated by France's "yellow vest" protests, important trade-offs undoubtedly exist between such problems and certain policies that aim to tackle climate change.[9] The good news, however, is that complementary policies can help ease these trade-offs, as can policies that make cities more inclusive while simultaneously helping them become both greener and more resilient to climate change. In this context, how inclusive a city is today is also an important determinant of how well it can cope with the climate change–related shocks and stresses of the future.

To ensure that cities thrive in a world confronted by climate change, policy makers at both national and local levels need to work together to implement bold policies to address the interrelated stresses that arise from climate change and urban growth. These include the stresses arising from the pressure of a city's population on its supplies of land, housing, and basic services; its stock of infrastructure; and its environment.[10] If not well managed, such stresses can give rise to slums and sprawl, deteriorating levels and quality of basic service provision, streets gridlocked with polluting cars and motorcycles, the excessive conversion of fertile agricultural land to urban uses, choking air pollution, and heightened greenhouse gas (GHG) emissions.

Drawing on a wide variety of data sources, this report combines original empirical analysis with insights from a diverse range of secondary literature to take stock of how green, how resilient, and how inclusive cities are, and to shed light on the interaction of stresses related to urban growth with those related to climate change. To address those interrelated stresses, policy makers need to enlist the use of five broad sets of policy instruments—information, incentives, insurance, integration, and investments—in short, the five I's. The report provides a compass to help cities tailor the use of these instruments to their own circumstances and problems.

How green, how resilient, and how inclusive are cities today?

To take stock of how green, how resilient, and how inclusive cities are today, this report defines a global typology of more than 10,000 cities, measuring a city's greenness, resilience, and inclusiveness using a variety of indicators *(box O.1)*. Based on the analysis of this typology and the indicators more generally, as well as on the report's other global analysis, 10 key findings emerge.

Box O.1

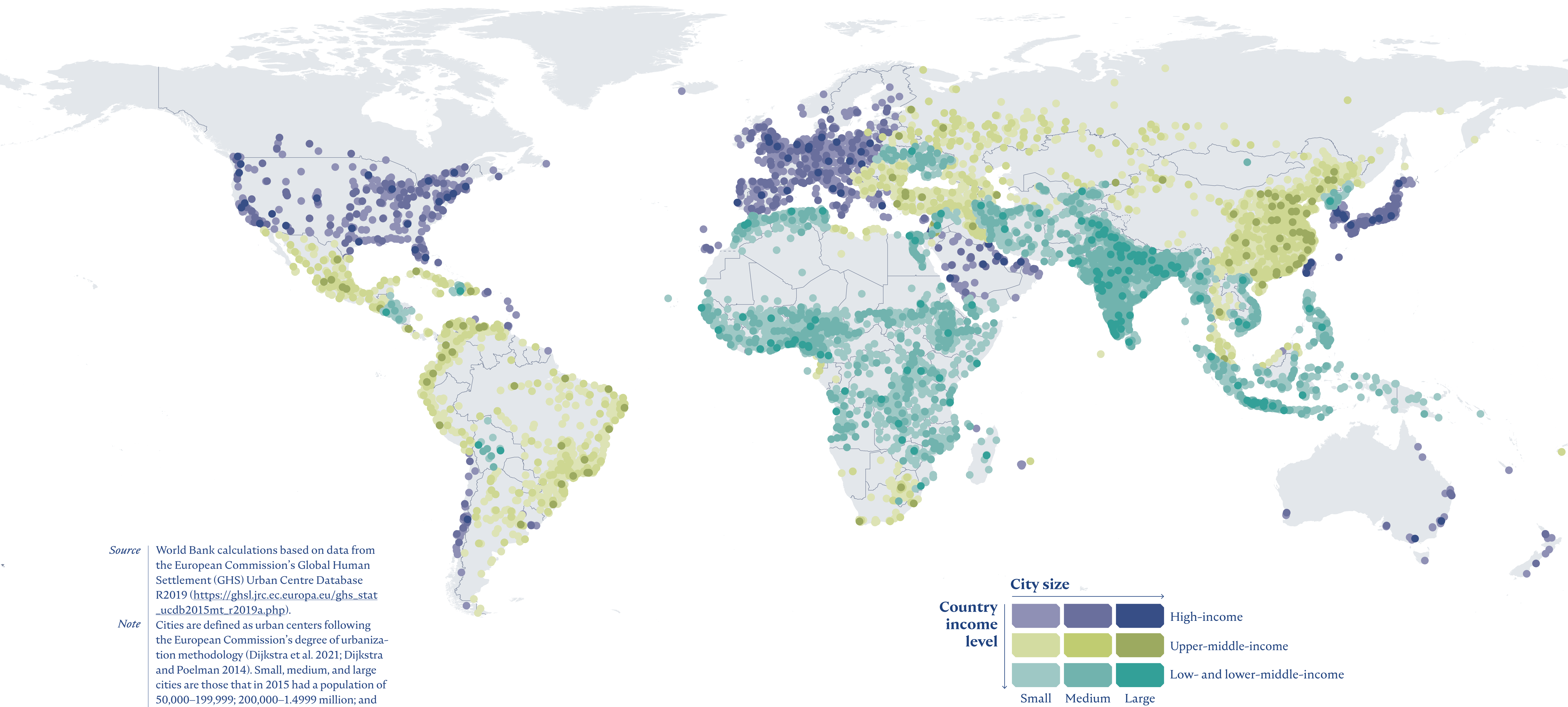
Defining a global typology of cities

This report measures a city's greenness, resilience, and inclusiveness using a variety of indicators. For greenness, these indicators include absolute and per capita production-based fossil fuel carbon dioxide emissions, emissions and concentrations of particulate matter of 2.5 microns or less in diameter, and measures of a city's level and extent of greenery or vegetation. For resilience, they include estimates of the size of impacts of weather events on a city's aggregate level of economic activity. Indicators of inclusiveness include levels of access to basic services such as improved sanitation and safely managed drinking water, poverty rates, and levels of intracity household income inequality.[a]

Although cities vary widely on these indicators, some general patterns are nevertheless evident, with many related to both a city's population size and its level of development. These patterns allow definition of a global typology that distinguishes between nine types of city—small, medium, and large cities in low- and lower-middle-, upper-middle-, and high-income countries *(map BO.1.1)*—and the relative severity of the greenness, resilience, and inclusiveness challenges they face. Chapter 2 of the main report offers a full discussion of this typology and the relative severity of challenges that different types of cities face.

a. In addition to these indicators, the main report also discusses a range of other dimensions of the greenness, resilience, and inclusiveness of cities and how these dimensions relate to climate change *(see also box O.2)*.

Map BO.1.1. Global typology of cities



Source World Bank calculations based on data from the European Commission's Global Human Settlement (GHS) Urban Centre Database R2019 (https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php).

Note Cities are defined as urban centers following the European Commission's degree of urbanization methodology (Dijkstra et al. 2021; Dijkstra and Poelman 2014). Small, medium, and large cities are those that in 2015 had a population of 50,000–199,999; 200,000–1.4999 million; and 1.5 million or more, respectively.

KEY FINDING 1

Cities in high- and upper-middle-income countries are the least green globally in terms of CO_2 emissions, whereas cities in lower-income countries barely contribute to global emissions.

Globally, about 70 percent of anthropogenic GHG emissions, the bulk of which are fossil CO_2 emissions, emanate from cities (Hopkins et al. 2016).[11] On a per capita basis, cities in high- and upper-middle-income countries have the highest fossil CO_2 emissions, and those in low-income countries have the lowest *(figure O.1, panel a)*. Indeed, in 2015 average per capita emissions in cities in high-income countries were almost 18 times higher than those of cities in low-income countries, whereas those in cities in upper-middle-income countries were more than 21 times higher. Higher average per capita emissions in cities in high- and upper-middle-income countries also translate into higher shares of global urban CO_2 emissions *(figure O.1, panel b)*. In 2015, these cities together accounted for nearly 86.00 percent of all global urban CO_2 emissions. Cities in lower-middle-income countries contributed almost 13.00 percent and cities in low-income countries less than 0.20 percent.

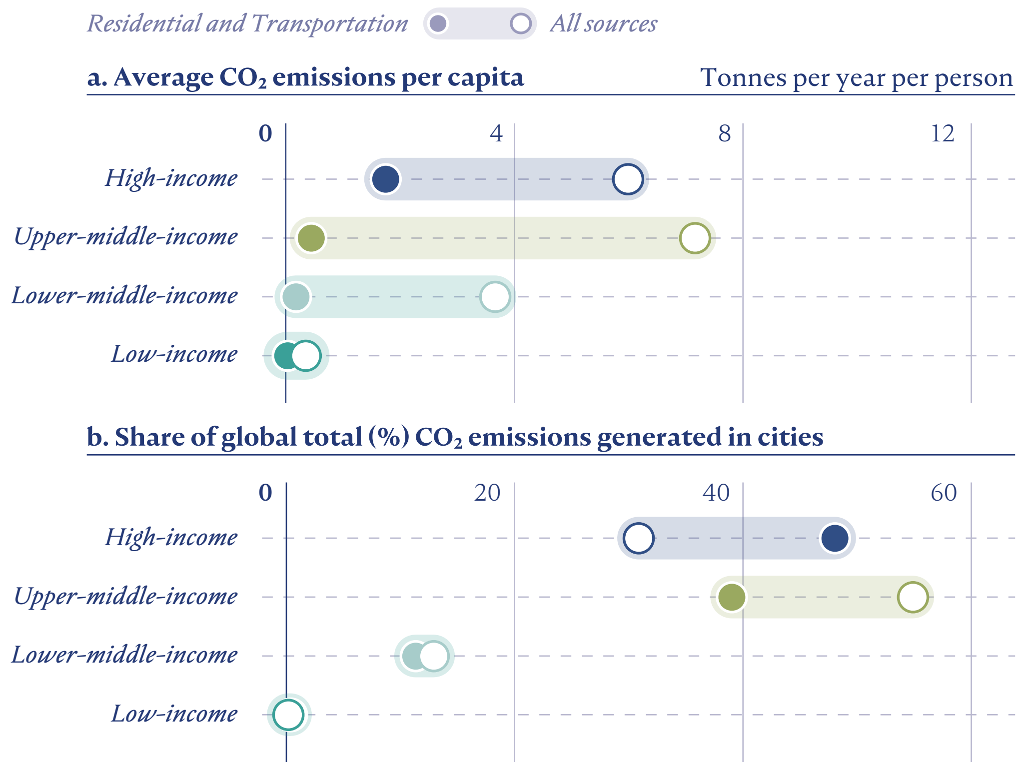
When focusing on just urban fossil CO_2 emissions from the residential and transportation sectors—the sectors that urban planning and policies can most directly influence—even stronger patterns emerge. In 2015, average per capita emissions from these sectors in cities in high-income countries were more than 76 times those in cities in low-income countries and more than 10 times those in cities in lower-middle-income countries *(figure O.1, panel a)*. Whereas cities in high-income countries accounted for 48.00 percent of total global urban emissions from the residential and transportation sectors, cities in low-income countries accounted for less than 0.40 percent *(figure O.1, panel b)*.[12]

The picture is clear: cities in high- and upper-middle-income countries are the major drivers of global urban CO_2 emissions and therefore of the urban contribution to global climate change. By contrast, cities in low-income countries barely register in terms of their contribution. Thus, from a mitigation perspective, the challenge facing cities in high- and upper-middle-income countries is how to reduce their high current levels of CO_2 emissions. Cities in low- and, to a lesser extent, lower-middle-income countries face a different challenge—how to develop without following the CO_2 emissions trajectories historically followed by cities in higher-income countries.

Figure O.2 depicts the importance of the challenge for cities in low- and lower-middle-income countries. It shows that—even if (and it is a very big if) high- and upper-middle-income countries can make a successful green transition consistent with net zero CO_2 emissions by 2050—global GHG emissions will remain

Figure 0.1 **Cities in high- and upper-middle-income countries emit the most CO_2 and contribute the most to global urban CO_2 emissions.**

Average CO_2 emissions per capita and share of global CO_2 emissions generated in cities, by country income group, 2015



Source World Bank analysis based on data from the European Commission's Global Human Settlement (GHS) Urban Centre Database R2019 (https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php), which derives its carbon dioxide (CO_2) emissions data from the European Commission's Emissions Database for Global Atmospheric Research (EDGAR v5.0). For the residential and transportation sectors, the data cover 10,179 cities. For all sources of emissions, the data cover 3,148 cities.

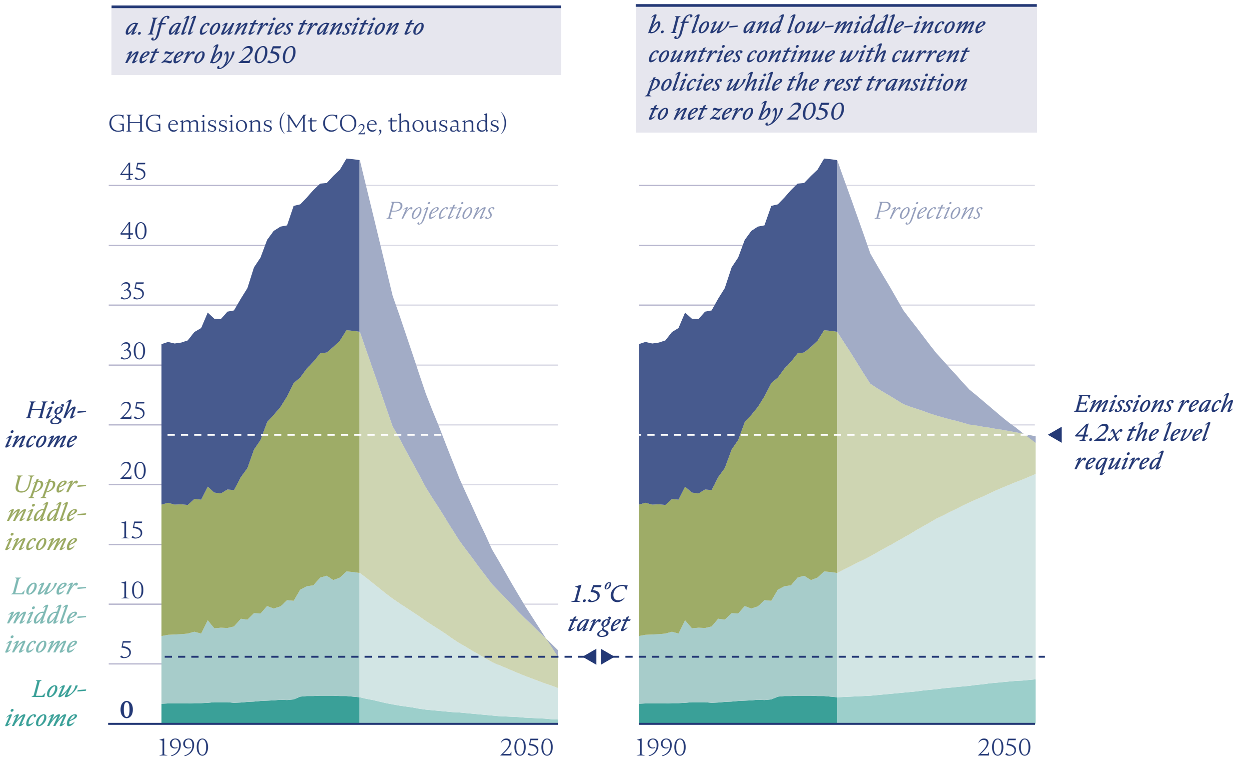
Note In panel a, each marker shows the unweighted average of long-cycle (fossil) CO_2 emissions per capita (measured in tonnes per year per person) of cities by country income group. In panel b, each marker shows the share of global urban long-cycle (fossil) CO_2 emissions generated in cities classified by country income group.

above the level required to limit global warming to 1.5 degrees Celsius as long as low- and lower-middle-income countries follow their current policies.[13] Thus, a comparison of panel a of the figure with panel b reveals that total global GHG emissions in 2050 will remain 4.2 times the level required to keep warming within 1.5 degrees Celsius if current policies remain the same in low- and lower-middle-income countries while higher-income countries achieve net zero.

Even if lower-middle-income countries were also to achieve net zero by 2050 but low-income countries were to continue with their current policies, GHG emissions would remain 60 percent higher than required to limit global warming to 1.5 degrees Celsius.

Figure O.2 **Global GHG emissions will remain above the level required to limit global warming to 1.5 degrees Celsius if low- and lower-middle-income countries continue to follow their current policies.**

Historical and projected aggregate GHG emissions trajectories under different scenarios, by country income group, 1990–2050



Sources World Bank analysis based on historical emissions data from Climate Watch (2022) and emissions projections from the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) v. 2 scenarios data.

Note GHG = greenhouse gas; Mt CO_2e = metric tons of carbon dioxide equivalent.

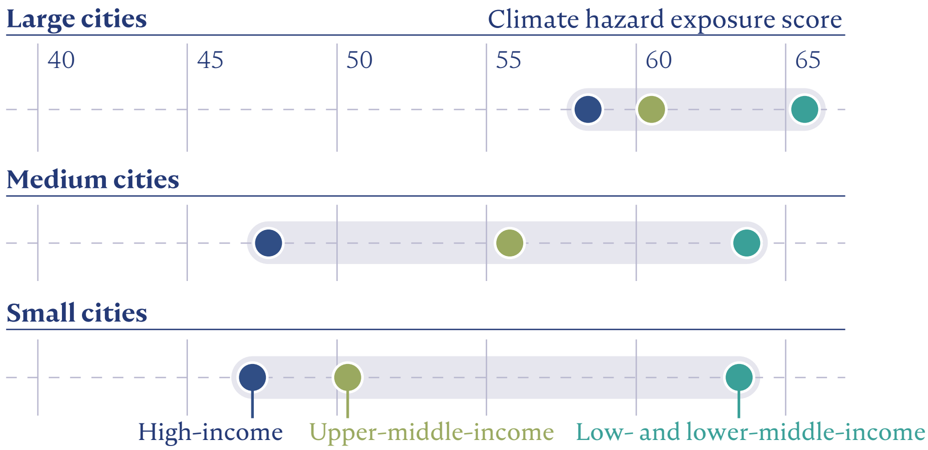
KEY FINDING 2

Cities in low- and lower-middle-income countries face the highest levels of projected climate change–related hazards.

Looking forward, although few cities globally will escape the effects of climate change, cities in low- and lower-middle-income countries face the highest overall levels of projected climate change–related hazards. Evidence of this situation is provided by an indicator that combines information on six key hazards—floods, heat stress, tropical cyclones, sea-level rise, water stress, and wildfires—projected forward to 2030–40.[14] Thus, among the nine types of city identified by this report's global typology *(box O.1)*, large, medium, and small cities in low- and lower-middle-income countries have the highest average climate hazard exposure scores *(figure O.3)*. For medium and large cities, these high average scores are driven mainly by projected flood hazards. For small and medium cities, they are driven by projected water, sea-level rise, and heat stress hazards. Wildfires also contribute to higher projected climate hazard scores for all sizes of city in low- and lower-middle-income countries.

Figure O.3 **Projected climate change related hazards are strongest for cities in low- and lower-middle-income countries.**

Average weighted overall climate change–related hazard exposure, by city size and country income group



Source World Bank analysis based on data from Moody's ESG Solutions, Sub-Sovereign Physical Climate Risk Scores, October 2021 (https://esg.moodys.io/climate-solutions).

Note The figure reports the mean projected climate hazard exposure scores for cities that belong to a given type. The mean scores are estimated by regressing a city's score on a series of dummy variables for the different types of city. Small, medium, and large cities are those that in 2015 had a population of 50,000–199,999; 200,000–1.4999 million; and 1.5 million or more, respectively.

KEY FINDING 3

Cities in low- and lower-middle-income countries are less resilient to increasingly frequent climate change–related shocks and stresses.

Historically, cities have, with a few exceptions, exhibited remarkable long-run resilience[15] to many forms of physical, and even human capital, destruction. Their resilience includes that to events such as earthquakes, widespread flooding, major fires, pandemics, and even large-scale, including nuclear, bombing (Glaeser 2022).

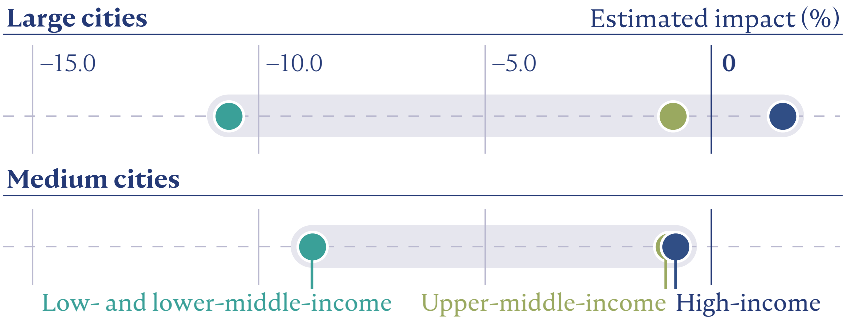
Notwithstanding this impressive long-run resilience, however, it is estimated that cities in low- and lower-middle-income countries suffer larger negative impacts from extreme hot, dry, and wet weather events (or "anomalies"), as well as from tropical cyclones, on their local levels of economic activity than do cities in higher-income countries.[16] This disparity comes at a time when climate change is increasing both the frequency and intensity of extreme hot, dry, and wet events.[17] Thus, although extreme weather events have relatively little impact on the levels of economic activity of cities in high- and upper-middle-income countries (as proxied by their nighttime light intensities) in the months when those events occur, they have much larger negative impacts on cities in low- and lower-middle-income countries *(figure O.4)*.[18]

Estimates also suggest that—for cities in low- and lower-middle-income countries—hot, wet, and dry weather anomalies have more severe negative impacts on economic activity when they mirror a city's baseline climate. Thus, hot, wet, and dry anomalies have larger negative impacts on cities with hot, wet, and dry baseline climates, respectively *(figure O.5)*. This effect is most evident for dry anomalies in cities in low- and lower-middle-income countries with dry baseline climates. Such cities are particularly prevalent in the Middle East and North Africa and parts of Sub-Saharan Africa.

The increasing frequency of extreme dry events contributes to the growing number of cities globally experiencing near "day zero" events, whereby water supplies are only weeks or days from running out. In a worst-case scenario, estimates suggest that a warming world could make day zero–type droughts 100 times more likely than they were in the early twentieth century in certain regions (Pascale et al. 2020). Such dwindling water supplies can cost a city up to a 12-percentage-point loss in gross domestic product and lead to damaging competition between urban and rural areas for water supplies as cities encroach on surrounding areas to satisfy their thirst. In the absence of equitable legal arrangements, transfers of water from rural to urban areas can even be coercive, such as in Chennai, India (Singh et al. 2021; Varadhan 2019; Zaveri et al. 2021). In allocation decisions, most legal systems give higher priority to drinking water, and often to industrial water, than to agricultural water. Such prioritization can reduce the water available for irrigated urban and peri-urban agriculture (Hoekstra, Buurman, and van Ginkel 2018).

Figure O.4 Cities in low- and lower-middle-income countries are less resilient to climate change-related shocks and stresses.

Estimated impact of extreme weather (hot, dry, wet, and tropical cyclone) events on a city's level of nighttime light intensity, April 2012–December 2020



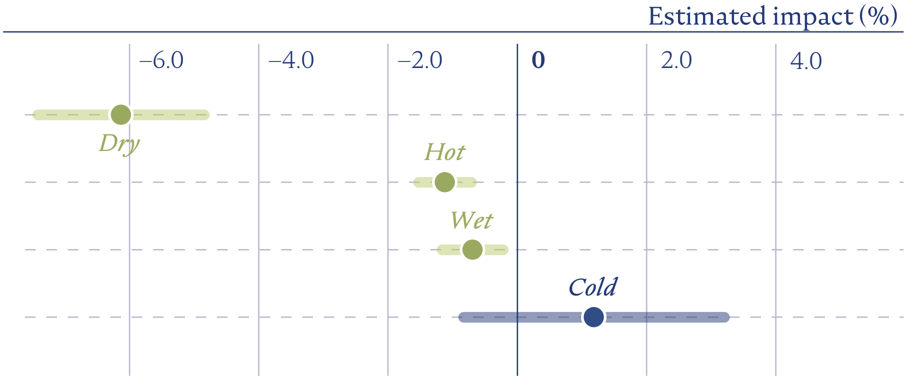
Sources Derived from Park and Roberts 2022. Results are based on analysis of monthly composites of nighttime lights derived from Visible Infrared Imaging Radiometer Suite (VIIRS) satellite data (https://payneinstitute.mines.edu/eog-2/viirs/), monthly weather data from Climatology Lab, TerraClimate (https://www.climatologylab.org/terraclimate.html), and tropical cyclone data from International Best Track Archive for Climate Stewardship (https://www.ncdc.noaa.gov/ibtracs/).

Note The horizontal axis shows the unweighted average estimated impact of extreme hot, dry, and wet weather events and tropical cyclones on a city's nighttime light in the month when the event occurred. For any given month, an extreme hot, dry, or wet event is defined as one in which the weather variable (temperature or precipitation) deviates by at least 2 standard deviations from a city's own long-run historical average for that variable, with that average calculated using monthly data for the period January 1958–March 2012. A tropical cyclone is defined as a category 2 or stronger cyclone based on the Saffir-Simpson wind scale that occurs within 200 kilometers of a city's geographic center. Medium and large cities correspond to those that in 2015 had a population of 200,000–1.4999 million and 1.5 million or more, respectively. The colors of the markers for different types of cities correspond to the colors in *map BO.1.1*.

The fact that, in general, cities in low- and lower-middle-income countries experience more severe estimated negative impacts of weather anomalies than do cities in higher-income countries is consistent with a greater level of resilience on the part of the latter. These estimates paint a partial picture of resilience, however, because they consider only the immediate impacts of a weather shock while disregarding the subsequent path of recovery of economic activity, or the lack thereof. Nevertheless, related research that also uses lights data suggests a quicker rebound of economic activity for a city in an upper-middle- or high-income country in response to a flood event than for a city in a low- or lower-middle-income country. Thus, although economic activity is restored to its preshock level in a city in higher-income countries within one month, restoration in a city in a lower-income country will take two months (Gandhi et al. 2022; Lall et al., forthcoming).

Figure 0.5 **For cities in lower-income countries, dry, hot, and wet weather anomalies have larger negative impacts when they reinforce baseline climatic conditions.**

Estimated impacts of dry, hot, wet, and cold anomalies on cities in low- and lower-middle-income countries with dry, hot, wet, and cold baseline climates, respectively, April 2012–December 2020



Sources Derived from Park and Roberts 2022. Results are based on the analysis of nighttime lights monthly composites derived from Visible Infrared Imaging Radiometer Suite (VIIRS) satellite data (https://payneinstitute.mines.edu/eog-2/viirs/) and monthly weather data from Climatology Lab, TerraClimate (https://www.climatologylab.org/terraclimate.html).

Note Each marker shows the estimated impact on a city's nighttime light intensity of a 1-standard-deviation departure of the relevant weather variable (either temperature or precipitation) from a city's own monthly long-run average for that weather variable, with that average defined using monthly data for the period January 1958–March 2012. The horizontal lines indicate the upper and lower bounds of the 95 percent confidence interval associated with the corresponding estimated impact. Hot and wet cities are in the top half of the global distribution of the long-run mean monthly temperature and precipitation, respectively, and cold and dry cities are in the bottom half.

KEY FINDING 4

Construction in countries is gravitating toward cities that will be most affected by climate change.

In the face of intensifying climate change–related hazards, one might expect that construction in countries would move away from cities whose climatic conditions are projected to deteriorate (that is, "future bad locations") and toward cities whose climate will be less affected or may even improve. Since the 1960s, however, the opposite has occurred. Construction in countries has increasingly gravitated toward cities projected to become unbearably hot because of climate change.

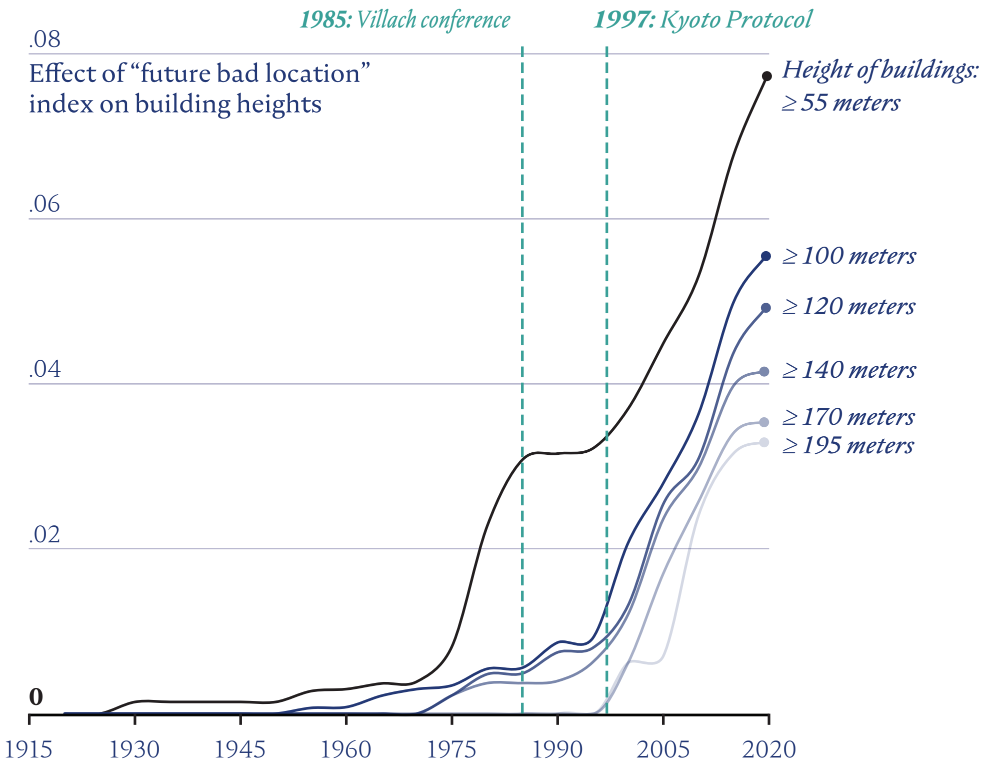
Evidence of this finding appears in *figure O.6*, which, for any given year, shows the estimated effect of a future bad location index on the aggregated height of a city's buildings. Higher values of this index indicate that a city's average maximum temperature during its hottest season is projected to pass a threshold of 43 degrees Celsius sooner—for example, an index value of 0 indicates that a city is not projected to pass this threshold during the current century, whereas an index value of 5 (the maximum value) indicates that the city passed this threshold during the period 1995–2014. If construction were moving away from future bad locations, one would expect this index to have an increasingly negative impact on the aggregated height of a city's buildings as the reality of the transition to unbearably hot temperatures becomes more evident. *Figure O.6* shows instead an increasingly positive impact of the future bad location index on the aggregated height of a city's buildings. Moreover, this trend is evident for buildings of all heights, from 55 meters (roughly 15 stories) or higher to 195 meters or higher, which includes the world's tallest skyscrapers. It is also evident for built-up area, which includes low-rise urban development more generally (Desmet and Jedwab 2022).

The trend of rising construction in cities deemed "future bad locations" (even as that future approaches) is emerging despite increasing public awareness of climate change and its potential impacts. Consistent with this finding, the major international conferences have had no discernible impact on construction trends. Such conferences include the 1985 Villach conference[19] and Conference of the Parties sessions held in Doha in 2012 (COP 18) and Paris in 2015 (COP 21), which increased global awareness of the threat posed by climate change. Adoption of the Kyoto Protocol in 1997 had no effect either. Moreover, not only has construction in countries been moving toward cities that are future bad locations, but also over the period 1985–2015 the global growth of urban built-up area in high-risk flood zones has outpaced that in low-risk flood zones. This trend has been most evident in middle-income countries, especially upper-middle-income countries (Rentschler et al. 2022).

These trends suggest a spatial misallocation of investments in buildings, with negative potential impacts on the future health, safety, and welfare of populations. Thus, because buildings, especially tall buildings, are durable structures that depreciate only slowly over decades, these construction patterns risk locking in urban development, and therefore urban populations, in suboptimal locations that will be most affected by climate change.

Figure O.6 **Within countries, construction of tall buildings of all heights is occurring fastest in cities that will be most affected by climate change ("future bad locations")**

Estimated effects of "future bad location" index on construction of buildings above various heights, 1920–2020



Sources Based on Desmet and Jedwab 2022, which uses data for cities from the European Commission's Global Human Settlement (GHS) Urban Centre Database R2019 (https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php) and on building heights from the Emporis database.

Note For each year shown on the horizontal axis, the vertical axis shows the estimated impact, relative to the base year of 1915, of a future bad location index on the aggregated height of a city's buildings above a certain specified height level (55 meters, 100 meters, 120 meters, 140 meters, 170 meters, and 195 meters). The future bad location index has a value between 0 and 5, where 0, 1, 2, 3, 4, and 5 indicate that a city is projected to surpass an average maximum temperature of 43 degrees Celsius after 2100, during 2080–99, during 2060–79, during 2040–59, during 2020–39, and during 1995–2014, respectively. A positive estimated impact indicates movement of construction toward cities that are future bad locations. The regression from which impacts are estimated includes both city fixed effects and country-year fixed effects.

KEY FINDING 5

Lack of inclusiveness contributes to the lack of resilience of cities in low- and lower-middle-income countries.

The movement of urban development in countries toward locations facing the greatest climate change–related hazards is particularly worrisome for low- and lower-middle-income countries because their cities lack resilience to the climate change–related shocks and stresses highlighted in key finding 3. This relative lack of resilience can be explained, in part, by these cities' higher rates of poverty and lower levels of access to basic services such as health care and education; water, electricity, and other utilities; solid waste management; digital and financial services; and emergency rescue services.

For example, households in cities in low- and lower-middle-income countries in East Asia and Pacific, Latin America and the Caribbean, South Asia, and Sub-Saharan Africa have lower levels of access to improved sanitation and safely managed drinking water than do households in cities in the upper-middle-income countries in these regions *(figure O.7)*.[20] For improved sanitation, small and medium cities in low- and lower-middle-income countries have particularly low levels of access. More generally within income classes, larger cities tend to provide better access to services and, thus, in this sense at least, to be more inclusive. This finding stems in part from the fact that larger cities can spread over a greater population the fixed costs of the large-scale infrastructure that underpins the provision of such services.

More generally, *inclusion* can be defined as the ability and opportunity of all who reside in a city to fully participate in markets, services (including digital and financial services), and spaces (including political, physical, cultural, and social), thereby enabling them to lead their lives with dignity *(box O.2)*. The ability of its residents to participate in markets, services, and spaces contributes to a city's resilience through a variety of channels. For example, participation in labor markets facilitates income growth, which helps provide households with the resources to invest in self-protection against climate change–related shocks, while also allowing them to accumulate savings that can act as a form of self-insurance against such shocks. Participation in financial markets can similarly assist households in buffering and insuring against shocks. Meanwhile, their ability to participate in political, physical, cultural, and social spaces helps provide a city's residents with voice. This voice can, in turn, lead to policies that are more inclusive of otherwise marginalized groups in society, thereby helping build their resilience.

Figure O.7 **Access to improved sanitation and safely managed drinking water is worse in cities in low- and lower-middle-income countries.**

Share of households with access to improved sanitation and safely managed drinking water by city type, circa 2015

Source World Bank calculations using data on household access to improved sanitation and safely managed drinking water from Henderson and Turner (2020) and downloaded from https://doi.org/10.7910/DVN/YZ46FJ.

Note In both panels, the share of households is calculated for cities in 40 countries (3 in the East Asia and Pacific region, 5 in Latin America and the Caribbean, 3 in South Asia, and 29 in Sub-Saharan Africa). In panel b, safely managed drinking water is defined as all improved water sources that take zero minutes to collect or are on the premises. Improved water sources include all piped water and packaged water, protected wells or springs, boreholes, and rainwater. Small, medium, and large cities correspond to those that in 2015 had a population of 50,000–199,999; 200,000–1.4999 million; and 1.5 million or more, respectively. The colors of the markers for different types of cities correspond to the colors in *map BO.1.1*.

Box 0.2

How this report defines *inclusiveness*

In this report, inclusiveness is broadly considered in terms of (1) ability and opportunity and (2) outcomes. Inclusion is defined as the ability and opportunity of all who reside in a city to fully participate in markets, services, and spaces (including political, physical, cultural, and social), thereby enabling them to lead their lives with dignity (World Bank 2013). Consistent with that definition, this report variously discusses how cities differ globally in the access they provide to basic urban services, financial services, digital technologies, and labor market opportunities. It also shines a spotlight on multidimensional exclusion and touches on issues of voice.

As for outcomes, this report analyzes, among other things, how cities vary globally in terms of both their rates of poverty and their levels of income inequality; the levels of socioeconomic mobility they afford their residents, especially new migrants; gender-differentiated patterns of population displacement following climate-related natural disasters; and the differential impacts of exposure to extreme heat on segments of a city's workforce, including informal versus formal, female versus male, and older versus younger workers.

Despite this broad coverage, however, the report is silent on some important dimensions of inclusion. For example, because of the lack of adequate data, it does not discuss the impacts of climate change on city residents who live with disabilities or who belong to a racial or ethnic minority.

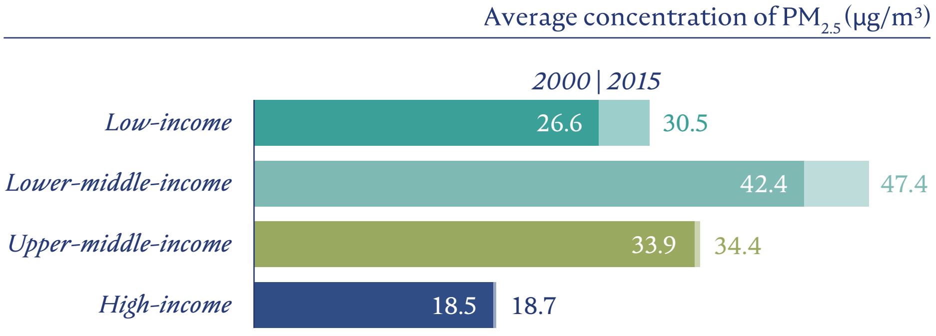
KEY FINDING 6

Cities in low- and middle-income-countries are less green in terms of air pollution, and air pollution from key urban sectors presents a greater challenge for larger cities in countries at all income levels

On average, concentrations of particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$) in both 2000 and 2015 were lower in cities in high-income countries than in cities in lower-income countries. A city's average $PM_{2.5}$ concentration also tends to first increase and then decrease with its level of development, with air pollution at its worst for cities in lower-middle-income countries *(figure O.8)*.[21] Meanwhile, evidence from regression analysis indicates that, controlling for the level of development of the country in which a city is located and for other determinants of pollution, a city's level of $PM_{2.5}$ emissions in its residential and transportation sectors tends to increase with its population. In other words, in the sectors that urban planning and policies can most directly influence, larger cities have higher emissions. This finding is consistent with higher levels of traffic congestion emanating from stronger urban stresses in larger cities.

Figure O.8 **Cities in low- and middle-income countries have worse air pollution than cities in high-income countries.**

Average of $PM_{2.5}$ concentrations across cities, by country income group, 2000 and 2015



Source World Bank analysis based on data for 10,303 cities from the European Commission's Global Human Settlement (GHS) Urban Centre Database R2019 (https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php), which derives its data on $PM_{2.5}$ concentrations from the Global Burden of Disease (GBD) 2017 database on ambient air pollution.

Note The graph shows the weighted average $PM_{2.5}$ concentration for cities in each income classification, with weights given by city populations. μg/m³ = micrograms per cubic meter; $PM_{2.5}$ = particulate matter of 2.5 microns or less in diameter.

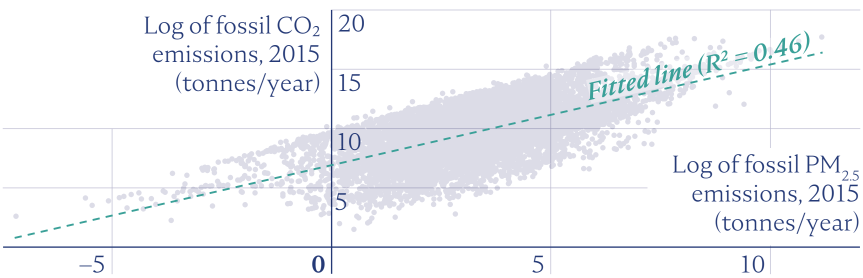
KEY FINDING 7

Policies that improve air quality can help cities both mitigate and adapt to climate change.

Many of the activities that contribute to poor air quality in cities, including both industrial activities and driving internal combustion engine vehicles, also contribute to global climate change. The reason: emissions of local air pollutants such as $PM_{2.5}$ tend to accompany CO_2 emissions, as illustrated in *figure O.9* for the residential and transportation sectors. Moreover, black carbon, a short-lived climate pollutant, constitutes a major part of $PM_{2.5}$. However, whereas local air pollution is, at least partially, a local negative externality of activities in a city, climate change is a global externality. As a result, a city's local policy makers have a greater incentive to address local air pollution—a problem they find more fixable—than to address global climate change, which requires collective action across cities globally. This is especially the case for cities in low-income countries, whose current collective contribution to global urban CO_2 emissions is negligible (*figure O.1, panel b*). As a result, at the local level cities may find the most politically effective approach to the mitigation of global climate change to be policies that aim to improve local air quality, but that carry climate change co-benefits.

Figure O.9 **$PM_{2.5}$ and CO_2 emissions are strongly positively correlated across cities globally.**

Relationship between CO_2 and $PM_{2.5}$ emissions across cities globally, residential and transportation sectors, 2015



Source World Bank analysis based on data for 10,179 cities with complete information on residential and transportation CO_2 and $PM_{2.5}$ emissions from the European Commission's Global Human Settlement (GHS) Urban Centre Database R2019 (https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php), which derives its emissions data from the European Commission's Emissions Database for Global Atmospheric Research (EDGAR v5.0).

Note The graph is a scatterplot of the log of the sum of residential and transportation long-cycle CO_2 emissions in 2015 on the log of the sum of residential and transportation $PM_{2.5}$ emissions in the same year. CO_2 = carbon dioxide; $PM_{2.5}$ = particulate matter of 2.5 microns or less in diameter.

KEY FINDING 8

Less sprawling development is associated with lower CO_2 and $PM_{2.5}$ emissions from the residential and transportation sectors.

One particularly promising set of local policies for improving local air quality with significant climate change co-benefits comprises those that address urban sprawl and promote more compact urban development. Across this report's global sample of cities, the compactness of a city's development has a strong negative correlation with its levels of both $PM_{2.5}$ and CO_2 emissions from the transportation and residential sectors. *Figure O.10* illustrates these negative associations for both the residential and the transportation sectors for $PM_{2.5}$ emissions and for the transportation sector only for CO_2 emissions. For both $PM_{2.5}$ and CO_2 emissions, more compact development is associated with lower emissions (comparing cities within countries at a given level of development and holding both a city's population and its built-up area constant). An important benefit of more compact development is that it tends to be associated with less driving and more transit-oriented development, both of which contribute to lower transportation sector emissions of local air pollutants and CO_2.

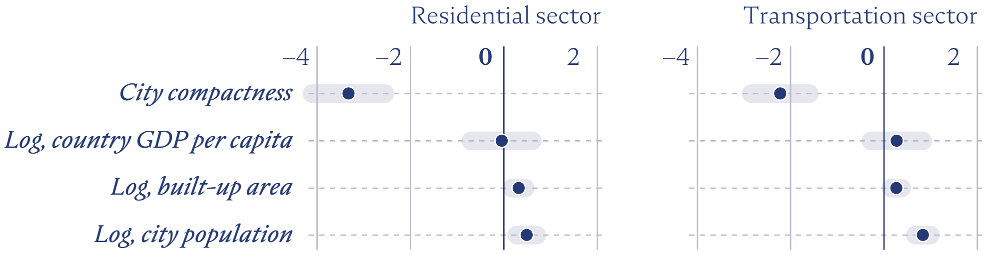
In this context, it is also important not to confound compact urban development with *overcrowded* urban development. Although both types of development involve high densities of population per square kilometer of built-up area, compact urban development involves accommodating this high density through more vertical development (that is, the construction of taller buildings). It thereby preserves, or even increases, the amount of living space per person. By contrast, overcrowded development involves the proliferation of slums and ever tighter living spaces that can contribute to, among other things, the faster spread of COVID-19 and other infectious diseases, not to mention less inclusive, and therefore less resilient, cities.

Local policies that improve local air quality can not only help mitigate climate change but also contribute to a city's adaptation to climate change. Better air quality generates significant health and productivity benefits (Kahn and Li 2020). These benefits, in turn, contribute to income growth, which helps make cities more resilient to climate change–related shocks and stresses.

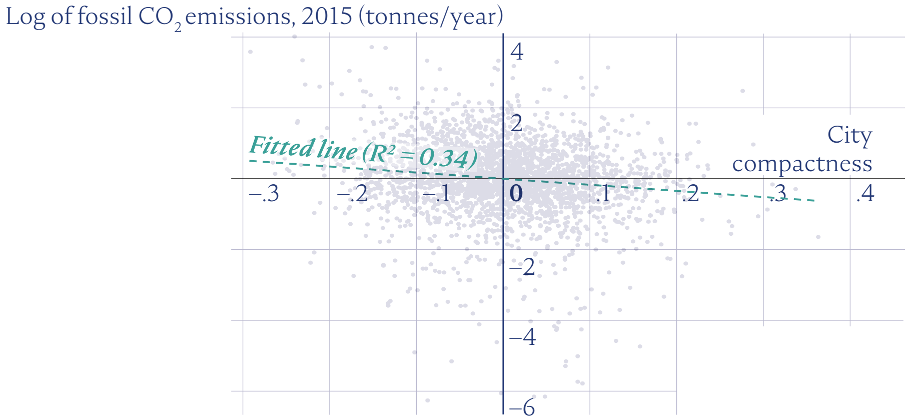
Figure 0.10 **More compact development is associated with lower emissions from the residential and transportation sectors.**

Relationship between city compactness and $PM_{2.5}$ and CO_2 emissions across cities globally, 2015

a. $PM_{2.5}$ – estimated effect of various city characteristics on emissions



b. CO_2 – transportation sector



Source World Bank analysis based on data for 2,785 cities with a 2015 population of over 200,000 from the European Commission's Global Human Settlement (GHS) Urban Centre Database R2019 (https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php), which derives its emissions data from the European Commission's Emissions Database for Global Atmospheric Research (EDGAR v5.0).

Note Panel a shows for each sector the estimated coefficients, together with the associated 95 percent confidence intervals, from a regression of a city's log $PM_{2.5}$ emissions in 2015 on the log of its population, the log of the GDP per capita of the country in which the city is located, the log of its built-up area, and a measure of the city's compactness (the Polsby-Popper Ratio compactness index). The regression also controls for a city's climate (precipitation, temperature, biome) and elevation, and it includes both a dummy variable that is equal to 1 if a city is in a high-income country (and to 0 otherwise) and its interaction with a country's log level of GDP per capita (results not shown). Panel b shows a partial scatterplot of log CO_2 emissions in 2015 on a measure of city compactness (the Polsby-Popper Ratio) controlling for the log of a city's population, the log of its built-up area, a city's climate (precipitation, temperature, biome) and elevation, and country fixed effects. CO_2 = carbon dioxide; GDP = gross domestic product; $PM_{2.5}$ = particulate matter of 2.5 microns or less in diameter.

KEY FINDING 9

Cities that develop vertically consume less land, accommodate more people, and are more prosperous.

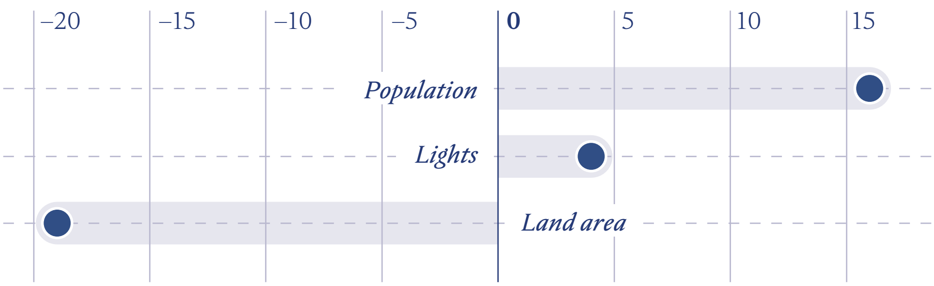
Compact cities develop vertically, as well as through infill development, rather than horizontally. But, theoretically at least, more upward growth through increased mid- and high-rise development, as opposed to low-rise, does not necessarily lead to less outward growth of a city. By increasing the supply of available floor space, more vertical development makes housing and commercial space within a city more affordable. Affordability, in turn, helps attracts more people to a city, thereby boosting its population. If it has a sufficiently large inflow of population, a city may expand horizontally in response to its original vertical expansion. In practice, however, empirical analysis of data on building heights for this report's global sample of cities reveals that, although a city's vertical development does indeed lead to population growth, such growth is insufficient to also provoke outward expansion. A city's vertical development leads it to consume less land overall than it would otherwise, which, in turn, could preserve fertile agricultural land on a city's periphery—land that for many cities is a "leading source of nutritionally important fresh fruit and vegetables" (Acharya et al. 2021, xviii). Moreover, the type of density arising from vertical development generates powerful agglomeration economies while avoiding overcrowding, so it is associated with greater economic prosperity. Overall, averaging across estimates that result from the application of different empirical strategies, a doubling of a city's total height leads to a roughly 16 percent long-run increase in its population and a 19 percent long-run reduction in its land area relative to other cities. These results are accompanied by a 4 percent long-run increase in the intensity of the city's nighttime lights per capita, which suggests increased prosperity *(figure O.11)*.

Although at any given level of development more compact cities tend to have lower CO_2 and $PM_{2.5}$ emissions in both the residential and transportation sectors, more vertical development does entail a dynamic trade-off when it comes to the mitigation of climate change. The construction of taller buildings tends to rely on materials such as concrete, steel, and glass, whose production entails high CO_2 emissions (Pomponi et al. 2021). Thus, a tall building constructed using current technologies embeds high up-front CO_2 emissions, which must be weighed against the future flow of lower CO_2 emissions associated with more compact urban development. This factor implies that, to transition to lower long-run emissions trajectories using a strategy of more compact urban development, policy makers in countries where such development is currently limited—because of, for example, dysfunctional land and property markets and failures in planning—may have to tolerate a short-run increase in emissions. Policy makers may, however, be able to soften this dynamic trade-off by combining policies that help facilitate more vertical development with complementary transportation investments and policies that both encourage a move toward less-polluting modes of transportation, including walking and cycling, and further promote compact and livable development. Technological innovations that reduce the carbon embedded in the production of concrete, steel, and glass will likewise soften the trade-off.[22]

Figure 0.11 **Cities that develop vertically accommodate more people, are more prosperous, and consume less land.**

Estimated elasticities of population, nighttime light intensity, and land area with respect to total sum of tall building heights

Estimated elasticity with respect to total height of a city's buildings (%)



Source World Bank analysis based on results from Ahlfeldt and Jedwab 2022. Their data for tall buildings come from Emporis.

Note Figure shows the estimated percentage change in each variable resulting from a doubling of the total sum of tall building heights. For population and land area, these estimates are based on averaging results from across three different econometric (instrumental variable) estimation strategies (for details, see chapter 4 of the main report and Ahlfeldt and Jedwab 2022). For lights, the estimate is based on the application of an ordinary least squares estimation strategy, in which "lights" refers to the intensity of nighttime lights per capita within a city's extent. Nighttime light intensity is measured using radiance calibrated data derived from Defense Meteorological Satellite Program satellite sensors.

KEY FINDING 10

Lack of vegetation, especially evident in large cities and cities in upper-middle-income countries, and poor urban design can exacerbate the impacts of extreme heat events in cities.

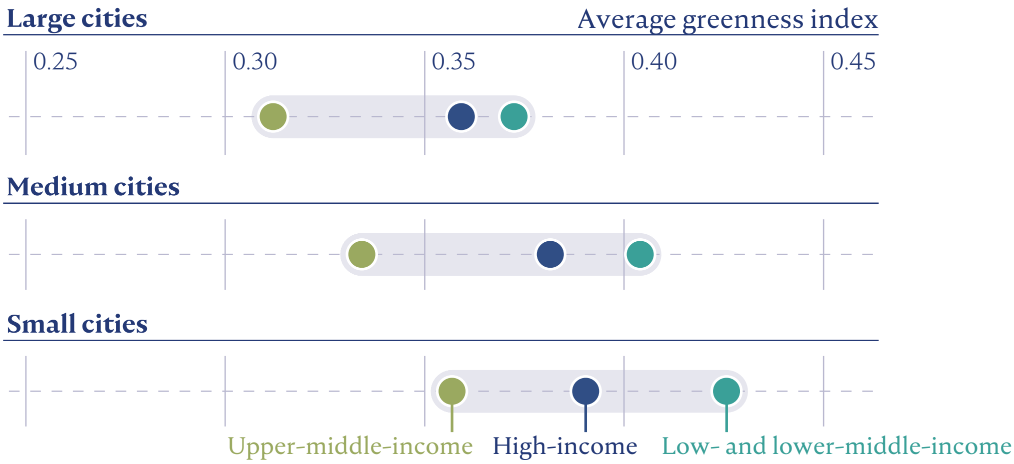
Although discussion of a city's vertical development conjures up images of concrete and steel, few people wish to live in a concrete jungle. Indeed, defining characteristics of many of the world's most well-known and successful cities—think of Singapore with its lush vegetation or London with its majestic parks—include not only the height of their skylines but also their extensive urban greenery. The greenery in cities—that is, the trees and other vegetation in parks and elsewhere—comes with important benefits for a city's residents. Not only does greenery have an inherent amenity, but its presence can also play an important role in mitigating the urban heat island effect. This effect can lead to urban land surface temperatures that are more than 10 degrees Celsius higher than the equivalent rural land surface temperatures (Deuskar 2022).

The demand for land that comes with the growth of urban population can place development pressure on green spaces in a city, further exacerbating the impacts of extreme heat events, which are becoming both more frequent and more intense with climate change. Cities in upper-middle-income countries are noticeably less green, on average, than cities in low-, lower-middle-, and high-income countries. At the same time, within any income class, larger cities tend, on average, to be less green than smaller cities *(figure O.12).*

Lack of vegetation is not the only culprit behind the urban heat island effect. The depth of street canyons—that is, the ratio of the height of buildings along a street to the width of the street—can affect air temperatures through its impact on shade and ventilation. The orientation of streets also affects both shade and ventilation. Streets with an east-west orientation receive more prolonged exposure to the sun than do those with other orientations and thus experience more heat, especially in cities close to the equator (Lai et al. 2019). Heat from motorized vehicles and the widespread and excessive use of air-conditioning are additional factors contributing to the urban heat island effect.

Figure O.12 **Average levels of vegetation are lowest for cities in upper-middle-income countries.**

Average levels of greenness, by city type, 2014



Source World Bank analysis using data from the European Commission's Global Human Settlement (GHS) Urban Centre Database R2019 (https://ghsl.jrc.ec.europa.eu/ghs_stat_ucdb2015mt_r2019a.php).

Note A city's average greenness is measured by the average greenness of the pixels in satellite imagery that fall within its urban extent. For each city type, the marker shows the unweighted average of the greenness index across cities of that type. The colors of the markers for different types of cities correspond to the colors in *map BO.1.1*.

The impacts of climate change on cities

Climate change–related shocks and stresses can affect the greenness, resilience, and inclusiveness of cities through a wide array of direct and indirect channels. Moreover, these shocks often do not occur in isolation and can be compounded by underlying urban challenges that arise from the pressure of growing urban populations on urban infrastructure, the supplies of basic services, land and housing, and the environment. Climate hazards can also cascade into cities from surrounding rural areas, as well as from areas on which a city might depend for its water supply. Inequalities within cities, which, especially for many cities in low- and lower-middle income countries, are already large, may be further exacerbated by climate change–related shocks and stresses. And while cities have traditionally been thought of as providing escalators out of poverty (Glaeser 2012), climate change may slow the speed of these escalators.

Climate hazards can be compounded by underlying urban challenges

The climate change–related shocks and stressors that affect green, resilient, and inclusive development in cities do not occur in isolation but often interact and compound, both with each other and with other urban stressors. Tropical cyclones and extreme heat events are related and often occur simultaneously. Poorly managed urban development pressures that lead to the removal of urban trees and destruction of urban wetlands could compound the effects of heat waves and floods. Losses in agricultural production from heat and drought, compounded both by the excessive loss of fertile agricultural land on the peripheries of cities due to sprawl associated with poorly managed urbanization and by heat-induced reductions in the productivity of workers, could affect the food supply. Risks can spill over across populations, places, and sectors, leading to cascading impacts.

Rural migrants fleeing drought events can settle in precarious informal settlements in urban floodplains, with cascading risks for some groups of people and locations. Wildfires in agricultural regions can increase urban air pollution while also disrupting the supply, and thus prices, of essential food products. The general interdependence within cities of critical infrastructure, such as transportation systems and power grids, means that failure of one element or node could result in a cascade of adverse events. Thus, storm surges and extreme heat could lead to power outages. Other underlying stresses within cities—not necessarily related to climate change—can also exacerbate its effects. For example, high rates of informal dumping of waste worsen pluvial floods because of the accumulation of refuse in drains, waterways, and open spaces. According to the Intergovernmental Panel on Climate Change, multiple climate hazards will continue to occur simultaneously, thereby compounding overall risk and causing risks to cascade across sectors and regions (IPCC 2022).

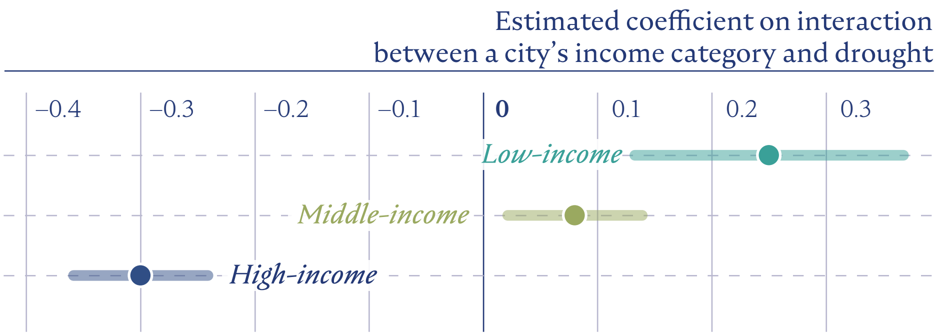
Nevertheless, as highlighted in key finding 4, construction patterns show little sign of responding to the growing threats. This situation could result, in part, from public policy that encourages settlement in more hazard-prone areas. For example, in the United States, subsidized flood insurance and relief aid may have increased people's willingness to live in disaster-prone areas (Deryugina 2014; Gregory 2017). Likewise, free federal fire protection may have increased construction in areas with high fire risk (Baylis and Boomhower 2019).

Climate hazards can also cascade into cities

Climate change–related shocks in rural areas also indirectly affect cities. When extreme weather events hit, people in the countryside often seek safe harbor in cities. In background research for this report, Chlouba, Mukim, and Zaveri (2022) show that periods of extended drought in the rural hinterlands of cities result in faster growth of the urban built-up area, presumably because of push migration. The relationship between drought and growth of urban built-up areas is particularly pronounced in low- and middle-income-countries, which suggests that climate change may be one of the factors behind the rapid urbanization of many of these countries *(figure O.13)*. Such climate-induced migration affects not just the pace of urban built-up expansion but also the nature of that expansion. Drought-driven urban expansion often takes the form of expanding informal settlements, where service delivery remains a challenge. When climate migrants arrive in urban areas, they often cluster in peripheral informal settlements. These settlements offer limited job opportunities, lack basic infrastructure, and have service delivery systems that remain in their infancy. Because the settlements are informal, settlers face the risk of eviction and forced relocation, creating secondary displacement because they no longer have the option to return to climate-decimated rural areas. Thus, climate-induced displacement can undermine the inclusiveness of urban development, leaving some of the most vulnerable members of society on the outskirts, both figuratively and literally.

Figure O.13 **Drought is associated with faster built-up area growth in low- and middle-income countries.**

Heterogeneous impacts of droughts on built-up area across a global sample of cities, by country income group, 1985–2014



Source Chlouba, Mukim, and Zaveri 2022.

Note The circles represent the point estimates of coefficients of interactions between country income group and a spatially and temporally lagged grid cell measure of drought. The solid lines running through the circles indicate the lower and upper bounds of the 95 percent confidence intervals of the estimated coefficients.

Nevertheless, such urban expansion can also come with opportunities. Rapid urban population growth induced by climate change can strain cities by putting pressure on land, housing, infrastructure, and service delivery; but it can also fuel urban economies by providing a steady flow of new laborers to growing sectors such as manufacturing, construction, hotels and restaurants, and transportation. Urban environments also hold the potential to break down traditional gender barriers by bringing women into professions previously reserved for their male counterparts (World Bank 2021b). Although most people displaced or migrating because of climate impacts stay within their countries of origin, the accelerating trend of global displacement can increase cross-border movements as well, particularly where climate change interacts with conflict and violence.[23]

Water stresses also affect cities—even from afar. Cities have always relied on water imported from other, sometimes distant, areas. From the time of ancient Rome to Los Angeles in the early twentieth century to contemporary initiatives from Mexico City to Kathmandu, Nepal, water imports have offered a path to urban water security. But the scale and intensity of these water transfers have undergone rapid changes. Nowadays, cities often rely on dozens of water sources hundreds of kilometers away. Thus, a faraway drought may profoundly affect a city. In addition to creating water supply problems for cities, climate-related shocks and stressors affect rural food-producing areas. In their background paper prepared for this report, Venkat, Dizon, and Masters (2022) demonstrate that impacts spill over to cities via higher urban food prices. These impacts vary significantly by the types of shocks and stressors and by the type of food (such as more nutrient-dense perishables versus calorie-dense nonperishables). Better transportation networks help mitigate the impact of shocks and stressors,[24] allowing potentially more resilient food supply chains.

Climate change could also exacerbate inequalities

Around the world, urban slums are often found in precarious locations—on steep slopes, on floodable land, or near open drains and sewers. Research conducted for this report by Rossitti (2022) shows that, for a selected sample of 18 cities in South Asia and Sub-Saharan Africa, slums do not necessarily have more exposure to floods or excessive heat. When focusing only on the probability of a high-risk event, however, slums do appear to have relatively higher exposure than formal residential areas to such potentially more destructive events (Rossitti 2022). Location sorting—the tendency of people with similar characteristics to cluster together in certain neighborhoods within cities—can explain the overexposure of the poor in some cities. The choice to live in hazard-prone areas often reflects a difficult trade-off—better access to jobs and services against environmental risks. In such contexts, a lack of affordable housing often prices people out of safer, well-connected locations. It is also possible that poorer households are less able to acquire information on the environmental risks of specific locations, or that these households consist of migrants from rural areas who, as newcomers to a city, do not possess needed information. Indeed, prospective dwellers often do not have accurate information on the risks associated with different locations (Bakkensen and Barrage 2022; Votsis and Perrels 2016). Because poverty involves a series of distractions that reduce productivity as well as the chances to gather information (Banerjee and Mullainathan 2008), poorer, less educated individuals may face higher costs in acquiring hazard-proneness information than their richer counterparts.[25]

The poor may or may not have greater exposure to natural hazards, but they are often the hardest-hit when disaster does strike. In absolute terms, the rich often lose more because their assets are worth more; in relative terms, however, the opposite holds true. Poorer households also suffer disproportionally from the indirect effects of natural hazards through infrastructure disruption, such as being cut off from roads and public transportation, which limits their access to jobs and economic opportunities, and their water supply. Not only do poor urban dwellers suffer higher relative losses from climate change–related shocks, but they also have less ability to engage in adaptation and mitigation. In general, poorer households have less access to financial markets (Erman et al. 2019) and insurance markets. Moreover, they are less likely to benefit from public investments in infrastructure that mitigates the risk of natural hazards. Such investments can translate into higher property prices, thereby pricing the poor out of now-safer areas of a city (Nakagawa, Saito, and Yamaga 2007). Finally, many poor households engage in recurrent self-financed short-term measures (such as temporary structural improvements) that place a large financial burden on them (Patankar 2015).

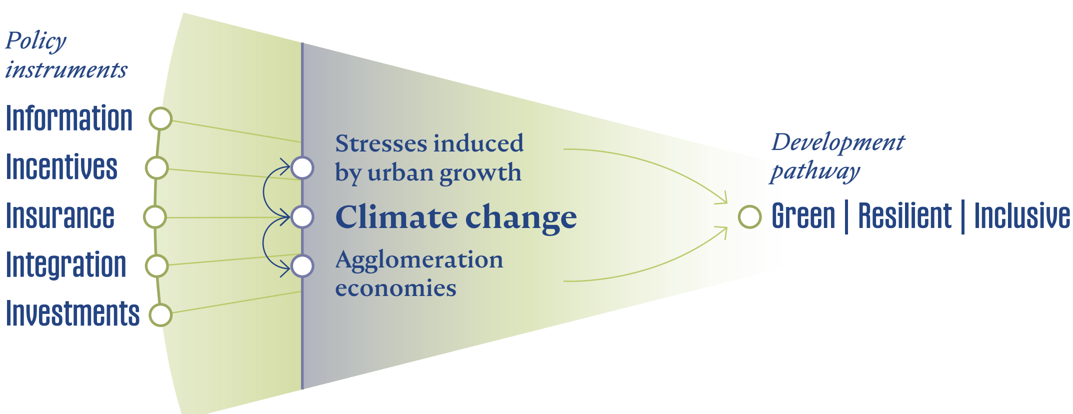
Climate change–related stresses, such as excessively high temperatures, are also expected to have negative distributional impacts. For one thing, the effects will likely be concentrated in low- and middle-income countries. Cities in lower-income countries often depend more on sectors focused on outdoor work. More important, they have less ability to implement adaptation measures. Adaptation measures such as air-conditioning in the workplace could decouple high temperatures from worker productivity, but such measures can be relatively expensive. Moreover, climate change–related stresses will exacerbate inequality within countries when informal workers, who already have lower income levels, see sharper reductions in those incomes. In their background paper for this report, Jiang and Quintero (2022) evaluate the effects of both high average annual temperatures and number of extremely hot days on the productivity of workers in thousands of cities across eight countries in Latin America and the Caribbean.[26] They find that both significantly reduce worker productivity, as measured by wages. Thus, for example, a doubling of average annual temperature is associated with an estimated 14.1 percent drop in wages.

Cities have traditionally served as escalators out of poverty; however, more frequent climate change–related shocks may slow down these escalators. Urban residents remain vulnerable or chronically poor if deprived of access to economic opportunities, basic services, and amenities. The impacts of climate change–related and environmental shocks exacerbate such failures. For example, as noted earlier, the poor and vulnerable are more likely to suffer disruption from flooding and other climate change–related shocks. Poorer households also have limited financial buffers to cope with shocks. In their background research for this report, Abanokova et al. (2022) estimate the probabilities of exit from poverty for urban residents in five countries—Chile, Colombia, Ecuador, Indonesia, and Peru. Consistent with the hypothesis that cities act as escalators out of poverty, they find that many people have indeed escaped from poverty in urban areas. And that escape is more likely in larger cities. As flood risks rise in large cities, however, the probability of exit from poverty falls. For cities with large populations, households in areas at high risk of flooding have a substantially lower probability of escaping from poverty than do households in low-risk areas.

Policies for making cities greener, more resilient, and more inclusive in a world confronted by climate change

As the preceding sections have made clear, stresses associated with urban growth interact with climate change–related stresses through a variety of channels. In doing so, they act against productivity-enhancing agglomeration economies, adversely affecting the greenness, resilience, and inclusiveness of a city's development pathway *(figure O.14)*.[27] It follows that, to improve development outcomes, policy makers at the national and local levels need to work together to target these interrelated stresses in a way that best addresses a city's specific greenness, resilience, and inclusiveness challenges, where these challenges vary with both a city's size and its level of development. To assist those efforts, this section lays out the general conclusions in three questions that policy makers should consider: *What* policy instruments are available? *Who* wields these instruments? *How* can policy choices be prioritized, sequenced, and financed for effective implementation?

Figure O.14 A framework for making cities greener, more resilient, and more inclusive



Source World Bank.

What are the choices?

Policy makers can draw on five broad sets of policy instruments: information, incentives, insurance, integration, and investments—the five I's. *Box O.3* summarizes these instruments, and the sections that follow provide more details on each.

Box O.3

The five I's: information, incentives, insurance, integration, and investments

This report distinguishes between the following five broad sets of instruments that policy makers can draw on in seeking to improve the greenness, resilience, and inclusiveness of a city's development in a world confronted by climate change.

Information	Policies and measures to improve the timely provision of credible information that helps people, businesses, and local governments better understand climate change–related risks both across and within cities, and, in doing so, helps promote both mitigation and adaptation.
Incentives	Policy instruments that provide incentives for individuals and businesses to internalize negative environmental externalities, as well as institutional and other types of reform that provide government officials with incentives to work better together to address green, resilient, and inclusive development challenges. Incentives also include the removal of fossil fuel subsidies and other incentives that encourage activities with negative environmental externalities.
Insurance	Policies and reforms that help people, businesses, and governments either to insure through the market or to self-insure against losses associated with climate change and other environmental shocks and stresses.
Integration	Policy interventions and reforms that promote more compact cities and better integration of cities both with each other and with rural areas as a means of facilitating adaptation through migration and trade.
Investments	Investments by national and local governments in green, resilient, and inclusive urban infrastructure, including nature-based solutions, as well as measures to promote the crowding-in of private sector finance for such investments.

Information

A necessary precondition for efficient decision-making by households and businesses that maximizes their expected well-being and profits, respectively, is complete and accurate information about all the potential risks they face. In this context, information comprises various policy instruments relating to both imminent threats, such as an impending extreme weather event, and the longer-term evolution of climate change–related hazards. Efforts surrounding information include disaster risk and risk management strategies or participatory initiatives that allow local, regional, and national authorities to convey information on climate change–related risks to urban residents, as well as vice versa.

Despite remarkable progress on the scientific front, some of the most vulnerable communities in climate change–threatened cities remain poorly informed about both looming extreme events that, if not adequately responded to, could spell disaster and slow-moving changes that affect everyday life. Availability of information, however, does not automatically translate into understanding, action, or even acceptance—after all, many people deny, dismiss, or cast unwarranted doubt on the scientific consensus around climate change.[28] Climate adaptation information, such as the results of climate modeling and future weather forecasts, constitutes a public good, providing a strong rationale for government provision or subsidization. The diffusion of information about risks can result in more efficient decisions by both households and businesses on, for example, where to live and invest, potentially countering the trend of construction in "future bad locations" and ensuring that households can accurately evaluate the trade-off between a location's environmental hazards and the access to job opportunities and services it provides. Such diffusion can also provide a city's residents with the information they need to hold their local elected officials accountable for addressing environmental hazards.

Information can take the form of early warning information and monitoring systems. Early warnings can provide huge benefits as a preventive measure, saving lives and, if issued sufficiently in advance, property. The earlier the warning, the more time a city's residents, businesses, and authorities have to prepare, including by protecting property and infrastructure and by positioning and reinforcing assets for protection and response. Often, coupling them with other preventive investments can maximize the benefits of early warning systems.[29] Even modest investments in such systems can have high returns.[30]

Finally, information entails regularly updated urban planning documents, building codes, and zoning regulations that help both guide and coordinate the decisions of households and businesses. It is also useful to think of information in the context of key urban markets—land, real estate, labor, and capital. The price of land is the primary element driving efficient land use in cities and decisions by households, developers, and businesses on how much to invest and on what type of structures in a particular location. A standard economic prescription is to provide transparent information that helps ensure that market prices accurately reflect both risk and supply and demand conditions (in the case of dynamically efficient volumetric water pricing, for example). Such transparency helps ensure that prices send the correct signals to economic agents making location, consumption, and investment decisions. Better information that facilitates the more transparent and efficient working of land markets could also contribute to climate change mitigation efforts with co-benefits in terms of, for example, the preservation of fertile agricultural land by lowering the costs of vertical construction. As research for this report by Ahlfeldt and Jedwab (2022) shows, vertical construction results in a more compact urban form *(see also key finding 9)*.

Incentives

Although the provision of information helps households and businesses factor climate change–related risks into their own decisions, information in and of itself may not be sufficient to motivate them to take into account the impacts of their own decisions on the environment and on others. Cities therefore need incentives to motivate households and businesses to internalize externalities such as pollution. Incentives come in various guises, including pricing policies, such as taxes on dirty fuels,[31] and congestion charging, environmental taxes, charges, and subsidies. These policies can also carry significant climate change co-benefits—for example, congestion pricing reduces vehicle miles traveled and motor vehicle emissions, with a significant positive impact on health in the short term and even larger longer-term effects as a community evolves to a new lower pollution equilibrium level. By contrast, carbon pricing policies (such as emissions trading systems and carbon taxes) tend to occur more at the national level and aim at addressing global externalities.

Incentives can also involve removing or reducing subsidies that, although perhaps well intended when originally introduced, nevertheless have the unintended consequence of inducing overconsumption of goods and services or overinvestment in activities that entail negative environmental externalities. For example, the Arab Republic of Egypt initiated a fuel subsidy removal program aimed at targeting wasteful consumption and balancing the public fiscal burden. This program resulted in targeted fuel price increases in November 2016 and June 2017 that, depending on the fuel category and period, varied between 30 and 80 percent. Heger et al. (2019) estimate that, by reducing traffic below the levels that would have otherwise prevailed, these increases led to a 4 percent reduction in Greater Cairo's concentrations of particulate matter of 10 microns or less in diameter. The reform also gave the country an opportunity to establish a nationally defined social protection floor.

Quota control policies can be effective in reducing polluting activities, but they need to be carefully designed. An analysis of Singapore's vehicle quota control by Song, Feng, and Diao (2020) finds that vehicle quotas substantially limit vehicle ownership and usage. Consumers' desire to maximize their return on investment, however, yields higher usage by existing car owners, partially offsetting the mitigation effects of the quotas. Globally, countries are making pledges and committing to phase out the sale, production, and use of vehicles dependent on fossil fuels. For example, Rwanda is on track to gradually phase out the use of polluting vehicles by 2040, starting with a pilot program in Kigali to convert motorcycles to electric. Ahead of the Republic of Korea's 2030 target, Seoul's plan to phase out diesel vehicles from the public sector and mass transit fleets by 2025 also seeks to push ahead with fleet changeover in the taxi industry with strong subsidies.

As originally pointed out by Nobel economist Kenneth Arrow (1963), addressing a market failure such as inadequate information or negative externalities can often lead to more efficient and equitable market outcomes. This result occurs because such market failures typically affect poorer households more heavily. For example, those who walk to work because they cannot afford either cars or motorbikes also suffer most from the pollution and additional heat generated by the inefficiently high levels of private motor vehicle use in the absence of congestion pricing or, even worse, in the presence of fuel subsidies.

More generally, the design of policy packages that involve incentives must include careful attention to the distribution of burden and favor across economic or social groups. And, when possible, complementary policy measures should be introduced to compensate those who stand to lose. In the case of increased fuel duties or congestion charging, for example, such measures could involve the hypothecation of the revenue raised for investments in public transportation, which London did when it introduced a congestion charge in 2003 (Santos, Button, and Noll 2008). Meanwhile, failure to take into account the distributional impacts of new incentives and, more generally, any policy intended to help address climate change and other environmental issues may result in insurmountable political opposition to the policy. One recent high-profile example of this opposition is the French government's freezing of its carbon pricing policy following the "yellow vest" protest movement of 2018 (Rubin and Sengupta 2018).

Insurance

Insurance aims to minimize the financial impact of disasters through risk sharing and to help secure access to postdisaster financing quickly and efficiently, thereby ensuring rapid, cost-effective resources to finance recovery and reconstruction efforts. Governments can implement policy and regulatory reforms to deepen insurance markets and improve access for businesses and households to complement their adaptation and resilience strategies. Market insurance that reflects disaster risks is often touted, and with good reason, by economists as the first best option to internalize risks and minimize disaster impacts (World Bank 2017). At the same time, market insurance can be difficult to implement, especially in lower-income countries that have lacking or asymmetric information, weak regulation, and limited risk capital. Developing insurance markets in this context may require government interventions beyond simple policy prescriptions and subsidy mechanisms.

Information about hazards, vulnerability, and exposure is essential not only for the sound pricing of insurance but also for other (physical) mitigation actions. Government actions to generate and share such information have broad co-benefits, and those co-benefits should be at the core of adaptation strategies, including efforts to develop market insurance.

Catastrophe risk insurance can have high capital and administrative costs. When it sells specific coverage, an insurance company promises to compensate its client in case of a disaster. It must set aside reserves and buy reinsurance to cover such an eventuality and have systems in place to assess losses and pay claims promptly and in full. Holding financial reserves, buying reinsurance, and processing claims can add substantial cost to that related to the expected loss, particularly when the company must deal with many small claims at once. In addition, uncertainty related to the underlying risk, which is growing for climate-related disasters because of climate change, will be reflected in the insurance premium through uncertainty loading.

What are some ways to reduce the high costs? High deductibles to manage moral hazard and avoid "penny claims" and mechanisms to cover first loss (for example, through government guarantees) can help reduce the cost of insurance. Making insurance compulsory ensures wider distribution of the risk and better risk pooling. Parametric or index-based instruments can help accelerate and reduce the cost of claim processing if the underlying index used to calculate the payout has a high correlation with the actual loss. Such financial engineering can substantially reduce the cost of insurance, particularly for the poorest, who are generally the first affected by a disaster.

Finally, the development of catastrophe insurance markets in lower-income countries has often suffered from a lack of clarity on when and where the government intervenes. Businesses and individuals tend to assume that the government acts as the insurer of last resort and thus do not purchase insurance. Making insurance compulsory, even if doing so requires some subsidies or guarantees to reduce the cost to a minimum, is sometimes more efficient if it helps clarify responsibilities and encourages private actors to cover at least part of their risk.

Integration

Within cities. Between 2022 and 2050, the number of people living in cities globally is projected to grow from 4.53 billion to 6.68 billion.[32] With this growth will come heightened urban demand for housing, basic services, infrastructure, and amenities. This demand could increase pressures on land and real estate markets, resulting in development patterns that further undermine the greenness, resilience, and inclusiveness of cities. Reforms that strengthen formal institutions for titling and property transfer, along with flexible and effective urban planning that is properly coordinated with investments in infrastructure, can ensure that cities are not locked into suboptimal physical forms and investments.

One notable example of such a lock-in is overly sprawling car- and motorcycle-dependent urban development. As shown under key finding 8, such development is associated with higher levels of production-based CO_2 emissions in both the transportation and residential sectors, and with higher $PM_{2.5}$ emissions.[33] According to research prepared for this report by Ahlfeldt and Jedwab (2022), reforms that reduce the costs of vertical development can encourage cities to expand upward rather than outward, while generating economic growth *(see also key finding 9)*. Ahlfeldt and Jedwab (2022) calculate that the welfare potential of tall buildings is highest for the largest cities. In low- and middle-income countries, these cities are precisely the ones hit hardest by the constraints to vertical development posed by dysfunctional land markets and failures.

Beyond sprawl and dependency on cars, further undesirable lock-ins include energy- or water-intensive building technologies and urban settlements located in vulnerable areas *(see also key finding 4)*. Although retrofitting infrastructures and buildings will be essential to greener and more resilient growth, doing so can be costly. Early efforts at integrated planning, however, could help cities—especially smaller but rapidly growing ones in low- and middle-income countries—avoid such retrofitting.

Integration is good for the poor—and good for budgets. The poor may know the hazards they face, but they depend more than the wealthy on public services that are often inadequate. In places without coordinated land use and urban infrastructure and development decisions, households end up disconnected from labor markets and having to trade safety for accessibility. Local governments often struggle to provide essential urban infrastructure; until they succeed in doing so, the poor will remain vulnerable. More secure land and property rights would encourage investment in prevention measures. Equally, the provision of land and affordable housing in safer areas, with accessibility to jobs and essential services, would go a long way toward lowering the risk exposure of poor people. City leaders can underinvest in time spent on long-term planning when dealing with a series of emergencies, because pressing matters crowd out important matters. Through investments undertaken before settlement, cities can more easily and cost-effectively deliver interventions aimed at improving and increasing density.[34] Such projects are often more effective when jointly developed and implemented alongside the communities that stand to benefit, and often must include awareness-raising components to appropriately manage behaviors.[35]

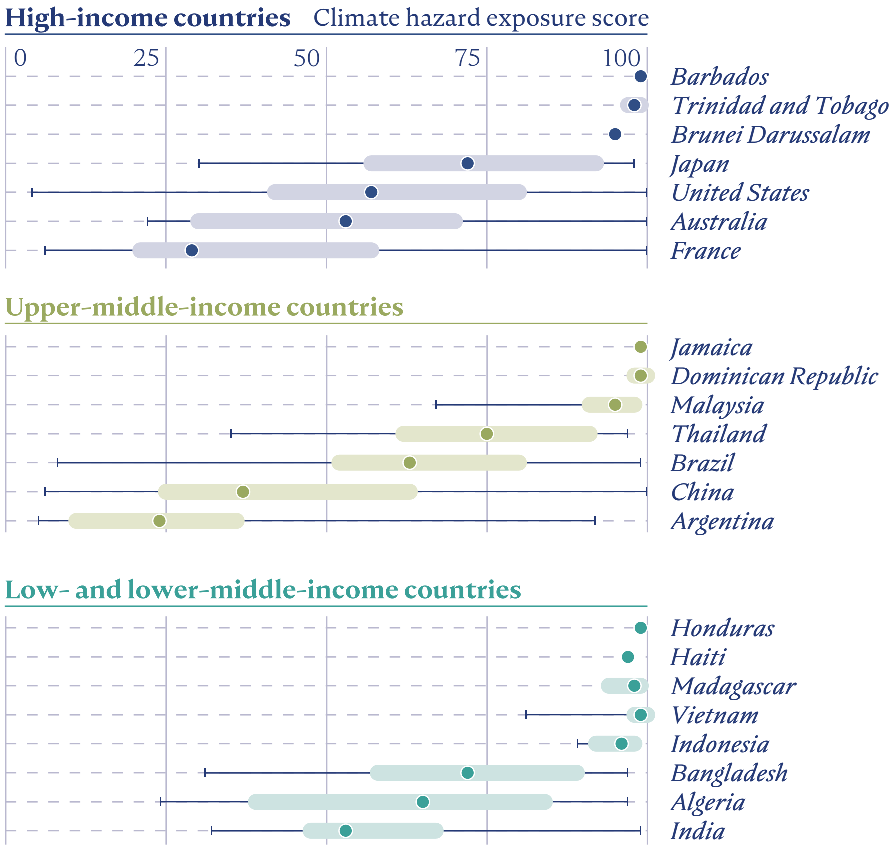
Between cities. Climate change is forcing individuals, families, and even whole communities to seek more viable and less vulnerable places to live. Governments have resorted to specific legislation, regulations, and policies to discourage or restrict domestic migration. These policies include residential registration systems, such as China's Hukou and Vietnam's Ho Khau systems that explicitly restrict internal migration (Bosker et al. 2012; World Bank 2020). Migration may also be stymied by failures in planning and policy, such as a failure to provide secure land tenure and overly restrictive regulations on building heights, that contribute to an insufficiency of affordable housing in the face of a growing urban population.

In the specific case of climate change–induced migration, the overall economic effect on the receiving city is ambiguous and will depend on local conditions and the capacity of the city to absorb a larger labor force of lower-skilled workers. Even as the precise policy mix will vary across countries, the fundamental ingredient for easing such migration transitions would likely remain unchanged. For example, decision-makers could focus on integrating migrants into the city to both limit impacts on host communities and ensure inclusive opportunities for new migrants (Zaveri et al. 2021). This emphasis would involve building human capital and investing in worker productivity through education and labor market policies that build skills and provide training. Governments could also help reduce the costs of migration by, for example, fostering increased access to financial markets and thereby relaxing the credit constraint, lowering the barriers to assimilation in receiving areas, or providing better information on jobs and other opportunities in destinations with lower climate change–related risks.

Finally, the extent to which migration between cities can act as a viable adaptation strategy to climate change further depends on two factors: the number of cities and the variation in the strength of climate change–related hazards across those cities. For a large country such as Brazil, China, or the United States that boasts many cities across which the strength of projected climate change–related hazards varies greatly, migration from cities that are more exposed to high levels of hazard to those that are less exposed represents an important potential adaptation mechanism *(figure O.15)*. However, for small Pacific and Caribbean Island nations, for example, which have only one or two major cities, intercity migration carries much less potential as an adaptation mechanism. The same holds true for large low- and middle-income countries such as Indonesia and Vietnam whose cities face uniformly strong projected climate change–related hazards.

Figure O.15 **Ranges of projected climate change–related hazard scores across cities for selected countries.**

Urban exposure to combined climate change–related hazard, selected countries, by country income group



Source World Bank analysis based on data from Moody's ESG Solutions, Sub-Sovereign Physical Climate Risk Scores, October 2021 (https://esg.moodys.io/climate-solutions).

Note The figure is organized in descending order of the average climate hazard exposure scores in each income group. The end points of the solid black lines indicate the maximum and minimum scores for each country. The solid horizontal colored line starts at the first quartile and ends at the third. The marker indicates the median value. Climate hazard exposure scores combine information on six key hazards—floods, heat stress, tropical cyclones, sea-level rise, water stress, and wildfires—projected to 2030–40.

Investments

Investments may come last in this list, but they are not least. Investments in infrastructure, when well designed, constructed, and maintained, can help cities prevent and respond to urban and climate change–related shocks and stressors, thereby reducing the probability of disasters and the associated loss of life and property. Infrastructure investments can include important prevention measures, such as flood control systems, construction of shelters, and protection of environmental buffers. Some infrastructure can serve multiple purposes. For example, safe schools in Bangladesh also serve as community cyclone shelters. Postdisaster investments can involve rehabilitation and reconstruction, including the repair and rebuilding of public and private property such as housing and infrastructure assets. Reconstruction may often include disaster-resistant measures for future prevention. Because the continued effectiveness of infrastructure will also depend on its quality, investment outlays must include maintenance, thereby boosting the resilience of infrastructure assets while reducing overall costs in the long run.

Investments in infrastructure that affect land use and a city's urban form can have implications far into the future. For example, investments in roads that promote motor vehicle over public transportation use, thereby encouraging sprawl, could significantly and permanently increase the costs of delivering basic services, such as water, sanitation, and electricity, and building social infrastructure, such as clinics and schools.[36] Indeed, investing in basic services in low-income cities represents a leap toward integration. It not only builds resilience in vulnerable communities but also enhances mobility by reducing migration barriers between them.

Investments can also anticipate the impact of shocks and stresses. One of the great benefits of cities is that they create the density of demand that can justify large sunk investments such as public transportation systems, including, for sufficiently large cities, mass transit systems. These public transportation systems not only have importance for urban productivity, accessibility, and labor market outcomes but also act as a key lever to reducing emissions of both CO_2 and local air pollutants such as $PM_{2.5}$. In a study of the 58 subway system openings that occurred in cities globally between August 2001 and July 2016, Gendron-Carrier et al. (2022) find that, for cities with higher initial pollution levels, subway openings led to a significant reduction in pollution in the area surrounding a city center. Such subway openings have, in turn, generated significant health benefits for cities with higher initial pollution levels.

Meanwhile, this report demonstrates that urbanization in high-risk areas—whether measured by heat or floods—seems to be outpacing settlement growth in safe areas (Desmet and Jedwab 2022; Rentschler et al. 2022). Relocating or retrofitting these neighborhoods is difficult and costly, and can prove politically sensitive. Instead, anticipating urban growth and guiding it spatially can be a much more effective and cost-efficient option. Laying out basic infrastructure can act as a powerful signal for households to settle in areas that authorities have identified, away from high risks. The early stages of growth require only the most basic infrastructure—essentially rights-of-way for roads and well-demarcated land plots (Angel 2012). Scaling up the infrastructure can happen in a second phase once households have settled in. Michaels et al. (2021) find that in Tanzania modest infrastructure investments in greenfield areas where people subsequently built their own houses helped facilitate long-run neighborhood development in terms of larger, more regularly laid-out buildings and better-quality housing.

Finally, investments can be used to retrofit. For example, retrofitting of residential homes and buildings could have important impacts on greening through its effects on energy consumption. Making improvements to the existing housing stock can increase resilience to tropical cyclones, landslides, floods, and other natural hazards. However, retrofitting building structures and infrastructure in densely populated areas to help them adapt to natural hazards can be a costly solution, requiring large outlays of time and money. Nature-based investments may be more cost-effective in such situations. Narayan et al. (2016) carried out a survey of multiple nature-based projects aimed at defending coastal habitats, comparing them with investments in "gray infrastructure."[37] They find that nature-based investments can be highly cost-effective for protecting coastal settlements. Trees, wetlands, green spaces, and rivers can alleviate the urban heat island effect (Raj et al. 2020; Tan, Lau, and Ng 2016). Nature-based solutions also reduce the impact of natural hazards, such as flooding, erosion, landslides, and droughts, in cities—often by complementing gray infrastructure such as storm drains, embankments, and retaining walls.[38]

Who makes the choices?

Because cities will likely bear an outsized share of climate impacts, city leaders are probably the most motivated political actors to take on climate change. City leaders also have knowledge of local context and the ability to mobilize their communities. As such, they can influence and implement climate policies put in place by higher levels of government; design and implement city-specific policies and initiatives; and, crucially, help coordinate collective climate action in their cities (De Coninck et al. 2018).

Higher levels of government may need to commit to policy and investment approaches that support local governments and give them incentives to better plan for and invest in addressing the impacts of climate change. National governments can provide strategic oversight, facilitate access to climate finance, and exercise their capacity and authority to drive climate action by creating a supportive enabling environment. National programs on emissions and clean energy standards, carbon pricing mechanisms, appliance standards, and green financing are more likely to achieve economies of scale by creating larger markets for high- to low-tech cleaner technologies. Through policy and regulatory interventions, governments could spur economic restructuring by managing transition and enabling green growth. National governments play the leading role in embedding social protection into climate plans and should focus on climate risks within social policies (Costella et al. 2021). Moreover, they hold the key to setting policy frameworks for insurance and can provide cover for high levels of physical and business risks.

It is widely agreed that climate action will require multilevel involvement not only by city and national governments but also by nonstate actors such as multilateral institutions, large multinational corporations, small enterprises, and civil society groups. Private financial flows can contribute in several ways to tackling climate risks—from portfolio equity to direct investments, to commercial bank lending, to bond finance. At the grassroots level, communities often take the lead on climate action.

How can choices be made?

How do policy makers choose among the different bundles of policies in a way that will produce the greatest positive impact on the most people in the most efficient manner? They must toggle between and sandwich together the bundles of policy interventions in the five I's to arrive at greener, more resilient, and more inclusive outcomes.

Sequencing of the five I's

The ordering of the five I's is deliberate and represents a potential sequencing of instruments. It goes from addressing information failures and issues of externalities and missing markets to government-funded investments in green, resilient, and inclusive infrastructure. The reasoning underlying the sequencing melds efficiency and efficacy—that is, it balances the need to maximize the desired effects of a policy with the need to do it in the most economical way.

— Early and easy interventions linked to the provision of *information* could have large knock-on effects on improving market outcomes. With access to more information, households and businesses can better understand the benefits and costs of their actions, including location decisions, in well-regulated markets. Such improved decision-making could stem the need for expensive government interventions, including postdisaster recovery.

— In the same vein, well-implemented *incentives* can scale quickly (for example, by affecting behaviors) at relatively low costs. Economic incentives (such as tax rebates or subsidies) can have monetary implications that could lead to snowballing costs, but they could also take the form of disincentives through monetary fines, taxes, and the like. Removing fossil fuel and other subsidies that distort behavior in a way that contributes to climate change and other environmental ills such as local air pollution could also free up government expenditure.

— Well-functioning markets for *insurance* could lower risks to a point that would minimize the need for governments to make expensive interventions and reduce the need for postdisaster relief. Insurance could transfer and mitigate risks, helping allocate economic resources more efficiently, thereby stimulating growth.

— *Integration* includes better planning for cities, often and ideally before the building of urban settlements. Given the durability of urban investments, well-planned integration could have long-lasting effects, not least for the balance sheet. Integration includes policies and reforms to reduce barriers to migration between cities and between cities and rural areas, which, especially for countries with a large number of cities across which the severity of climate hazards vary, can help adaptation.

— Finally, *investments* in infrastructure often involve large public outlays, but they can help shape a city's form in a way that fundamentally affects its emissions of both CO_2 and local air pollutants. In many cases, investments also constitute the primary (and very necessary) response following disasters. Durable investments in mitigation and adaptation strategies are crucially important because of their implications for longer-term outcomes.

The policy instruments represented by the five I's provide a relatively simple approach to organizing the many policies available into distinct bundles. Nevertheless, many interdependencies exist between these sets of instruments. In some, the instruments play out in complementary ways, wherein some policies across the bundles have a stronger impact when implemented together. Examples include how information helps facilitate migration decisions and thus integration, and how information allows prices to better reflect risks, thereby better incentivizing behaviors. Large public investments themselves signal businesses and households (information) about the direction of future development. And incentives via prices or regulation can drive insurance markets more efficiently, affecting, in turn, investment decisions by households and businesses. Thus, decisions across the five I's are not made in isolation of each other but are, in fact, interrelated and compounding.

Tailoring of the five I's

Policy makers need to tailor the application of the five I's, and the specific policy instruments that fall within them, to a city's greenness, resilience, and inclusiveness challenges, keeping in mind that these challenges vary with both a city's size and its level of development. In that context, building on this report's global typology of cities *(box O.1)*, annex OA provides a detailed matrix that maps the five I's policy options to the interrelated challenges arising from urban growth and climate change that confront small, medium, and large cities in all countries. Only with such tailoring can policy be effective—that is, one size does not fit all. However, even the tailoring presented in annex OA represents but a crude guide to the most appropriate policies for any given city, and policy makers will need to further tailor them on the basis of the specific local circumstances that confront a city of any given type.

Challenges related to climate change and urbanization are intensifying across cities globally, especially cities in low- and middle-income countries. To achieve green, resilient, and inclusive urban development, policy makers at both the national and local levels need to work together to address these interrelated challenges head-on. They can do so by drawing on the five I's suite of policy instruments. By acting now to apply these instruments in an appropriately tailored manner, policy makers can ensure that the world's cities not only survive but thrive in the face of the perils of climate change.

ANNEX 0A

Tailored policy options by type of city and instrument

MAIN CHALLENGES

	Low- and lower-middle-income country			Upper-middle-income country			High-income country		
	City size								
	Small	*Med.*	*Large*	*Small*	*Med.*	*Large*	*Small*	*Med.*	*Large*
Resilience	●	●	●	○	○	○	○	○	
Poverty	●	●	○	●	○	○			
Basic services	●	●	●	○	○	○			
Inequality	○			●	●	●	○	○	●
Vegetation			○	○	●	●		○	○
Greenhouse gas (GHG)			○		○	●	○	○	●
Pollution	○	○	●	○	○	●			○

○ = Moderate | ● = Severe

Note Med.: Medium.

INFORMATION INCENTIVES INSURANCE INTEGRATION INVESTMENTS

policy options to address challenges

	Low- and lower-middle-income country			Upper-middle-income country			High-income country		
	City size								
	Small	*Med.*	*Large*	*Small*	*Med.*	*Large*	*Small*	*Med.*	*Large*
Early warning systems; hazard mapping and assessment	●	●	●	●	●	●	●	●	●
Build institutional capacity	●	●	●						
Decentralized land administration services	●	●	●						
Participatory risk awareness	●	●		●					
Job fairs and local forums	●	●		●					
Greenhouse gas (GHG) emissions inventories						●	●	●	●
Pollution monitoring			●			●			
Better zoning of polluting industries			●			●			
Urban planning documents			●		●	●	●	●	●
Urban design guidelines					●	●	●	●	●
Building codes						●	●	●	●
Disaster risk-informed land value							●	●	●
Disaster-risk land development penalty									●

Note For brevity, this table only covers policy options for severe challenges for low- and middle-income countries.
Med.: Medium.

INFORMATION **INCENTIVES** INSURANCE INTEGRATION INVESTMENTS

policy options to address challenges

	Low- and lower-middle-income country			Upper-middle-income country			High-income country		
	City size								
	Small	*Med.*	*Large*	*Small*	*Med.*	*Large*	*Small*	*Med.*	*Large*
Phase out fossil fuel subsidies	●	●	●	●	●	●	●	●	●
Cash transfers	●	●		●					
Workfare programs	●	●		●					
Subsidized housing	●	●	●	●	●	●			
Congestion control schemes/pricing			●			●		●	●
Parking charges/reform			●			●		●	●
Reforms to reduce costs of vertical construction; relaxed height restrictions			●			●		●	●
Carbon taxes						●	●	●	●
Inclusionary zoning				●	●	●	●	●	●
Density bonus						●	●	●	●
Expedited permitting						●	●	●	●
Fast-track project review								●	●
Building retrofit and clean energy subsidies and tax credits						●	●		
Electric vehicle tax credit						●	●		
Performance zoning							●	●	●
Retrofit incentives								●	●
Linkage fees								●	●
Air rights program								●	●

Note For brevity, this table only covers policy options for severe challenges for low- and middle-income countries. Med.: Medium.

INFORMATION INCENTIVES **INSURANCE** INTEGRATION INVESTMENTS

policy options to address challenges

	Low- and lower-middle-income country			Upper-middle-income country			High-income country		
	City size								
	Small	*Med.*	*Large*	*Small*	*Med.*	*Large*	*Small*	*Med.*	*Large*
Social protection	●	●	●	●	●				
Subsidized insurance (low-risk areas)	●	●	●	●	●				
Catastrophe insurance	●	●	●	●	●				
Incorporate climate risk considerations in asset (re-)pricing, new insurance product launches, and underwriting process						●	●	●	●

Note For brevity, this table only covers policy options for severe challenges for low- and middle-income countries. Med.: Medium.

INFORMATION INCENTIVES INSURANCE **INTEGRATION** INVESTMENTS

policy options to address challenges

	Low- and lower-middle-income country			Upper-middle-income country			High-income country		
	City size								
	Small	*Med.*	*Large*	*Small*	*Med.*	*Large*	*Small*	*Med.*	*Large*
Integrate climate change adaptation and urban management; urban planning and regulation	●	●	●	●	●	●	●	●	●
Basic services; education	●	●	●						
Flexible urban planning				●	●	●	●	●	●
Connect to medium and large cities	●	●		●			●		
Lower migration barriers	●	●	●	●			●		
Laying-out of street network in anticipation of future expansion	●	●		●					
Secure land and property rights	●	●							
Integrated land use and transportation planning			●		●	●			
Transit-oriented development			●		●	●	●	●	●

Note For brevity, this table only covers policy options for severe challenges for low- and middle-income countries. Med.: Medium.

INFORMATION INCENTIVES INSURANCE INTEGRATION **INVESTMENTS**

policy options to address challenges

	Low- and lower-middle-income country			Upper-middle-income country			High-income country		
	City size								
	Small	*Med.*	*Large*	*Small*	*Med.*	*Large*	*Small*	*Med.*	*Large*
Well-located affordable housing	●	●	●	●	●	●	●	●	●
Local bus services	●	●		●			●		
Land provision	●	●							
Improve building stock	●	●							
Climate adaptation infrastructure	●	●	●				●	●	
Nature-based solutions	●	●	●	●	●	●	●	●	●
Renewable energy	●	●	●	●	●	●	●	●	●
Bus rapid transit (BRT)			●		●	●		●	●
Mass rapid transit (MRT); Light rail transit (LRT)			●			●		●	●
Energy-efficient retrofits			●			●	●	●	
Urban green space					●	●		●	
Mobility						●	●	●	●

Note For brevity, this table only covers policy options for severe challenges for low- and middle-income countries. Med.: Medium.

Notes

1. The Earth's natural "greenhouse effect" was first described by French physicist Joseph Fourier in 1824. Swedish chemist Svante Arrhenius subsequently concluded in 1869 that industrial age coal burning enhances the natural greenhouse effect. In 1938, the British engineer Guy Callendar used records from 147 weather stations around the world to show that temperatures had increased over the previous century and that, over the same period, carbon dioxide (CO_2) emissions had also increased. On the basis of this correlation, he suggested that the increase in CO_2 emissions had been responsible for global warming (an effect referred to as the "Callendar effect"). For a "brief history of climate change," see BBC News (2013).

2. The global urban population climbed from 1.19 billion in 1970 to 4.53 billion in 2022. The urban population data cited here are drawn from the following database: United Nations, Department of Economic and Social Affairs, World Urbanization Prospects 2018 (revision), https://population.un.org/wup/.

3. The surface temperature is averaged across land and water. The preindustrial period is defined as 1880–1900. Data come from Lindsey and Dahlman (2021).

4. Conversely, extreme cold events have decreased in frequency since the 1970s.

5. Cities help generate prosperity both through the agglomeration economies to which they give rise and the structural transformation from agrarian to nonagrarian activities they help facilitate. Historically, this prosperity has, in turn, helped drive demand for energy and therefore fossil fuels. Causation has also historically run in the reverse direction, with the supply of fossil fuel energy helping spur the growth of industry and cities.

6. This is, in part, through networks such as the C40 Cities Climate Leadership Group, the World Mayors Council on Climate Change (WMCCC), and the Urban Climate Change Research Network (UCCRN).

7. Nature provides essential inputs for human life, health, and prosperity; economists therefore treat it as an asset, or *natural capital*.

8. The welfare impact of air, water, and soil pollution was estimated to have been equivalent to 6.2 percent of global output in 2015. Ninety-two percent of pollution-related deaths and the highest burden of economic losses were in low- and middle-income countries. Globally, poorly managed urbanization has been among the major drivers of pollution-related deaths (Landrigan et al. 2017).

9. France's "yellow vest" protests started in November 2018 as a response by motorists to the announcement that a green tax on fuel would go into effect on January 1, 2019, as part of the French government's environmental policy strategy. The original protestors, from peri-urban and rural areas, had to drive long distances daily. The protests quickly spread to Paris, however, and turned violent. The French government abandoned its planned introduction of the green tax in December 2018.

10. Economists refer to these stresses variously as congestion and crowding effects, and diseconomies of agglomeration.

11. Fossil CO_2 emissions accounted for 77 percent of the world's anthropogenic GHG emissions in 2015. Since 2000, their increase constitutes the main source of the global increase in GHG emissions (Crippa et al. 2019).

12. Additional regression analysis, discussed in chapter 1 of the main report, shows that, for both the residential and transportation sectors, a statistically significant positive correlation remains between a city's CO_2 emissions and the income level of the country in which the city is located even after controlling for a city's own climate (temperature, precipitation, biome, and elevation). Thus, the relationships are not driven solely by differences in demand for heating and cooling associated with temperature.

13. On the basis of current policies, upper-middle- and high-income countries, as an aggregate, are not on course to achieve net zero emissions by 2050, according to version 2 scenario modeling by the Network of Central Banks and Supervisors for Greening the Financial System. According to these scenarios, if all countries maintain their current policies, global GHG emissions in 2050 will be almost 16 percent higher than they were in 2020. Even if upper-middle- and high-income countries achieve their nationally determined contributions while low- and lower-middle-income countries retain their current policies, global GHG emissions in 2050 will be only 8.2 percent lower than in 2020. This level falls far short of that required to limit global warming to 1.5 degrees Celsius.

14. The data on projected climate hazards cover 2,208 cities globally and come from Moody's ESG Solutions. Chapter 2 of the main report includes a description of the methodology on which the Moody's climate hazard scores is based.

15. *Resilience* is defined here as the ability of cities to recover their population levels and economic vitality after an adverse shock.

16. Tropical cyclones in the Atlantic are also referred to as "hurricanes"; in the Pacific they are also referred to as "typhoons."

17. For example, globally, the average number of days a year a city's temperature was extremely hot relative to its own historical experience increased from just under two days in the 1970s to more than 41 days over the period from 2011 to 2020—a staggering 21-fold increase in just four decades. Extreme heat events also increased in intensity over this period. Chapter 1 of the main report provides more details on the evolution of extreme weather events.

18. The results presented in figure O.4 are limited to cities with a 2015 population of at least 200,000.

19. The 1985 Villach conference, organized by the United Nations Environment Program, World Meteorological Organization, and International Science Council, was notable for its recognition that climate change was occurring much more rapidly than previously thought. The conference also issued the first call from the world's leading climate scientists for collaboration between scientists and policy makers to explore policy options for addressing climate change.

20. Data used for the calculations cited here cover 3 countries in East Asia and Pacific (Cambodia, Myanmar, and Timor-Leste); 5 countries in Latin America and the Caribbean (Colombia, Dominican Republic, Guatemala, Haiti, and Honduras); 3 countries in South Asia (Bangladesh, India, and Nepal); and 29 countries in Sub-Saharan Africa (East Africa: Burundi, Comoros, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe; West Africa: Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Nigeria, Senegal, Sierra Leone, and Togo; Central Africa: Angola, Cameroon, Chad, Democratic Republic of Congo, and Gabon; southern Africa: Lesotho and Namibia).

21. This finding is suggestive of the so-called environmental Kuznets curve relationship.

22. For a description of a proposed technological innovation for reducing the CO_2 emissions embedded in Portland cement, the most widely used standard variety of cement, see Ellis et al. (2019).

23. The United Nations High Commissioner on Refugees estimates that 89.3 million people worldwide were forced to flee their homes in 2021 because of conflicts, violence, fear of persecution, and human rights violations. This number is more than double the 42.7 million people who remained forcibly displaced a decade ago and the most since World War II (https://www.unhcr.org/en-us/figures-at-a-glance.html).

24. However, even good transportation networks may not be able to mitigate the impacts of some nonclimate stressors, as illustrated by the conflict in Ukraine.

25. For example, a rich body of literature in development economics documents how the poor possess lower financial literacy and how the provision of financial information can have substantial positive welfare effects. See, among others, Hastings, Madrian, and Skimmyhorn (2013); Karlan, Ratan, and Zinman (2014); Lusardi and Mitchell (2014).

26. Jiang and Quintero (2022) define an extremely hot day as one in which the temperature during at least one hour during the day exceeds 35 degrees Celsius, even if the average temperature of the entire day is lower.

27. As figure O.14 indicates, climate change may also potentially interact with agglomeration economies. For example, more frequent extreme weather associated with climate change could make it less likely that people can mingle, thereby reducing the likelihood of knowledge spillovers, or it could interrupt dense local supply chains. In general, however, the mechanisms through which climate change may affect the strength of agglomeration economies are less well understood and researched and thus are downplayed in this report.

28. See *Guardian* article on whether climate reporting shifts viewpoints (Harvey 2022).

29. For example, Hong Kong SAR, China, has invested in housing improvements that allow for sheltering at home during tropical cyclones and in early warning systems that allow people to return safely to their homes using an adaptive public transportation system (Rogers and Tsirkunov 2010).

30. The 2019 Global Commission on Adaptation report finds that early warning systems provided a 10-fold return on investment—the greatest of any adaptation measure included in the report (GCA and WRI 2019).

31. In the presence of a low-price elasticity—such as suggested by the meta-analysis carried out by Galindo et al. (2015) in Latin America—a fuel tax will be inadequate to control rising consumption.

32. The urban population data cited here are drawn from the following database: United Nations, Department of Economic and Social Affairs, World Urbanization Prospects 2018 (revision), https://population.un.org/wup/.

33. See also evidence presented in chapter 1 of the main report.

34. It has been estimated that the cost of proactive planning (such as via sites and services) for the provision of affordable and safe housing to accommodate the burgeoning population in Freetown, Sierra Leone, would cost approximately US$375 million (Mukim 2018). By contrast, the provision of a public housing scheme would cost almost nine times as much (US$3.2 billion).

35. In Jamaica, coastal hazard mapping is under way with the intent to update land use regulation, but in tandem local authorities continue to successfully enforce minimally intrusive and low-cost hurricane straps, which are connectors, often made of galvanized or stainless steel, used to strengthen wood-framed roofs and homes.

36. For African cities, Foster and Briceño-Garmendia (2010) estimate that doubling urban density reduces the per capita cost of a package of infrastructure improvements by about 25 percent.

37. *Gray infrastructure* refers to built structures and engineering equipment (such as reservoirs, embankments, and canals) that are embedded in watersheds or coastal ecosystems.

38. See World Bank (2021a) for an overview of the literature and examples in which such solutions can help cities target climate resilience.

References

Abanokova, K., H-A. Dang, S. Nakamura, S. Takamatsu, C. Pei, and D. Prospere. 2022. "Is Climate Change Slowing the Urban Escalator out of Poverty? Evidence from Indonesia and LAC." Background paper prepared for this report, World Bank, Washington, DC.

Acharya, G., E. Cassou, S. Jaffee, and E. K. Ludher. 2021. *RICH Food, Smart City: How Building Reliable, Inclusive, Competitive, and Healthy Food Systems Is Smart Policy for Urban Asia*. Washington, DC: World Bank.

Ahlfeldt, G. M., and R. Jedwab. 2022. "The Global Economic and Environmental Effects of Vertical Urban Development." Background paper prepared for this report, World Bank, Washington, DC.

Angel, S. 2012. *Planet of Cities*. Hollis, NH: Puritan Press, Inc.

Arrow, K. J. 1963. "Uncertainty and the Welfare Economics of Medical Care." *American Economic Review* 53 (5): 941–73.

Bakkensen, L. A., and L. Barrage. 2022. "Going Underwater? Flood Risk Belief Heterogeneity and Coastal Home Price Dynamics." *Review of Financial Studies* 35 (8): 3666–709.

Banerjee, A. V., and S. Mullainathan. 2008. "Limited Attention and Income Distribution." *American Economic Review* 98 (2): 489–93.

Baylis, P., and J. Boomhower. 2019. "Moral Hazard, Wildfires, and the Economic Incidence of Natural Disasters." NBER Working Paper w26550, National Bureau of Economic Research, Cambridge, MA. https://ssrn.com/abstract=3504434.

BBC News. 2013. "A Brief History of Climate Change." *BBC News*, September 20, 2013. https://www.bbc.com/news/science-environment-15874560.

Benton, G. 1970. "Carbon Dioxide and Its Role in Climate Change." *Proceedings of the National Academy of Sciences* 67: 898–91.

Bosker, M., S. Brakman, H. Garretsen, and M. Schramm. 2012. “Relaxing Hokou: Increased Labor Mobility and China’s Economic Geography.” *Journal of Urban Economics* 72 (2): 252–66.

Chlouba, V., M. Mukim, and E. Zaveri. 2022. “How Do Climate Change-Related Stressors Affect Urban Form?” Background paper prepared for this report, World Bank, Washington, DC.

Climate Watch. 2022. “GHG Emissions.” World Resources Institute, Washington, DC. https://www.climatewatchdata.org/ghg-emissions.

Costella, C., A. McCord, M. van Aalst, R. Holmes, J. Ammoun, and V. Barca. 2021. “Social Protection and Climate Change: Scaling Up Ambition.” Social Protection Approaches to COVID-19 Expert Advice Service (SPACE), Development Alternatives Incorporated (DAI) Global, LLC, Bethesda, MD.

Crippa, M., G. Oreggioni, D. Guizzardi, M. Muntean, E. Schaaf, E. Lo Vullo, E. Solazzo, et al. 2019. *Fossil CO_2 and GHG Emissions of All World Countries*. EUR 29849 EN. Luxembourg: Publications Office of the European Union.

De Coninck, H., A. Revi, M. Babiker, P. Bertoldi, M. Buckeridge, A. Cartwright, W. Dong, et al. 2018. “Strengthening and Implementing the Global Response.” In *Global Warming of 1.5°C,* edited by V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, et al. Geneva: Intergovernmental Panel on Climate Change.

Deryugina, T. 2014. “The Fiscal Cost of Hurricanes: Disaster Aid versus Social Insurance.” *American Economic Journal: Economic Policy* 9 (3): 168–98.

Desmet, K., and R. Jedwab. 2022. “Are We Over-building in ‘Bad’ Locations Globally? Future Climate Change and Durable Real Estate.” Background prepared paper for this report, World Bank, Washington, DC.

Deuskar, C. 2022. “Beating the Heat: Measuring and Mitigating Extreme Heat in East Asian Cities.” Unpublished manuscript.

Dijkstra, L., A. Florczyk, S. Freire, T. Kemper, M. Melchiorri, M. Pesaresi, and M. Schiavina. 2021. “Applying the Degree of Urbanisation to the Globe: A New Harmonised Definition Reveals a Different Picture of Global Urbanisation.” *Journal of Urban Economics* 125: 103312.

Dijkstra, L., and H. Poelman. 2014. “A Harmonised Definition of Cities and Rural Areas: The New Degree of Urbanization.” Regional Working Paper, Directorate-General for Regional and Urban Policy, European Commission, Brussels.

Ellis, L.D., A. F. Badel, M. L. Chiang, and Y.-M. Chiang. 2019. “Toward Electrochemical Synthesis of Cement-An Electrolyzer-Based Process for Decarbonating $CaCO_3$ while Producing Useful Gas Streams.” *PNAS* 117 (23): 12584–91.

Erman, A., M. Tariverdi, M. Obolensky, X. Chen, R. C. Vincent, S. Malgioglio, J. Rentschler, et al. 2019. “Wading Out the Storm: The Role of Poverty in Exposure, Vulnerability and Resilience to Floods in Dar es Salaam.” Policy Research Working Paper 8976, World Bank, Washington, DC.

Foster, V., and C. Briceño-Garmendia. 2010. *Africa’s Infrastructure: A Time for Transformation.* Africa Development Forum. Washington, DC: World Bank.

Galindo, L., J. Samaniego, J. Alatorre, J. Ferrer Carbonell, and O. Reyes. 2015. “Meta-analysis of the Income and Price Elasticities of Gasoline Demand: Public Policy Implications for Latin America.” *CEPAL Review* 117: 7–25.

Gandhi, S., M. E. Kahn, R. Kochhar, S. V. Lall, and V. Tandel. 2022. “Adapting to Flood Risk: Evidence from a Panel of Global Cities.” Working Paper 30137, National Bureau of Economic Research, Cambridge, MA.

GCA (Global Center on Adaptation) and WRI (World Resource Institute). 2019. *Adapt Now: A Global Call for Leadership on Climate Resilience.* Rotterdam: GCA.

Gendron-Carrier, N., M. Gonzalez-Navarro, S. Polloni, and M. A. Turner. 2022. “Subways and Urban Air Pollution.” *American Economic Journal: Applied Economics* 14 (1): 164–96.

Glaeser, E. L. 2012. *Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier*. New York: Penguin Press.

Glaeser, E. L. 2022. “Urban Resilience.” *Urban Studies* 59 (1): 3–35.

Gregory, J. 2017. “The Impact of Post-Katrina Rebuilding Grants on the Resettlement Choices of New Orleans Homeowners.” Unpublished manuscript.

Harvey, F. 2022. "Truthful Climate Reporting Shifts Viewpoints, but Only Briefly, Study Finds." *Guardian*, June 20, 2022. https://www.theguardian.com/environment/2022/jun/20/truthful-climate-reporting-shifts-viewpoints-but-only-briefly-study-finds.

Hastings, J. S., B. C. Madrian, and W. L. Skimmyhorn. 2013. "Financial Literacy, Financial Education, and Economic Outcomes." *Annual Review of Economics* 5 (1): 347–73.

Heger, M., D. Wheeler, G. Zens, and C. Meisner. 2019. *Motor Vehicle Density and Air Pollution in Greater Cairo: Fuel Subsidy Removal and Metro Line Extension and Their Effect on Congestion and Pollution*. Washington, DC: World Bank.

Henderson, J. V., and M. Turner. 2020. "Urbanization in the Developing World: Too Early or Too Slow?" *Journal of Economic Perspectives* 34 (3): 150–73.

Hoekstra, A. Y., J. Buurman, and K. C. H. van Ginkel. 2018. "Urban Water Security: A Review." *Environmental Research Letters* 13 (5): 053002.

Hopkins, F., J. Ehleringer, S. Bush, R. Duren, C. Miller, C. Lai, Y. Hsu, et al. 2016. "Mitigation of Methane Emissions in Cities: How New Measurements and Partnerships Can Contribute to Emissions Reduction Strategies." *Earth's Future* 4: 408–25.

IPCC (Intergovernmental Panel on Climate Change). 2021. *Climate Change 2021: The Physical Science Basis.* Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

IPCC (Intergovernmental Panel on Climate Change). 2022. "Summary for Policymakers." In *Climate Change 2022: Impacts, Adaptation, and Vulnerability*, edited by H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, et al. Cambridge, UK: Cambridge University Press.

Jiang, H., and L. Quintero. 2022. "Can't Stand the Heat: Climate Stress on Labor Productivity in 16 Latin American and Caribbean Countries." Background paper prepared for this report, World Bank, Washington, DC.

Kahn, M. 2010. "Climatopolis: How Will Climate Change Impact Urbanities and Their Cities?" *VOX-EU Blog*, September 11, 2010, Center for Economic Policy Research, London.

Kahn, M. E., and P. Li. 2020. "Air Pollution Lowers High Skill Public Sector Worker Productivity in China." *Environmental Research Letters* 15 (8): 084003.

Karlan, D., A. L. Ratan, and J. Zinman. 2014. "Savings by and for the Poor: A Research Review and Agenda." *Review of Income and Wealth* 60 (1): 36–78.

Lai, D., W. Liu, T. Gan, K. Liu, and Q. Chen. 2019. "A Review of Mitigating Strategies to Improve the Thermal Environment and Thermal Comfort in Urban Outdoor Spaces." *Science of the Total Environment* 661 (April): 337–53.

Lall, S. V., J. Kher Kaw, S. B. Murray, and F. Shilpi. Forthcoming. *Vibrant Cities: Priorities for Green, Resilient and Inclusive Urban Development.* Washington, DC: World Bank.

Landrigan, J., R. Fuller, N. J. R. Acosta, O. Adeyi, R. Arnold, N. Basu, A. Bibi Baldé, et al. 2017. "The *Lancet* Commission on Pollution and Health." *Lancet* 391 (10119): 462–512.

Lindsey, R., and L. Dahlman. 2021. "Climate Change: Global Temperature." Climate.gov, March 15, 2021. National Oceanic and Atmospheric Administration, Washington, DC.

Lusardi, A., and O. S. Mitchell. 2014. "The Economic Importance of Financial Literacy: Theory and Evidence." *Journal of Economic Literature* 52 (1): 5–44.

Madden, R. A., and V. Ramanathan. 1980. "Detecting Climate Change due to Increasing Carbon-Dioxide." *Science* 209: 763–68.

Michaels, G., D. Nigmatulina, F. Rauch, T. Regan, N. Baruah, and A. Dahlstrand. 2021. "Planning Ahead for Better Neighborhoods: Long-Run Evidence from Tanzania." *Journal of Political Economy* 129 (7): 2112–56.

Mukim, M. 2018. *Freetown Urban Sector Review: Options for Growth and Resilience*. Washington, DC: World Bank.

Nakagawa, M., M. Saito, and H. Yamaga. 2007. "Earthquake Risk and Housing Rents: Evidence from the Tokyo Metropolitan Area." *Regional Science and Urban Economics* 37 (1): 87–99.

Narayan, S., M. W. Beck, B. G. Reguero, I. J. Losada, B. van Wesenbeeck, N. Pontee, J. N. Sanchirico, et al. 2016. "The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences." *PLoS ONE* 11 (5): e0154735.

Park, J., and M. Roberts. 2022. "Urban Resilience and Weather Shocks: A Global Nighttime Lights Analysis." Background paper prepared for this report, World Bank, Washington, DC.

Pascale, S., S. B. Kapnick, T. L. Delworth, and W. F. Cooke. 2020. "Increasing Risk of Another Cape Town 'Day Zero' Drought in the 21st Century." *Proceedings of the National Academy of Sciences* 117 (47): 29495–503.

Patankar, A. M. 2015. "The Exposure, Vulnerability, and Ability to Respond of Poor Households to Recurrent Floods in Mumbai." Policy Research Working Paper 7481, World Bank, Washington, DC.

Pomponi, F., R. Saint, J. H. Arehart, N. Gharavi, and B. D'Amico. 2021. "Decoupling Density from Tallness in Analysing the Life Cycle Greenhouse Gas Emissions of Cities." *Urban Sustainability* 1: 33.

Raj, S., S. K. Paul, A. Chakraborty, and J. Kuttippurath. 2020. "Anthropogenic Forcing Exacerbating the Urban Heat Islands in India." *Journal of Environmental Management* 257: 110006.

Rentschler, J., P. Avner, M. Marconcini, R. Su, E. Strano, S. Hallegatte, L. Bernard, and C. Riom. 2022. "Rapid Urban Growth in Flood Zones: Global Evidence since 1985." Policy Research Working Paper 10014, World Bank, Washington, DC.

Rogers, D., and V. Tsirkunov. 2010. *Costs and Benefits of Early Warning Systems*. Global Assessment Report on Disaster Risk Reduction 2011. Washington, DC: World Bank.

Rossitti, G. 2022. "Who Is Affected? Which Segments of City Populations Are Most Exposed to Climate-Related Stresses?" Background paper prepared for this report, World Bank, Washington, DC.

Rubin, A. J., and S. Sengupta. 2018. "'Yellow Vest' Protests Shake France. Here's the Lesson for Climate Change." *New York Times*, December 6, 2018. https://www.nytimes.com/2018/12/06/world/europe/france-fuel-carbon-tax.html.

Santos, G., K. Button, and R. G. Noll. 2008. "London Congestion Charging." *Brookings-Wharton Papers on Urban Affairs* 2008: 177–234.

Singh, C., G. Jain, V. Sukhwani, and R. Shaw. 2021. "Losses and Damages Associated with Slow-Onset Events: Urban Drought and Water Insecurity in Asia." *Current Opinion in Environmental Sustainability* 50: 72–86.

Song, S., C.-C. Feng, and M. Diao. 2020. "Vehicle Quota Control, Transport Infrastructure Investment and Vehicle Travel: A Pseudo Panel Analysis." *Urban Studies* 57 (12): 2527–46.

Tan, Z., K. K.-L. Lau, and E. Ng. 2016. "Urban Tree Design Approaches for Mitigating Daytime Urban Heat Island Effects in a High-Density Urban Environment." *Energy and Buildings* 114: 265–74.

Varadhan, S. 2019. "Villagers Accuse City of Seizing Water as Drought Parches 'India's Detroit.'" Reuters, July 3, 2019.

Venkat, A., F. Dizon, and W. Masters. 2022. "The Impact of Climate Shocks and Stresses on Urban Food Prices." Background paper prepared for this report, World Bank, Washington, DC.

Votsis, A., and A. Perrels. 2016. "Housing Prices and the Public Disclosure of Flood Risk: A Difference-in-Differences Analysis in Finland." *Journal of Real Estate Finance and Economics* 53 (4): 450–71.

World Bank. 2013. *Inclusion Matters: The Foundation for Shared Prosperity*. New Frontiers of Social Policy. Washington, DC: World Bank.

World Bank. 2017. *Sovereign Catastrophe Risk Pools: World Bank Technical Contribution to the G20.* Washington, DC: World Bank.

World Bank. 2020. *Vietnam's Urbanization at a Crossroads: Embarking on an Efficient, Inclusive, and Resilient Pathway.* Washington, DC: World Bank.

World Bank. 2021a. *A Catalogue of Nature-Based Solutions for Urban Resilience.* Washington, DC: World Bank.

World Bank. 2021b. *Somalia Urbanization Review: Fostering Cities as Anchors of Development*. Washington, DC: World Bank.

Zaveri, E., J. Russ, A. Khan, R. Damania, E. Borgomeo, and A. Jagerskog. 2021. *Ebb and Flow Vol. 1: Water, Migration and Development.* Washington, DC: World Bank.

Between 1970 and 2021, the number of people living in cities increased from 1.19 billion to 4.46 billion, while the Earth's surface temperature climbed by 1.19 degrees Celsius above its preindustrial levels. Because of the prosperity they helped generate, cities have been a major cause of this climate change. However, it is also in cities that many of the solutions to the climate crisis—in terms of both adaptation and mitigation—will be found, not least because by 2050, almost 70 percent of the world's population will call cities home. As such, cities are the key to arguably the greatest public policy challenge of our times.

To take stock of how green, how resilient, and how inclusive cities globally are today, *Thriving: Making Cities Green, Resilient, and Inclusive in a Changing Climate* defines a global typology of more than 10,000 cities. It finds that there is wide variation in how green, resilient, and inclusive cities are around the world. It asks how climate change impacts cities and, conversely, how cities affect climate. Vicious cycles in development could occur as cities become more vulnerable to extreme events and the challenges compound and cascade. Finally, this report provides a compass for policy makers on policies that can help cities not only survive but also thrive in the face of the perils of climate change. Policy makers can and must act now to chart a more sustainable trajectory.

City Resilience Program

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