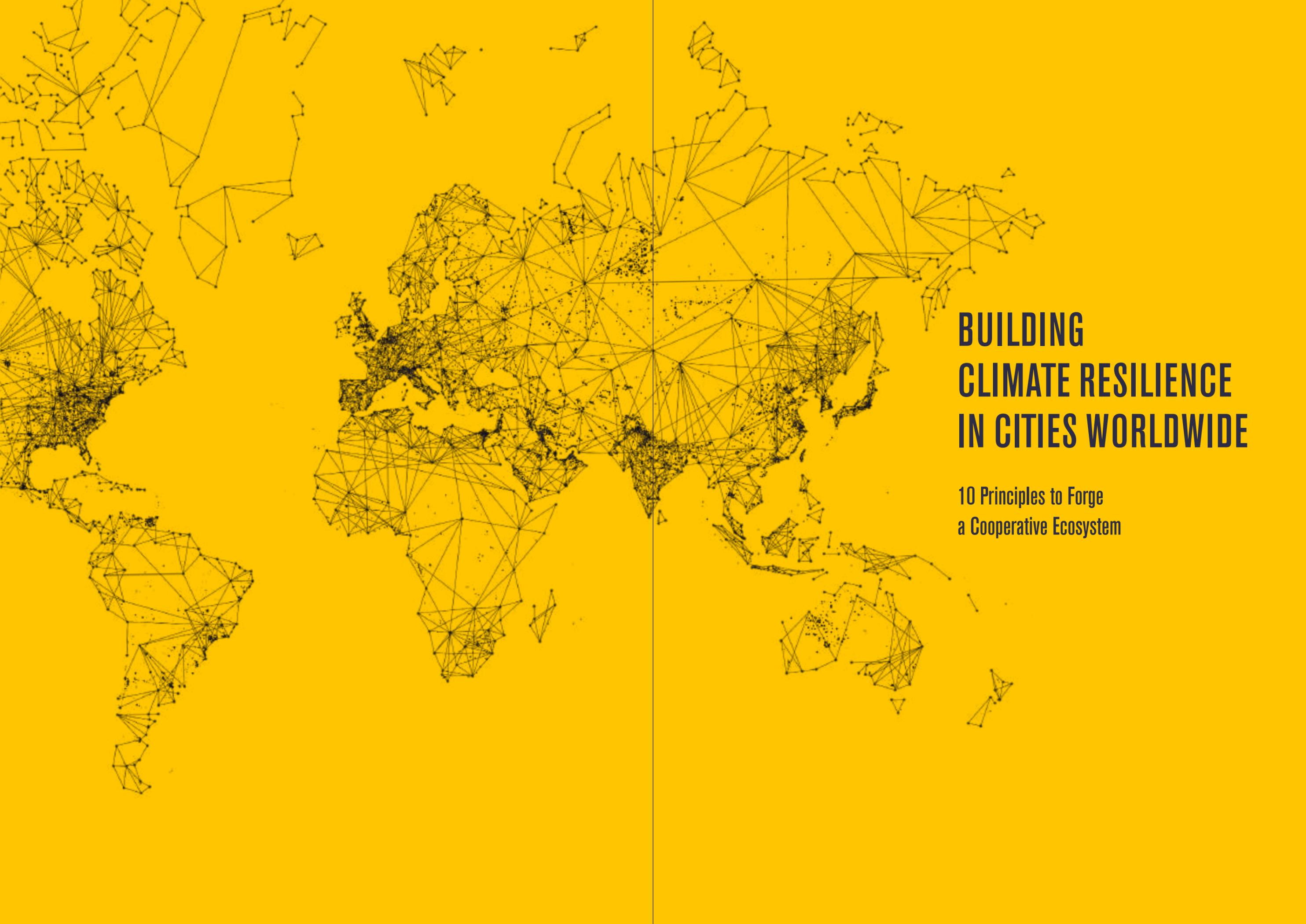


BUILDING

**CLIMATE
RESILIENCE**

**IN CITIES
WORLDWIDE**

10 Principles to Forge a Cooperative Ecosystem



BUILDING CLIMATE RESILIENCE IN CITIES WORLDWIDE

**10 Principles to Forge
a Cooperative Ecosystem**

© 2020 by the Centre for Liveable Cities and the Urban Land Institute. All rights reserved.



Printed on Enviro Wove, a paper made from 100% pre-consumer recycled pulp

ISBN-978-981-14-9597-7 (print)
ISBN-978-981-14-9598-4 (e-book)

No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, electronic or mechanical, including photocopying and recording, or by any information storage and retrieval system, without written permission of the publisher. Every effort has been made to trace all sources and copyright holders of news articles, figures, and information in this book before publication. If any have been inadvertently overlooked, CLC and ULI will ensure that full credit is given at the earliest opportunity.

The e-book can be accessed at
<http://bit.ly/Building-Climate-Resilience-in-Cities-Worldwide>



Recommended bibliographic listing:

Centre for Liveable Cities and Urban Land Institute. *Building Climate Resilience in Cities Worldwide: 10 Principles to Forge a Cooperative Ecosystem*. Singapore: Centre for Liveable Cities and Urban Land Institute, 2020.

Principal Sponsor of ULI Asia Pacific:



CONTENTS

07	About the organisations About the Centre for Liveable Cities About the Urban Land Institute
08	Foreword by Desmond Lee, the Minister for National Development, Singapore
09	Foreword by Ed Walter, Global Chief Executive Officer, Urban Land Institute
10	Preface & Introduction
12	Chapter 1: Climate Change, Cities, and Resilience Climate change and its impacts The case for coastal cities Climate mitigation, adaptation, and resilience
18	Chapter 2: Partnering on Climate: The Business Case Built environment and the real estate sector: the connection with climate change The private sector's role in partnership with government
28	Chapter 3: 10 Principles for Building Climate-Resilient Cities
32	Envision Principle 1: Elevate resilience as a goal for all sectors and stakeholders Principle 2: Work across space, time, and organisations Principle 3: Leverage opportunities to enhance liveability
44	Empower Principle 4: Provide transparency through data and knowledge sharing Principle 5: Strive for equity, access, and inclusion Principle 6: Spur united action through a common narrative
55	Execute Principle 7: Nurture a culture of collaboration Principle 8: Embody flexibility in approaches and solutions Principle 9: Motivate the market, spur innovation Principle 10: Normalise green finance to fund projects
72	Chapter 4: City Case Studies
74	Singapore
90	Hong Kong
104	Rotterdam
118	New York
132	Miami
144	Chapter 5: Applying the Principles: Getting Started in Your City, Company, or Community Thinking globally, acting locally Lessons for cities and companies worldwide
150	References

This book contains hyperlinks to useful information for further reading. Open it digitally to best experience its features.

PROJECT TEAM

Centre for Liveable Cities, Singapore

Project team Elaine Tan, Deputy Director
Kevin Fan Hsu, Senior Assistant Director
Nicole Lum, Manager
Heng Su Li, Manager
Naufal Khan, Manager

Supporting agencies Building and Construction Authority
Housing & Development Board
Ministry of Communications and Information
Monetary Authority of Singapore
National Climate Change Secretariat
National Parks Board
PUB, Singapore's National Water Agency
Urban Redevelopment Authority

Urban Land Institute

Project team Katharine Burgess, Vice President, Urban Resilience
May Chow, Senior Vice President, Asia Pacific
Pauline Oh, Senior Vice President, Asia Pacific
Augie Williams-Eynon, Senior Associate, Sustainability

Supporting staff Billy Grayson, Executive Director, Center for Sustainability and Economic Performance
Leah Sheppard, Manager, Urban Resilience
Elizabeth Foster, Manager, Urban Resilience

With support from

Civic Exchange Hong Kong Lawrence Iu, Programme Manager

Rotterdam Office of Climate Adaptation Johan Verlinde, Programme Manager

C40 Jacqueline Lam, Deputy Regional Director for Southeast Asia and Oceania

Editor Koh Buck Song, Adjunct, Centre for Liveable Cities
James A. Mulligan, Senior Editor, Urban Land Institute

Copyeditor Laura Glassman, Manuscript Editor, Publications Professionals LLC

Designer Wildtype Media Group

ABOUT THE ORGANISATIONS

About the Centre for Liveable Cities

Set up in 2008 by the Ministry of National Development and the then Ministry of the Environment and Water Resources, the Centre for Liveable Cities (CLC)'s mission is to distil, create and share knowledge on liveable and sustainable cities. CLC's work spans four main areas — Research, Capability Development, Knowledge Platforms, and Advisory. Through these activities, CLC hopes to provide urban leaders and practitioners with the knowledge and support needed to make our cities better. For more information, visit www.clc.gov.sg.

CLC led the strategic direction, writing and research of this publication, as well as organised workshops and interviews, with support and collaboration from ULI.



About the Urban Land Institute

The Urban Land Institute is a global, member-driven organisation comprising more than 45,000 real estate and urban development professionals dedicated to advancing the Institute's mission of providing leadership in the responsible use of land and in creating and sustaining thriving communities worldwide. ULI's interdisciplinary membership represents all aspects of the industry, including developers, property owners, investors, architects, urban planners, public officials, real estate brokers, appraisers, attorneys, engineers, financiers, and academics. Established in 1936, the Institute has a presence in the Americas, Europe, and Asia Pacific regions, with members in 80 countries.

The extraordinary impact that ULI makes on land use decision-making is based on its members sharing expertise on a variety of factors affecting the built environment, including urbanization, demographic and population changes, new economic drivers, technology advancements, and environmental concerns.

More information is available at uli.org. Follow ULI on Twitter, Facebook, LinkedIn, and Instagram.

ULI supported the development of this publication by hosting workshops, collaborating on strategic direction and contributing research.



FOREWORD BY DESMOND LEE, MINISTER FOR NATIONAL DEVELOPMENT AND MINISTER-IN-CHARGE OF SOCIAL SERVICES INTEGRATION



As the world confronts the climate crisis, it is vital that cities and their stakeholders work together to mount a concerted response. This is all the more important as more than half the world's population lives in cities, and this will continue to grow.

As a low-lying city-state, Singapore faces an existential threat from climate change. We are taking decisive steps to reduce our carbon emissions while putting in place measures to protect our city and our people. We will need to sustain these efforts over the long haul. To do this, we have committed significant resources, designated lead agencies for climate action and coastal protection, and are incorporating new mitigation and adaptation measures into our infrastructure plans. We are also intensifying the

planting of greenery to tackle the urban heat island effect, and ensuring that critical infrastructure is constructed at least 5m above today's sea level.

However, climate change affects all of us, and everyone has a part to play. As the COVID-19 pandemic has shown, we must mobilise the whole of society to address this very serious threat. Public agencies, the private sector, and the community must collaborate through Alliances for Action to come up with feasible and workable solutions, put them into practice, and make them our way of life.

“Building Climate Resilience in Cities Worldwide: 10 Principles to Forge a Cooperative Ecosystem” arose out of the spirit of international partnership, benefiting from the support of Civic Exchange in Hong Kong, the Rotterdam Office of Climate Adaptation, the Office of the Mayor in New York City, and C40, all of whom contributed case studies or co-facilitated workshops. I would like to thank these organisations and other individual contributors who have generously shared their knowledge in this publication.

Our ultimate response to climate change cannot be to protect the status quo. Instead, we must strive for solutions that respect the natural environment, and generate new opportunities for communities. By forging a cooperative ecosystem, we will grow cities that are more liveable, sustainable and resilient to challenges, including climate change.

Desmond Lee

Minister for National Development and Minister-in-Charge of Social Services Integration, Singapore

FOREWORD BY ED WALTER, GLOBAL CHIEF EXECUTIVE OFFICER OF THE URBAN LAND INSTITUTE



In 2020, the coronavirus pandemic, increasing societal recognition of long-standing racial inequality, and an active hurricane and wildfire season have demonstrated the urgent necessity of building resilience to interconnected social, economic, and environmental issues. As the leading organisation in the world of real estate, the Urban Land Institute recognises the essential role of the private sector in rising to that occasion, and, in particular, supporting cities and the built environment to be more prepared for the impacts of climate change.

Climate change is already having a significant impact on the places where we live, work, learn, and play, and recognition is growing across the real estate industry that now is the time to take action. Unifying

the efforts of the private and public sectors is key to that process, as neither can achieve the goal of enhanced resilience alone. ULI's Urban Resilience program and Center for Sustainability and Economic Performance continue to convene stakeholders and leaders across companies, communities, and governments to determine how best to mitigate climate risks, adapt to the increasingly apparent impacts of climate change, and form partnerships that benefit everyone.

To that end, ULI has been proud to partner with the Singapore Ministry of National Development's Centre for Liveable Cities on this important publication. International collaboration is vital in a time of global crises, and the partnership has created opportunities of exceptional value. This research effort presented a unique chance to transcend oceans, national borders, and time zones to gather input from ULI members and experts from around the world through workshops on how to build a cooperative ecosystem for resilience. The lessons learnt and the connections made through this diverse collection of contributors provide new insight into the possibilities for global exchange and knowledge sharing on cities and climate.

It's clear that changing market conditions will require the real estate industry to adapt. As a former CEO of a real estate investment trust, I know firsthand the value of thoughtful, proactive action for protecting and enhancing the assets and infrastructure we rely on. While much of our discussion of climate change has focused on risk, the need to build resilience is also an opportunity to think deeply about value creation, for the sector and the communities we serve. The COVID-19 pandemic has shown that collaboration, and leadership from government, are essential for managing acute shocks and chronic stresses. I hope this book will encourage the continued cross-sector and cross-border engagement of ULI's global membership, and the industry at large, in meeting the challenges ahead.

W. Edward Walter

Global Chief Executive Officer, Urban Land Institute

PREFACE



The inception of this project was made possible by then Minister for National Development Lawrence Wong and ULI Asia Pacific Chair Nicholas Brooke, who had met in May 2019 and discussed the need to plan for climate resilience. Sure enough, this need was reinforced by

Singapore's Prime Minister when he called climate change a matter of "life and death" and "one of the gravest challenges facing humankind" at the National Day Rally in August 2019.

A series of workshops in the case study cities with stakeholders from governments, the industry, academia and civic organisations, as well as interviews on climate resilience strategies, were conducted to gather insights. At the workshops, participants discussed the state of play in their own cities — both challenges and opportunities — and the interventions needed for themselves and for others to move the resilience agenda forward.

The series of physical workshops was kick-started with Singapore on 26 August 2019, followed by Rotterdam on 1 November 2019, then New York on 6 February 2020. With the onset of the COVID-19 pandemic early in the year, Hong Kong's workshop on 11 May 2020 shifted online while a virtual small-group conversation convened Miami stakeholders on 14 August 2020. These discussions helped distil a preliminary set of principles that were refined through additional consultation.

Participants across the five cities then reconvened for a global discussion at the online Expert Forum on 25 June 2020. A sharing of best practices facilitated cross-city learning and further augmented the principles.

In addition to the city workshops, the research looked deeper into the existing resilience efforts and plans of the five case study cities as well as those of others. This approach helped to refine the 10 principles, best practices and action steps that are widely applicable for building climate resilience. More details about the city workshops and preliminary findings (i.e. workshop report and key city ideas) can be found here: <http://climate-resilience.mystrikingly.com/>

This project came to fruition with the support of many and exemplifies the cooperative ecosystem that we are striving towards. We are honoured to have a diversity of partners contribute to this collective, global effort.

The COVID-19 pandemic shows that cities that have been the most resilient are those that have an integrated whole-of-society approach with good governance and well-planned execution. Therefore, I hope this project brings valuable insights as we journey towards a resilient, liveable and sustainable future.

Khoo Teng Chye
*ULI APAC Vice-Chair and Global Governing Trustee
 Fellow at the Centre for Liveable Cities*



INTRODUCTION



Cities around the world must expect to deal with climate challenges greater than ever before; some are already facing these today. A myriad of risks, ranging from more extreme weather, the wider spread of hitherto "tropical" diseases and rising sea levels, loom ahead, threatening cities'

functions and the well-being of their residents. The urgency to act on the issue is more apparent for cities that are nexuses of human and economic activity. One way to build resilience lies in a city's urban landscape and built environment, which play key roles in protecting communities, alleviating potential impacts and unlocking co-benefits.

However, transforming cities to become resilient to the impacts of climate change can be an immense challenge — one that cannot be tackled in isolation or without consideration for the economy, public health and the overall quality of life for city-dwellers. A cooperative ecosystem is hence paramount, one in which government and the private sector cooperate to mobilise resources, innovate, empower stakeholders and support one another in the work of building resilience.

In the past year, the Centre for Liveable Cities and the Urban Land Institute have collaborated on a multi-city study (Singapore, Hong Kong, Rotterdam, New York and Miami) to produce a publication that seeks to provide an actionable guide for cities to enhance their climate resilience

in cooperation with the private real estate and land use sector.

The research draws examples of coastal city strategies and investments, documents international best practices, proposes principles for stronger public-private cooperation, and evaluates approaches that are transferable based on a city's context or risk profile. It covers both municipal and business perspectives, focusing on the built environment, real estate, finance and insurance sectors, with an eye toward mobilising funding and governance structures to effectively raise resilience against the effects of climate change.

Under the three themes of *Envision, Empower and Execute*, the 10 principles for building climate resilience offers a framework for stakeholders in the city — public officials, the private sector, civic organisations and the community — to create an enabling environment in which everyone is aligned to our common goal of achieving climate resilience. By integrating our efforts, we can surpass limits, unlock new value and realise synergies for transformative change.

With ULI as a longstanding partner in knowledge sharing, CLC looks forward to continuing the joint commitment to foster liveable cities that are dynamic, vibrant, cohesive, sustainable and climate resilient.

Hugh Lim
*Executive Director
 Centre for Liveable Cities*





Breaking ice sheets in Iceland. Photo courtesy of Roxanne Desgagnés on Unsplash.

Chapter 1

CLIMATE CHANGE, CITIES, AND RESILIENCE

CLIMATE CHANGE AND ITS IMPACTS

Earth's climate is increasingly affected by human activities. Observed greenhouse gas emissions have increased by more than 130 parts per million from 1970 to 2017.¹ Hard to ignore are increasingly extreme climatic conditions — hotter, wetter, colder, drier — and sea-level rise, as well as more intense and frequent storms, droughts, and wildfires.

The effects of climate change are vast and devastating. The World Meteorological Organization reported that 2015 to 2019 were the five hottest years on record.² Since 1880, land and ocean temperatures combined have increased by 0.07°C per decade, more than doubling to 0.18°C per decade starting from the 1980s.³ Warming is experienced disproportionately: in equatorial cities like Singapore, surface air temperatures have risen by 0.25°C per decade since the 1950s, double the rate of the rest of the world.⁴ The global mean sea level has increased by more than 80 millimetres from 1993 to 2018,⁵ a phenomenon attributed to thermal expansion of oceans and global ice sheet melting caused by higher temperatures, which has accelerated in recent decades.⁶ The ice sheet in Antarctica alone could cause more than one metre of sea-level rise by 2100 and more than 15 metres by 2500.⁷

Rising temperatures are expected to cause more heat-related illnesses and deaths.⁸ Likewise, vector- and water-borne diseases are becoming common. Warmer and wetter climates are favourable breeding conditions for infectious agents and can worsen outbreaks of diseases such as dengue, while floods can encourage the spread of afflictions like malaria.⁹ Worsening disasters such as tropical storms, heatwaves, and wildfires loom.^{10,11}

Economies will be badly hit by costly climate impacts. During the North Atlantic hurricane season in 2017, total storm damages were estimated to top US\$170 billion,¹² a figure expected to rise with more frequent and severe storms. The real estate sector in particular faces serious



Aerial view of Singapore's urban development along the southern coastline of Marina Bay. Photo courtesy of Meriç Dağlı on Unsplash.

financial implications. The U.S. Congressional Budget Office estimates that storm-related winds and floods cost the residential sector US\$34 billion, commercial businesses US\$9 billion and the public sector US\$12 billion in losses every year.¹³ Wildfires impose similar consequences: the United States recorded more than US\$12.35 billion of direct property damage caused by large-loss wildfires in 2018.¹⁴

Globally, about 2.4 billion people live within 100 kilometres of a coastline.

THE CASE FOR COASTAL CITIES

According to 2018 estimates, 55 percent of the world's population resides in urban areas, and this proportion is expected to increase to 68 percent by 2050.¹⁵ As populations grow and urbanisation intensifies, an additional 2.5 billion people are expected to live in urban areas,¹⁶ many of them near the coast. To accommodate this increase, the world's floor area is growing by 2.3 percent each year,¹⁷ with global building stock expected to double by 2060.¹⁸

While climate change affects communities worldwide, coastal cities are particularly vulnerable given their dense populations,^{19,20} extensive infrastructure, and geography. Globally, about 2.4 billion people live within 100 kilometres of a coastline. Of these, more than 600 million are

in areas less than 10 metres above sea level,²¹ increasing their risks from sea-level rise and inundation. Coastal communities in subtropical regions may also experience more frequent and intense storms, as more heat and energy are trapped in oceans. *The Fifth Assessment Report* by the Intergovernmental Panel on Climate Change noted that hurricane rainfall will likely increase with enhanced warming influenced by human activity and higher atmospheric moisture content.²²

As population and land use trends intensify, coastal cities will become even more vulnerable to climate impacts. Building the resilience of coastal communities against future climate shocks and stressors requires an integrated strategy of climate change mitigation and adaptation.



CLIMATE MITIGATION, ADAPTATION, AND RESILIENCE

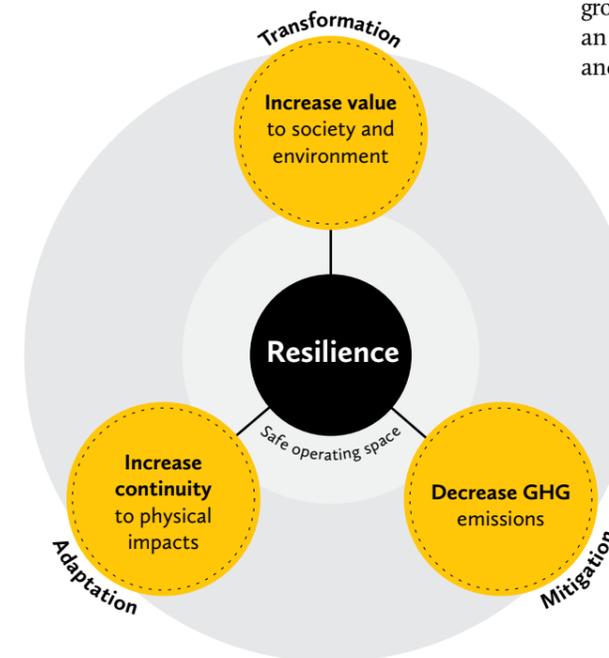
Responses to climate change can be broadly categorised into climate change mitigation and adaptation, each contributing to resilience.²³ Both approaches are integral to strengthening a city’s climate resilience and can be combined with efforts to enhance value and improve liveability and sustainability.

Climate change mitigation refers to measures that reduce greenhouse gas emissions or enhance carbon sinks.²⁵ These include switching from fossil fuels to renewable energy or enhancing carbon sequestration through afforestation and reforestation. Such mitigation actions may slow the rate of global warming and reduce the severity of climate impacts.

Climate change adaptation refers to interventions that prevent, or soften, the real and anticipated damages caused by climate change.²⁶ Adaptation strategies might range from building dykes and polders to manage rising sea levels, using natural and artificial shade to reduce the effects of rising temperatures, and changing behaviours to cope with adverse conditions.

Resilience — as defined by the National Academy of Sciences and adopted by the Urban Land Institute — is “the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events”.²⁷ For climate resilience, the ability of a city to “bounce back” depends on the adaptive capacity of its systems²⁸ — physical environments, businesses and institutions, communities and individuals — to survive and adapt to potential damage, and thrive by tapping into opportunities, in response to the chronic stresses and acute shocks of climate change.

The benefits of resilience investments are reaped in the short and long terms, through times of calm and in crisis. These benefits are known as “resilience dividends”,²⁹ which include economic

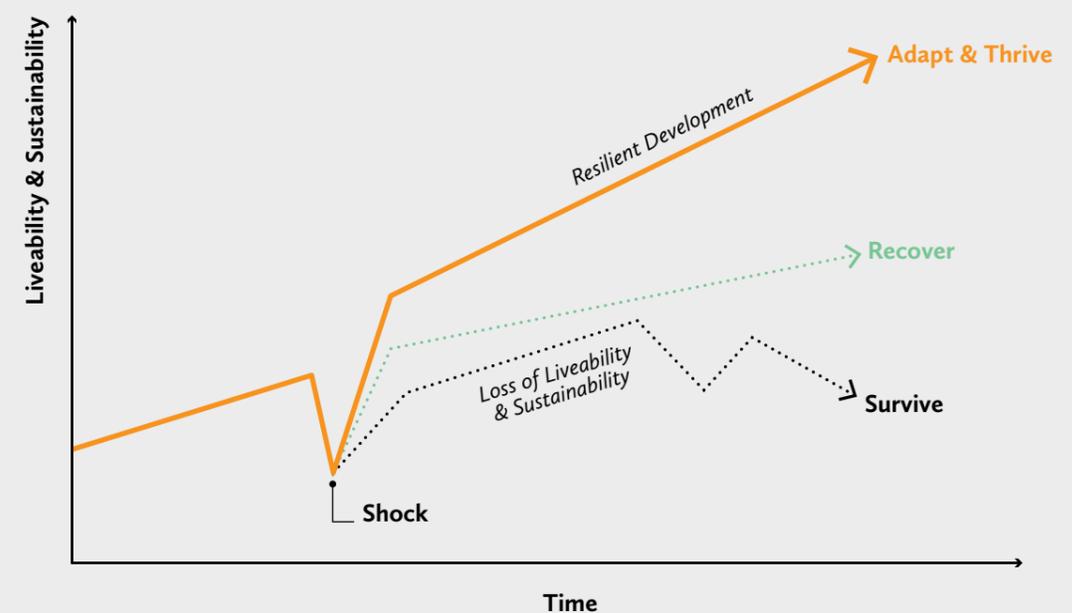


growth, job creation, improved social infrastructure, an enjoyable public realm, ecological vibrancy, and stronger community bonds.

Cities are made up of diverse stakeholders — governments, the private sector, civic organisations, academic institutions, residents — who are all affected by climate change in terms of finances, quality of life, or the environment. Building climate resilience involves a holistic “whole-of-society” effort: more than individual actors pursuing mitigation or adaptation. These stakeholders need to cooperate to build an enabling ecosystem in which they can mobilise their resources and empower each other to strengthen climate resilience.

Far left
Reforestation helps restore degraded forests while enhancing carbon sinks. Photo courtesy of Eyoel Kahssay on Unsplash.

Left
A three-pronged approach to resilience. Graphic adapted from *The World Bank*.²⁴



Survive
Reduce damage by preparing for shocks and stresses

Recover
Withstand shocks and return to status quo functions

Adapt & Thrive
Surpass status quo functions to emerge stronger and better

A resilient city emerges from a disruption stronger than before. Efforts to build resilience should occur before, during, and after a crisis. Adapted from *A Resilient Singapore* by the Centre for Liveable Cities and *100 Resilient Cities*.



Chapter 2

PARTNERING ON CLIMATE: THE BUSINESS CASE

BUILT ENVIRONMENT AND THE REAL ESTATE SECTOR: THE CONNECTION WITH CLIMATE CHANGE

Real estate and urban development have a significant and multifaceted challenge ahead in addressing climate change given rising populations, increased rural-urban migration, and the continued growth of cities. Buildings often constitute more than half a city's total greenhouse gas emissions.¹ The building and construction trades are responsible for 39 percent of global emissions,² with emissions associated with building energy consumption making up an estimated 18 to 28 percent of the global total.³ Compounding this, older buildings are likely to be less energy efficient, as many structures were built before the onset of energy codes — about 68 percent of Europe's residences and 59 percent of those in the United States.⁴ Accordingly, the real estate and construction industries will have key roles to play in climate mitigation.

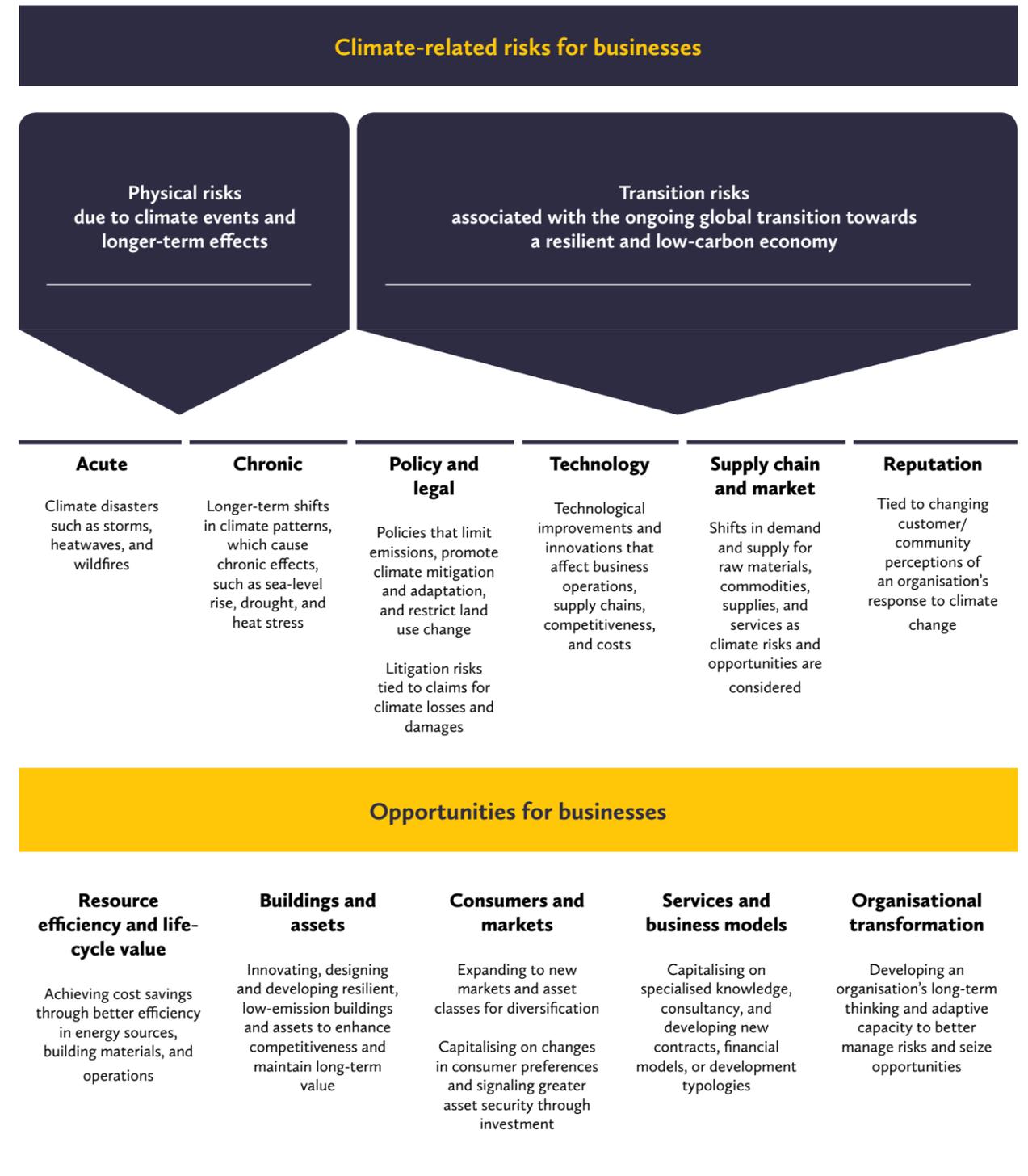
At the same time, the real estate sector will feel the consequences of climate change acutely, especially in cities, where the safety of infrastructure and communities are key to protecting local economies. The increasingly present impacts of climate change, including more frequent and intense storms, extreme heat and wildfire risk, will require the real estate sector to adapt to the impacts of climate change. Companies face increasing pressure to respond and preserve the value present in cities by improving the structural resilience of their developments, protecting occupants, coping with negative impacts such as flooding and the urban heat island effect on existing developments, and making different decisions about where to locate new development, infrastructure and critical facilities to reduce vulnerability and risks from climate events.

RISKS

The risks to real estate are becoming increasingly apparent. In a global study by Four Twenty Seven and GeoPhy, which assessed the exposure to physical risks of more than 73,000 properties owned by 350 listed real estate investment trusts, 35 percent of the properties were found to have a high probability of experiencing medium- to high-impact events. Of these, 17 percent are exposed to inland floods, 15 percent to storms, and 6 percent to coastal floods and sea-level rise. These figures are alarming in their own right, and also a reminder of the limitations of existing climate risk data sets — current data is not yet able to incorporate the effects of potential building or infrastructure resilience interventions that may reduce risk.

The whole city, including its built environment and operations, can break down when exposed to the physical impacts of climate change. Stronger storm events can cripple critical infrastructure and services such as transport networks and airports. In addition to physical damage, asset values of unprotected properties may drop, affecting not just the occupants, but also harming finances (revenues, expenditures, assets and liabilities, and capital and financing) of building owners in the long run. A study on U.S. residential properties found that those at risk of flooding were sold at a 7 percent discount compared to those that were not.⁶ This effect increased with greater consumer awareness of global warming — a phenomenon that will continue as awareness of the impacts of climate change increases. Meanwhile, insurance policies may not be able to cover mounting losses.

A myriad of climate-related risks threaten the built environment and real estate sector, categorised into physical risks and transition risks that affect infrastructure, finances, and business models.



Adapted from the Task Force on Climate-related Financial Disclosures.

OPPORTUNITIES AND BENEFITS

Beyond mitigating risk, the built environment and real estate sector can capitalise on new opportunities associated with building climate resilience. As noted by the Task Force on Climate-related Financial Disclosures, developing resilience is especially relevant to companies with long-lived fixed assets or extensive supply or distribution networks, those that depend critically on utility and infrastructure networks or natural resources in their value chain, and those that may require longer-term financing and investment — all of which describe the real estate sector.

Fortunately, climate change adaptation is not only about higher risk — it also creates openings to reduce costs, build asset value, and boost competitiveness in an evolving market. Notably, a recent economic analysis of adaptation options in Southeast Florida by the Urban Land Institute (ULI) and AECOM found that every US\$1 invested in building-level strategies would generate US\$4 in benefits for the region.⁷

Value generation can occur directly, through preventing damages from intense climate events or implementing solutions that simultaneously reduce climate risk exposure and operations expenses (like reflective roofs or impact-resistant windows, which protect against heat and storm impacts while lowering electricity bills), or simply through higher property values.

Indirectly, resilience can provide returns through faster lease-up, increased rental or sale prices, lower insurance premiums, and the advantage gained through improved company branding and marketing, particularly key as consumer awareness and preferences for resilient spaces continue to rise. ULI's report *Returns on Resilience: The Business Case* profiles 10 resilient developments that have shown strong dividends on upfront investment. Building climate resilience creates value for the real estate sector, cities and businesses in the following ways:

Building longevity and efficiency

- Increased likelihood of business continuity and productivity
- Decreased liability with ability to withstand and recover from disaster
- Long-run cost savings from greater energy efficiency, and avoided maintenance and capital improvements
- Reduced disruptions from transition risks

Financial performance

- Enhanced long-term asset viability and value
- Avoided costs for recovery from extreme events
- Increased productivity of building occupants
- Improved sales and rents from increased demand and added foot traffic

Liveability and survivability

- Enhanced liveability and economic vibrancy in the local area
- Improved tenant satisfaction and occupant safety and well-being
- Sustained energy reliability during shocks
- Increased protection for surrounding communities, which preserves flow of revenue

Marketability and corporate social responsibility

- Greater buy-in from stakeholders such as governments, investors, tenants, buyers, and consumers
- Enhanced reputational value while fulfilling environmental responsibility
- More competitive insurance premiums or better access to insurance coverage
- Enhanced access to better financing options

Adapted from the Urban Land Institute's *Scorched: Extreme Heat and Real Estate*.

CASE STUDIES: RETURNS ON RESILIENT BUILDINGS AND INFRASTRUCTURE



EY Centre Sydney, Australia

Developer:
Mirvac Projects

Architects/Designers/Engineers:
Francis-Jones Morehen Thorp

The EY Centre is a 37-story office building that exemplifies heat-responsiveness and thermal efficiency. Its closed-cavity facade system made of timber and glass reduces influence from external ambient conditions and allows automatic adjustment for light and temperature control. This allows deflection of unwanted solar heat gain, which is fast becoming a threat in Australia. The building also houses an array of smart sustainability features to improve air quality, power, water, and ventilation. An on-site capture and reuse system helps manage rainwater.¹¹

Value creation:

- 30 percent reduction in overall heating and cooling costs (estimated A\$188,800)
- Uplift in asset value (estimated A\$3.7 million market value)
- Enhanced long-term operational performance
- Enhanced user well-being and comfort

Photo courtesy of Mirvac Projects.



Nihonbashi Muromachi Mitsui Tower Tokyo, Japan

Developer:
Mitsui Fudosan Co. Ltd

Architects/Designers/Engineers:
NIHON SEKKEI, INC., KAJIMA DESIGN, Landscape Plus Ltd, Pelli Clarke Pelli Architects, Uchihara Creative Lighting Design Inc.

The 26-story, mixed-use office building has a large-scale gas co-generation energy plant to provide power and heat to 20 neighbouring buildings. Besides sustainability initiatives in terms of building specifications, technology, and energy performance ratings, the building includes modern seismic features such as structural control oil dampers to lower building sway. In addition, to preserve the area's history, the building is integrated into the existing urban fabric through design and placemaking.¹⁰

Value creation:

- Provided redundant energy supplies to the neighbourhood when the national/metropolitan grids were out during the Great East Japan Earthquake in 2011
- Estimated 30 percent reduction in CO₂ emissions
- Enhanced the urban fabric for the Nihonbashi Revitalisation Plan

Photo courtesy of Mitsui Fudosan Co. Ltd.



Stonebrook Estates Texas, United States

Developer:
Terra Visions LLC

Architects/Designers/Engineers:
Aguirre & Fields LP, R.G. Miller Engineers Inc.

A 51.4-acre private residential development, Stonebrook Estate uses a hybrid stormwater management system comprising natural drainage and traditional storm sewer, linked to an interior detention basin.⁹

Value creation:

- Withstood the Tax Day and Memorial Day floods in 2016
- Average home prices about 25 percent higher than expected (about US\$500,000), even after the 2014 downturn
- The natural drainage system reduced the site detention requirement by 24 percent, which increased lot yield
- Green amenities such as trail systems, water features for residents

Photo courtesy of Terra Visions LLC.

CASE STUDIES: RETURNS ON RESILIENT BUILDINGS AND INFRASTRUCTURE



Arverne by the Sea New York, United States

Public-private partnership

Developers: The Benjamin Companies, The Beechwood Organization

Architects/Designers/Engineers: EE&K Architects, Meltzer/Costa and Associates, Wohl & O'Mara LLP, C.A.C. Industries Inc.

Arverne by the Sea is a 120-acre mixed-use neighbourhood with 2,296 residential units. Hurricane Sandy had hit midway through construction, but the area emerged largely unscathed because of its resilience features and thus became a disaster response hub for the peninsula.

Its resilience features include natural barriers such as beaches and dunes; an underground stormwater drainage system alongside waterproofed utilities; raised homes at least 3 ft above street level with reinforced foundations and durable, low-emissions installations; and streets designed to reduce wind impact.¹³

Value creation:

- Minimal water-, wind- and fire-related damage post-Sandy
- US\$100 million in resilience investments with 10 to 15 percent returns
- Higher-than-market rental and prices
- Cost savings for homeowners on insurance premiums GmbH
- Enhanced reputation of community and company

Photo courtesy of Arverne by the Sea LLC.



Hafencity Hamburg, Germany

Public-private partnership

Master Developer: Hafencity Hamburg GmbH

Architects/Designers/Engineers: Kees Christiaanse, KCAP/ASTOC et al.

Situated in the flood zone, the 127 ha Hafencity has been undergoing redevelopment since 1997. It is elevated on three levels — from areas designed to flood (0 and 4.5 m above sea level), to buildings on artificial compacted mounds 8 m above sea level.

Shops at the promenade level are retrofitted with floodgates, water-tight glass windows and doors, and remain accessible from an elevated entryway. Public spaces and walkways are designed to move in tandem with the water. Hafencity's energy mix is 92 percent from renewable sources, and developers are required to obtain a Gold Environmental Label.¹²

Value creation:

- Avert losses from periodic flooding
- Maintain accessibility to public space and quality of the environment
- Estimated to accommodate 12,000 residents and 45,000 workers by 2025
- The wind-protected and temperature-responsive Unilever building was one of the first buildings to be constructed, achieving reduced power consumption by up to 70 percent; many architectural and building awards; investment from real estate fund HOCHTIEF Projektentwicklung GmbH

Photo courtesy of Hafencity Hamburg GmbH.

Adapted from the Urban Land Institute's Returns on Resilience and Developing Urban Resilience website.



The Magellan Terraces (German: Magellan-Terrassen) in the Hafencity quarter. Photo courtesy of foto-select/Shutterstock.com.

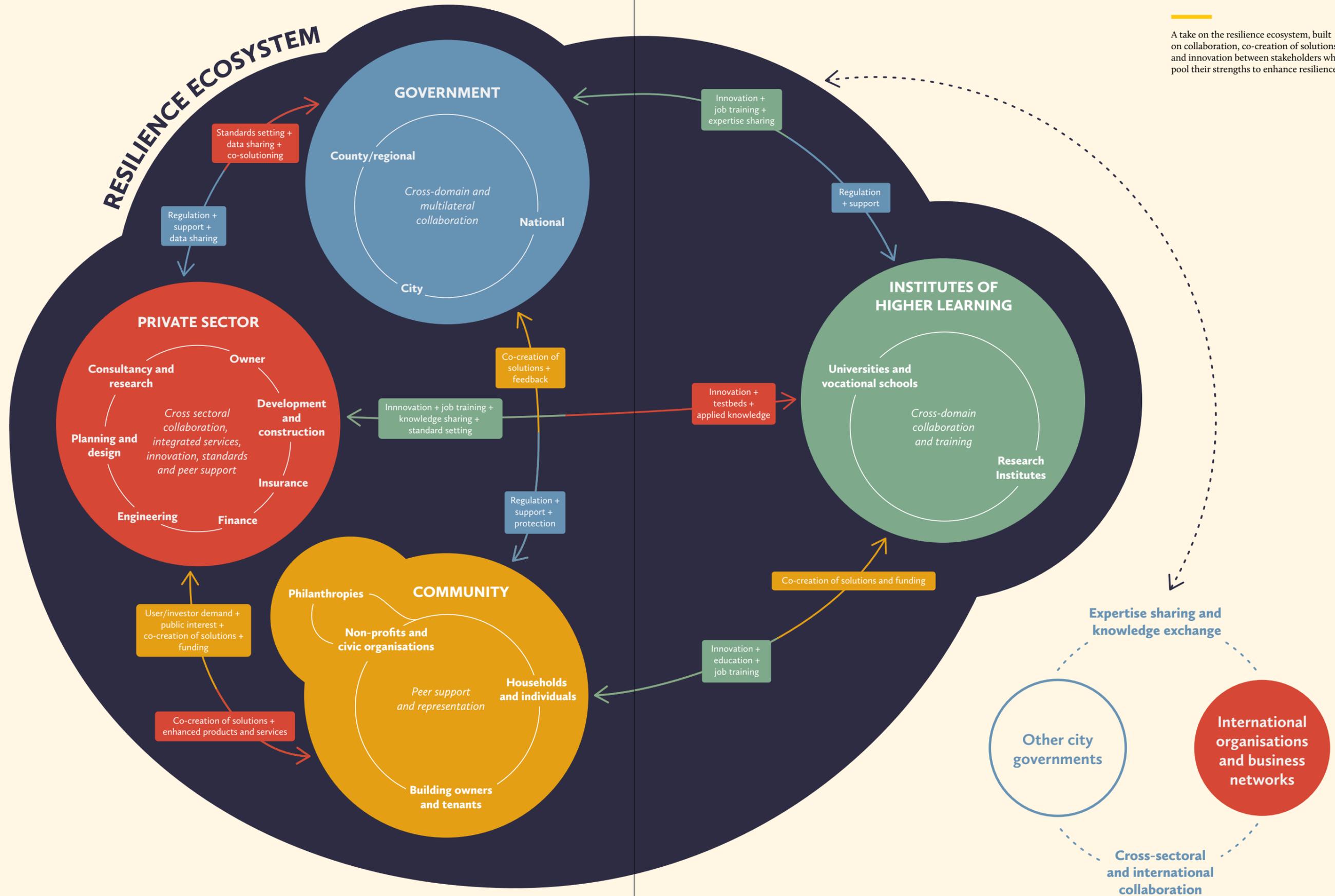
THE PRIVATE SECTOR'S ROLE IN PARTNERSHIP WITH GOVERNMENT

The impacts of climate change will cost the global economy a gross domestic product loss of 3 percent by 2050, according to the Economist Intelligence Unit.¹⁴ Indeed, adapting to climate change will require significant investment; for example, in Singapore, the government expects to spend approximately S\$100 billion on adaptation over the next hundred years to address sea level rise and flooding.¹⁵ However, these investments are needed to protect communities and economies, as well as nurture the ongoing demand for urban living and generate opportunities for capturing new sources of value. Given the scope of the challenge, it is clear that there is a strong partnership role for the private sector to complement government responses.

Businesses can be actors and enablers of climate action by reducing their emissions, enhancing their adaptive capacity, funding much-needed building and infrastructure interventions and supporting other stakeholders to take action.

Furthermore, they can grow the resilience workforce, unlock co-benefits, invite citizen participation, pioneer innovations and test solutions, engage in public-private partnerships for climate-resilient investments and nurture cross-industry collaboration for knowledge-sharing. In so doing, they contribute to the economic, societal, and environmental transformation required for resilience.

Beyond improving individual buildings, coordination among the private sector, the government, and the public is crucial to align business priorities and the government's socioeconomic goals. Hardening one property to survive the effects of a storm means little if public transport fails and neighbouring businesses are flooded — the district as a whole remains vulnerable. If all stakeholders incorporate climate resilience into their collective game plans, cities will experience transformative progress that can be sustained over time.



A take on the resilience ecosystem, built on collaboration, co-creation of solutions, and innovation between stakeholders who pool their strengths to enhance resilience.



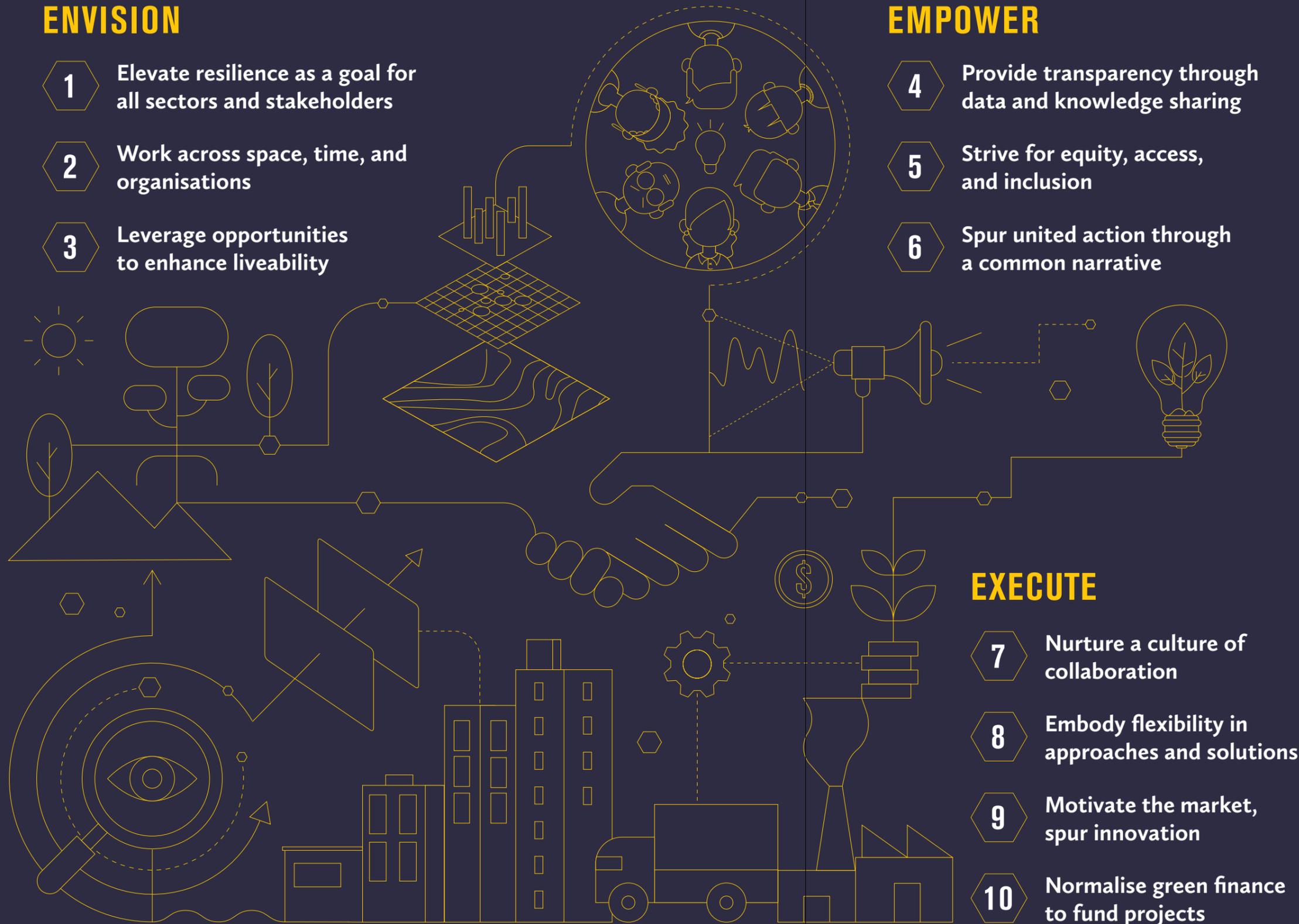
The Berkelplein water plaza in Rotterdam. Photo courtesy of Erik Fecken.

Chapter 3

10 PRINCIPLES FOR BUILDING CLIMATE- RESILIENT CITIES

ENVISION

- 1 Elevate resilience as a goal for all sectors and stakeholders
- 2 Work across space, time, and organisations
- 3 Leverage opportunities to enhance liveability



EMPOWER

- 4 Provide transparency through data and knowledge sharing
- 5 Strive for equity, access, and inclusion
- 6 Spur united action through a common narrative

EXECUTE

- 7 Nurture a culture of collaboration
- 8 Embody flexibility in approaches and solutions
- 9 Motivate the market, spur innovation
- 10 Normalise green finance to fund projects

As set out in earlier chapters, addressing the challenges of climate change requires collective action by multiple stakeholders: governments, the private sector, civic organisations, research institutions, and individuals. Contributions from all these groups will be essential for transformative change.

How can stakeholders be encouraged to protect cities and communities against the worst effects of climate change? What can spur stakeholders to look beyond individual concerns, to commit to firm action and work for real change, driven by a responsibility to the common goal of building a climate-resilient city, with a “stable society and a healthy environment” for all?¹

This chapter offers a framework for how the private sector, public officials, community groups and other stakeholders can together create a cooperative ecosystem for climate resilience. The key ideas encapsulated within the principles are drawn from workshops with industry leaders in five cities around the world. Practical action steps are guided by the 10 principles, organised under three themes: Envision, Empower, Execute.



The BIG U proposal to protect Lower Manhattan in New York City, developed by a consortium of private sector experts in partnership with the city government. Photo courtesy of Rebuild by Design.

I. ENVISION

Establishing a common vision for a climate-resilient city — one that accommodates a variety of values, navigates different scales, and fully leverages opportunities to enhance liveability

By framing climate challenges in ways that highlight the interests of all parties, society can spur greater cooperation. The following three principles address the idea of “adopting a resilience mindset”, a critical first stride towards achieving climate resilience.

PRINCIPLE 1: ELEVATE RESILIENCE AS A GOAL FOR ALL SECTORS AND STAKEHOLDERS

A city’s resilience is shaped by all who participate in its social, economic, and environmental systems, not merely by its location or infrastructure A

central goal of resilience-building is not simply to prepare for the climate and weather-related events an area will experience, but to acknowledge and reduce the compounding challenges that make residents vulnerable in the first place. These challenges exist primarily as functions of unaddressed inequities such as poverty, racial or ethnic discrimination, unaffordable housing, or disparate access to healthcare.²

To address these broad and interconnected issues, resilience must be conceptualised as a cross-cutting idea that should be embedded into all aspects of public, private, and community governance and function. Different sectors must support each other and find ways to incorporate the diverse values, needs, and interests of various stakeholder groups if a city is to become more prepared for the multifaceted challenges of a changing climate. Government, business, communities and households all have a critical role to play to help cities be more prepared for the impacts of climate change and to strengthen community networks and adaptive capacity.

ACTION STEPS

Consult broadly to appreciate the diverse values of stakeholders

To develop robust plans for creating a more climate-resilient city, the values of different stakeholders must first be understood and taken into account. The built environment, and the decision-making processes which lead to urban development outcomes, offers many examples, showing how public dialogues can help inform planning and design and turn potential opponents into allies.

- In the United States, New York City’s Economic Development Corporation has incorporated methods to reach a broad array of stakeholders into many development proposals which face climate risk, such as waterfront redevelopments. EDC profiled its Financial District and Seaport Interactive Open House as an entertainment and “see-and-be-seen” event, thus reaching a much broader audience. Families and youth — not just land use or environmental experts — came together to share ideas on climate risks, the city’s plans, and potential solutions.

- Likewise, Miami’s resilience master plan, Resilient 305, held public engagement sessions that included linguistically and ethnically diverse communities, as well as economically disadvantaged groups — a key step for a region in which over 50 percent of the population was born in another country. Conducted over a period of three years, participation by thousands of stakeholders in public meetings, focus groups, and surveys was essential to developing the plan’s resilience strategies and building support.



The role of broad public participation in Miami’s resilience plan and those of other cities created through the Rockefeller Foundation’s 100 Resilient Cities initiative, underscores the importance of evaluating diverse values gathered through meaningful public engagement.

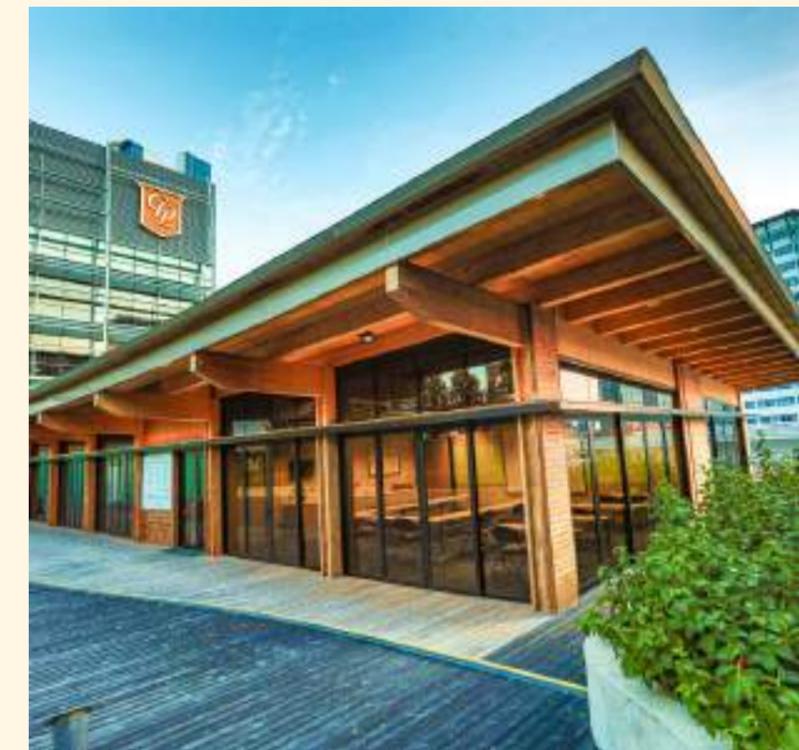
Build climate change literacy to help communities articulate their values

Awareness is growing among many stakeholders of how climate change can affect their personal lives and livelihoods, which allows them to determine their own specific priorities and communicate their values. Knowledge experts can lead outreach and education campaigns to stimulate community interest and enhance capacity to engage on local climate issues.

- The Singapore Sustainability Academy was established by property developer City Developments Limited (CDL) and the Sustainable Energy Association of Singapore to promote awareness on sustainability and provide space to civic organisations to conduct public education programmes on climate change-related topics, from youth involvement to food waste.

Left
Cross-sector planning collaboration as part of Miami’s Resilient 305. Photo courtesy of Arup.

Bottom
The learning space of Singapore Sustainability Academy. Photo Courtesy of CDL Singapore.



Resource and knowledge banks can also be developed to bridge the gap between climate science and public understanding.

- The Singapore Youth for Climate Action and other nongovernmental organisations (NGOs) developed the Greenwatch initiative to assess political parties' proposed policies on carbon emissions and waste. A political scorecard enables voters to support parties whose policies align best with their values, building momentum for broader government movement on climate issues.

Reflect the goals of resilience in solutions that fund recovery and adaptation

Finding financial resources and solutions to respond to the costs of climate adaptation is a challenge, as is moving the market to a reckoning with such a complex issue. Moreover, financial recognition of physical climate risk could change quickly with shifts in one market dynamic, such as insurance or the availability of disaster recovery funding.

Nonetheless, to align with the aim of resilience-building as reducing vulnerability to climate risks, the mechanisms that pay for adaptation and recovery measures are slowly recognising resilience as an essential goal. For example, an insurance system that looks only at restoring systems or buildings to nearly identical pre-disaster conditions will not reduce a community's vulnerability. Instead, insurance providers should identify resilient development strategies which are practical for the building or site — such as design strategies, building code enhancements and even changes to building location — and provide incentives such as reduced premiums for the incorporation of these approaches. As the industry begins to integrate climate concerns into its risk modelling and pricing practices, it can support a broad resilience vision by rewarding better design that promotes preparedness and resilient (re)construction,³ and integrates a “build back better” approach for climate risk management.

Insurers and reinsurers are engaging with the resilience conversation and are key stakeholders, especially as vulnerable areas experience climate

events more regularly and climate risks begin to affect new areas. Some programmes that reflect resilience goals are already available.

- FORTIFIED, a programme by the U.S. Institute for Business and Home Safety, works with reinsurers to promote voluntary post-disaster reconstruction based on an improved set of building standards. Its FORTIFIED Roof Standards encourage homeowners to adopt science and engineering-based standards for better wind and hail protection and so become eligible for premium discounts. In a study by ULI on FORTIFIED in Alabama, use of the code has been proven to enhance property values.

Besides insuring for conventional financial damage from acute events, insurance mechanisms that enlarge coverage to include losses from climate stresses (e.g., both wetter and drier weather leading to crop yield drop) will assist with industry and government efforts to better understand and prepare for chronic climate change impacts.

- The Philippine Crop Insurance Corporation is expanding coverage by piloting new insurance techniques such as weather-based index insurance and area-yield crop insurance, which protects farmers if prolonged wet weather or droughts significantly reduce agricultural yields.

As the industry begins to integrate climate concerns into its risk modelling and pricing practices, it can support a broad resilience vision by rewarding better design that promotes preparedness and resilient (re)construction, and integrates a “build back better” approach for climate risk management.

Broadly incorporate sustainability/resilience considerations in land use policy and planning

Meaningfully adapting to climate change will require the use of a broad range of regulatory, design and development tools. Land use is perhaps one of the clearest arenas for climate adaptation solutions: how properties, neighborhoods, cities and regions are built and patterned can mitigate or exacerbate the climate risks they face. Physical climate risks also intersect in complex ways with pre-existing stresses, such as the availability of affordable housing or the distribution of density within a city or larger region, that can be affected by land use policy, making it a ripe area for intervention.

Proactive land use solutions that address climate risks consider how and where is best to develop, given which parts of a city are at higher risk, and shift future development into safer areas through strategies such as zoning, development incentives and investment in infrastructure and transit. The prospects for densification must be balanced with supporting communities who currently occupy the riskiest areas. These communities, many of whom have been marginalised by land-use policy for generations, should be supported and included in determining how land use evolves (See Principle 5: Strive for Equity, Access, and Inclusion).

In addition, how land use is regulated can greatly affect the future resilience of development projects. Private sector planning and design actors can explore the restructuring of current zoning codes and planning parameters for resilience and environmental objectives, aside from satisfying financial requirements for “highest and best use”.

- In China, multi-disciplinary consultancy Arup and the Beijing Urban Planning and Design Institute developed an innovative zoning plan, after the completion of the Master Plan for Beijing's Changxindian area, with local government support. A set of low-carbon zoning codes that incorporated sustainable performance indicators on energy, waste, ecology, and transport are intended to overcome the limits of current planning parameters to achieve more ambitious energy, resource, and emissions objectives. To ensure that sustainability objectives were met, targets and technical requirements for individual

sites and block levels were prescribed directly into the statutory zoning plans, resulting in the initiative winning multiple global as well as national planning awards.

Newly-built residential apartments in Changxindian.
Photo courtesy of Arup.





PRINCIPLE 2: WORK ACROSS SPACE, TIME, AND ORGANISATIONS

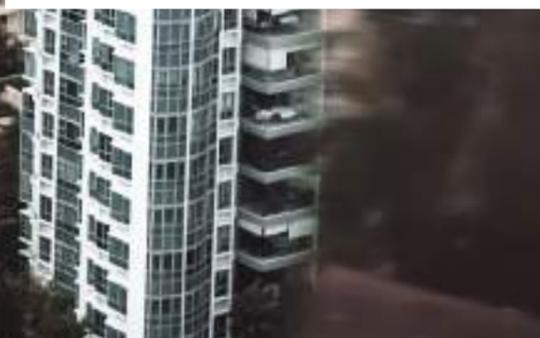
Resilience is best promoted when stakeholders conceive of the challenge across space and time, and work beyond their own organisations.

Operating across space, a climate-resilient city knits together protection of individual buildings or sites with coordinated action at the level of the neighbourhood, district, city, and beyond. Many issues are addressed more effectively as a collective, and economies of scale emerge when stakeholders can rely on — and contribute to — a common service or solution.

Working across time scales, stakeholders should evaluate their approach to resilience for the long term. Long-term thinking is required to address climate change, as resilience challenges will last decades, if not centuries.

In pursuit of resilience, stakeholders should expand their approach beyond their business interests or traditional responsibilities by reaching across sectoral boundaries, connecting to allied industries, and considering both hardware (infrastructure) and software (community). Such coordination across firms, sectors, and industries prevents one party's actions from undercutting those of others. A harmonised ecosystem in which stakeholders navigate spatial, temporal, and organisational scales will enjoy greater returns on investments in resilience.

Singapore's polycentric development strategy brings amenities closer to homes, which can better allow communities to survive and emerge stronger from disruptions. *Photo courtesy of Mark C on Unsplash.*



ACTION STEPS

Look beyond a city's borders: cooperate regionally

A resilient ecosystem thrives on galvanising broad coalitions.

- In the United States, the Southeast Florida Regional Climate Change Compact, a four-county collaboration on adaptation policy, features four local governments joining forces to address climate challenges, such as sea-level rise (see Miami Case Study on p. 88). The counties pool resources in coordinated efforts that align with the regional vision, and provide guidance to local municipalities in developing local resilience strategies.

Build self-sufficiency into “complete neighbourhoods”

If a city has self-sufficient, mixed-use neighbourhoods, it can be more efficient in its emergency response, continuity, and recovery during intense environmental stresses and shocks. Events like COVID-19 have changed the way we live and work, spurring demand for “complete neighbourhoods” where residents have safe and convenient access to critical utilities and services. Cities such as Toyama, Japan, and Paris, France, are moving towards this paradigm. The mayor of Paris has advocated a “15-minute city” where housing, work, education, leisure, and health and well-being are all accessible by walking or cycling within that ambit. With more nodes of amenities and activities, if a city is affected by flooding, businesses outside the flood zone can still function, instead of relying on a single at-risk central business district.

Maximise synergy between local solutions and large-scale initiatives

Decentralised smaller-scale solutions can complement large-scale projects and be seen as components of overall resilience initiatives. Governments, planners, and the private sector can ensure that solutions — regardless of their

scales — are synergistic, to maximise their coordinated strengths.

- In Singapore, while the government works to upgrade the city-state's drainage network, any development larger than 0.2 hectares (about half an acre) must also install its own stormwater detention tank system to reduce the burden on the overall system.

With constant stress on public stormwater infrastructure from rising precipitation, a stormwater fee can also incentivise developers to reduce impervious surfaces on their properties and add stormwater detention tanks and green infrastructure, such as rain gardens. Also common in the United States, the fee is used to fund maintenance and upgrades of the municipal system.



Naturalised waterway at Bishan-Ang Mo Kio Park. Photo courtesy of Minoru Kuroda/Shutterstock.com.

Develop strategies using time frames that transcend political cycles and recessions

Climate solutions that transcend political terms would have greater longevity and long-term value.

- In the Netherlands, the Delta Commissioner, an apolitical officer appointed every seven years as head of the Delta Programme, oversees climate and water-related issues.⁴ This appointment is delinked from the typical five-year political election cycle, insulating the office from political changes. Longer time horizons also benefit environmental/economic impact assessments regarding the viability of capital projects and infrastructure investments. A dedicated long-term budget for resilience building, such as the Delta Fund, can also safeguard project financing through economic downturns.

Overall, short-, medium-, and long-term resilience plans would be key in ensuring an adequate response to evolving climate risks. Stakeholders can develop a matrixed timeline of strategies in which imminent climate issues are promptly addressed and complex climate challenges are incrementally tackled. A future-forward approach that is constantly reviewed, and aligns with updated climate science, allows stakeholders to deliver more effective solutions.

Resilience thinking can help the private sector identify synergies between life-cycle stages and potentially save on operations and maintenance costs.

Analyse co-benefits and impacts based on a building's full life cycle

The building industry increasingly recognises that greenhouse gas footprints and other environmental impacts should be measured across a building's full life cycle. This includes acquisition, planning and design, construction and refurbishment, operations, maintenance, demolition, waste, and redevelopment. Resilience thinking can help the private sector identify synergies between life-cycle stages and potentially save on operations and maintenance costs. For instance, using photocatalytic concrete, a self-cleaning building material, in the construction phase could reduce energy consumption and downstream costs for repair or refurbishment.

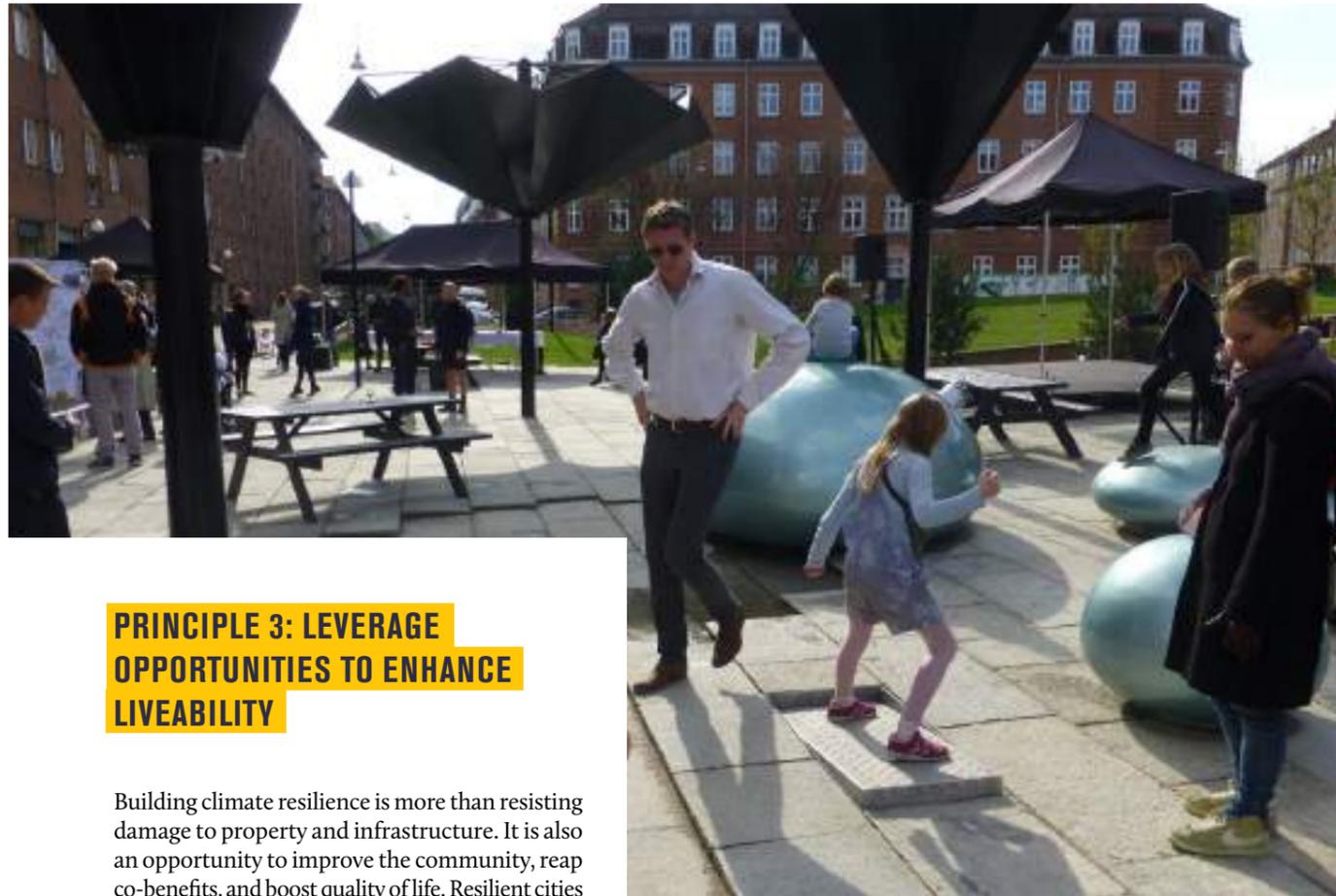
Assess risk and resilience beyond immediate operations: evaluate supply chains and networks

Climate resilience must apply to the entire value chain. Supply chain breakdowns can disrupt the operations of businesses, communities, and cities. Hence, companies can formally incorporate climate change risks as part of their supply chain risk management strategy and enhance supply chain resilience through bridging (enhancing the capability of a supplier to withstand risk events and recover more quickly from a disruption) and buffering (protect the company from inevitable supplier failures and supply disruptions).⁵

- Recognising the threats from climate change, Mars Corporation's Sustainable in a Generation Plan looks beyond direct operations into its supply chain to reduce environmental impact and increase climate resilience. For a long time, the confectionery manufacturer has striven to operate solely on renewable energy, already achieving this goal in the United States and Mexico. Mars also calls on its suppliers to participate in climate action by setting science-based targets, signing on to the Climate Group's RE100, and moving towards renewable energy. Olam, one of Mars' suppliers of cocoa and palm oil, has signed on to this pledge.



Bosco Verticale's urban vegetation helps improve air quality, reduce noise pollution, provide shade, and enhance biodiversity. Photo courtesy of Ricardo Gomez Angel on Unsplash.



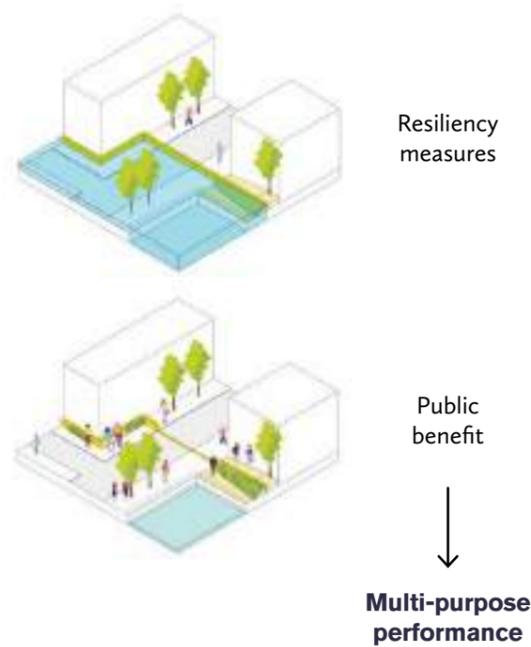
PRINCIPLE 3: LEVERAGE OPPORTUNITIES TO ENHANCE LIVEABILITY

Building climate resilience is more than resisting damage to property and infrastructure. It is also an opportunity to improve the community, reap co-benefits, and boost quality of life. Resilient cities ride out stresses and disturbances to eventually “build back better”.⁶ Both public and private adaptation projects can plug existing gaps and address fundamental inequalities, so that the city can enjoy a broader resilience dividend.⁷ Eventually, a “new normal” enhances the public realm; addresses ongoing inequalities; trains the next generation for jobs in emerging markets spanning resilience retrofits, green finance, and climate justice; and works to restore degraded ecosystems.

Above
An active water playground in Tasinge Plads, Denmark with climate-resilient features that encourage citizens to do their part in pumping water from retention systems. *Photo courtesy of Tina Saaby.*

Right and far right
The North Battery Park City Resiliency project in New York City aims to provide public benefits and enhance resilience through careful planning and design. Spaces are designed to be multi-purpose, allowing temporary storage of water during periods of high rainfall and enabling promenade access close to the water's edge when rainfall is low. *Photos courtesy of AECOM.*

Project Priorities



ACTION STEPS

Combine public space amenities and climate-resilient infrastructure projects

Public amenities can offer climate protection while fulfilling other public aspirations.

●● Such a holistic approach to building public spaces by governments, NGOs, and the private sector is exemplified by Rotterdam’s Dakpark, a rooftop park incorporated into a dyke in the Netherlands. The resilience redevelopment project funded by the European Union involved a 15-year process of design and construction with business owners, residents, the Municipality of Rotterdam, property developers, and experts. Today, the 1.2-kilometre-long public park, which acts as a multifunctional flood defence, is a boon to business and the community. Those benefiting from the park chip in to sustain its success — local volunteers maintain and programme the park, as well as manage a neighbourhood garden, while privately owned shops below the park fund its maintenance.



Dakpark integrates community facilities into a dyke. *Photo courtesy of Frans Schouwenbur licensed under CC BY-NC 2.0.*



Conceptual drawings only. Design subject to further review & approval

THE RESILIENCE DIVIDEND AND THE VALUE OF NATURE-BASED SOLUTIONS

A city's liveability is enhanced when co-benefits of resilience projects are enjoyed by residents. In the United States, Hunter's Point South Park in Queens, New York City, is a multi-agency project including infrastructure, roadway improvements, and seven residential buildings of 5,000 new units, 60 percent of which are affordable for a cross section of low- to middle-income families. Notably, the waterfront park incorporates nature-based solutions — such as bioswales and marshlands — that not only serve as a natural form of stormwater absorption during flood events and storm surges, but also deliver recreational value through a public walkway that doubles as a scenic lookout.

Visitors stroll along a lower revetment trail that enjoys a unique dialogue between habitat marsh, the river, and the skyline. *Photo courtesy of SWA/BALSLEY and WEISS/MANFREDI.*



Link mitigation and adaptation to achieve economic, social, and environmental co-benefits

In many nations, climate change mitigation measures (i.e., reducing carbon emissions) are more widely recognised, whereas adaptation strategies (i.e., preparing for climate impacts) are off to a slower start. To help streamline efforts, cities might structure initiatives to address mitigation and adaptation in tandem, allowing stakeholders to piggy-back on existing mitigation programmes to simultaneously implement adaptive measures, instead of navigating multiple programmes. Bundling resilience into a holistic many-in-one programme of sustainability, carbon mitigation, and behavioural change could realise a few synergistic outcomes together, where cost is minimised and impact amplified. (For more information on how the real estate sector and city governments can collaborate on mitigation action, see the ULI report, *Decarbonizing the Built Environment: 10 Principles for Climate Mitigation Policies*).

- The World Bank-backed Kenya Agricultural Carbon Project by non-profit Vi Agroforestry leverages agroforestry to mitigate emissions and enhance adaptation and ecosystem resilience. Agroforestry is a land management system that combines trees, crops, and livestock on the same plot of land. It mitigates climate change by enhancing biomass carbon storage and regulates erosion, water, and sediment flow, simultaneously



reducing vulnerability to flooding and drought. The project has grown over 3 million indigenous trees in western Kenya; realising a range of co-benefits that enhance liveability, almost 30,000 farmers have improved food security during intense events, and agricultural yield increased by 150 percent over eight years. The farmers also receive payment for the carbon sequestered.

Offer training geared to climate resilience; nurture a 21st-century “green workforce”

Promoting climate resilience also means creating “green workforce” jobs for the future. Economies benefit from cultivating sunrise industries and providing vocational training for emerging jobs in sustainability and resilience. Retrofits will play a large part in preparing existing buildings for future challenges, requiring many more skilled workers.

- The EU-funded Train-to-NZEB (Net-Zero Energy Buildings) programme established a network of training centres (called Building Knowledge Hubs) in Bulgaria, Romania, Turkey, the Czech Republic, and Ukraine to enhance the skills of construction workers and designers and empower them to implement energy efficiency measures in building projects. It was followed by Fit-to-NZEB, focused on training for deep

energy building retrofitting where 4 new BKHS — in Ireland, Italy, Greece and Croatia — were opened. Based in the United States, the BlueGreen Alliance brings together a coalition of labour groups and environmental organisations at the nexus of good jobs and a clean-energy economy. Its Jobs21! Blueprint lists key strategies to create jobs, leverage private investment, and attract bipartisan political support.

- In 2020, the University of California, Berkeley, Center for Labor Research and Education released an influential report on expanding employment opportunities as California transitions toward a carbon-neutral future.⁸ According to the report, the state must focus on job quality, not just quantity — and the state government and industry can jointly fund training programmes that “prepare workers for careers, rather than niche programmes that train on one particular ‘green’ skill or ‘green’ technology”. Many community colleges in the United States are already expanding their offerings for “green collar” jobs.

The insurance industry might also experience growing demand for green finance and holistic assessments on climate impacts (see Principle 10: Normalise Green Finance to Fund Projects), which would mean that economists, actuarial analysts, and real estate valuers must be trained to take an interdisciplinary approach.

A community health worker uses her farm to demonstrate agroforestry practices and links them to food security and nutrition, gender and women's empowerment, and economic security. *Photo courtesy of Vi Agroforestry.*

II. EMPOWER

Empowering a variety of stakeholders to join in and support one another in the work of climate resilience through data, information, and knowledge sharing; equitable and inclusive processes; and a common narrative

Resilient cities encourage interaction among stakeholders while building their capacity to contribute. How can different stakeholders be identified and rallied to the cause of building climate resilience? How can it be easier for organisations and individuals from the private sector, government, and civil society to participate? The next three principles address how a city can activate and empower a much broader, and more inclusive and diverse, range of stakeholders.

Catalyst Miami's 10-week CLEAR programme trains community members in resilience advocacy, building local empowerment. *Photo courtesy of Catalyst Miami.*



PRINCIPLE 4: PROVIDE TRANSPARENCY THROUGH DATA AND KNOWLEDGE SHARING

In an enabling ecosystem, stakeholders make informed decisions based on scientific understanding, which requires access to raw data, metadata, and paradata. Relevant data sets that can be shared and analysed include climate projections and impact estimates, infrastructure plans, and socioeconomic indicators. The government is an important source and custodian of data that informs and empowers individuals, businesses, non-profit groups, and scientific consortia in climate resilience planning. Transparency also boosts accountability by allowing for checks-and-balances. At all times, data integrity — including completeness, accuracy, consistency, security, validity, and reliability — must be preserved.



ACTION STEPS

Encourage data sharing to enhance risk assessment and development of climate strategies

Data is key to understanding how climate change will impact our cities, communities and lives. As more sophisticated data is increasingly available to analyze climate change trends, data owners, such as governments, the private sector, and research institutions, can do more to publicly share infrastructural and climate data for joint fact-finding. Cities can then centre their resilience policy work on climate data, and make investments in infrastructure and future housing and development decisions accordingly.

- Scientific experts with the New York City Panel on Climate Change are able to generate their own or make use of other public datasets to deliver reports that allow businesses and the city to make better risk assessments and recommendations which then power policymaking.
- The Open Data Institute supports data sharing by working with companies and governments to build an open, trustworthy data ecosystem in which people can make better decisions using data and manage any harmful impacts. Similarly, the UK's Icebreaker One convenes private- and public-sector leaders to develop data infrastructure, unlock standards-based marketplaces, and reduce friction for data at scale. NYC Open Data is another example of an open data platform on which citywide data sets are made available to all.

Develop a programme or platform to consolidate, organise, and share high-quality data

Consolidating the best data for decision-making is a key role in resilience that can be played by organisations with the capability to host and

The Open Data Institute Summit gathers people from all over the world to discuss how the power of data can be harnessed in a changing world. *Photo courtesy of Paul Clarke licensed under CC BY-SA 2.0.*

SHARING BUILDING OPERATIONS DATA

Sharing operational performance and building management data can help private-sector players see a more complete picture of the impact of sustainability strategies and how they can contribute to building climate resilience. It also enables benchmarking on energy and carbon use across different industries, land use and building types (e.g., commercial, retail, civic facilities, and residences), and household typologies.

In the United States, large commercial buildings have worked with the government to publicly disclose energy use for benchmarking in over 30 cities, often through the Environmental Protection Agency's Energy Star Program. These data are useful inputs for building efficiency modelling and for making comparisons between like buildings. Similarly, the ULI Greenprint Center for Building Performance manages a coalition of real estate owners and managers dedicated to reducing carbon emissions and energy use that facilitates benchmarking and data sharing among member companies.

New York City's Climate Mobilization Act includes Local Law 95, which mandates energy reporting for buildings larger than 25,000 square feet, and eventually requires them to post "letter grades" of their energy use intensity. Building owners may be motivated to improve operations to respond to consumer demand for sustainability and keep up with their peers. Under Local Law 97, by 2024, these buildings will be required to meet annual greenhouse gas limits.

Beyond building operations and maintenance, it is becoming more common to monitor carbon emissions and resource use throughout a building's entire life cycle, from construction to demolition, a concept known as embodied carbon (See Principle 2: Work across Space, Time, and Organisations).

disseminate data for public use. In some contexts, this may be a local university, and in others a non-profit or even a city government department. A one-stop repository can be managed by a dedicated team that streamlines access to information traditionally held by multiple departments, research institutes, and public archives like Datadryad. These data managers can identify, consolidate, and clean key data sets and ensure that they are compatible for stitching and layering, while working with end-users to understand priorities for future data acquisition.

- In the United States, the San Francisco Open Data platform (DataSF), coordinated by the city's chief data officer, standardises and streamlines data sets for specific uses to "empower the use of data in decision-making and service delivery." In the publishing process, it helps city departments with data transformations, automation services, and handling of sensitive or protected data.

Implement safeguards to prevent data misuse and mitigate unintended effects

Data must always be protected — to address concerns over security and privacy, including breaches of personal data, misuse, and cyber espionage or terrorism. Additionally, publicising data related to climate risk assessments can shift responsibility for addressing risks onto homeowners for problems they may not have created and cannot solve on their own. For many, the family home is their largest investment; declines in home values based on exposure to climate impacts can feel devastating. Therefore, risk disclosure must be coupled with government support for resilience-building. This may include financial incentives; flood insurance; or technical assistance for retrofits through programmes like FloodHelp NY. Safeguards such as home buyouts or other assisted relocation measures may be considered as a last resort.

Sharpen data resolution for local applications and responses

The best data is up-to-date, detailed, and specific. Ideally, publicly available data on flood exposure and risks should be updated frequently and be of sufficient granularity to encourage planning and design down to regional,

neighbourhood, and zip-code levels. In many locations in the United States, residents can search for their exposure to flood risks using the Federal Emergency Management Agency (FEMA) flood maps. However, updates to the maps are irregular; some localities have not seen updates in several decades. Residents in regions with outdated flood maps may not be aware of or able to respond to current flood risks.

Data on energy and resilience retrofits is a key area of interest in New York City, where buildings account for 67 percent of emissions. Complicating this is the issue of an ageing building stock, which has a median age of 53 years, and which has designs that may not be adequate to withstand and adapting to worsening climate impacts. Hence, existing buildings, not only new developments, have to improve their resilience.⁹ Because risk varies with building typology, microclimates, and location, fine-grained risk assessment data can help property owners understand, and respond to, their specific vulnerability (See Principle 2: Work across Space, Time, and Organisations).

- For example, the non-profit First Street Foundation tries to bridge this gap by quantifying and updating total flood risks for individual properties. Fine-grained data for each property is most useful, but analysing below the zip code level requires resources and expertise.

Diversify modes of data and information sharing; make them truly accessible to laypersons

Many ways exist to share data even more widely and easily. Key data owners can make data available for climate planning by the private sector and the community.

- In Rotterdam, the Netherlands, extreme rainfall events are analysed and used to calculate flood risk using hydrodynamic models. Through the Rotterdam BlueLabel, risk labels that are easily understood (grade A to E) on individual buildings, streets, and infrastructure enhance residents' awareness of their exposure to floods. Detailed information down to the square metre is made easy to understand through visualisation, allowing residents to take protective measures on their properties.

Information on climate events and updates can also be disseminated quickly through real-time texts and social media. For instance, Singapore shares its rain and flood risk information via Twitter, and the public can subscribe to announcements via text message. Likewise, insurance companies communicate with clients through social media and text messages, tracking storms and sharing information on the claims process.



BlueLabel flood risk map that identifies infrastructure at risk of flooding. Photo courtesy of the Rotterdam Office of Climate Adaptation.

PRINCIPLE 5: STRIVE FOR EQUITY, ACCESS, AND INCLUSION

Climate change will have the greatest impact on low-income and historically marginalised communities, who have the fewest financial resources to respond to and recover from disruptive events. Governments, planners, investors and businesses must recognise this disparate impact, and understand that different segments of society have varying vulnerabilities and capacities to respond. For example, heat waves and seasonal flooding usually have disproportionate impacts on minority communities, as a result of historically discriminatory land use and lending and investment policies. The COVID-19 pandemic has reinforced the need to consider equity as

disadvantaged communities are often hardest hit and may lack the resources to recover.

When solutions are being scoped, residents of all backgrounds should be given the opportunity to meaningfully voice their needs, hopes, and aspirations. Only then can resilience plans respond to their interests, not only the priorities of the most powerful or best connected. Diverse communities should be provided the tools and information needed to help drive the resilience-building process.

The public engagement for Calgary's West Eau Claire Park involved a variety of stakeholders — residents, park users, adjacent property owners and businesses — through diverse engagement methods including open houses and workshops, online surveys and map tools, and on-site interviews and sounding boards. *Photo courtesy of Klassen Photography.*



SOCIAL INCLUSION IS CRITICAL FOR RESILIENCE

Ensuring that all members of society are provided for and can benefit from protective measures is a key goal of government; yet in many cities, affluent citizens have more resources to amplify their voices. A traditional cost-benefit approach is to locate resilience solutions where property values are highest, which can prioritise wealthy and “economically productive” areas over less affluent neighbourhoods. This further disadvantages vulnerable, less well-resourced populations whose circumstances make them more predisposed to adverse impacts.

Vulnerable segments of society are affected by climate change in various ways. Elderly residents may be more susceptible to heat stress, while lower-income households tend to live in hotter neighbourhoods and sometimes have limited access to air conditioning or cooler public green spaces. Planners should also recognise and alleviate detrimental impacts such as displacement and gentrification that can arise as unintended consequences of adaptation strategies. Tools could include equitable housing strategies and alternative financing approaches, such as community land banks, that can be incorporated into climate adaptation plans.

Inclusion is about increasing everyone's ability to make choices. The lens of equity is crucial in adjusting the priorities of adaptation to ensure that all city residents can enjoy a resilient future. Additionally, some communities deemed vulnerable may also have creative methods of adapting to adverse conditions which everyone can learn from. Resilience strategies should ensure both distributive justice — in which communities, especially the marginalised, are fairly allocated the material benefits of resilience — and procedural justice, in which marginalised communities are included in political processes to correct historical exclusion and ensure representation.

ACTION STEPS

Empower diverse groups to join in decision-making: co-develop solutions

The best solutions are developed together with those most affected. For example, when local governments or planning organisations conduct community engagement, they should serve as facilitators working with community members to understand and help articulate the community's needs rather than imposing outside perspectives of what is needed. This enables creating ground-up solutions that meet specific local needs, as opposed to nudging the community to agree to prescriptive actions. As Amy Chester of Rebuild by Design has observed: “The city is the expert in governing, but the community is the expert in living in that neighbourhood.” It is important to note that issues that communities bring to the table may not always focus on mitigating physical risk, but rather on the underlying inequities that create vulnerability.



Scale It Up: Bridgeport involved a youth design workshop (above) at which students reimaged future scenarios for the Pequonnock River in Bridgeport, Connecticut. The workshop began with a bicycle tour of the River (below) to highlight opportunities for redesign. *Photo courtesy of Rebuild by Design.*



A wildfire preparation community event where residents learn about fire prevention and safety as well as participate in activities such as forest clean-ups.. Photo courtesy of State Farm licensed under CC BY 2.0.

- In Thailand, the Bangkok Homeless Network designed and built its own homeless shelter in the Taling Chan District, with support from the Baan Mankong Program, Community Organizations Development Institute (CODI), and others. This project represents a new co-production strategy to address homelessness in which the government provides the land and finances the construction, while people experiencing homelessness design and run the shelter according to their needs. Similar co-production approaches can be adopted in developing climate solutions and encouraging community ownership in building resilience.

Amplify voices that can communicate the community's assets, aspirations, and challenges

Inclusion is best achieved when all communities have effective voices in decision-making processes. In addition to direct public outreach, stakeholders can also identify and partner with organisations and individuals in the community and position them in roles with meaningful influence. For example, real estate developers can designate a community partner or local champion for a development project, with these roles extending beyond the consultation process.

- In its request for proposals for vacant land in East Harlem, the New York City Department of Housing Preservation & Development required a community organisation to be co-owner and co-developer. Sendero Verde, the 100 percent affordable housing project that resulted, includes developers L+M Development Partners, Jonathan Rose Companies, and the community organisation Acacia Network.

Provide fairer access to information, tools, resources

Knowledge experts and resource owners can make information and other tools more accessible to those who lack adequate resources or understanding of the issues.

- For example, New York City's Retrofit Accelerator provides free, one-on-one advice and services to enable building owners to develop energy-efficient solutions tailored to their particular needs and capabilities. To further encourage access to these resources, materials should be translated into relevant languages spoken locally, or communicated by advocates fluent in those languages, in order to share such information with their communities.

Better access to tools and resources can foster community-driven projects that benefit society more broadly.

- The National Fire Prevention Association (NFPA) in the United States runs a National Firewise Communities Program USA that encourages homeowners to reduce their wildfire risk with the help of toolkits. It also supports residents working together to adapt their neighbourhoods and strengthen emergency response skills with firefighters and paramedics. NFPA has differentiated outreach strategies that vary across age groups, from Sparky the Fire Dog for children to Wildfire Risk Reduction Community Service Projects for teenagers.

Some insurers have been proactive in sharing climate risk-related information and resources.

- In Japan, the University of Tokyo, Shibaura Institute of Technology, and MS&AD Insurance Group undertook a study to map out flood frequency predictions throughout Asia. The model was released to the public to promote adaptation, natural disaster response, and social resilience to flooding. MS&AD also provides training on how to use the data. Similarly, Folksam, a major Swedish insurance company, offers online guidance to homeowners in general, not just its clients, on how to climate-proof their properties.

Conduct equity analyses for just allocations of funds and investment

Resources for climate adaptation should be distributed carefully and fairly to support households and communities which stand to lose the most from climate change. Discrepancies may emerge among where funds are available, where there is inherent physical risk, and where there is low capacity to respond. Besides targeting aid based on geography and economic value, stakeholders should find strategies to apportion resources according to the financial, social, organisational, and physical capacities of recipients.

- In the United States, the city of Pittsburgh, Pennsylvania, investigates structural and systemic factors in allocating resources to reduce inequality. Its Equity Indicators are a set of 80 measures that report disparities by race, gender, and income in four domains: 1) health, food, and safety; 2) education, workforce development, and entrepreneurship; 3) housing, transportation, infrastructure, and environment; and 4) civic engagement and communications. Similar indicators could be incorporated into city resilience planning.

Besides targeting aid based on geography and economic value, stakeholders should find strategies to apportion resources according to the financial, social, organisational, and physical capacities of recipients.

Reduce structural disadvantages for some businesses; broaden access to opportunities for all

The impacts of climate change and the capacity to respond are not the same across all businesses. Some types of businesses may find it inherently costlier to adapt, while others may not have access to capital or know-how. Resources that are welcome include guidebooks and toolkits; lists of affordable building improvement measures; and even grants, low-interest rate loans, or technical assistance.

- As an example of how these barriers can be overcome, the Floodwater Management Grant Assistance Program under San Francisco Public Utilities Commission's RainReadySF initiative provides grants to eligible homeowners, small businesses, and non-profit organisations and includes full coverage for those facing financial hardship.

The private sector can also contribute to levelling the playing field.

- Mesa, a plug-and-play building automation product developed by Sidewalk Labs, provides commercial building owners and facility managers energy automation. This affordable innovation enables improved environmental performance especially for smaller, resource-constrained building owners.

The components of Mesa kits. Photo courtesy of Sidewalk Labs.



PRINCIPLE 6: SPUR UNITED ACTION THROUGH A COMMON NARRATIVE

People collaborate better when they are inspired by shared stories. A persuasive and inclusive climate resilience narrative drives consensus, garners public support, and motivates broad participation. In an ideal ecosystem, stakeholders not only share scientific data and project decisions, but also affirm common values and ideals. A positive vision developed among government, industry, and the public (see Section 1: Envision) can motivate “whole-of-society” action by not only focusing on the risks of climate change, but also highlighting the big picture benefits of resilience, alongside local community wins. Through platforms for knowledge exchange and communication, the public has ample opportunity to be educated about the urgency of climate challenges and the array of potential solutions, as well as how they can protect their lives and properties and even contribute to the city’s efforts.



ACTION STEPS

Craft the climate narrative with adequate input from experts, the private sector, and citizens

To be effective, a city or nation’s climate narrative offers a vision rooted in science, that is reinforced by the interests of — and inputs from — city residents and the business community.

- In South Korea, citizen committees aided by expert advisers formulated a vision and decided key issues and strategies for the long-range 2030 Seoul Plan on spatial development. This was supported by institutionalised participatory planning processes and regulatory frameworks. In Cambodia, the Ministry of Environment’s Climate Change Department worked with organisations such as Oxfam and the United Nations Development Programme to conduct the country’s first climate change public survey across all demographics to inform its climate change policy and planning.

Align business plans and community projects with the city’s or organisation’s climate narrative

All corporate and civic initiatives should be consistent with overall goals.

- In Denmark, to realise Copenhagen’s climate goals (to become the world’s first carbon-neutral capital city by 2025), the city government, led by the mayor, engaged more than 200 private-sector and community stakeholders to develop 22 specific business plans and 65 separate projects. A road map outlines key city initiatives to inform stakeholders about plans for analysis, testing, and implementation.

Left

Citizens taking part in an open debate as part of Seoul’s policy-making process. *Photo courtesy of Seoul Metropolitan Government.*

Right

Mexico Beach’s Sand Palace (far right) that weathered Hurricane Michael. *Photo courtesy of Tabitha Kaylee Hawk.*

At the organisational level, companies can ensure that all business units are aligned with their own climate resilience narrative.

- In striving towards a company-wide net-zero emission target by 2050, the Walt Disney Company is exercising carbon footprint accounting across its operations through the use of a “shadow” (or internal) carbon price. The entertainment conglomerate’s theme parks and resorts must develop plans to account for, and ultimately reduce, energy and water consumption and waste generation. Disney’s climate vision trickles down to its staff, with alternative commute options and incentives offered through its Commuter Assistance Program to reduce emissions.

Highlight the urgent need to be proactive, not reactive: start with the physical reality of risks

Typically, people respond readily to calls for action only when they can clearly see how they would be personally affected.

- In Florida in the United States, Mexico Beach’s Sand Palace, built to weather disasters, withstood most of Hurricane Michael’s impacts in 2018, whereas three-quarters of the houses in the same region were lost to the storm. The standing palace illustrates risk and reminds residents of the need to go beyond complying with mandated standards and FEMA maps.



Florida suffered extensive damage from Hurricane Andrew in 1992, partly due to building codes that were inadequate for stronger storms or not evenly enforced. Although the codes were subsequently updated, they only apply to new developments; mandated standards for retrofitting existing buildings are still lacking. Across the state, 60 percent of homeowners may be without flood insurance, despite exposure to storms and rising sea levels. Stronger narratives around the need for flood insurance and retrofit initiatives may help spur greater action to proactively address these gaps before another major hurricane strikes.

In Singapore, climate change used to be a relatively abstract, distant issue, given the absence of cataclysmic climate events. Traditionally seen as a concern only of scientists and policymakers, climate change was contextualised for all residents when Prime Minister Lee Hsien Loong illustrated flood risks and the potential extent of inundation with a map during a major speech, the 2019 National Day Rally. Because residential areas are clearly at risk, there is growing awareness that climate change will affect people's daily lives.

The Historic Fourth Ward Park in Atlanta was reimagined into a sustainable green space surrounding a functional stormwater retention pond. The idea was put forth by residents, who championed for co-benefits including enhanced community life. Photo courtesy of Steve Carrell.

Communicate benefits of programmes and solutions to capture public interest

One way to foster wider interest in climate adaptation or mitigation is to centre the conversation on co-benefits, especially those that people care about. For example, residential energy retrofits offer co-benefits such as cost savings, improved air quality, and greater thermal comfort, not just greenhouse gas reductions.



●● In New York City, free retrofit and clean energy programmes such as the Retrofit Accelerator and Community Retrofit NYC focus on comfort, utility cost savings, and increasingly health. This leads to the city's growing interest in Passive House, a European energy efficiency and green concept for new construction and retrofits. Likewise, C40's Fossil Fuel Free Streets Declaration was renamed the Green and Healthy Streets Declaration to highlight the health benefits of zero-carbon transport. When the benefits are clear, the private sector in particular is incentivised to build resilience.

One way to foster wider interest in climate adaptation or mitigation is to centre the conversation on co-benefits, especially those that people care about.

Vary communication tools and channels to increase outreach and awareness

In today's segmented media landscape, many outreach channels can, and must, be used.

●● As part of climate change efforts in Cambodia, the government conducted a public survey and then rolled out a series of awareness campaigns using traditional Khmer media (TV, radio, and newspapers); translated multimedia materials (original short films, documentaries, and magazine articles); and activities (student debates, drawing contests, and exhibitions). These initiatives provided accessible and comprehensible climate policy information to different segments of the population, and established trusted emergency response channels.

III. EXECUTE

Executing resilience strategies by nurturing a culture of collaboration, delivering flexible approaches and solutions, motivating the market and spurring innovation, and normalising green finance to fund projects

With an appropriate vision and an array of empowered stakeholders coming together to build climate resilience, what are the systems and processes that should be developed to support climate action? The next four principles illustrate approaches to incubate ideas, formulate programmes, and effectively implement solutions.

PRINCIPLE 7: NURTURE A CULTURE OF COLLABORATION

To achieve collective goals, stakeholders must break out of their silos and step out of their conventional work scopes to collaborate and contribute to resilient outcomes for the city as a whole. This involves seeking integrated solutions and engaging with others to share knowledge, expertise, and resources, and co-develop best practices. To do this, they need the support of strong mechanisms that promote collaboration.

Museum Park in Miami, United States. In the redesigning of the park in 2001, a public charrette, which more than 350 people attended, helped to shape three development options. Photo courtesy of Brian Lundquist on Unsplash.



EXPLORE DIFFERENT MODELS OF COLLABORATION

The ways people collaborate may need a reset. Traditional governance may not work as efficiently in times of crisis and recovery, and may also be slow to deliver resilience at the community scale. Complementing hierarchical models of top-down national governance with more flexible, networked, multi-stakeholder models of local and metropolitan governance, can bring together a broader set of stakeholders who are empowered to develop targeted solutions.

As earlier mentioned, the Southeast Florida Regional Climate Change Compact (made up of Broward, Miami-Dade, Monroe, and Palm Beach counties) is one of the most innovative regional climate collaborations in the United States, and has inspired compacts in other regions. The four counties jointly agree on data sources and projections for climate vulnerabilities such as sea-level rise and share knowledge on resilience-building. This networked governance model promotes collaboration and reaps benefits from economies of scale by sharing common data sets and costs.

Besides regional collaboration, collaborative governance models such as business improvement districts (BIDs) or community benefit districts could also be vehicles to

tackle climate challenges. These public-private-people partnerships thrive on direct involvement of the private sector and the community to address streetscapes and the public realm. BIDs, sanctioned and sometimes funded by the city but operated independently by the private sector,¹⁰ represent the interests of businesses and stakeholders in a local area and offer a unique local ecosystem driven by self-funded mechanisms and active participants. Although resilience has not been a historic focus for BIDs, some BIDs are beginning to incorporate climate resilience within their mandate to improve the public realm. For example, the National Landing BID in Arlington, Virginia — the future host of Amazon's second headquarters in the United States — has integrated resilience as a key strategy within its vision to build neighborhood liveability and equity, including green infrastructure, stormwater management, and urban heat island mitigation as part of public realm improvements. An additional example is Sunset Park Green Resilient Improvement District (GRID), kick-started by community organisation UPROSE. GRID comprises small businesses that work together to ensure sustainable revitalisation and resilience, especially along the waterfront.



A pocket park in the National Landing BID. Photo courtesy of National Landing BID/Sam Kittner Photography.

Break organisational silos to tackle cross-cutting challenges

Silos are hard to break, but cross-cutting climate challenges can be tackled better by assembling an interdisciplinary team. Decisions and solutions developed by the team can be effectively implemented when supported by the organisation's leadership as it encourages greater intra-organisational collaboration.

- For instance, the U.S. Army Corps of Engineers brought in landscape designers to work with its engineers through the Engineering With Nature (EWN) initiative. The interdisciplinary teams were able to devise new ideas that would never have been raised in a traditional engineering process. For example, the strategic mounding of material to create Horseshoe Bend Island in Louisiana intentionally aligned natural processes in the river with engineering processes. This created new wetlands for natural habitats, recreation, and sequestered carbon, while reducing the need for ongoing dredging, resulting in more than \$12 million in savings over a three-year period.¹¹ The conventional approach would have required additional equipment and land

rights to transport dredged material over long distances.¹²

Alternatively, seconding officers to other business units or organisations increases their exposure and contribution to new priorities and approaches.

- To develop plans for Singapore's Active, Beautiful, and Clean (ABC) Waters Programme, a landscape architect from the National Parks Board was seconded to the Public Utilities Board, which is mostly staffed by engineers. This exchange of knowledge led to projects such as the redevelopment of Bishan-Ang Mo Kio Park,¹³ which now has superior flood control with the naturalisation of the concrete river channel that flows through and the use of innovative techniques such as soil bioengineering.

Beyond projects, stakeholders can continue to share cross-sectoral expertise in informal "communities of practice" within a company and with external collaborators. Internationally, organisations such as the Urban Land Institute can drive collective efforts by convening global professionals for knowledge exchange and advisory services.

The Bishan-Ang Mo Kio Park floodplain that was developed to accommodate rising levels during torrential rainfall events. Photo courtesy of Choo Ruizhi.



New York City's Brooklyn Bridge-Montgomery Coastal Resiliency project will feature flood walls and deployable flip-up barriers while improving waterfront access and gathering. Interactive scale models at engagement sessions enabled the public to understand the proposed infrastructure and give feedback. Photos courtesy of AECOM.



Allocate time and funds for public engagement, education, and co-creation of local ideas

Community engagement is crucial for fostering collaboration.

- In several projects in New Jersey and New York — such as the Brooklyn Bridge-Montgomery Coastal Resiliency Project, the South Battery Park City Resiliency Project, Rebuild by Design Meadowlands, and Rebuild by Design Hudson River Project — local governments carved out community engagement stages in their timelines, and the engineering firm AECOM's designers developed toolkits, models, and presentations to interact with the public to educate it about different types of solutions and find out preferences. Town halls and neighbourhood-specific meetings allowed the people to inform designs that addressed their needs and enhanced the public realm, while providing critical flood protection.

- In Paris, Budget Participatif is a participatory budget programme in which 5 percent (about €0.5 billion) of the city's capital budget can be used for citizen-led, ground-up initiatives.

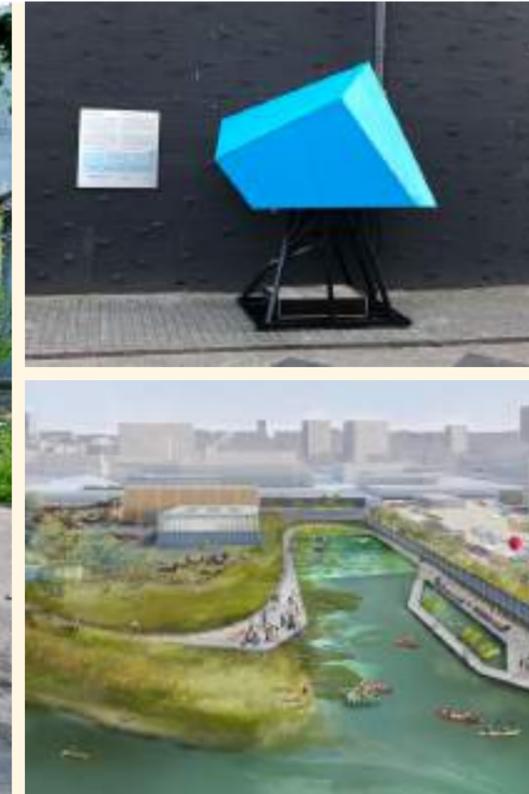


Citizens propose and vote for ideas on an online platform that facilitates exchange between the government's technical departments and the public. The “fight against all pollution” project was awarded €3 million in 2019, raising awareness regarding air and noise pollution, as well as enabling stronger citizen participation in data collection and experiments with sensors in public spaces.

- In the Netherlands, Amsterdam's Rainproof platform facilitates sharing of information, ideas, and initiatives on water management by residents, civil servants, professionals, and entrepreneurs. It then connects the relevant public- and private-sector experts with interested citizens so they can co-develop water solutions that contribute to a common goal of a “rain-proof city” through smart solutions that make the best use of increasingly heavy rainfall.

Formalise multi-stakeholder, multi-level processes

Committees with representatives from the public, government, the private sector, and academia can



The Amsterdam Rainproof projects that have been undertaken through the programme, such as the Smart Rain Barrel by Studio Bas Sala at Osdorppein (right top) and community greening along streets (left). Photos courtesy of Amsterdam Rainproof.

The Gowanus Lowlands Master Plan envisions a network of parks and open spaces that retains the area's historic character while improving neighbourhood and ecological health (bottom right). Photo courtesy of SCAPE and Gowanus Canal Conservancy.

help gather inputs and set strategic directions for a city's climate resilience plan.

- In the United States, the Boston Green Ribbon Commission, co-chaired by the mayor and an influential trustee of a community foundation, consists of business and civic leaders who advise on the city's Climate Action Plan. They make up cross-cutting working groups that deliver reports and design projects that respond to the needs of the city and suggest new projects using a data-driven, action-oriented approach.

- An innovative way to institutionalise multi-level processes is the Netherlands' national-level Delta Programme. This sets out climate change and water-related plans by engaging research institutes, industry, and civic organisations in joint fact finding and solutioning, a process known as the Dutch Diamond approach. Its annual average budget of €1.3 billion (2019–2023), called the Delta Fund, incentivises localities to propose projects aligned with the programme. Multi-level, multi-stakeholder collaboration is evident in the plans for the Frisian IJsselmeer shores. Localities such as

the province of Fryslân and municipalities of Súdwest-Fryslân and De Fryske Marren work with the central government and civic organisations like the Netherlands Society for the Protection of Birds. The government set aside €12 million from the Delta Fund, while local groups co-invested €4.9 million, to develop measures for shore protection.

Partner with local stakeholders to develop place-based projects

Partnering with local stakeholders is always more effective because of their extensive, detailed knowledge of place. Both industry and government can support place-based projects and master plans that deliberately integrate proposals from local community organisations.

- In the United States, the Gowanus Canal Conservancy — a community-based environmental steward for the Gowanus Canal in Brooklyn, New York — initiated its own master plan process, “The Gowanus Lowlands” for the neighbourhood, in collaboration with the landscape and urban design studio SCAPE and stakeholders that included



Cooper's Point in Camden, New Jersey, is a project that brought WEDG principles of resilience, ecology, and access to Camden's waterfront. Photo courtesy of Cooper's Ferry Partnership.

agency representatives from the city, including representatives from the Department of City Planning and the New York City Department of Environmental Protection.

Local stakeholders can also contribute to design toolkits.

- The Waterfront Alliance, another New York City-based non-profit organisation, developed a set of benchmarks called the Waterfront Edge Design Guidelines (WEDG) to evaluate resilience for waterfront park projects. The organisation supports engineers, designers, developers, and community members to apply WEDG in a local context. Using these guidelines, cities can improve their land use policies to be more resilient. For example, the city of Camden, New Jersey, worked with the Waterfront Alliance and Cooper's Ferry Partnership to better understand how WEDG could be used to inform new waterfront developments as well as the city's sustainability ordinance. It then produced a local guide of appropriate strategies for building at the water's edge using WEDG, for use by design and engineering professionals.

Work with universities to innovate, scale up new ideas

Universities are rich with ideas and have many willing hands to test them. Cities, companies, and universities can develop a resilience research agenda that includes science and application of solutions.

- Singaporean real estate developer CDL works with universities to run experiments and scale up useful ideas on their properties. The company collaborated with the Solar Energy Research Institute of Singapore at the National University of Singapore to use building-integrated photovoltaic technology with prefabricated pre-volumetric construction technology in a residential development. In Iceland, the government consulted with the University of Iceland on the United Nations Sustainable Development Goals (SDGs) when creating its 2030 Agenda for Sustainable Development; it also established an Icelandic Youth Council for the SDGs to allow young people to voice concerns to policymakers.

PRINCIPLE 8: EMBODY FLEXIBILITY IN APPROACHES AND SOLUTIONS

To build climate resilience, every level of decision-making should stay flexible. It is an ongoing process of adaptation, not a one-time megaproject. Stakeholders should think about the well-being of generations to come: they should address climate change with a long-term mind-set, adopting a variety of multi-functional, adaptable solutions. Incremental implementation in phases prevents “analysis paralysis” or giving up prematurely in the face of the enormity of the challenges.

Stakeholders should strive for flexibility, seeking customised solutions in which buildings and localities are approached differently — considering critical versus regular assets; sheltered versus exposed locations; new build versus redevelopment; and diverse housing and commercial typologies.

Integrated solutions, such as rainwater squares, are only possible if planning guidelines and governance structures are flexible and updated to permit their development, and residents are educated to use them safely. Photo courtesy of Rotterdam Office of Climate Adaptation.



ACTION STEPS

Adopt climate solutions in phases to make progress

Development projects can be implemented in stages to improve their effectiveness.

- Commissioned by New York City and developed by SWA/Balsley, Weiss/Manfredi, and Arup, the Hunter's Point South Park was a two-phased, multi-stakeholder effort. Planning for the project began more than 20 years ago with phase one completed in 2013 and phase two in 2018. The incremental process aimed to test the park's innovative catch-and-release approach, in which rainwater is evacuated at different speeds through a planned run-off system. As phase one neared completion in 2012, Hurricane Sandy inundated the area with four-foot storm surges. The project's resilient design allowed water to drain from the area at a pace the sewer system could handle, leaving the park intact.

- The phased implementation also presented an opportunity to gain consensus from community members, who could interact with a real-life project, and allowed the development team to see how the native ecosystems were experienced on site. The details they gleaned on materials and vegetation as well as user behaviour could inform the second phase and ultimately improve the quality of life for all. In adopting iterative processes, businesses can benefit from developing and refining frameworks to guide projects towards their goals.

Aside from specific development projects, land use stakeholders can collaborate to implement mandates in phases, allowing a period for adjustment and reducing long-term costs. This occurred in Miami when building codes underwent a progressive revamp to ensure that structures could withstand higher wind speeds after Hurricane Andrew. Through workshops with architects, engineers, builders, and real estate developers, a new building code was tested and implemented over five years so that relevant stakeholders had time to plan and adapt. The building code continues to be improved and has succeeded in reducing damages in recent disasters such as Hurricane Michael in 2018.

Innovative sustainability and resilience strategies informed the multi-disciplinary team's investigations and design decisions. Hunter's Point South Park has become an international model for coastal resilience and ecological design. *Photo courtesy of SWA/BALSLEY and WEISS/MANFREDI.*



Through workshops with architects, engineers, builders, and real estate developers, a new building code was tested and implemented over five years so that relevant stakeholders had time to plan and adapt.

Systematically encourage use of pilots before scaling up

Pilot projects demonstrate early results of what is possible, thus spurring marketplace innovation. They provide opportunities to experiment with and iterate innovative ideas for climate adaptation. They also act as proofs of concept (for estimating cost, time, resources, etc.) and more smoothly introduce non-conventional solutions to the public.



- In Asia, Dutch company FlexBase promoted floating platform initiatives using tried-and-tested materials such as reinforced styrofoam. Despite its popularity among local businesses, Flexbase's initiatives lost momentum because governments were unfamiliar with the technology. On-site pilots, with strong support from the construction sector, may help familiarise local stakeholders and decision-makers with unconventional solutions.

Private stakeholders such as developers, engineers, and building owners can also play an active role in government pilots in such ways as providing specialised design expertise or sharing building-level insights.

- In Monroe County, Florida, road elevation pilot projects in six of the most vulnerable neighbourhoods will be selected. The projects commissioned private engineers to analyse vulnerabilities through climate science modelling and to test innovative drainage solutions based on transparent design criteria. The pilots will then inform long-term road infrastructure adaptation for statewide application.

Government buildings can be a good place to initiate demonstration projects because they are not focused on immediate return on investment and can be more comfortable justifying innovation for public benefit.

- In Singapore, the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) programme pushes government office buildings to achieve higher targets in energy, water, and waste than a typical commercial building and show the feasibility of stretch targets. In the United States, the "Sustainability Base" in the NASA Ames Research Center demonstrates the possibilities of state-of-the-art energy-saving designs in a working office building.



Left
The Floating Pavilion in Rotterdam was one of FlexBase's pilot initiatives before it was scaled up. *Photo courtesy of FlexBase BV, Netherlands.*

Bottom
The exoskeleton of "Sustainability Base" provides structural protection during seismic events. Its electrical and ventilation systems, solar panels, and other passive design elements, makes the building "net-positive" for energy. *Photo courtesy of NASA.*

Use holistic performance-based guiding frameworks, instead of solely relying on fixed standards

Many building codes focus on energy consumption, but could be refined to include resilience measures and their benefits. Buildings and infrastructure benefit from both prescriptive standards and more flexible risk-informed, performance-based guidelines that incorporate provisions on sustainability and resilience. Performance-based approaches to regulations, codes, and tender requirements can give building owners and developers the flexibility to innovate and adapt over time.

- The International Code Council develops the International Codes, a set of holistic building codes based on prescriptive and performance-related requirements to ensure safe, sustainable, affordable, and resilient structures. It also lists various potential energy-resilience provisions that building codes could incorporate. These codes can be adopted by jurisdictions, and

anyone can participate in the code development process, which is renewed every three years.

Incorporate flexibility into land use and building functions

Buildings are a major part of the larger resilience ecosystem and thus must adapt over time according to climate risks and market demands. Developers should build greater flexibility into their assets to enable repositioning as climate risks evolve. In tandem, governments can allow more flexible zoning in land use to permit change of uses within buildings.

- In Singapore, “white sites” are parcels where a range of uses are permitted, giving developers flexibility to decide on the mix of uses, as long as they meet stated conditions. During the lease period, developers can respond to a changing market by updating the mix of uses. This makes projects more flexible and resilient in the long run.

Examples of energy-related resilience provisions that building codes could incorporate. Source: International Code Council.

Pre-disaster/ mitigation

Social resilience: reduce energy burden to free up financial resources for other household needs or adaptation steps

Community health: reduce air pollution-causing energy generation to lower vulnerabilities and reduce need for healthcare resources post-disaster

Urban heat island: encourage use of reflective roofing materials to reduce severity of extreme heat and reduce energy use for cooling

Disaster/ life safety

Extreme temperatures: require efficient heating or cooling systems to reduce grid strain

Impacts from hazards: encourage energy-efficient installations that enhance structural stability

Post-disaster/ recovery

On-site power generation: ensure the continued operation of critical energy facilities and encourage use of renewable energy

Passive survivability: design for energy-efficient installation like glazing and daylighting that keep buildings occupiable even if grid power is shut down

Rot, mould, and mildew: control heat, air, and moisture to enhance building durability

PRINCIPLE 9: MOTIVATE THE MARKET, SPUR INNOVATION

Markets are powerful forces for delivering change and sparking innovation. In a vibrant marketplace, stakeholders are incentivised to try novel ideas — including new designs, development concepts, or procurement models — that improve resilience. Through pilot projects, grants, incentives, and new forms of partnership, effective solutions are identified, implemented, and translated across different scales. A motivated real estate sector responds to and grows new consumer demand for climate innovation, which drives other stakeholders to pursue improved solutions. Sustainability retrofit programmes are also tapped to simultaneously motivate retrofits for resilience.

ACTION STEPS

Highlight costs of inaction, in contrast with benefits and opportunities of climate solutions

Comprehensive studies that link the priorities of businesses to investment in resilient infrastructure or development approaches can demonstrate the value of climate resilience and stimulate private-sector action.

- In the United States, several localities in Greater Miami, Florida, conduct triple-bottom-line (financial, social, and environmental) economic analyses to assess the potential implications of adaptation solutions, such as the Living Shoreline Demonstration Project. This project considered the cost of three scenarios: inaction, building a seven-foot seawall, and building a seven-foot seawall with a living shoreline. The economic assessments provided holistic projected returns on investments, including construction costs, and averted damages from a 10-year event, capturing greater buy-in from private partners.

Studies like this can also look beyond the potential for damages and avoided losses from a climate event in the absence of investment, to also understand potential impacts on tax dollars, jobs, property value and the regional economy.

Designed by architecture firm WOHA, Kampung Admiralty in Singapore is an integrated community hub that incorporates several sustainability features such as extensive roofscape, community gardens, solar panels, and a rainwater harvesting system. Photo courtesy of Patrick Bingham-Hall.



Lower financial barriers to encourage innovation and increase participation

Governments, economic blocs, and multi-development banks can catalyse businesses to innovate by offering grants and loans where barriers to participation are high.

- For instance, the EU rolled out the €10 billion Innovation Fund in 2019 to support businesses in their development of low-carbon technologies, such as carbon capture and geological storage (CCS), which has great potential for climate mitigation but high costs for research and development.¹⁴ The fund will support up to 60 percent of the additional capital and operational costs linked to innovation and is flexibly disbursed according to market conditions, project needs, and milestones achieved during the project's lifetime. Private investment can be mobilised to fill in funding gaps.

Besides drawing on external sources of funding, the private sector can band together and pool resources to co-develop innovative solutions.

- What Design Can Do, an international platform of design experts and investors, holds global design challenges for fresh solutions that address the world's pressing issues. In 2017, its Climate Action Challenge encouraged bold ideas that combat the impacts of climate change. Winning projects underwent a six-phase process in which the idea, with support from a shared award package of €900,000, was translated into a prototype, product, then business case via networks of partners such as the IKEA Foundation and Autodesk Foundation.

Design mechanisms, policies, and incentives aligned with business goals

Given businesses' typical focus on corporate goals, government-led mechanisms, policies, and incentives that align with a commercial mind-set are more likely to bring the private sector on board.

- In Europe, Energiesprong is a retrofit approach that refurbishes homes to net-zero-energy properties based on innovative new-build standards and funding. The retrofits are financed by future energy cost savings and the budget for

planned maintenance and repairs over 30 years. This mechanism allows residents to maintain their cost of living while construction companies benefit from redirected funds. Amendments to the legislation (e.g., to allow the conversion of monthly energy bills to service fees for housing associations) are carried out in collaboration with independent market development teams, policymakers, and banks in order to create and scale viable financing pathways.

- Countries like South Korea and U.S. states like California have implemented carbon cap-and-trade schemes that allocate emissions permits to businesses. If businesses exceed their limits, they must buy additional allowances. Other jurisdictions, like Singapore, have pursued a carbon tax. These market-based systems drive demand for more sustainable buildings and operations while revenues from the scheme can be reinvested in green growth initiatives and other resilience measures.

Identifying and removing institutional barriers can also lead to a more enabling environment



for businesses that wish to pursue resilience. To level the playing field between developers, resilience could be factored into tender prices for land, either as a penalty for projects without resilience measures or as a bonus for firms that include them. It could also be included in design criteria in a two-envelope bid (where design and price are separately evaluated). The bid process could be structured to include longer lead times to encourage resilient designs and avoid penalising companies that devote resources to this effort.

As new climate-relevant needs emerge, land tenders will evolve. Bidders — especially those who are less competitive due to resource limits — could benefit from more flexible timelines and greater clarity of requirements for resilience during the design and planning phases.

Non-monetary incentives for resilient design can also manifest as building density bonuses, expedited approval processes (time savings), and recognition and awards (reputational benefits) that translate into bottom-line benefits.

Mainstream resilience into development projects through competitions, partnerships

Design competitions run by partnerships among government, NGOs, and the private sector are another useful tool for spurring new, innovative thinking for resilience.

- C40's "Reinventing Cities" programme is a competition that seeks carbon-neutral and resilient urban regeneration projects from multi-disciplinary teams. Under this programme, Singapore's Bukit Timah Fire Station, a heritage site, will be identified and redeveloped in accordance with C40's low-carbon and resilient planning parameters. In the United States, after Hurricane Sandy, the Rebuild by Design competition fostered innovation for rebuilding proposals and also encouraged cross-sector collaboration and extensive community engagement in identifying design solutions. Later, the federal government adapted this model on a national scale with the National Disaster Resilience Competition, led by the U.S. Department of Housing and Urban Development.

Public-private partnerships (PPPs) can also stimulate private investment for resilient projects.

- Sendai Airport is Japan's first state-owned airport built, and currently operated, by Sendai International Airport Co. Ltd. (a consortium led by Tokyu Group). Central to its development was the need to future-proof against earthquakes, floods, and tsunamis following the 2011 Sendai earthquake disaster. In addition to aligning with updated and localised seismic design guidelines, the project built the adjacent Sendai Bay dykes, an inland barrier of manmade hills and raised roadways to further defend the airport.

To maximise PPP potential, the World Bank Group, International Finance Corporation, and PPIAF recommended using the whole asset/lifespan approach to assess structures for sharing risk, cost, and profits. This holds parties accountable for the infrastructure's long-term resilience.

Component suppliers and solution integrators who want to enter the net zero-energy market can visit the Flat van de Toekomst in Utrecht, Netherlands, to learn best practices. Photo courtesy of Ilse Wolf Fotografie and Energiesprong International.

PRINCIPLE 10: NORMALISE GREEN FINANCE TO FUND PROJECTS

More can be done to make green finance an industry norm. Recognising both social and financial costs of inaction, dedicated funds and resources can be mobilised to scale up resilience measures. Funding sources that capture and share value — such as property assessments, sustainability-linked loans, green bonds, and revolving loan funds — must be safeguarded from greenwashing. They make up a carefully designed green finance system that factors resilience into investor returns, thereby reinforcing environmentally sensitive choices and spurring other climate strategies. In the long run, projects that are truly green and contribute to resilience become part of the new normal of climate resilience.

Refinanced by Hong Kong's first green loan, K11 ATELIER King's Road by New World Development is a mixed-use office complex that has since utilised HK\$2.5 billion of the loan with discounted interest rates. It sports over 70 sustainability features such as a facade-integrated solar energy generation system, which are complemented by outreach to tenants on sustainability practices. *Photo courtesy of New World Development.*



ACTION STEPS

Nudge investors, businesses towards green finance through market levers and mechanisms

The government and the financial sector can work together to develop more favourable conditions for the growth of green finance, including setting preferential interest rates for genuinely sustainable projects. These conditions signal that building sustainably lowers long-term risk and should allow access to better rates.

- For instance, Dutch banking corporation ING Group lowers interest rates for green projects and raises rates for projects that do not adhere to green principles. Other stakeholders, such as a company's investment committee, can create an internal business environment that favours green finance by scoring green projects higher in investment rubrics.

More important, risk-adjusted returns need to be reflected in investments, primary loans, and financial activities. In the Netherlands, banks can increase mortgage interest rates for flood-vulnerable developments that have yet to be retrofitted, compelling adherence to resilience best practices. A green mandate led by forward-looking investors, shareholders, and consumers presents a strong business case for banks to reflect climate risks accurately. North America and Europe are already driving investors' interests towards sustainability and resilience. Subsequent interest rate signals could bring along the rest of the market.

Large, influential, or government-linked institutional investors can lead their peers to build green investment portfolios and enhance environmental, social, and governance (ESG) transparency in investment decisions. Investors can establish "green pockets" (i.e., budgets that are used to fund only green projects) to shift significant equity allocations to green funds, companies, and low-carbon indices.

- For example, the Scottish government developed a £3 billion Green Investment Portfolio for large-scale projects that aim to

reduce emissions. Over a three-year period, it seeks to match investable public and private projects with adequate capital flow through pitches, for which 85 percent of funding will come from the private sector.

To identify a pipeline of viable projects that mobilise multiple types of funding, cities can use technical assistance programmes such as the City Resilience Program by the World Bank and the Global Facility for Disaster Reduction. The availability of such programmes calls on the private sector to respond with bankable projects that have clear green benefits.

Companies may also consider creating a green revolving fund (GRF) to finance internal resilience improvements. Cost savings from sustainability-related projects are used to replenish the funds for the next round of green investment, thereby establishing a sustainable funding cycle, in which operating costs and environmental impacts are reduced.

- In the United States, the University of Vermont's Energy Revolving Fund was seeded with US\$13 million from the university's cash reserve fund. Cash reserve funds are available for energy efficiency projects, but projects must pay back 5 percent interest on outstanding loans annually, in addition to principal repayments, to qualify. The funds must be repaid within seven years of project completion.¹⁵

Participate in industry climate reporting and carbon disclosure initiatives

Disclosure is another important element of sustainable green finance because it enables review of environmental performance and benchmarking against other firms. Businesses, as well as government activities, may eventually shift from voluntary to mandatory reporting on physical climate risks based on common standards. In a January 2020 open letter to CEOs, U.S. investment management corporation Blackrock called for a common standard in ESG-related disclosures, endorsing industry-specific standards developed by the Sustainability Accounting Standards Board (SASB) and the climate-specific framework developed by the Task Force on Climate-related Financial Disclosures (TCFD). ESG reporting framework GRESB has also recently

adopted a Resilience Module. The financial sector should build on the critical mass of these influential drivers.

Central banks and asset owners can play a bigger role in the move towards sustainable investing and disclosure for projects and portfolios.

- Japan's Government Pension Investment Fund (GPIF), the world's largest pension fund, has made a public commitment to require all asset managers to include ESG factors in their investment analyses and decision making. GPIF has also conducted a TCFD analysis of its investment portfolio.

Community demand is a possible accelerator for open reporting on ESG and resilience, as seen in climate mitigation.

- With commuters calling for reporting on New York City's transit emissions, the STV Group uses the CDP disclosure system to measure and report environmental impacts. Governments, financial institutions, and civic organisations can leverage their networks to incentivise private-sector reporting for a company as a whole and for asset-level resilience plans.

Establish standardised parameters and green bond ratings

As green markets continue to grow, moves towards standardisation can help unite the rest of the industry. For example, globally consistent "green bond" policies — definitions, assessment criteria, and parameters — can be co-created by the government and financial sector.

- The EU Taxonomy is a unified classification system that assesses the extent of sustainability in economic activities. It considers life cycle impacts, examining not only the primary and secondary impacts of the activity, but also the upstream enabling activity, domino/spillover effects, and downstream impacts on industries and people. The EU Taxonomy will be gradually integrated into EU legislation, which could help institutions set accurate performance thresholds in alignment with others. Likewise, the EU Green Bond Standard lays the ground rules for green bonds and aligns adopters with market best practices. These EU tools are currently being

expanded and improved upon in partnership with various stakeholders as part of the EU's financial plan for sustainable growth.

To enhance commitment while minimising greenwashing, it is important to set strict interest rate-linked criteria in the loan covenant (penalties are incurred when criteria are not met) and to evaluate performances according to definite monitoring parameters and targets.

- The Loan Market Association, Asia Pacific Loan Market Association, and Loan Syndications & Trading Association published the Guidance on Green Loan Principles to reduce greenwashing in the four components of a green loan: use of proceeds; process for project evaluation and selection; proceeds management; and reporting. While not many international standards have been enforced, businesses could proactively tap such resources when structuring their green products.

Implementing effective standards would require a joint effort between the public and private sectors.

- As part of the Hong Kong Monetary Authority (HKMA) studies to develop its own green finance policies, a list of sustainable banking and green finance-related considerations from local and foreign banks is being assembled. To date, the HKMA has introduced three key measures to support and promote green finance in Hong Kong, as well as a self-assessment tool for institutions to evaluate their readiness.

Large, influential, or government-linked institutional investors can lead their peers to build green investment portfolios and enhance environmental, social, and governance (ESG) transparency in investment decisions.



Punggol Waterway in Singapore runs through a housing estate where water frontage is maximised to create opportunities for recreation. At the same time, careful design such as terraced plantings help slow down water entering the waterway.

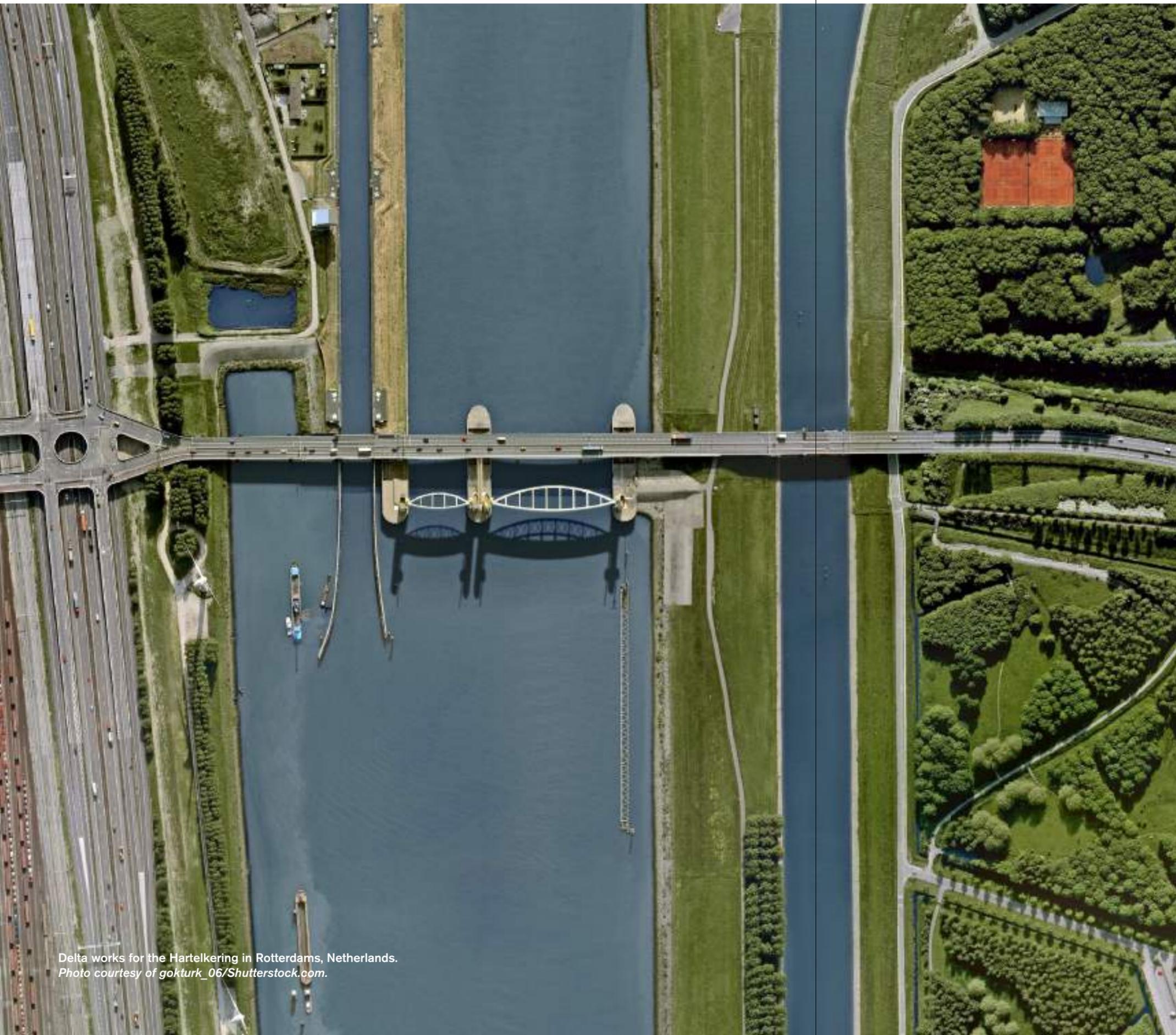
CONCLUSION

Transforming cities to become climate resilient is a whole-of-society effort. It involves strategic and inclusive top-down implementation, concerted bottom-up initiatives, and cross-sectoral collaboration to address climate change. The 10 principles enumerated in this chapter underpin a cooperative ecosystem, demonstrating the ways in which the private sector, governments, civic organisations, academic experts, and the public can work together to mobilise resources and empower each other to join in the work of resilience. Examples from around the world illustrate how local governments, businesses, and communities have begun to translate these principles into action.

The process of nurturing a resilience ecosystem must first include and appreciate the values and considerations of all key stakeholders, which can be quite diverse, or even divergent. Building up the ecosystem would entail breaking silos — thinking and working across time and space and beyond single organisations. It would mean applying resilience approaches at the neighbourhood, district, and city levels and beyond so as to maximise the many options to enhance the city's liveability. Along the way, data and knowledge, as well as resources and incentives, should be made available openly and

fairly, including to disadvantaged segments of society. A shared overall narrative would spur concerted action — everyone coming together to use an array of approaches and solutions towards a common goal. Finally, there are many market levers that can help motivate the market and spark innovation, including boosting green finance to fund more initiatives. By working holistically, in a culture of collaboration, climate resilience can eventually become the new normal.

The next chapter contains case studies of five cities — Singapore, Hong Kong, Rotterdam, New York City, and Miami — showcasing their efforts in the fight against climate change. As prominent nexuses of economic activity, these coastal cities are compelled to respond to environmental challenges that threaten their liveability — and even survival. They also hold great power and thus have the responsibility to galvanise other cities in a concerted global effort towards climate resilience. Representing multiple nations and governance systems, the five cities also showcase a range of cultural contexts and approaches for designing policy and funding for resilience. Each city profile draws on the 10 principles to suggest next steps for advancing resilience, which can also be adopted by other cities.



Delta works for the Hartelkering in Rotterdams, Netherlands.
Photo courtesy of gokturk_06/Shutterstock.com.

Chapter 4

CITY CASE STUDIES

SINGAPORE
HONG KONG
ROTTERDAM
NEW YORK
MIAMI



SINGAPORE

CITY CHARACTERISTICS

Physical

Land area:

724.2 sq km¹

Proportion and metres of land above sea level:

30% <5 m above mean sea level²

Coastline:

203 km (main island only)³

Percentage of publicly-owned land:

76.2%⁴

Annual rainfall:

2,166 mm (1981–2010 long-term mean)⁵

Green cover:

>40%⁷

From 1980 to 2016, annual rainfall rose at an average rate of 101 mm per decade⁶

Geography:

17 reservoirs (9 estuarine), almost two-thirds of the island is a water catchment⁸

Temperature (°C):

27.9°C annual mean temperature (2018)⁹

The rate of warming over Singapore from 1951 to 2012 was 0.26°C per decade, more than double the global average of 0.12°C¹⁰

Social

Population:

5.64 million (2019)¹¹

Population density:

7,804 per sq km¹²

Population proportion:

71% local, 29% foreign-born¹³

Infrastructure

Drainage infrastructure:

~8,000 km of drain, canal and river network¹⁴

Coastal defence infrastructure:

70% to 80% of the coastline is protected by hard structures. The rest are natural areas such as beaches and mangroves¹⁵

Economic

GDP:

S\$508 billion (2019)¹⁶
(US\$380 billion)

GDP per capita:

S\$88,991¹⁷
(US\$66,545)

Median household income:

S\$9,293/month¹⁸
(US\$6,949/month)

City budget for climate agendas:

An estimated S\$100 billion (~US\$70 billion) in the next 100 years, with an initial S\$5 billion (US\$3.7 billion) for the Coastal and Flood Protection Fund

Risk assessment

Temperature increase:

Between 1.4°C and 4.6°C by 2100¹⁹

Infrastructure at risk:

29 ha of flood-prone areas²³

Sea-level rise:

Up to 1 m by 2100²⁰
Up to 4 m in the rare event of simultaneous occurrence of high mean sea levels, high tide, and high surges²¹

Ageing population:

Proportion of residents ≥ 65 years old has increased from 8.8% to 14.4% (2009–2019)²⁴

Flood-prone area:

30.5 ha²²

Proportion of foreign workforce:

1.4 million, of whom ~70.1% are migrant workers who live in dormitories²⁵

CLIMATE IMPACTS AND CHALLENGES



Aerial view of Singapore's southern coastline. Photo courtesy of Svetlana Maylatova/Shutterstock.com.

As a low-lying city-state, Singapore faces an existential threat from sea-level rise caused by climate change. With natural shorelines making 20 to 30 percent of its coastline and 30 percent of its land less than five metres above mean sea level (defined at the Singapore Height Datum), Singapore is at risk of both inland and coastal flooding. In particular, places at less than four metres above sea level are at risk of flooding when sea-level rise (of one metre by 2100), high tides, and storm surges coincide. These places host key socioeconomic functions, such as the Central Business District in Singapore's South-East, and Jurong Island in the South-West, where many industries and utilities are based. Singapore's Prime Minister has explicitly announced these climate concerns at the National Day Rally 2019, signalling defence against climate impacts as a national priority.

Despite a projected increase in rainfall frequencies and volumes, droughts may also become more frequent. In 2014, Singapore experienced a record 27-day dry spell, with rainfall less than one millimetre per day. Rising temperature is also acutely felt by Singapore's residents. Singapore is warming twice as fast as the global average, at 0.26°C per decade.²⁶ Coupled with a high annual relative humidity of 83.9 percent,²⁷ thermal comfort and general liveability in Singapore may be affected. There are also knock-on effects on public health, such as greater risks of mosquito-borne diseases like dengue.²⁸

Although Singapore faces a multitude of climate change impacts, most of them, with the exception of pluvial floods, are not at a scale or magnitude where they demand immediate remedies. Singapore's



For illustration purposes only

Overview of areas with higher risk of flooding (for illustration only). Photo courtesy of Prime Minister's Office Singapore.

geophysical characteristics — equatorial location, relatively even terrain, and surrounding land masses — have given Singapore an advantage in averting climate-induced disasters like tropical cyclones and landslides.

Previously, a key challenge the Singapore government faced in building a climate-resilient city was the uncertainties in climate projections. Global- and regional-scale climate models did not provide data of adequate resolution for detailed understanding of climate change impacts on the island.

Commissioned studies and the establishment of scientific advisory groups in recent years have enabled more frequent public announcements on climate change threats and measures. However, while interest in climate change has grown, specific action has yet to be forthcoming. Of respondents to the Climate Change Public Perception Survey 2019,²⁹ 84.8 percent strongly believed that climate change is already happening and will affect future generations if nothing is done, yet only 48.3 percent of those polled knew what steps they could take to address climate change.³⁰ A possible explanation for this disconnect could be that guidance and platforms for the public and companies to contribute are still in their infancy, with the government more focused on communicating climate change impacts and consulting broader policy actions in its public engagement.

Companies in Singapore may also be reserved in taking climate actions because they do not feel the socioeconomic pinch to fully engage in

climate resilience. This is in contrast to their counterparts in Rotterdam, New York, Miami, and Hong Kong, who have experienced losses from climate-induced disasters, which were turning points for them to actively engage in climate action. In addition, concerns surrounding climate change have only recently made their way into the consciousness of Singapore's financial services industry.³¹ This explains the government's recent effort to bolster Singapore's fledgling green finance market.

The practice of these relatively newer climate change concepts — mitigation, adaptation, and resilience — can be perplexing to companies untrained in the field, as these concepts coalesce into actions that have largely been framed for environmental sustainability. As such, the distinction of climate actions (e.g., carbon mitigation through energy conservation measures versus adaptation to urban heat by incorporating greenery) in the ongoing climate change conversation has been softened. It is hoped that as the government enhances its public and stakeholder engagement on climate change impacts and solutions, more companies will have a better understanding of climate change and be compelled to go beyond existing environmental sustainability actions to enhance climate resilience.

Of respondents to the Climate Change Public Perception Survey 2019:
84.8 percent strongly believed that climate change is already happening and will affect future generations if nothing is done, yet only 48.3 percent of those polled knew what steps they could take to address climate change.

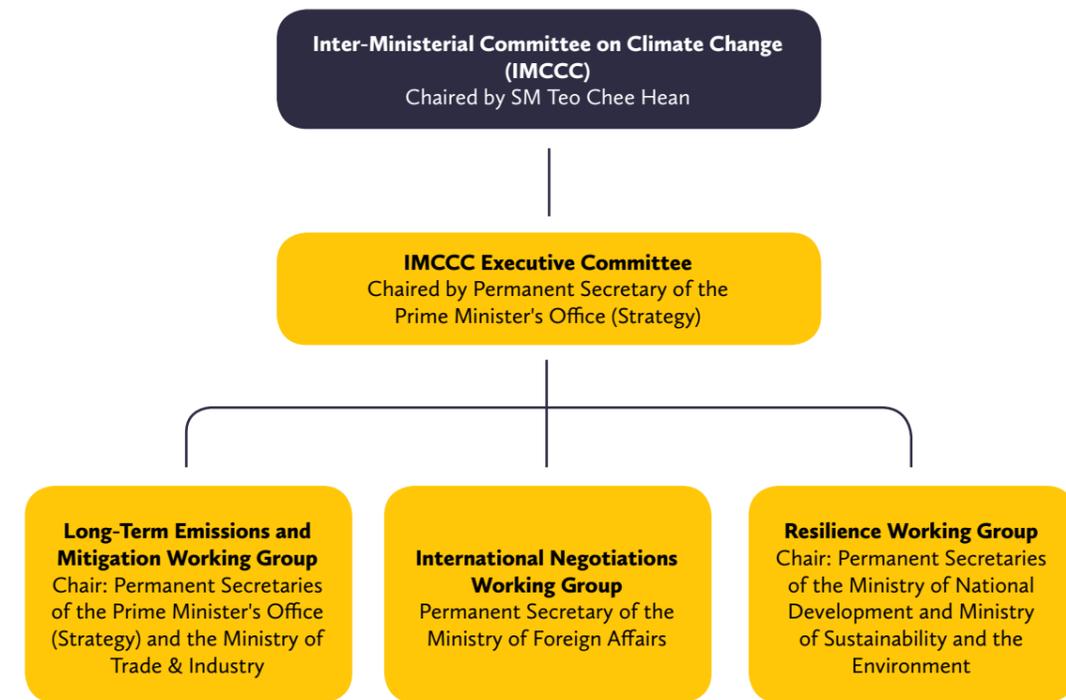
RESPONSE TO CLIMATE CHANGE

a Governance structures

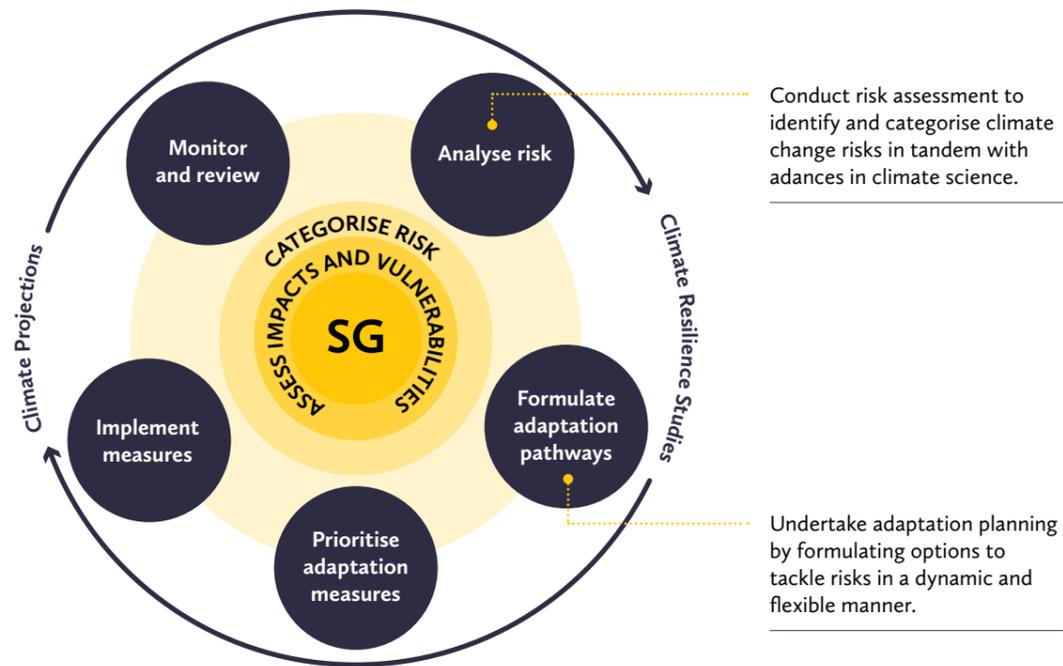
As a city-state, Singapore has only one layer of government. To institutionalise Singapore's domestic and international climate change efforts, the Inter-Ministerial Committee for Climate Change (IMCCC)³² was set up in 2007 to coordinate actions across government agencies and ministries. It consists of the Long-Term Emissions and Mitigation Working Group, the International Negotiations Working Group, and the Resilience Working Group (RWG), with the RWG studying Singapore's vulnerability to the effects of climate change and recommending long-term adaptation plans. Later in 2010, the National Climate Change Secretariat (NCCS), Secretariat to the IMCCC, was established under the Prime Minister's Office to set priorities, harmonise accounting, and strengthen strategic alignment across the government.

The Singapore government has developed a Resilience Framework³³ to guide the city's plans for climate change adaptation. The framework helps identify climate change risks to residents and property and formulate adaptation plans to minimise climate impacts. However, the framework could be expanded to integrate mitigation strategies and involve other institutions and stakeholder groups in a more inclusive and integrated manner.

Government financing covers most of Singapore's public infrastructure for climate mitigation and adaptation. The Ministry of Finance focuses on budgeting priorities while Singapore's central bank, the Monetary Authority of Singapore (MAS), serves as the nation's financial regulatory authority. The government's S\$100 billion (US\$75 billion) estimate of climate change protection measures is planned to come from several sources: ministry budgets, borrowing, and reserves. National reserves are currently drawn to fund land reclamation projects.³⁴



Organisational Structure of the Inter-Ministerial Committee for Climate Change



Building local capability on climate science

The CCRS will invest S\$10 million (US\$7.5 million) from 2019 to 2023 for the National Sea Level Research Programme. The programme funds research on sea levels around Singapore and seeks to develop more robust projections for future sea-level rise.

Coastal-specific climate change research

Singapore's first climate change study on vulnerability and long-term impacts was completed in 2009 by the National Environmental Agency (NEA).³⁵ More recently, the Coastal Adaptation Study was completed in 2017 by the Building & Construction Authority (BCA). It assessed the potential impacts of coastal inundation under possible climate change scenarios and long-term adaptation strategies, and aims to develop site-specific measures to enhance existing coastal protection.

b Government-led strategies

The government's climate change efforts are multi-pronged. They involve improving the scientific understanding of climate change impacts on Singapore, which then informs the development and implementation of both climate mitigation and adaptation strategies.

Knowledge

Besides referencing the Intergovernmental Panel on Climate Change reports, government agencies conduct and support research initiatives to strengthen the city's understanding of climate science. Launched in 2013, the Centre for Climate Research Singapore (CCRS) aims to advance scientific knowledge on tropical climate variability and change, and how associated weather systems affect Singapore and the wider Southeast Asian region. Its new Climate Science Research Programme Office will formulate Singapore's climate science research masterplan and build local capabilities.

Engagement

Public consultations through online submissions and focus-group discussions were conducted by the NCCS to gather feedback on Singapore's climate policies and create roadmaps for carbon-

intensive industries. General sessions include 2015's "Climate change and Singapore"; 2017's "Singapore's climate change strategy and carbon tax"; and 2019's "Developing Singapore's long-term low-emissions strategy". More targeted discussions and completed technology roadmaps include e-mobility, green data centres, carbon capture and storage, and solar photovoltaic power.³⁶ Encouraging public and private sectors alike to pledge for carbon reduction, the Ministry of Sustainability and the Environment designated 2018 as the "Year for Climate Action".

Adaptation

At the National Day Rally 2019, Singapore's Prime Minister highlighted that S\$100 billion (US\$75 billion) or more could be needed over the next 100 years to prepare Singapore for rising sea levels.³⁷ Government agencies have implemented on-site measures to protect the coastline and reduce flooding risks; they are also studying new initiatives.

Singapore's adaptation to inland flooding also includes water and drainage management. Helmed by PUB, Singapore's National Water Agency, the Active, Beautiful, Clean Waters Programme was launched in 2006. The programme seeks to transform Singapore's waterways and reservoirs beyond their drainage and storage functions to create environments for recreation and community bonding.³⁸ It promotes the use of natural systems to enlarge drainage capacity and absorb stormwater temporarily so that peak runoff is reduced, thus lowering flood risk during heavy storms. Certified projects such as the Bishan-Ang Mo Kio Park establish successful flood resilience on a catchment level. In managing surface runoff on a neighbourhood level, the Housing Development Board's Biophilic Town Framework advocates for nature-based, resilient landscape features in public residential developments.³⁹ At the individual development level, certain underground facilities have been retrofitted with elevated entrances and flood barriers.

To cope with intense rainfall, PUB has also implemented the "source-pathway-receptor" approach for catchment-wide solutions to achieve greater flood protection since 2012. This holistic approach introduces flexibility and adaptability to Singapore's entire drainage system, addressing



not just the drains and canals through which stormwater travels (i.e., pathway), but also areas generating stormwater runoff (i.e., source) and potential flood areas (i.e., receptor).⁴⁰

Top to bottom

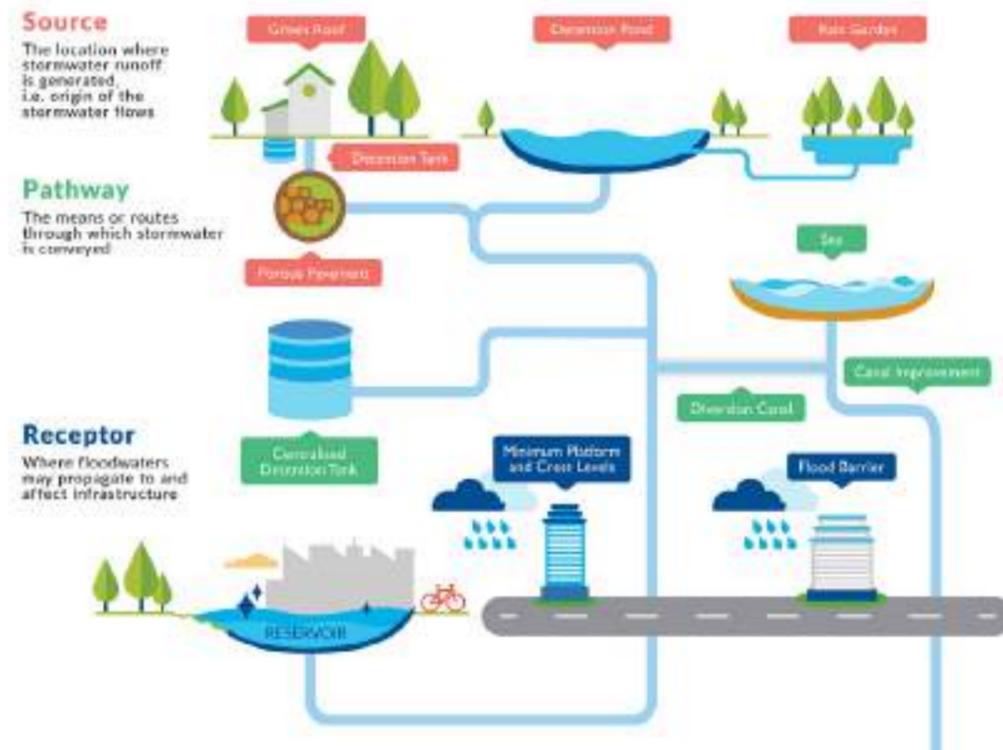
Before and after photos of the Kallang River being naturalised at the Bishan-Ang Mo Kio Park. Photos courtesy of Ramboll Studio Dreiseitl Pte Ltd.

The waterway in Bishan-Ang Mo Kio park was developed to swell during torrential rainfall events (left) and return to normal levels after (right). Photos courtesy of PUB, Singapore's National Water Agency.

Singapore's drainage network is supported by large-scale infrastructure, such as the Marina Barrage constructed in 2008. It was initially envisioned to protect low-lying areas in the city from sea tides. The Barrage now also functions as a recreational site and a freshwater reservoir, in turn enhancing community bonding and water resilience.

More intense and frequent storms brought about by climate change may still overwhelm current drainage systems, especially as areas with no history of flooding now experience flash floods.⁴¹ The flash flood in December

The “Source-pathway-receptor” approach in Singapore’s water management system.
Graphic courtesy of PUB, Singapore’s National Water Agency.



Right
The Marina Barrage.
Photo courtesy of PUB, Singapore’s National Water Agency.

2019 flooded Singapore’s western regions with 93 millimetres of precipitation recorded in an hour — about a third of the projected average rainfall for the entire month of December.⁴²

Besides flood management, Singapore combats heat by providing trees for shade as well as sheltered walkways and linkways of over 250 kilometres. Singapore has committed to planting 1 million trees by 2030 to enhance shade and biodiversity. Industrial estates, one of the hottest areas in Singapore, will get more than 100,000 trees over the next 10 years.⁴³

Carbon mitigation

Carbon tax, research into “clean fuels”, incentives to adopt electric vehicles, and the provision of charging infrastructure indicate progress towards the net-zero carbon status that is needed to prevent dangerous anthropogenic warming. Energy efficiency strategies, such as district cooling, better building design, and programmes such as the Minimum Energy Performance Standards on household and industrial appliances can minimise fossil fuel-sourced electricity generation and reduce greenhouse gas (GHG) emissions.



Given Singapore’s limited alternative energy options,⁴⁴ the city may be unable to reliably generate sufficient baseload electricity from renewable sources for its use. Nonetheless, Singapore is putting research and investment into renewable energy projects and plans to progressively phase out of internal combustion engine (ICE) vehicles towards cleaner alternatives by 2040. These can enable Singapore to reduce heat emissions from vehicles which contribute to the urban heat island effect. Studies show that EVs emit less heat than conventional ICE vehicles⁴⁵ — the operating temperature of an ICE engine is 90–100°C, but 30–40°C for EV battery powering.⁴⁶

Building resilience through coastal protection and conservation of the mangrove ecosystem

Works were undertaken to conserve and rehabilitate mangroves and arrest coastal erosion along the northern coast of the offshore island of Pulau Tekong. The main bio-engineering infrastructure is a hybrid model of a low-rock revetment interspersed with mangroves. Materials used to backfill and support fallen mangroves were contained in biodegradable sacks to ensure water quality. The project currently supports marine organisms that have colonised on the green infrastructure.



Top to bottom
Artist’s impression of Singapore’s pilot polder development at Pulau Tekong.
Photo courtesy of the Housing & Development Board.



Inside of the Stamford Detention Tank.
Photo courtesy of PUB, Singapore’s National Water Agency.

Flooding at Orchard Road in 2010. Photo courtesy of Jaschocolate licensed under CC BY-NC-ND 2.0.

Inland flooding adaptation

In 2010 and 2011, Singapore’s prime shopping belt, Orchard Road, and its surroundings experienced unprecedented flooding. To enhance the shopping belt’s flood resilience and minimise economic losses, the Stamford Detention Tank and Diversion Canal were built. Completed in 2018, the underground tank has a capacity of 15 Olympic-sized pools; excess stormwater is subsequently pumped back into the river. The project cost S\$227 million (US\$170 million).

The Carbon Pricing Act

Valid since 1 January 2019, the carbon tax is set at S\$5/tonne (US\$3.70/tonne) of GHG emissions (tCO₂e) from 2019 to 2023. The carbon tax rate will be reviewed in 2023, with plans to increase it to S\$10–15/tCO₂e (US\$7.50–11.20/tCO₂e) by 2030.

Support for the transition to EVs

Buyers of electric cars and taxis can receive rebates up to S\$20,000 (US\$15,000), from 2021 to 2024. Singapore will also expand the EV charging infrastructure significantly from 1,600 points now to 28,000 by 2030.

Regulations and incentives

The Singapore government guides the private sector's climate resilience work through regulations and incentives. Aligning with the risk of inundation for areas less than four metres above sea level, all new buildings must comply with new drainage codes. Since 2011, the minimum land reclamation level has been raised from three to four metres above mean sea level. Similarly, the PUB mandates that all new development or redevelopment projects of 0.2 hectares (0.49 acres) or more⁴⁷ implement "source" solutions such as detention tanks to slow stormwater runoff. Other requirements to reduce flood impacts include setting minimum platform and crest levels and placing flood barriers, which are specified in PUB's Code of Practice.⁴⁸ Guidelines specific to the engineering, development, and design communities are also outlined in handbooks on the best practices in the planning, development, and operations of flood-resilient developments.⁴⁹

BCA Green Mark criteria for non-residential buildings
Graphic courtesy of the Building and Construction Authority.

The government encourages developers to adopt environmentally-friendly building specifications through its BCA Green Mark Scheme. Buildings are assessed based on environmental impact and performance to promote sustainable design, construction, and operation. In 2009, the Inter-Ministerial Committee on Sustainable Development set the goal for 80 percent of Singapore's buildings' Gross Floor Area (GFA) to meet green building standards by 2030.⁵⁰ To accelerate this, the Building Control Act was changed in April 2008 to mandate Green Mark certification for both new and existing buildings undergoing major retrofits or energy use change. The scheme could potentially be expanded to include resilience criteria.

The MAS has made environmental, social, and governance (ESG) reporting mandatory on a comply or explain basis since 2017. This ensures sustainability is a criterion in companies' decision-making processes. The move has prompted



Mandates for new critical infrastructure

Project consortiums for the upcoming developments of Tuas Port and Changi Airport Terminal 5 must abide by the mandate to build 5 metres and 5.5 metres above the mean sea level respectively, respectively.^{51,52}

BCA Green Mark Scheme incentives

Higher Green Mark rating requirements have been imposed for key growth areas through Government Land Sales (GLS). To generate lead demand, the private sector is incentivized through various initiatives such as additional GFA and monetary support.

as a green finance hub. To build resilience to environmental risks, MAS will issue Environmental Risk Management guidelines across banking, insurance, and asset management sectors. The guidelines will set governance, risk management, and disclosure standards, and promote new opportunities for green investment.

In 2017, MAS introduced the Sustainable Bond Grant Scheme to catalyse the issuance of green, social, and sustainability bonds in Singapore. It is also developing a grant scheme for green and sustainability-linked loans that seeks to defray the costs incurred in developing sustainability frameworks and engaging external reviewers. In addition, Singapore launched the S\$2.9 billion (US\$2.1 billion) Green Investments Programme in November 2019, which places funds with asset managers committed to drive regional green efforts and contribute to other national green finance initiatives.

Strategies by private sector and businesses

Businesses have adopted an array of strategies to promote both environmentally-friendly practices and climate solutions. They include incorporating climate-sensitive designs in their developments, engaging in industry-university research, developing for smarter and greener living, and supporting social good innovators.

Keppel Bay Tower, which seeks to exceed the performance limits of a Green Mark Platinum building, is Singapore's first commercial development to power all its operations using renewable energy. Keppel Land is working towards achieving super-low-energy status for the development by combining new and emerging technologies such as a high-efficiency air distribution system, a cooling tower water management system, smart lighting, and intelligent building controls.

Other climate-sensitive buildings include the PARKROYAL COLLECTION Pickering, a hotel and office development which promotes natural cooling from vegetation and wind, and sensors to cut irrigation when rain is detected. These measures reduce energy consumption and combat anthropogenic heat by lowering heat waste produced from air-conditioning use.

companies to adopt established industry standards, encouraged industry-led capacity-building efforts, and developed Singapore's green investment market.

C Private-sector strategies

Opportunities for green financing

Green finance, a financial instrument dedicated to promoting environmentally-friendly and sustainable economic growth, has boomed in international markets. Singapore's foray into green finance has been cautious and calibrated.⁵³ MAS data show that just S\$6.5 billion (US\$4.9 billion) worth of green, social, and sustainability bonds have been issued, a small portion of Singapore's S\$420 billion (US\$314 billion) corporate debt market.⁵⁴

MAS launched a Green Finance Action Plan in November 2019 to move Singapore forward

Keppel Bay Tower (top) and the Parkroyal on PARKROYAL COLLECTION Pickering (bottom). Photos courtesy of Keppel Land and Patrick Bingham-Hall.



CLIMATE STRATEGIES BY CITY DEVELOPMENT LIMITED (CDL)

CDL, a Singapore-listed global real estate development company, has integrated ESG into its business strategy, targets, standards, and reporting since 1995. It is the first Singapore developer to set greenhouse gas reduction targets validated by the Science Based Targets initiative, with corporate-wide commitments that strive for low-carbon operations, climate change scenario planning, increased renewable energy use, and supply chain engagement. CDL also employs vertical gardens, sustainable construction materials, and greener construction methods such as prefabricated prefinished volumetric construction.

LESSONS LEARNT

August 2019 Singapore workshop for climate resilience with stakeholders from different sectors.



a Key insights from Singapore

During the Singapore workshop, participants discussed how things could be improved to enhance the private sector's contributions towards building a more climate-resilient Singapore.

A “systems-based approach” in tackling climate resilience

Participants agreed on the importance to view climate resilience strategies using a “systems-based” lens, where urban systems — whether geophysical, economic, or community — interact,

and at various scales. Specifically, the physical infrastructure's climate-proofing should be considered in the project development phase, the design phase, and the construction phase. Strategies should be built on cross-sectoral collaboration and integration across spatial scales (e.g., building, neighbourhood, district, city) to enhance synergy.

Constraints on business response from climate impact uncertainty

Stakeholders must be mindful of each other's constraints and different capacities to respond to climate change. Some companies shared that their uncertainty over specific impacts and inadequate comprehension of climate change projections prevent them from undertaking resilience measures. Insufficient data on climate change effects are publicly available, which also limits action.

Roadblocks for climate-sensitive designs

For most companies, resilience is not a core business activity, and many of them prefer a government mandate to drive resilience action. Most businesses in Singapore remain unconvinced of a business case to tackle climate resilience for fear of losing out to competitors who avoid upfront adaptation costs. Some companies who are willing to incorporate climate-sensitive designs into their development proposals expressed concerns about being unintentionally

disadvantaged. For instance, in the real estate development industry, developers face time and resource constraints in adopting resilient and sustainable designs during the bidding period. Such designs may entail additional capital, resources, and complexity, on top of existing land and building requirements. Mechanisms to level the playing field are needed, whether through penalising those who do not incorporate resilience, recognising the additional commitment taken to achieve resilience at the project level, pricing resilience into the two-envelope tender system, or implementing performance-based standards. Smaller businesses will look towards industry heavyweights and government directives to follow suit and initiate climate-resilient changes.

Varied financing mechanisms for climate resilience

The government provides most of Singapore's public infrastructure development and funding.⁵⁵ Private sector funding is an untapped opportunity, but financing mechanisms and safeguards must be present so that projects are bankable and offer adequate return. The public and private sectors could explore co-sharing costs and evaluating climate risks upfront, similar to how finance and insurance are shared. However, climate change risks may be difficult to project and price in.

The government has been moving towards public-private partnerships (PPPs) to finance, maintain, and operate some public infrastructure



National Stadium at the Singapore Sports Hub. Photo courtesy of Jason Goh.

like the Singapore Sports Hub, which is designed specifically to be climate sensitive, using natural lighting and a zero-carbon-impact cooling system for its stadium. However, current PPPs do not always specify climate-resilient infrastructure as a requirement.

b Evaluation of the ecosystem

At present, efforts to build a more climate-resilient Singapore have primarily been led by the government, with some participation by well-resourced companies. Given prevailing uncertainties, lack of capacity, and little impetus to initiate change, most businesses remain passive in building climate resilience.

Although the role of consumers and local community organisations has not been discussed in depth, businesses point to their importance in driving market demand. Greater user demand and willingness to pay for sustainable and climate-sensitive solutions will make a stronger business case for the private sector to venture further into building Singapore's climate resilience.

c Opportunities and way forward

Elevate communication and collaboration across and within sectors

To advance the systems-based approach and better understand the conditions that can motivate joint endeavours for climate resilience, targeted, multi-stakeholder dialogues should be facilitated frequently. Although current engagements with the public and private sector have contributed to Singapore's climate policies, concerns from some real estate development companies show that the engagements can be expanded beyond industries that are traditionally energy intensive, to include companies in other sectors. Such a model of engagement is increasingly pertinent, as the new generation of Singapore's political leaders are seeing the need to “work with the people” to design and implement policies.⁵⁶

Right

Lower Seletar Reservoir, an ABC Waters site, serves as a local catchment and provides opportunities for recreation. Photo courtesy of Derek Teo/Shutterstock.com.

Enhance norms and market conditions with industry leaders

Larger companies with the means to invest in climate resilience can lead the way by acting first, lowering the perception of risk and potentially changing industry norms. Corporations and governments could work more closely together to implement changes based on market needs and government priorities, as a way to signal smaller companies and businesses. Interventions to shift overall market conditions, change industry norms, and raise consumer expectations can include regulatory sandboxes for climate-responsive innovations.

Integrate climate resilience with sustainability

Singapore's sustainability efforts have been comprehensive, given its limitations, and therein lies the opportunity to synergise resilience with these efforts. For instance, encourage the adoption of solar panels for energy efficiency and continuity during power disruptions, and expand the Green Mark Scheme to encompass clear performance-based resilience requirements.

Spur public interest and demand

While awareness of the growing climate change threat is rising, the public's appetite to steer the climate change agenda is nascent. Other than small-scale individual actions, the public in Singapore remains relatively passive, given an over-reliance and trust in the government and lack of strong system-level signals to spur consumer demand, investments, and actions. Conditions may be changing — evidence of climate change and science is manifest, and vocal youth and environmental groups are raising awareness and trumpeting the urgency to respond to climate challenges. Stakeholders with data, such as the government, academia, and more resourceful companies, can spur climate literacy and consumer demand through data and information sharing to in turn bolster the business case for climate resilience. A holistic directive supported by the regular sharing of information on climate impacts and opportunities would be a good starting point for Singapore.





HONG KONG

CITY CHARACTERISTICS

Physical

Land area:

1,106 sq km¹
(24% urbanised land)

Proportion and metres of land above sea level:

~15% is <5 m above Hong Kong's Principal Datum²

Coastline:

456 km along the coast of the New Territories, and 722 km from 263 islands³

Public housing (as a percentage of total housing):

45.4%⁴

Annual rainfall:

2,400 mm⁵

Green cover:

443 sq km of country parks⁶

Social

Population:

7.50 million (2020)⁷

Population density:

6,940 per sq km⁸

Population proportion:

92% local, 8% foreign-born⁹

Infrastructure

Drainage infrastructure:

2,427 km of drains and about 36 pumping stations¹⁰

Economic

GDP:

HK\$2,868,171 billion (2019)¹¹
(US\$369,896 billion)

GDP per capita:

HK\$382,046¹²
(US\$49,271)

Median household income:

HK\$35,500/month¹³
(US\$4,514/month)

Real estate sector's share of GDP:

26%¹⁴

City budget for climate agendas:

No specific fund

Risk assessment

Temperature increase:¹⁵

1.3° to 2.2°C by 2051–2060

1.3 to 4.2°C by 2091–2100

Infrastructure at risk:

US\$416 billion as of 2011, rising to US \$3.5 trillion by 2070¹⁶

Sea-level rise:¹⁶

0.36 to 0.43 m by 2051–2060

0.60 to 0.98 m by 2091–2100

Infrastructure at risk:

Estimated US\$35.9 billion (2012) in assets; rising to US\$1.2 trillion by 2070¹⁹

Flood-prone area:

Five flooding blackspots of minor, small, and medium scales^{17,18}

Ageing population:

About 26% over 65 years old by 2040

All conversions of Hong Kong dollars to U.S. dollars in this case study reflect the exchange rate of the Hong Kong Monetary Authority for November 2020 (HK\$1 = US\$0.130).

CLIMATE IMPACTS AND CHALLENGES

Typhoon Mangkhut in 2018 gave a glimpse of the aggravated climate risks Hong Kong is facing when Victoria Harbour incurred damages of HK\$3.1 billion (US\$400 million) in insurance claims. Yet Hong Kong was spared the worst-case scenario; had Mangkhut been a direct hit at high tide, the sea level in Victoria Harbour would have peaked at 5.65 metres, inundating Victoria Harbour.²⁰

By 2060, Hong Kong's mean sea levels are projected to increase between 0.36 and 0.43 metres, under a Representative Concentration Pathway, or RCP 8.5 scenario.²¹ Much of Hong Kong's central business district could be hit by extreme storm tides as early as 2030, with key financial services (e.g., HKEX, HSBC, Standard Chartered) and critical infrastructure (e.g., HK Port, Hong Kong West Kowloon Station) at risk of flooding.²²

The Hong Kong Observatory (HKO) noted that more extreme weather conditions and weather patterns are expected and can complicate public health issues.²³ More frequent temperature-related illnesses, non-communicable and communicable diseases, physical injuries in extreme events, and mental health issues are expected.²⁴ Heat stress, exacerbated by Hong Kong's dense, high-rise urban conditions, asymmetrically affects vulnerable groups such as children, the elderly, and those in substandard living conditions (e.g., poor ventilation).²⁵ The government should review the carrying capacity of the city's health care system and evaluate its preparedness for such extreme events and the reallocation of health care facilities to maintain accessibility across all districts.

Natural terrain covers 60 percent (650 sq km) of Hong Kong's total land area,²⁶ and most developed



Hong Kong was lucky! Mangkhut could have caused a storm tide of 5.65 metres. Infographic courtesy of CWR.

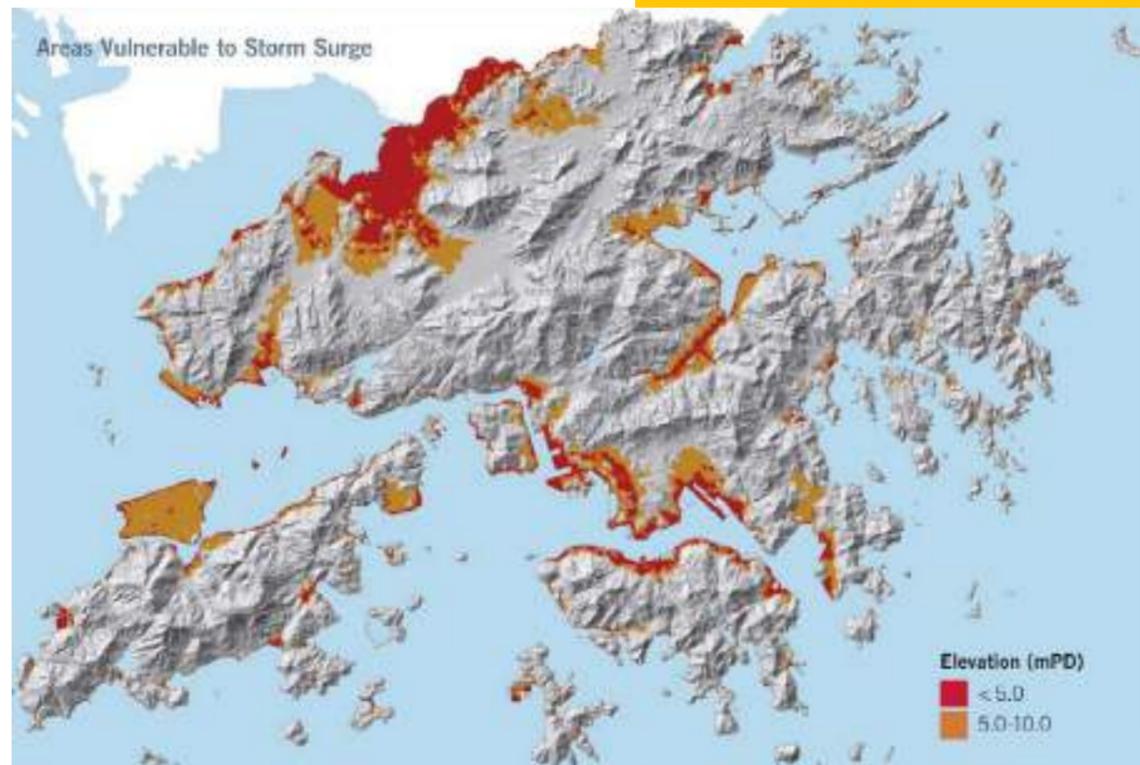
areas extend to very steep slopes. Extreme weather, flooding, and landslide occurrences are expected to increase, entailing cascading hazards across supply chains,²⁷ water security and logistical issues for developers and insurance companies. Severe disruptions to food supply²⁸ would pose a major challenge as Hong Kong imports 90 percent of its food.

The government's sparse provision of information has translated into a substantial knowledge gap in the private sector. This is a pertinent issue as the private sector operates or owns many of Hong Kong's critical assets. Despite some awareness of the risks involved, companies do not have access to the crucial information to make comprehensive risk assessments and plans. Knowing the extent of projected sea-level rise, the Hong Kong International Airport (HKIA) has constructed a 6.5-metre-tall seawall to protect its third runway. However, this can do little to support HKIA's future operations if nothing is done to protect the transport lines feeding into HKIA from flooding.³¹ Disruptions to transport would prevent the airport from operating at full capacity.

One challenge Hong Kong faces is the misaligned approaches and sporadic efforts in tackling climate change issues. These could result from insufficient communications and engagement within and across stakeholder groups. Separately, despite abundant research by the government on climate science and impacts, the public do not seem to share the same sense of urgency. A public opinion survey on People's Attitudes towards Climate Change²⁹ found that 84 percent of respondents deemed livelihood (such as economic downturn or housing) and health issues more important than climate change, although climate change can also negatively affect livelihood and health. Most respondents also agreed that climate change is a significant problem, but should only be addressed in the future.

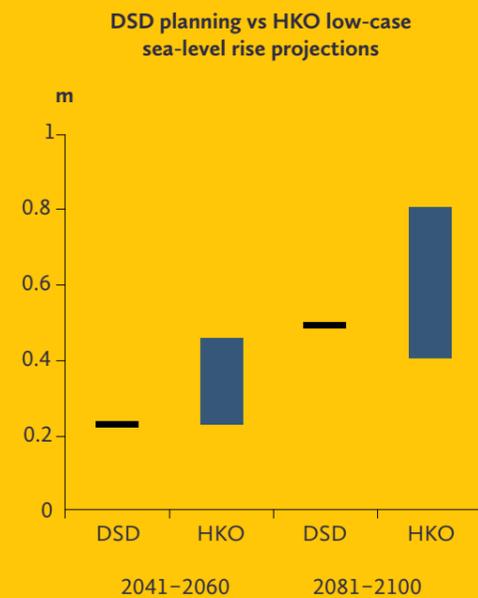
Misalignment in climate understanding and strategies is observed at the governance level, where updates

Areas vulnerable to storm surge. mPD refers to the Hong Kong Principal Datum (in metres). Map courtesy of Hong Kong Climate Change Report 2015.



to climate change projections have not spurred the development of a cohesive coastal flood management strategy. New projects are still being approved on floodplains and in high-flood-risk areas.

Although the Drainage Service Department (DSD) has thus far listed flooding blackspots and locations vulnerable to pluvial flooding during heavy rainstorms, fluvial and coastal flood risks from storm surges remain inadequately accounted for in planning. As warned by China Water Risk (CWR), DSD's current preparations are based on RCP 2.6, which falls far short of the current climate path, which is closer to RCP 8.5. CWR also highlighted that DSD uses 0.23 metre sea-level rise for future drainage and coastal adaptation; this is the low end of HKO's low-case projection of 0.23 to 0.46 metres (for 2041–2060). The discrepancy widens for 2081–2100. Using the low-end estimates of the wrong scenario for planning will result in insufficient drainage capability to handle future flood levels as the RCP 8.5 high-end estimate for sea-level rise is 1.1 metres by 2100.³⁰



CWR, DSD, and HKO. Graph courtesy of CWR.

Established by the Hong Kong Special Administrative Region (HKSAR) government in 2016, the high-level Steering Committee on Climate Change³² sets an overall direction to combat climate change. The committee issued a *Hong Kong Climate Action Plan 2030+*³³, detailing its decarbonisation target following the Paris Agreement and the corresponding adaptation needs and actions to reach these goals and build further resilience. Despite such goals, the next three years saw few efforts besides the Council for Sustainable Development's Public Engagement in 2019 regarding the city's long-term decarbonisation strategy. Given the pressing need for climate action, the HKSAR government is increasingly urged to assume a more proactive role for policy action and public education. Hong Kong's traditional policy style, which favours "positive non-interventionism",³⁴ should be revisited to promote climate change interventions from the government.

RESPONSE TO CLIMATE CHANGE

a Governance structures

The high-level Steering Committee on Climate Change, under the chairmanship of the Chief Secretary for Administration, serves to steer and coordinate the climate actions of various bureaus and departments.³⁵ The Environment Bureau (ENB) oversees emissions mitigation efforts and steers policy coordination; the Development Bureau covers adaptation efforts related to projected climate impacts and risks; and the Security Bureau handles resilience efforts to cope with and absorb climate change-related stresses and maintain the functional operation of public services, economic, and social activities. The Climate Change Working Group on Infrastructure (CCWGI) was also established to coordinate efforts among works departments to climate-proof government infrastructure.

Although the committee amalgamates all policy secretaries, there is no dedicated climate change authority to keep climate change high on the policy agenda. Departmental fragmentation may have hampered integrated policymaking on climate change issues. The ENB holds the main responsibility in taking climate action but is tasked with the difficult job of steering policy coordination across the many bureaus and departments.³⁶ The ENB alone is unable to spur quick and far-reaching changes beyond its departmental responsibilities.

Membership of the Steering Committee on Climate Change³⁷

Chairman
Chief Secretary for Administration

Members
Secretary for Commerce and Economic Development or representative
Secretary for Development or representative
Secretary for Education or representative
Secretary for the Environment or representative
Secretary for Financial Services and the Treasury or representative
Secretary for Food and Health or representative
Secretary for Home Affairs or representative
Secretary for Innovation and Technology or representative
Secretary for Security or representative
Secretary for Transport and Housing or representative
Director of Information Services or representative
Government Economist or representative
Director of Hong Kong Observatory or representative

Secretary
Assistant Director of Environmental Protection

Under the Hong Kong 2030+ blueprint, the smart, green, and resilient city strategy outlined in the framework aims to reduce carbon intensity by 65 to 70 percent from 2005 levels by 2030. A corresponding range of strategies were introduced to minimise resource use, increase climate resilience to landslides, flooding, and typhoons, and enhance overall quality of life.

b Government-led strategies

Knowledge and adaptation

Considering the rise in sea level, rainfall, and wind speed in connection with climate change, the Civil Engineering and Development Department (CEDD) and DSD, under CCWGI, updated the *Port Works Design Manual and Stormwater Drainage Manual* in January and February 2018, respectively. Other relevant works departments are also reviewing their design manuals and guidelines to account for climate change.

The transition towards nature and natural processes has also prompted the review of planning and development zones as a complete system. Studies, such as the ongoing *Drainage Master Plan Review Studies*, allow the government to identify vulnerabilities in the local drainage system to enhance local flood resilience.

Under the Hong Kong 2030+ blueprint, the smart, green, and resilient city strategy outlined in the framework aims to reduce carbon intensity by 65 to 70 percent from 2005 levels by 2030.

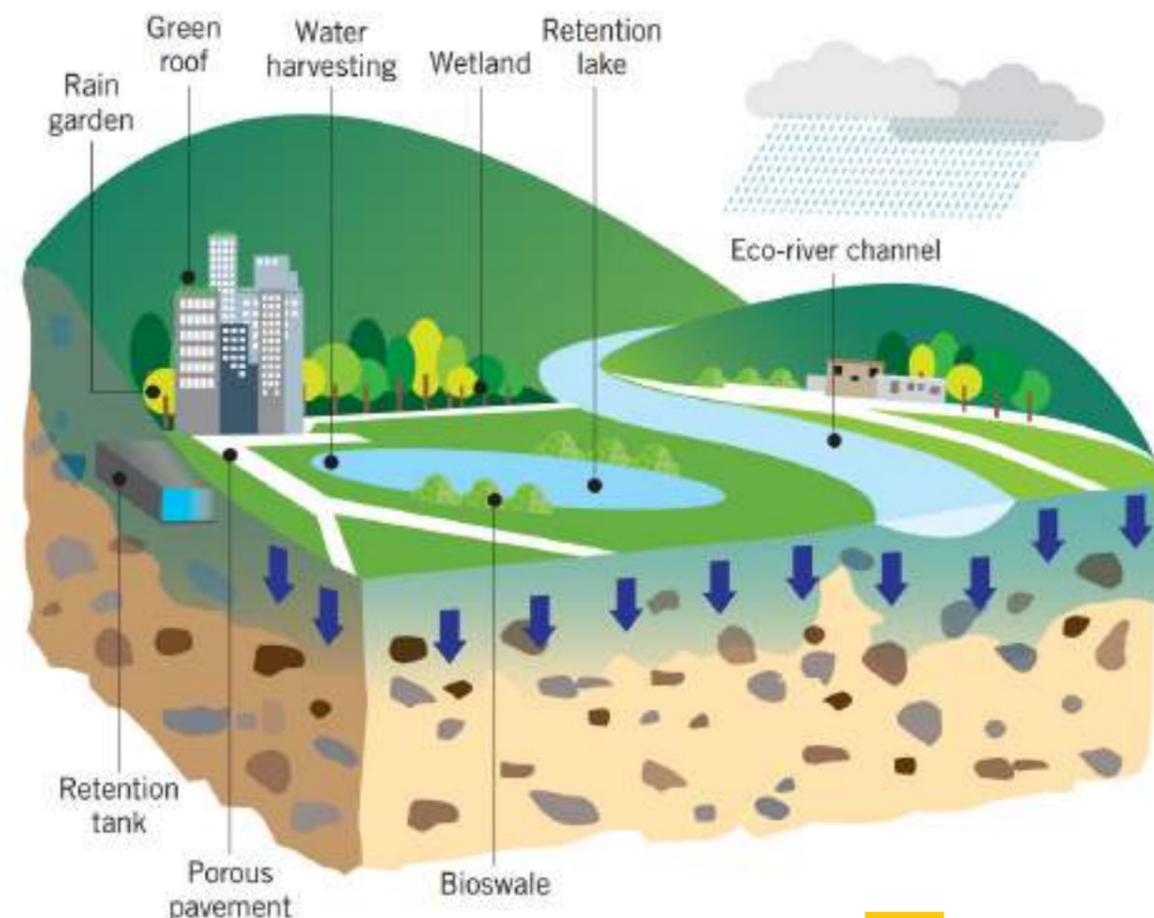
Current measures include the construction of a stormwater storage tank in the low-lying Happy Valley area and investment in the Hong Kong West Drainage Tunnel.³⁸

Blue-green infrastructure and “sponge city”

DSD is striving to implement blue-green infrastructure to revitalise water bodies by incorporating green and eco-conservation elements into channel and river-training works. These efforts include planting in nullahs and rivers, engineering natural stream settings, preserving river ecosystems, and introducing

landscape design to promote biodiversity and environmental beautification while maintaining drainage capacity. The Kai Tak Nullah upgrade will see a greener and more pleasant river with enhanced drainage capacities, as well as improved microhabitats and diversity through the installation of fish shelters and boulders.

DSD also introduced the “sponge city” concept of “following nature with resilience” to facilitate stormwater infiltration and reduce surface runoff through flood storage and retention. Part of the stormwater is collected and reused to optimise water recycling while enhancing the city’s flood resilience.



Variety of blue-green infrastructure and solutions in a “sponge city” concept. Illustration from Drainage Services Department.³⁹

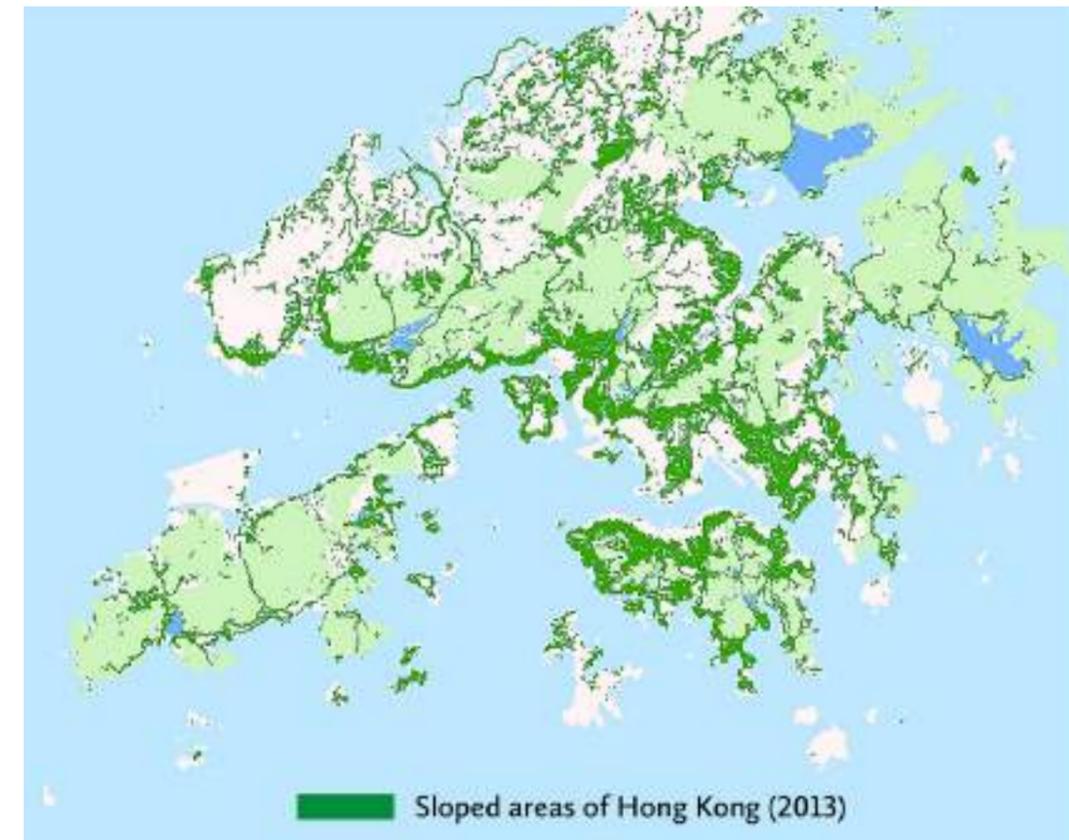
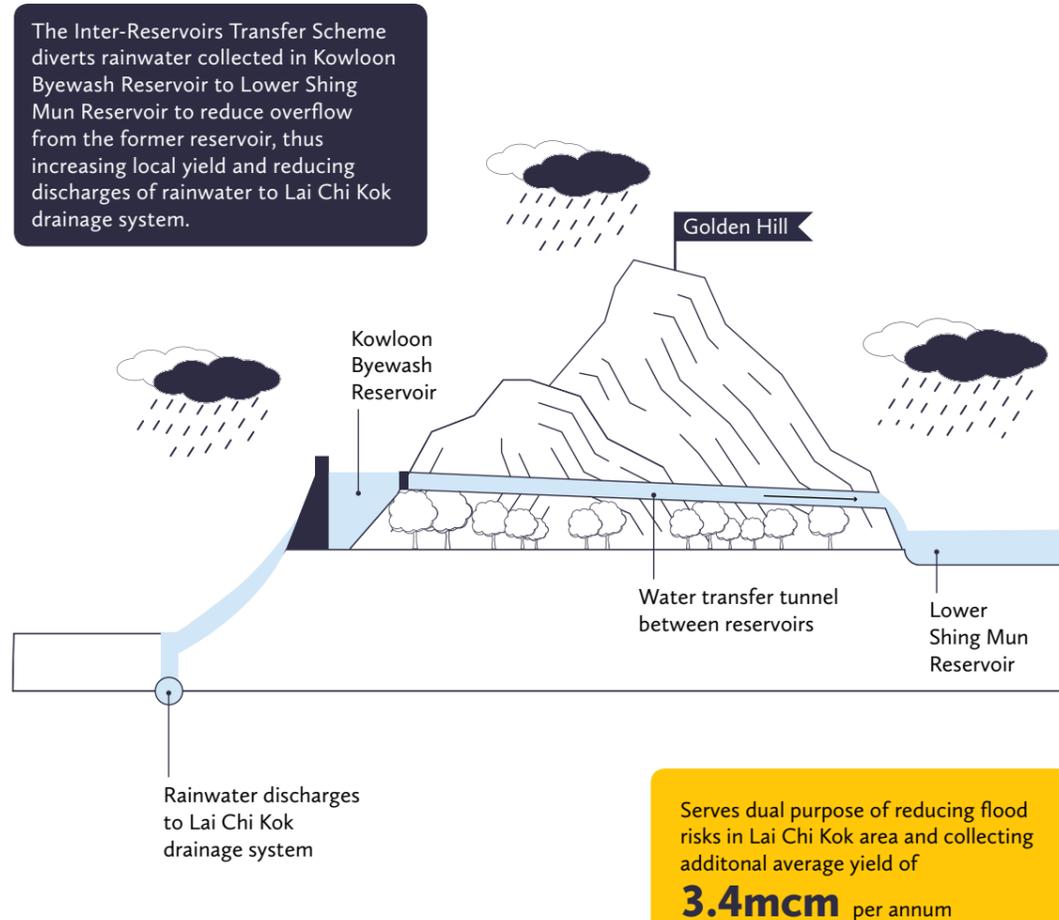
Water security and resilience

Hong Kong produces only 20 percent of its own fresh water. The government has thus been proactive in strengthening the city's water security. The recently updated *Total Water Management Strategy 2019* outlines the plans of the Water Supplies Department to diversify the city's water portfolio to six sources.⁴⁰ The department will also strengthen its collaboration with DSD to develop policies in accordance with the "sponge city" concept, including the Inter-Reservoirs Transfer Scheme, which envisages a 2.8-kilometre-long water tunnel to connect Kowloon Byewash Reservoir and Lower Shing Mun Reservoir to increase local yield and reduce flood risk.⁴¹ The tunnel also serves to improve water resource allocation during times of intense rain and drought.

Enhancing slope safety

Over 70 percent of Hong Kong's land consists of slopes. The concentration of urban areas on or near slopes generates a persistent threat of landslides, especially with more frequent and intense rainfall.⁴³ Besides developing an extensive landslide monitoring network and a new landslide barrier system, the CEDD is promoting personal precautionary measures for emergency situations such as extreme rainfall and severe landslides.⁴⁴ The Landslide Potential Index, a globally unique metric, is part of an early-warning system that estimates the risk of landslides based on the intensity and location of rain and the distribution of slopes.

Illustration adapted from Water Supplies Department.⁴²



Sustainable urban design and retrofits

In Hong Kong, mean temperature and the number of very hot days are projected to increase, exacerbating the urban heat island effect.⁴⁶ Hence, the government has implemented a range of land use planning and urban design interventions over the past decade. These include issuing the *Hong Kong Planning Standards and Guidelines*, which promote better urban ventilation; mandating compliance for all major government projects and encouraging the private sector to undertake assessments for air ventilation⁴⁷; promulgating the *Sustainable Building Design Guidelines* to mitigate the urban heat island effect; and encouraging the adoption of BEAM Plus to assess the sustainability performance of buildings.⁴⁸

By 2046, Hong Kong will have about 326,000 private housing units aged 70 years and older. These buildings must also cope with climate change effects. The Urban Renewal Authority is committed to facilitate building rehabilitation

and encourage building maintenance of existing buildings by launching an all-in-one Integrated Building Rehabilitation Assistance Scheme. The scheme aims to offer subsidies and technical support to affected owners, such as the Mandatory Building Inspection Subsidy Scheme and Operation Building Bright 2.0.

Outreach, data sharing, and engagement

To raise public awareness on climate change, the government has stepped up publicity and education. Besides circulating relevant materials through the media, promotional posters, and roving exhibitions, a dedicated website (<https://www.climateready.gov.hk>) was created as the one-stop platform to share the latest information on climate change. The Environment and Conservation Fund was also created to support non-profit organisations in their educational activities and demonstration projects. In addition, the city launched a large-scale

public education campaign, called Safer Living 2.0, in June 2019 to build public awareness on natural disasters, motivate community efforts, and enhance community resilience.

The government is promoting the establishment of a Common Spatial Data Infrastructure (CSDI) to provide bureaus, departments, and private organisations with an information infrastructure to share geospatial data and support various smart city initiatives. Users could get timely geographical location information, thereby facilitating the development of spatially enabled, community-centric applications and services. Various maps have been produced and map services provided (e.g., free mobile map application MyMapHK) for the public. The government plans to roll out CSDI for public use by the end of 2022.

C Strategies by non-governmental actors

Research and risk assessments

Non-governmental experts complement the role of the government in climate change research and dissemination to enhance the knowledge of the community and business sector and provide a critical perspective for quicker, more robust and transparent policy action.

Since 2015, the Joint Environmental Forum co-organised by the Environment Protection Department and the Mass Transit Railway Corporation provides a platform to discuss and cultivate mutual understanding among professionals, practitioners, and contractors.^{49,50}

Strengthening the urban fabric

Non-governmental organisations (NGOs) are important in assisting districts to prepare for climate change and consolidate community resources, with a focus on the disproportionate impacts on lower-income groups and residents living in low-lying areas. During Typhoon Hato in 2017, the YWCA collaborated with various government departments, NGOs, the District Council, Rural Committee, and other local organisations to handle flood impacts, including evacuation and operation of a temporary shelter.⁵²

Efforts on a non-governmental level that push for policy outcomes include the following:

- The Collaborative Centre for Oxford University and the Chinese University of Hong Kong (CUHK) for Disaster and Medical Humanitarian Response publicized their findings on the effects of climate change on health impacts in 2016.
- The public policy think tank Civic Exchange, Hong Kong University of Science and Technology, and additional participating groups have been active in conducting research, devising action plans, and co-hosting regular forums⁵¹ to address pertinent environmental issues in Hong Kong.
- The Asia Investor Group on Climate Change is an initiative to create awareness among Asia's asset owners and financial institutions about the risks and opportunities associated with climate change and low carbon investing.

Catalysing climate adaptation and sustainable development through community and business leadership

Within the business community, industry leaders have emerged to drive adaptation and sustainable development. Link REIT piloted projects on implementation of the Task Force on Climate-related Financial Disclosures (TCFD) and took a leading role in the United Nations Environment Programme Finance Initiative to develop comprehensive guidance and emergency response procedures to address the impact of climate change on investment portfolios. Link also launched the first issue of a HK\$3.9 billion (US\$500 million) green bond, accompanied by an extensive Green Finance Framework that outlines procedures on green project selection and contains provisions that address climate change resilience (e.g., through BEAM Plus, energy efficiency improvements).⁵³ These efforts lay the

foundation for companies to become actively engaged in transforming Hong Kong into a city prepared for climate change.

ESG reporting and green investment

In 2019, green bonds, worth a total value of HK\$78 billion (US\$10 billion), were issued in Hong Kong, and cumulative green bond issuance reached HK\$202.8 billion (US\$26 billion) by the end of 2019.⁵⁴ In addition, HK\$7.8 billion (US\$1 billion)⁵⁵ of green bonds with a borrowing ceiling of HK\$100 billion (US\$12.8 billion) were issued in support of Hong Kong's sustainable

development. Furthermore, the Hong Kong Stock Exchange (HKSE) is demanding greater disclosure on environmental, social, and corporate governance (ESG) issues from its listed companies. Previously, HKSE had proposed making ESG reporting mandatory, but the Chamber of Hong Kong Listed Companies wanted HKSE to leave disclosure to the companies' discretion. Nonetheless, greater disclosure is expected to attract more Western investors to Hong Kong as greater transparency will enable companies to better identify opportunities to reduce operating cost and enhance governance, risk mitigation and growth from sustainable development.

LESSONS LEARNT

a Key insights from Hong Kong

Participants in the Hong Kong virtual roundtable noted that the HKSAR government has been addressing the substantial risks and impacts of climate change, especially water security and landslides. However, dialogue between government and the private sector is much needed. Recognising the government's receptiveness to initiatives from the private sector, business representatives in the roundtable noted that they can organise themselves better to develop solutions for enhancing climate resilience before reaching out to the government for further support. Successful cases of private-sector-driven solutions may prompt the siloed governmental departments to come together to adapt the solutions for public uses.

Businesses are vulnerable to climate change, and with infrastructural assets susceptible to climate disasters, they are increasingly leading initiatives in research, corporate strategies, and technological innovation in response to the government's comparatively unassertive policies. Corporate action and further pressure from NGOs are needed to stimulate the government to strengthen its ambitions in tackling climate change. The Fair

Winds Charter, a policy initiative launched by Civic Exchange to reduce shipping emissions, showcased the significant leverage of civil society on the policymaking process when it was passed into legislation in 2019.

b Evaluation of the ecosystem

While the private sector has started to embrace sustainability as a core issue, most efforts are still limited to large corporations and conglomerates and lack an economy-wide spread. A study on 500 randomly chosen ESG reports found only 12 percent have plans to deal with climate change issues, and only 20 percent of them divulged information on actions taken.⁵⁶ Though several businesses, such as the Swire Group, have carried out risk assessments, few have specifically addressed climate change risks and several limit their account to rather optimistic global warming scenarios.

The financial sector largely overlooks climate and water risks, despite their financial significance. Some companies acknowledge physical climate risks and TCFD but do not disclose the exposure of their loan books to these risks.⁵⁷

Low-income families in Hong Kong are often exposed to precarious living conditions, for example in cage homes or subdivided flats in old private residential buildings of inadequate ventilation, shelter structures, and weather-proofing. Because climate change will exacerbate these vulnerabilities and deepen Hong Kong's existing socioeconomic inequalities, resilience-building must also focus on equitable development.

C Opportunities and way forward

Stronger government leadership and collaboration with the business sector

Participants observed that in Hong Kong, the private sector is relatively motivated to spearhead and implement climate actions and investments. The government's culture of being receptive to

private sector-led improvements motivates this. Frequent and perhaps more formalised discussion platforms for the private sector to gather, exchange knowledge, and discuss climate resilience issues can be encouraged to align the cooperation of the various industries (e.g., banking, investment, real estate).

Conversely, the government needs to consolidate cross-disciplinary action and citywide coordination in a coherent strategy to expand its existing plans such as the Hong Kong 2030+ Framework. The city's infrastructure is in urgent need of attaining climate readiness by increasing its capacity to adapt and respond to future climate changes.

Because the severity of climate impacts depend in part on the preparedness of communities, the government's approach should be flexible and incorporate a continuous learning and review process to build adequate contingencies and

systematically eliminate vulnerabilities. Property developers can continue to collaborate with built-environment professionals and district councils to improve on urban ventilation and open-space solutions.

Development of Hong Kong as a green finance and insurance hub

With the finance industry a key economic sector, the insurance industry can support the economy's resilience to climate change by incentivising resilience and funding recovery from weather events.

To start, investment in adaptation should be strengthened. The Climate Adaptation and Resilience Conference 2018 summary report suggests that by fostering innovation in the insurance of climate-related risks, particularly in designing and prioritising risk capacity, along

with providing new coverage for changing insurance needs, Hong Kong could reassert its position as the leading insurance market. This includes measures such as offering parametric natural catastrophe insurance for corporate bodies (e.g., an Asia equivalent of the CCRIF⁵⁸) and local communities, as well as infrastructure and catastrophe bonds.

The government can also collaborate proactively with industries towards developing finance mechanisms for climate change mitigation. An increasing receptiveness towards green finance initiatives, combined with the strength of Hong Kong's financial sector, places Hong Kong in a position to lead the discourse on using capital for sustainable development. The government needs to highlight the unique business opportunities of climate change in terms of investment and collaboration, and introduce guidelines on the use of proceeds.

Aerial view of Hong Kong. Photo courtesy of Mario Sixtus licensed under CC BY-NC-SA 2.0.





ROTTERDAM

CITY CHARACTERISTICS

Physical

Land area:

206.44 sq km

Proportion and metres of land above sea level:

85% <5 m above mean sea level

Total coastline of the Netherlands:

30 km

Percentage of publicly-owned land:

40%

Annual rainfall:

850 mm

Green cover:

43.46 km (10.6% of total land area)

Social

Population:

0.64 million (2019)

Population density:

3,060 per sq km

Population proportion according to age group:

0-3		4.6%
4-11		8.6%
12-17		6.0%
18-25		14.0%
26-39		20.7%
40-54		19.4%
55-64		11.6%
65+		15.3%

Population proportion:

48.5% local, 51.5% foreign-born

Tourists/visitors each year:

1.3 million

Infrastructure

Drainage infrastructure:

2,400 km gravitational sewage system, 250 km pressurised pipes, 1,000 pumping stations, 4,000 km waterways

Coastal defence infrastructure:

Levees and dykes, supported by water plazas and tanks within the main city centre

The storm surge barrier, Maeslantkering, is expected to be able to protect Rotterdam from sea-level rise and storm surges at least until 2070.

Economic

GDP:

€170 billion (2019)
(US\$201 billion)

GDP per capita:

€270,010
(US\$319,638)

Median household income:

€30,150 (annual; 2017)
(US\$35,698)

City budget for climate agendas in 2020:

Total budget: €3.5 billion (US\$4.1 billion)

Water management: €76 million (US\$90 million)

Rotterdam WeatherWise: €2.5 million (US\$3 million)

Risk assessment

Temperature increase:

1.4 °C by 2050

Infrastructure at risk:

15,000 properties and 2,000 vulnerable objects at risk of flooding

30% of residents without cooling in their home or district for heat waves

Sea-level rise:

1 m by 2100

30,000 properties at risk of groundwater level disruption due to foundation problems

Flood-prone area:

31 ha

Population proportion of vulnerable:

15.3% of population ≥ 65 years old

CLIMATE IMPACTS AND CHALLENGES

The Netherlands is located in a temperate sea climate, which means cool summers and cool winters. In recent years, the Dutch summers have become extremely hot and dry, with the country recording its highest-ever temperature of 39.2 °C in 2019.¹ Excessive amounts of water have always been a key challenge for Rotterdam as a delta city and will continue to be, given higher occurrences of extreme weather.

Going forward, Rotterdam will have to grapple with new challenges of urban heat, which adds stress to existing infrastructures/buildings that were built for the temperate climate. The city plans to develop area-specific measures with regard to rainfall, heat, and water safety in the near term, while concurrently enhancing their knowledge of groundwater, land subsidence, and drought impacts in the future.²

However, the city government of Rotterdam have not been alone in responding to climate change. The city has been successful in mobilising collective action and encouraging various stakeholders to play their part. This is partly owing to the “Dutch Diamond” model, where strong partnerships among the government, the private sector, civil society, and knowledge institutions³ have supported the development and piloting of resilient solutions in the city. Tried and tested successful pilots lay the foundation for more integrative and collaborative models of solutions in the future.

Climate change poses an existential threat to the low-lying delta and coastal city of Rotterdam. The impact of sea-level rise would hit the city hard for two main reasons. First, the entire 30-kilometre Dutch coastline affects Rotterdam, and second, 85 percent of the city has an elevation of less than five metres above mean sea level. Current risk assessment estimates that a rise of one metre is expected by 2100.⁴

Left
Photo courtesy of the Rotterdam Office of Climate Adaptation



In addition, the city currently receives 850 millimetres of annual rainfall, which is projected to increase because of more intense and frequent cloudburst events as extreme weather events become the norm. Rainfall events are estimated to occur five times more frequently by 2050 and 10 times more often by 2085. This puts 31 hectares of flood-prone area at risk of inland flooding should rainfall events become more severe.

Increasingly, heatwaves and drought have become problems for the city. In 2019, the city had one of its hottest summer days on record, where temperatures rose to 42°C. This complicates existing infrastructure design and causes building

heating problems where historically citizens have adopted double-glazed window panels to trap heat effectively for winter months. This has since led to more heat being trapped indoors during the summer months, posing serious health and economic risks to the city as around 30 percent of Rotterdammers do not have cooling systems in their buildings.

Instances of drought would affect groundwater supply, which threatens properties that rest on wooden piles and peat dykes. This causes foundation problems for approximately 20,000 properties and puts another 11,000 properties at risk of land subsidence and damage.⁵

Benthemplein water square on a sunny day. Photo courtesy of David Rozing



RESPONSE TO CLIMATE CHANGE

a Governance structures

National governance

The municipality’s climate response takes guidance and direction from the Netherlands’ nationwide laws, the Water Act and the Spatial Planning Act. Under these acts, the Netherlands developed the National Adaptation Strategy and the National Delta Programme.⁶ Although these programmes promoted adequate flood management solutions following devastating floods in 1953, the Netherlands came to a turning point in its water management strategies after the flood events of 1993 and 1995.⁷ Then, the national programme moved towards integrating water and flood management with spatial planning for a more holistic disaster management.

Subsequently in 2006, the country recommended a strategy that encouraged “living with water”, resulting in the national Room for the River

project, under which river beds were widened to reduce flood risk and reconnect the urban environment to rivers.⁸ The National Water Plan in 2008 went a step further to ensure that flood prevention strategies also help reduce the impacts of floods. This has led to the *Meerlaagse veiligheid* flood risk management approach, a multi-layer security method where flood risk is reduced by a mix of implementing flood prevention measures and adapting the spatial planning and urban design of the city to include water and disaster management.⁹ This ensures that flood mitigation strategies are not restricted in silos and are holistically linked to urban development.

Municipal governance

In Rotterdam, different aspects of water and flood management are managed by various organisations and financed on different levels through the Water Plan.

Organisation	Task	Financing
National/state water services under the Ministry of Infrastructure and Water Management (Rijkswaterstaat)	<ul style="list-style-type: none"> Flood protection Water quantity Water quality (main system) 	General resources, pollution levy, national waters
Province of South Holland	Care for groundwater and rainwater runoff	Regional tax
Water boards: Water Board of Schieland and Krimpenerwaard <ul style="list-style-type: none"> Hollandse Delta Water Board Water Board of Delfland 	Flood protection (regional) <ul style="list-style-type: none"> Water quantity Water quality (protection of surface water from pollution) and wastewater treatment in embanked areas Wastewater treatment plants To be consulted during land use zone planning and has its own water legislation “keur”, which describes water activities allowed near and in watercourses and near and on embankments	Regional tax (amount of tax differs between the 22 regions in the country)
Water company: Evides (semi-public)	Drinking water supply	Price
Rotterdam municipality	<ul style="list-style-type: none"> Collection of stormwater Construction, management and maintenance of sewerage systems 	Local tax (sewage levy, dependent on household size)

Primary flood protection and defence infrastructure from major rivers and storm surges from the North Sea are managed by the national government and financed by the state's general funds through the Delta Tax. For internal management of water infrastructure and drainage within the city, the Delta Plan provides a broad direction and sets national goals for municipalities and water boards to meet. How to achieve the goals, however, is left to city governments, which plan and strategize based on individual city characteristics.¹⁰

The city works with the provincial authority and water boards to provide facilities to discharge rainfall runoff and manage water in public areas.

The water boards (e.g., Hollandse Delta Water Board and Delfland Water Board), tasked with the Netherlands' flood protection on a regional

level, fund Rotterdam's flood protection projects through respective regional taxes. The water boards also have their own set of water legislation that determines the type of activities and land use planning allowed for waterways and embankments.

To complement water boards, the municipality is responsible for collecting stormwater as well as the construction, management, and maintenance of the sewerage system. Following the *Meerlaagse veiligheid* flood risk management approach, the municipality has since integrated urban planning with stormwater collection strategies (e.g., water plazas and green buffers) to enhance the city's collection capacity.¹¹

Moving forward, Rotterdam's climate resilience strategies have since been broadened to incorporate more challenges as weather becomes more extreme. These would be managed and funded separately by the city council.

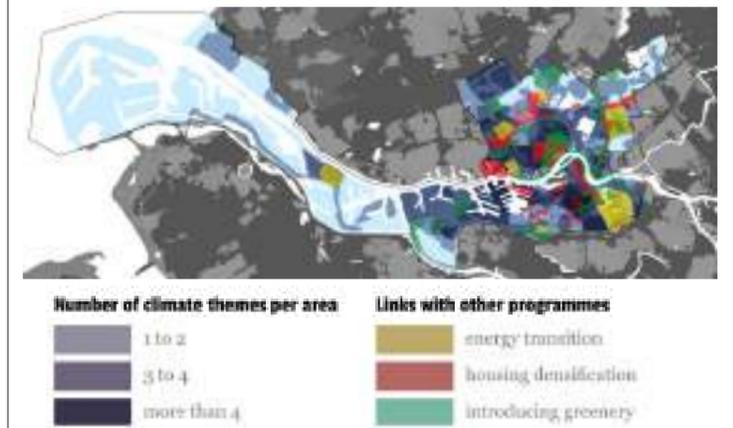
Financing

At the national level, the Climate Adaptation Administrative Agreement (2018) will disburse a total of €600 million (US\$710 million) to various municipal governments to make the Netherlands more adaptable to climate change effects. Rotterdam also receives subsidies and grants from various European Union programmes (e.g., Sponge, LIFE UrbanAdapt, Life@Urbanroofs, Interreg).¹²

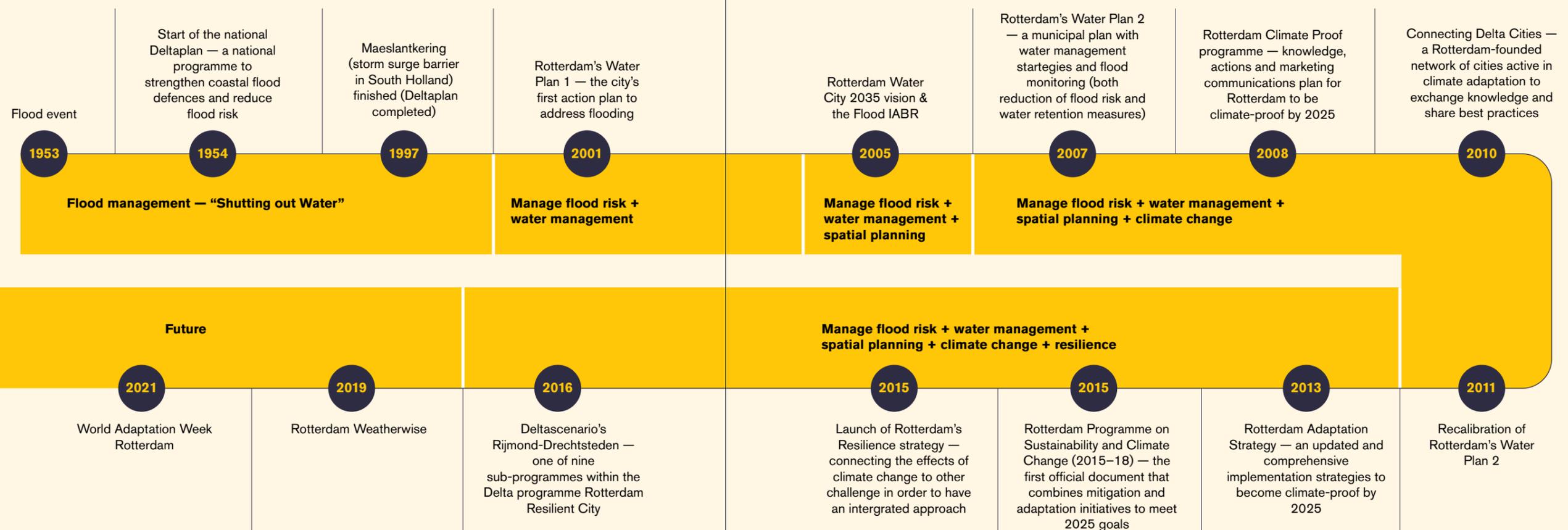
Adaptation measures not directly linked with the drainage system cannot be funded from the municipality's drainage plan, and additional funding would be required to realise these multi-functional strategies.¹³ This could come from other city council programmes or co-financing by other parties (e.g., investments by residents and professional private companies). For instance, the Rotterdam Weatherwise programme would be receiving a total of €20.6 million (US\$24.4 million) in 2021 and 2021 to finance climate

resilience solutions. The opportunities for climate resilience solutions and links with other non-climate programmes can be found in the accompanying map.¹⁴

Opportunities for integrated solutions to multiple climate challenges in Rotterdam. Map courtesy of the Rotterdam Office of Climate Adaptation.



Water Management Policies in Rotterdam



b Government-led strategies

Integrating water with urban planning (city government-led strategy)

The Rotterdam Climate Proof Programme (2008) and the Rotterdam Adaptation Strategy (2013) reflected the city's climate adaptation efforts and the amplified role that urban planning plays in climate proofing the city beyond just water-related risks.

For a start, Rotterdam revised its Water Plan and looked at opportunities within the urban environment to store up to 600,000 cubic metres of water through green roofs, water squares, and building facades to slow urban runoff and store rainwater. To manage this more effectively, Rotterdam was divided into 14 detailed sub-municipal zones, each of which has a specific problem and action plan related to the water system.¹⁵ These small-scale adaptive measures

form part of the multilayer *Meerlaagse veiligheid* security approach.

The city collaborated with stakeholders from the water boards to develop water-sensitive solutions for the urban environment. The process was financed by the Supplement for Top Sector Alliance for Knowledge and Innovation (TKIs) of the Ministry of Economic Affairs and Climate Policy through grants and funding.¹⁶ Comprising a consortium of industry, knowledge institutions, and authorities, TKIs work in research initiatives across knowledge-intensive and export-oriented sectors to better translate Dutch science policy to societal and economic impacts. TKIs were introduced in early 2011 and received an initial budget of €500 million (US\$592 million) from the national government, with an additional €800 million (US\$947 million) supplemented by the public and private sectors by 2020 (industry making up 40 percent of it).¹⁷

FLEXIBLE INFRASTRUCTURES AND CLIMATE-RESILIENT NEIGHBOURHOODS

Flexible infrastructural solutions are key to dealing with changing rainfall and climate uncertainties, given the interdependencies of the urban infrastructure system.

To achieve this, the Zomerhofkwarter (ZOHO) neighbourhood is a climate-proof neighbourhood where public spaces are reconfigured to have climate-adaptive infrastructure that not only focuses on clearing water away during tidal flooding and rain fall events, but also improves quality of life through vibrant spaces, water features, and water recycling.

The climate-proofing process saw the replacement of paved surfaces and the old sewage system into green buffers and rain gardens to absorb rainwater and reduce the urban heat island effect. The city also moved towards a new strategy of locating water-storage solutions on the surface

and making them visible to contribute to the environmental quality of urban neighbourhoods. This resulted in the Bentemplein Water Square, a collaborative effort kick-started by landscape architecture firm De Urbanisten.

Leveraging smart technology and multi-sectorial efforts between Technical University of Delft and local firm Studio Bas Sala, the university conceptualised a rain barrel system that monitors weather forecasts online and is rigged to automatically release stored rainwater into gardens before predicted rainfall events.

The climate-proofing initiative subsequently received a sizeable European Union subsidy to further develop the ZOHO district for the development and maintenance of rain gardens and greening projects, carried out together with citizens.



Converted rain gardens in ZOHO soften the effects of intense rain events and cool the urban environment. Photo courtesy of Eric Fecken.

URBAN WATER BUFFERS

Rotterdam's urban water buffers programme incorporates climate adaptation measures into the city's urban areas and neighbourhoods. The urban water buffers are able to absorb approximately 1,400 cubic metres of surplus stormwater and reduce the likelihood of flooding in the city. In addition to rainwater absorption, some of these water buffers prototyped a bio-filtration system to collect and purify rainwater that falls on rooftops and parking areas before being reused for the neighbourhood Sparta Football Stadium artificial turf field.

Aside from the environmental benefits, these urban water buffers provide green relief and soften the landscapes within neighbourhoods — injecting added social value and reducing ambient temperature.

Collective action strategy

In enhancing Rotterdam's climate adaptation, the Rotterdam Weatherwise programme introduced in 2019 tackles the effects of climate change more holistically to build an adaptive and resilient city. Beyond water and sea-level rise, Rotterdam faces risk of heatwaves, droughts, land subsidence, and depletion of groundwater because of climate change. Rotterdam Weatherwise will identify climate change impacts, significant solutions, and associated costs across Rotterdam's various districts, which would then be included in district agendas drawn up by respective district committees. By capitalising on each district's unique social and physical characteristics, it hopes to tackle local district climate risks in a more targeted manner.

However, city-led initiatives within public space would only cover 40 percent of Rotterdam's land area. The other 60 percent of the city is owned by private stakeholders.¹⁸ To ensure effective and successful adaptation to climate change's far-reaching effects and cross-cutting nature, Rotterdam Weatherwise brought in social housing corporations, real estate developers, and private homeowners to climate-proof future homes, streets, and buildings. Through emphasising collective action, Weatherwise aims to reduce the severity of climate change's localised impacts by increasing Rotterdam's preparedness across different levels of the city. This would be achieved through "risk dialogues" with the city government, district water boards, and district partners.¹⁹

The process of communicating urgent action was supplemented with financial incentives promoting climate-resilient solutions. This translated into a greater push by citizens to improve public spaces as well as their own private homes.

c Private-sector strategies

Rotterdam has adopted a co-financing and incentive model to encourage real estate developers in adopting climate resilient strategies. This is in tandem with top-down requirements for climate-resilient features (e.g., water retention and retardation capacity, green buffers, well-shaded design, etc.) to be included in construction plans or redevelopment. This has led to a series of

Goals set by the City Council under Weatherwise Programme

Protect 90% of properties from risk of flooding

Add 20 hectares of green space by 2022

Reduce carbon emissions 49% by 2030 measured against 1990

Improve air quality compared to 2017

Increase citizen participation in neighbourhoods



The BlueLabel map allows residents to understand their flood risk and initiate their own adaptive measures. Photo courtesy of Royal Haskoning. Photo courtesy of Royal Haskoning

BLUELABEL

BlueLabel project is a private-sector initiative by Achmea, Royal HaskoningDHV, and Nelen & Schuumanns. It is a risk classification system to identify risk levels of private properties and roads to flash floods. It encourages the public to be proactive in preventing disasters rather than devising recovery measures in the aftermath.²³

The project hopes to raise public awareness on exposure to flood risk by harnessing smart technologies to make complex data visual and easy to understand. Extreme rainfall events were analysed and used to calculate risk of floods with models.

The information is then made publicly available online where citizens can enter their addresses to view their flood risk and seek subsidies to undertake flood-resilient activities (e.g., infrastructure enhancements like raised steps or green spaces).

Insights from the BlueLabel project can be used to plan both small and large-scale interventions to build greater flood resilience. The project assists the authorities in monitoring flood vulnerability patterns over time to make spatial and infrastructural planning more climate proof and water resilient as well as in policymaking around flood protection standards.

pilots and effective small-scale climate-resilient projects done by developers at various levels of the city to experiment with future strategies.

For example, the Rotterdam Green Roofs programme capitalises on the city's 14.5 million square metres of flat roofscapes to encourage private owners and developers to undertake sustainable roof development and invest in climate adaptation measures.²⁰ For a start, green roofs are found to provide cost savings of €500 (US\$592) per cubic metre of water avoided at the ground/underground level. Some green roofs are designed with a retention capacity of 25 millimetres to reduce annual overflow volume by 19.5 percent.²¹ Currently, Rotterdam has activated approximately 270,000 square metres through the Rotterdam Weatherwise programme encouraging greater participation from citizens and private developers.

Going forward, Rotterdam is in the process of developing climate adaptive building codes and identifying solutions that are workable for developers based on the district's level of urgency and exposure to various climate risks. This would be in addition to the mandatory requirement of 50 millimetres of water storage for all future developments; storage requirements for buildings would be further differentiated based on certain prescribed amounts depending on the neighbourhood's characteristics.

Rotterdam also works with developers to experiment with alternative solutions. To adapt to rising sea levels, entities like Holland Floating Solutions were brought in to engineer possible floating buildings/designs. At the climate resilience workshop hosted by CLC and ULI Europe, discussions pointed out that while early pilots for floating buildings were successful in exploring future possibilities, a lack of clarity on the type of regulation (e.g., building regulations or maritime ship regulations) that would apply to floating structures complicated implementation as well as future innovations.

d Non-profit-driven actions

Rotterdam's spirit of partnership and co-delivery of resilience solutions is evident at the local or building level, with notable landmarks and

ROTTERDAM ROOFTOPS

The municipality of Rotterdam encouraged the installation of green roofs by providing subsidies for homeowners and demonstrating a range of possibilities at several city government buildings.

The small-scale measures allow rooftops to buffer and absorb rainwater instead of draining it straight into streets and sewers. Given Rotterdam's climate and rainfall conditions, these measures to maximise green spaces within the city could make a significant difference to the city's overall absorption capacity during intense rainfall.

To further encourage private owners in taking up green roof solutions, a social cost/benefit analysis was carried out to provide greater information and clarity. The analysis further revealed that green roofs have led to a 10 percent increase in property value because of increased aesthetic appeal and reduced ambient temperatures in the immediate surroundings.

social enterprises taking the lead for greater climate resiliency. These efforts in support of the municipality's longer-term climate adaptation plan help build resilience through social means and methods.

Tussentuin, which stands for "Garden between Buildings", supports local communities in converting common outdoor spaces into community gardens. It encourages collective action and establishes a common sense of responsibility (through self-management) for green spaces. Apart from gardening and greening courses, the company believes in using simple and relatable concepts to citizens as an entry point into more complex issues to motivate action for climate change.²²

The Seven Square Endeavour, led by Theatre Rotterdam, develops climate adaptation plans together with the community for the transformation of a local public square, the *Schouwburgplein*. The process explores multi-use and multi-functional designs as well as an inclusive design approach for various parties to raise climate resilience as a society.²³



Green roof on the Groothandelsgebouw building. Photo courtesy of Peter Schmidt.

LESSONS LEARNT

a Key insights from Rotterdam

During the Rotterdam workshop, participants discussed the current state of play. Rotterdam — and by extension the Netherlands — has a strong culture of collaboration as part of the “polder culture”. This model of collaboration stemmed from a history of living with polders and behind seawalls. The idea that everyone chips in to maintain the dykes otherwise everyone would suffer has contributed to key outcomes in research and development to meet economic and societal needs.

For instance, collaboration with different segments of the city is essential for achieving resilient climate solutions that are multi-functional within the urban environment. The “Dutch Diamond” model that underpins Rotterdam’s adaptation strategies brings multiple stakeholders into the process of finding a solution. Through this, innovation can be achieved as funds can be stretched further to leverage maximum benefits.

Following that, getting buy-in from multiple stakeholders allows the city to mobilise action by citizens and the private sector to support its longer-term goals. This was achieved through government-led efforts to showcase and reimagine possibilities within the public realm. Such re-imaginings of public space that bring about benefits beyond climate resilience serve as an attractive pull factor in motivating individual citizens — as well as the private sector — to adopt such efforts within their private realm. This is where government incentives were helpful in kick-starting and facilitating uptake amongst citizens.

b Evaluation of the ecosystem

Nonetheless, climate change awareness and action are still mostly government led. Rotterdam’s levees may not be sufficient on their own to

protect the entire population, highlighting a need to spur even greater community action — particularly for climate risks stemming from increased temperatures, droughts, land subsidence, and so on. Being a low-lying city delta city, participants noted that Rotterdam needs to raise more awareness and imbue its response to climate change effects with greater urgency.

One key gap that could help address this need is to bring the financial and insurance sectors into discussions of climate resilience. A concerted effort to reflect greater transparency over costs and risks of properties is one way of motivating action and increasing urgency. For instance, higher premiums for developments in flood-prone areas could be another way of conveying flood risk in addition to existing methods.

Current building codes may not be sufficient to allow or encourage more innovative solutions. For instance, the type of regulation that would apply to the floating pavilion in Rotterdam was not clear: Was it considered a building or a ship? Greater flexibility and adaptability in planning processes and guidelines could match the constantly shifting nature of climate science as well as relevant innovation.

Funding for Rotterdam’s climate resilience comes mostly from the EU, federal, and city levels. There is scope for greater community and/or private funding to support major projects. Hence, where the Rotterdam Weatherwise programme is hoping to effect change is by exploring new models of co-financing to tap into new sources of funding to support climate resilience projects. This presents an opportunity to connect private industries with local neighbourhoods and local communities to develop localised solutions that fit conditions on the ground. The Benthemplein Water Plaza and Luchtsingel have demonstrated that such a collaborative, crowd-funded, and multi-stakeholder approach could work in Rotterdam. In the long term, this supports development of community and climate resilience towards climate change at various levels of the city.

c Opportunities and way forward

Discussions surrounding private-sector reluctance to pursue climate-resilient solutions could be tied to a lack of guarantee on a return of investments. Cities, like Rotterdam, can do more to create new or highlight existing financial incentives and rewards for implementing resilience features, such as reduced insurance premiums, avoided losses from climate events, or continuity of operations during extreme weather.

The release of the Rotterdam Weatherwise programme is a concerted effort across Rotterdam’s city council and a clear signal on their long-term climate strategy. This should be encouraging to private developers as it lays out clear direction and opportunities for developers to make higher investments in the city while being assured of policies that keep Rotterdam relevant and protected from climate change impacts. This prevents the risk of locational obsolescence and is one strategy for capturing highly mobile businesses that transcend city/national boundaries. Clear adaptation frameworks and transparent information would help build a good business case for real estate developers. To further support developers, governments could consider setting goals and create a sandbox for private-sector innovation and exploration, with different sandboxes tailored to different spaces/districts within the city based on ground characteristics.

There are opportunities to build from the significant resilience work already underway or completed. Frequently updated climate models with standardized guidelines for all developers could enable developers, consultants, and analysts to speak the same language and better assess climate risks across portfolios and calibrate climate resilient adaptations accordingly. Uncertainty in climate change scenarios and low carbon plans makes it difficult for developers to plan for future strategies. Flexibility in regulations and updated data sets can thus increase risk appetites for the private sector — allowing for more innovative climate resilient solutions.

Aerial view of Rotterdam. Photo courtesy of Claire Droppert.





NEW YORK

CITY CHARACTERISTICS

Physical

Land area – city and metropolitan:

City: 783.84 sq km
Metropolitan: 34,490 sq km

Proportion and metres of land above sea level:

62 sq km (8% of city land) under 2 m (6 ft) above sea level¹

Coastline:

836 km

Percentage of publicly-owned land:

58%²

Annual rainfall:

1,270 mm

Green cover:

30,000 acres (14% of city land), managed by the NYC Department of Parks and Recreation³

Geography:

The city is between several major water bodies that meet the Atlantic Ocean

Much coastal land on the city's outer edge is low-lying, reclaimed using fill of geologically "soft" soil

Social

Population:

City: 8.3 million
Metropolitan area: 22.7 million (2019)⁴

Population density:

10,586 per sq km in the city

Population proportion:

62% local, 38% foreign-born⁵

Infrastructure

Drainage infrastructure:

Over 11,909 km of sewer pipes, 135,000 catch basins and 95 wastewater pumping stations⁶

Coastal defence infrastructure:

A system has been proposed including protective beaches, hardened shorelines, rebuilt/enhanced dunes, offshore breakwaters, wetlands/living shorelines/offshore reefs, and deployable flood protection systems⁷

Economic

GDP:

US\$842.3 billion (2019)⁸

GDP per capita:

US\$73,463⁹

Median household income:

US\$96,100 (annual)¹⁰

Real estate indicators:

~1 million buildings¹¹

Residential: 92%

Commercial: 3%

Industrial: 3%

Institutional: 2%

City budget for climate agendas:

US\$3 billion in resilience initiatives in 2019¹²

Risk assessment

Temperature increase (°C):

Up to 3°C (5.6°F) by 2050¹³

Up to 5.7°C (10.3°F) by 2100¹⁴

Flood-prone area:

12,950 ha (~17% of city land) could be flooded by a 1% annual chance event¹⁶

Sea-level rise¹⁵:

0.5–0.8 m (1.75–2.5 ft) by 2050

1.2–2 m (4–6.25 ft) by 2100

Infrastructure at risk:

US\$101.5 billion (~8% of city total) is located within current 100-year floodplain^{17,18}

Population proportion of vulnerable:

17.3% living in poverty¹⁹

14.1% of population over 65 years old²⁰

Note: Blank cells indicate data not available.

CLIMATE IMPACTS AND CHALLENGES

The largest city in the United States by population and economy, New York City is a global centre of finance, media, and culture. It is a low-lying city of islands, a coastal archipelago composed of five boroughs (large administrative districts), four of which are located on islands. The city has 837 kilometres of coastline,²¹ and much of it is vulnerable to sea-level rise and coastal storms. It is arranged around a harbour at the confluence of the Hudson River, the Long Island Sound, and the Atlantic Ocean, exposing it to flood risks from multiple locations.

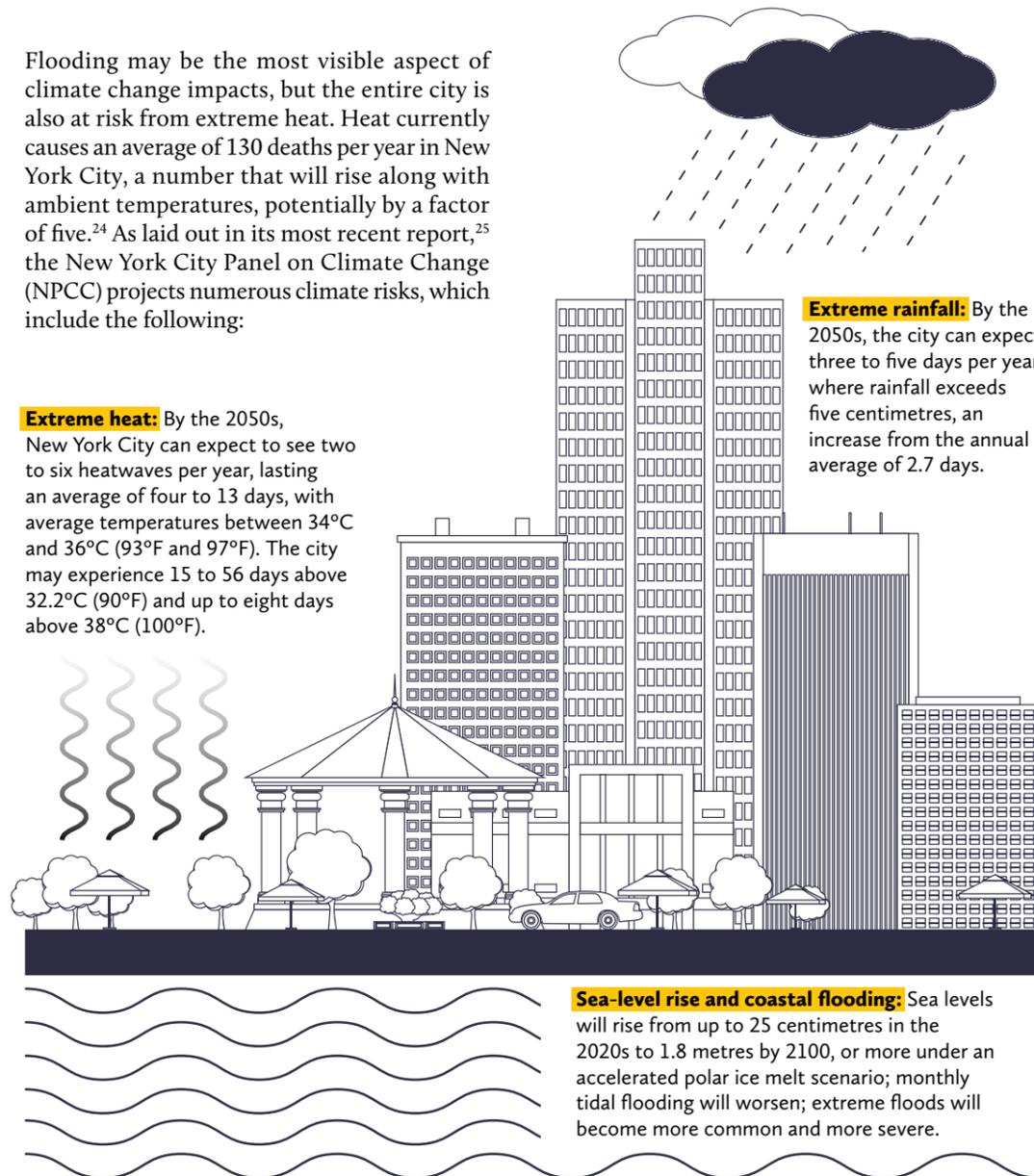
By the 2050s, nearly 1 million of its residents — more than in any other U.S. city²² — will live in the 100-year floodplain,²³ which will expand significantly as sea levels rise. The population in flood-prone areas includes some of the city's most vulnerable residents. One of the most at-risk areas includes the city's, nation's, and world's most important economic centre — Lower Manhattan, a high-density, high-land-value area that is home to Wall Street and a growing residential community, which experienced significant flooding during Hurricane Sandy in 2012.

Aerial View of Lower Manhattan, New York City. Photo courtesy of TierneyMJ/Shutterstock.com.



Flooding may be the most visible aspect of climate change impacts, but the entire city is also at risk from extreme heat. Heat currently causes an average of 130 deaths per year in New York City, a number that will rise along with ambient temperatures, potentially by a factor of five.²⁴ As laid out in its most recent report,²⁵ the New York City Panel on Climate Change (NPCC) projects numerous climate risks, which include the following:

Extreme heat: By the 2050s, New York City can expect to see two to six heatwaves per year, lasting an average of four to 13 days, with average temperatures between 34°C and 36°C (93°F and 97°F). The city may experience 15 to 56 days above 32.2°C (90°F) and up to eight days above 38°C (100°F).



Extreme rainfall: By the 2050s, the city can expect three to five days per year where rainfall exceeds five centimetres, an increase from the annual average of 2.7 days.

Sea-level rise and coastal flooding: Sea levels will rise from up to 25 centimetres in the 2020s to 1.8 metres by 2100, or more under an accelerated polar ice melt scenario; monthly tidal flooding will worsen; extreme floods will become more common and more severe.

Despite mounting challenges, New York City has always been a city of innovation. Led by the Mayor's Office of Resiliency (MOR), and leveraging financial and programmatic support from the state and federal governments, the city has proactively used localised climate projections in land use and building policies and infrastructure designs. This began in 2006 with a City Council mandate to create a city agency dedicated to climate policy; the 2007 release of *PlaNYC*, the city's first climate plan; and the creation of the NPCC in 2008. These efforts accelerated rapidly after Hurricane Sandy

struck in October 2012. Causing catastrophic damage to buildings, infrastructure, and lives, the storm catalysed a sea change in policy and sharply heightened awareness of the city's vulnerability to climate risk.

The city, together with government, community, and private sector partners, is undertaking multiple programmes to address flooding and extreme heat. While MOR is involved in the strategic planning of many programmes, other city agencies are generally responsible for implementation and operations.

RESPONSE TO CLIMATE CHANGE

a Governance structures

New York City's climate adaptation currently includes over US\$20 billion in coastal protection infrastructure. Roughly US\$15 billion is sourced from the federal government, and the rest is provided by the city's own budget and a small contribution from New York state. The city government has directed the bulk of federal aid to infrastructure projects that will reduce climate risk exposure, rather than simply rebuilding structures damaged by Hurricane Sandy. The city also plans to diversify its construction and operations funding sources from federal, state, city, and private funds.

The city government collaborates with the New York state and U.S. federal governments on large climate resilience infrastructure when greater capacity and depth of response are required. For example, the city received the bulk of its post-Sandy funding from the U.S. Department of Housing and Urban Development (HUD) and U.S. Federal Emergency Management Agency (FEMA), and several larger coastal flooding construction projects are either being completed or proposed by the U.S. Army Corps of Engineers, which oversees similar projects around the country.

This coordination among levels of government adds time and complicates administrative procedures for the approval of large climate resilience infrastructure projects. However, the magnitude of funding needed for major projects requires ongoing support from the federal government.

b Government-led strategies

Knowledge

New York City's first climate adaptation efforts began in 2008 with the formation of the NPCC, a scientific panel focusing on climate and related policies. Then-mayor Michael Bloomberg convened the NPCC with funding from the Rockefeller Foundation to create and interpret climate

data and projections for the city. It comprises scientists, academics, and private sector experts. The NPCC submits recommendations to the city government within one year of the release of Intergovernmental Panel on Climate Change reports or at least once every three years, based on review of global scientific findings and the results of its own local climate modelling and observations.

Intra-government collaboration, policy development, and planning

Organisationally, climate adaptation initiatives are overseen by the New York City Mayor's Office of Resiliency. As a link between NPCC and other city agencies, MOR provides a high-profile centre for policy leadership on climate adaptation. It cultivates a systems approach to climate change by integrating resilience as a function of all local government departments, to be continually addressed at building, neighbourhood, and citywide scales. MOR partners closely with the Mayor's Office of Sustainability (MOS), which is focused on supporting New York City's ambitious carbon emissions reduction efforts.

The city is required by the law to update its climate programmes every four years, which were first called *PlaNYC 2030* when they started under the Bloomberg administration in 2007. After Hurricane Sandy, the offices released a special report called *A Stronger, More Resilient New York (SIRR)*, a 10-year, US\$20 billion plan with 257 initiatives for adapting the city's infrastructure to storm surge and sea-level rise. Eventually these plans were rebranded to *OneNYC* under Mayor DeBlasio's administration in 2015. These documents, along with studies, form the scientific basis for climate policy and infrastructure design guidelines for New York's adaptation strategies.

The city continues its resiliency and sustainability planning in *OneNYC 2050*, released in 2019. *OneNYC 2050's* many initiatives call for increased flood insurance enrolment, resilience retrofitting incentives, enhanced community-led disaster response, support for small businesses and

CLIMATE RESILIENCY DESIGN GUIDELINES

New York City's *Climate Resiliency Design Guidelines* provide instruction on incorporating climate projections into the design of city facilities and its capital projects, on top of the consideration of historic data. The re-orientation toward future climate conditions represents a shift in approach, as well as a key means of operationalising the NPCC's regional climate data into policy.

The most recent version of the guidelines released in 2019 includes a new exposure screen tool and risk assessment methodology. The screening tool serves as a scoring system to assess a project's relative risk from climate impacts while the methodology provides a broader framework for assessing lifetime risk for the entire project.

Providing specific risk assessment procedures to agencies mainstreams climate adaptation in New York City's large, relatively decentralised governance system. The guidelines act as a model framework to incorporate future climate projections into city projects and inspire private sector design.

community groups, and health initiatives to address extreme heat. *OneNYC 2050* also calls for the continued implementation of SIRR's coastal resilience projects.

Land use and zoning

New York City also uses land use policy, through zoning and building codes, to encourage resilient construction in designated floodplains. After Hurricane Sandy, the Department of City Planning (DCP) released the Flood Resilience Zoning Text, a set of temporary city code amendments that removes regulatory barriers to building or reconstructing buildings to more resilient standards. The amendments address allowing greater flexibility on height limits, placement of parking spaces and vulnerable mechanical systems, and uses of ground floors, thereby facilitating flood-proofing and building elevation.²⁶ DCP proposed expanding these changes and making them permanent to ensure ongoing resilient construction in flood-prone areas.²⁷

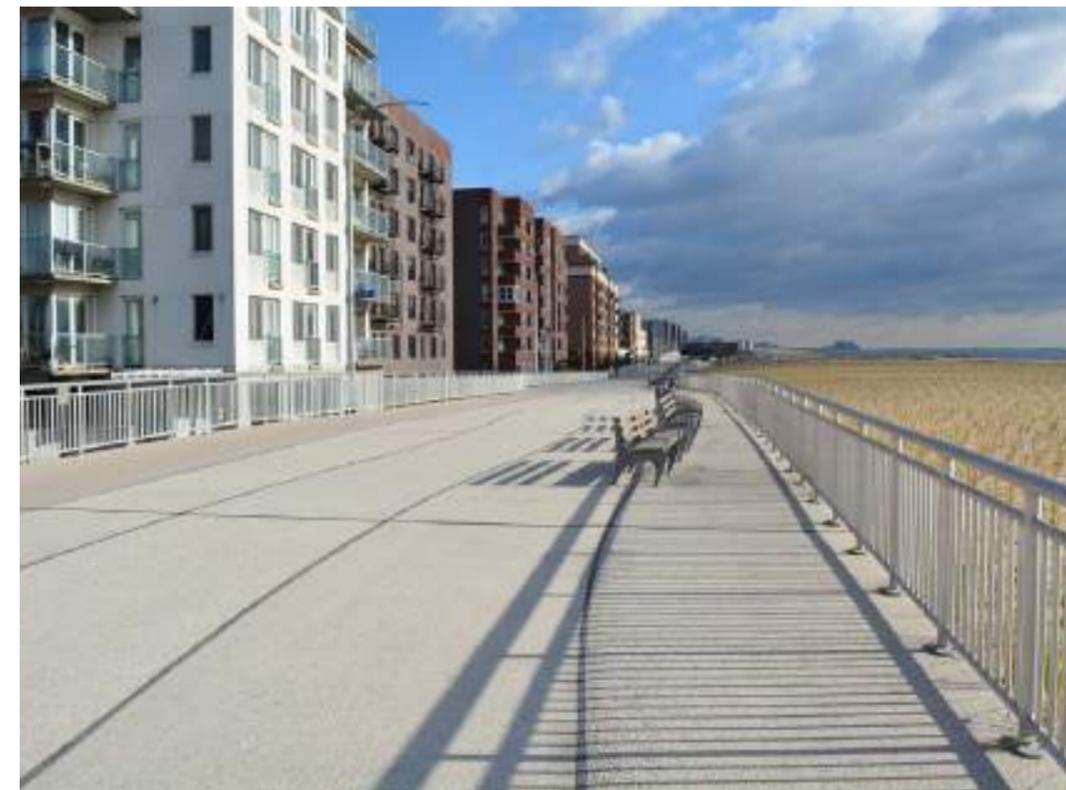
Coastal infrastructure projects

In addition to its adaptation policies, the city embarks on multiple large-scale coastal infrastructure projects to maintain the city's viability as a place for living and doing business.

SIRR illustrated plans for New York City's waterfront to address storm surge and sea-level rise hazards. It continues to drive the city's large-scale coastal infrastructure projects, such as the Lower Manhattan Coastal Resiliency and East Side Coastal Resiliency projects.

Coastal infrastructure in southern Manhattan

In 2014, as part of the Rebuild by Design competition, a design team led by Bjarke Ingels Group (BIG) developed the BIG U, a proposal for a 16-kilometre coastal protection system of interconnected infrastructure and resilience elements that would surround the southern third of Manhattan. The proposal was broken into multiple components, several of which were eventually funded. One of these components, East Side Coastal Resiliency (ESCR), was initially awarded US\$335 million in federal assistance. However, costs rose and the city has since committed the additional funding needed for the nearly US\$1.5 billion



The Rockaway Boardwalk Reconstruction. Rebuilt by city government after being destroyed by Hurricane Sandy in 2012, the new boardwalk is more resilient and protects the neighborhoods behind it, using a stronger concrete design, a sand retaining wall, and dune plantings for stabilisation. Photo courtesy of Mishella and Cory Seamer/ Shutterstock.com.



The multiple planned projects to build resilience in Lower Manhattan. Photo courtesy of the New York City Economic Development Corporation³⁰

project.²⁸ ESCR will strengthen 3.9 kilometres of urban coastline, shielding several physically and socially vulnerable neighbourhoods on the Lower East Side of Manhattan with infrastructure such as elevated parks, flood gates, and flood walls.²⁹

A second phase of the work, known as the Lower Manhattan Coastal Resiliency project, which is more complex and costly than ESCR, has several segments that extend protection from where ESCR ends on the east to the western edge of Lower Manhattan. Flood prevention measures similar to ESCR's will be implemented. However, the area directly in front of the Financial District itself will present a particular challenge.

The mile-long segment of the Financial District, because of its intense density of utilities, buildings, bridge piers, tunnels, and a major highway, cannot accommodate coastal protection infrastructure on existing land. Instead, land has to be reclaimed outward into the East River. This project could cost up to US\$10 billion, requiring significant financial assistance from the federal government, and "will be one of the most complex environmental and engineering challenges [the] city has ever undertaken".³¹

These infrastructure projects in Lower Manhattan demonstrate the depth and complexity of efforts to reduce New York City's flood risk. While they aim to protect a key economic and cultural zone, the city will also need to move ahead on risk reduction infrastructure for other vulnerable coastal areas.

Rebuild by Design and the National Disaster Resilience Competition

A major milestone in the funding, conceptualisation, and execution of New York's climate adaptation planning was the city's participation in design contests: Rebuild by Design (RBD) in 2013 as a sponsor and the National Disaster Resilience Competition (NDRC) in 2014 as an applicant. The contests, with awards funded by HUD, aimed to stimulate innovative (often nature-based) infrastructural and social resilience projects submitted by private sector design firms.

A local initiative convened to respond to Hurricane Sandy, RBD ultimately funded three proposals in New York City, including the BIG U. RBD's main outcome, besides a series of design proposals, was the successful partnership between the private

design sector and local government to collaborate on large-scale resilient infrastructure projects, which became a model for climate change risk assessments and adaptation. The New York City government now relies heavily on private design firms to offer advice and expertise in design and construction and to conduct the community engagement and public meetings required by law to inform the public and generate support.

RBD's success spurred the federal government to host the NDRC for the whole of the United States,³² which included an additional US\$176 million fund for a flood protection compartment to the south of ESCR known as the Brooklyn Bridge–Montgomery Coastal Resilience project.³³

Retrofits

Under the leadership of the MOR, the city is evaluating how to help New Yorkers retrofit vulnerable buildings in coastal locations without protective waterfront infrastructure and inland. MOR will prioritise retrofitting existing buildings, which the city estimates will continue to represent over 90 percent of its buildings by 2050.³⁴ As the majority of these buildings are privately owned residential and commercial properties, the city recognises the need for significant incentive and financing programmes to support owners with unequal financial capacity and motivation to pursue retrofits.



Opened in 2010 with city and state construction funding, the waterfront park uses naturalised landscape edges to enhance coastal resilience while providing access to the water. Photo courtesy of Elzbieta Sekowska/Shutterstock.com.

C Private-sector strategies

Hurricane Sandy increased the real estate industry's awareness of the potential damages and business disruption caused by climate change. Post-Sandy, the main response by private property owners was to relocate sensitive building systems, such as electrical and heating systems, to higher floors within buildings in the floodplain to avoid power and heat loss during floods.³⁵ Some property owners with greater resources and capacities have gone further by incorporating flood resilience into building and public space design and emphasizing this as part of project branding. However, these advanced projects are exceptional rather than commonplace.

The Domino Sugar Factory redevelopment located on the northern Brooklyn waterfront offers one example of private sector adaptation. The developer, Two Trees, purchased the property a month before Hurricane Sandy flooded the site. In response, the entire site was raised 0.6 to 2.1 metres above the floodplain, and new buildings were set back an additional 15.25 metres (50 ft) from the shoreline.³⁶ Two Trees also invested US\$50 million into an adjacent public waterfront park (required by zoning).³⁷ Designed by James Corner Field Operations, the park is intended to act as a sponge for stormwater and an initial line of defence against storm surges.³⁸

Not all property owners are capable of this level of adaptation or have the necessary space to facilitate sitewide solutions. A significant level of support (through incentives, insurance, or other finance structures) will be needed for smaller companies and owners to prepare existing buildings for flooding and heat exposure and to initiate retrofits, which can be more complex than designing new resilient developments. Building- and neighbourhood-level flood protection will be of even greater importance as the city's waterfront continues to be targeted for redevelopment into expensive, high-profile housing, potentially placing future residents at risk.

d Non-profit-driven actions

New York City has a rich ecosystem of non-profits that are deeply invested in working with communities to become more resilient to climate change. Nongovernmental organisations often partner with one another and with city government to achieve greater collective impact.

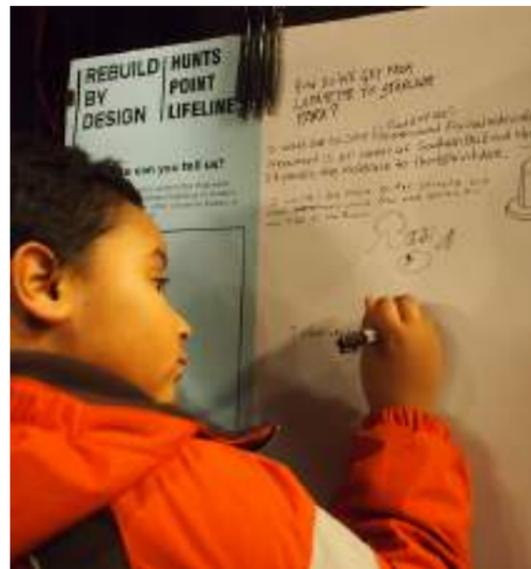
Community-based organisations (CBOs) are non-profit groups deeply embedded in local, place-based initiatives, playing vital roles in neighbourhood-level adaptation. Organisations like WE ACT in the Harlem neighbourhood, THE POINT Community Development Corporation in the Hunts Point neighbourhood, UPROSE in

the Sunset Park neighbourhood, and the Fifth Avenue Committee in South Brooklyn — all waterfront or flood-prone neighbourhoods with significant proportions of racially diverse, low-income residents — are leading resilience and planning initiatives similar to those often taken on by city departments for planning or economic development. CBOs often liaise between residents and government, communicating local needs and influencing government-led resilience initiatives.

CBOs are important in advancing social equity in climate resilience. Some collaborate with the NPCC to explore how equity and social vulnerability can be fully incorporated into climate change vulnerability assessment and community adaptation planning.³⁹

New York is also home to numerous non-profits that advocate for resilience and address other citywide urban issues relevant to resident quality of life. Several examples include the following:

- The Center for New York City Neighborhoods (CNYCN): A non-profit which links resilience and affordable homeownership, CNYCN assists homeowners with the risks of foreclosure with the FloodHelpNY.org tool that provides resources on flood retrofits, flood insurance, and free resilience audits for eligible owners.
- Rebuild by Design (RBD): After the post-Sandy design competition, RBD transitioned into an advocacy non-profit that continues its design-driven process of enhancing physical, social, and ecological resilience in cities.
- Regional Plan Association (RPA): RPA is a longstanding planning non-profit that advocates for responsible development within the larger New York region. With the social justice non-profit, Make the Road NY, RPA recently co-released the *Climate Action Manual*, a set of policy recommendations to tackle climate adaptation and social change simultaneously.
- The Waterfront Alliance: This non-profit increases coastal resilience citywide and regionally with the Waterfront Edge Design Guidelines (WEDG), a set of design suggestions and a rating and certification system for waterfront projects based on the principles of resilience, ecology, and access.



Rebuild by Design organised a community workshop for Hunts Point, where people from diverse backgrounds shared about their vision for a more coastal-resilient and economically vibrant waterfront. Photo courtesy of Rebuild by Design.

LESSONS LEARNT

a Key insights from New York City

During a stakeholder workshop held in February 2020, experts from the private, public, and non-profit sectors in New York City gathered to discuss a key area for growth for New York's policymaking on resilience: retrofits of existing buildings. Although the city's upcoming protective waterfront infrastructure is innovative and extensive, it cannot protect the city's entire 837-kilometre coastline. In addition, inland areas face a different set of risks from extreme precipitation, and citywide extreme heat risk must also be addressed.

Accessibility to high-quality data on risk and adaptation

Participants identified that high-quality localised data are a key tool for building owners to have a more accurate understanding of risk and a motivator to advance adaptation. To be used widely, this type of data must be low cost or free to owners with few resources. Currently, federally provided floodplain maps are the main source of this information; however, these maps are based on historical flood conditions that may no longer be accurate and often do not consider future climate projections. More accurate data are available from private consultants, but this service is often financially out of reach for small businesses and individual property owners. Owners also need information from local government regarding wider plans to guide their individual efforts.

Collaborative and multi-scalar approach to climate adaptation

Though individual actions at the property level have an impact when aggregated across the city, some resilience investments, such as temporary flood walls, require coordination to deploy. Piecemeal installation at the property level will not always be sufficient but is often too costly for individual owners to afford. However,

it was unclear to participants what a district- or neighbourhood-wide, rather than property-by-property, approach could look like, especially in terms of funding, delivery, and technical feasibility.

Potential overlaps between energy efficiency retrofit programmes and resilience goals

The city and state governments already provide technical support programmes and financial incentives for private owners to retrofit their properties for greater energy efficiency, such as the local Retrofit Accelerator or the incentives for efficient construction and renovation from the MOS. These programmes have potential to stimulate retrofits that increase a building's resilience too. For example, increasing building insulation can keep indoor temperatures low during heatwaves, reducing health effects and saving energy, while net-zero buildings maintain their own power sources if storms or heatwaves cause local power outages. In addition, participants noted that new energy efficiency legislation, such as New York City's Local Law 97 (which requires large buildings to cut carbon emissions by 40 percent by 2030 or face steep fines) could have been an opportunity to stimulate progress on resilience retrofits in addition to sustainable retrofits.

Accounting for private-sector rationales and financing mechanisms in policies

The local government should be aware of the timing of private sector capital cycles when regulation is announced to increase the feasibility of new required investments. In addition, the cost/benefit analysis private owners might conduct is affected by how long they, or the next owner, might hold their assets before selling, as well as whether the effect of climate risk is priced into the asset's value. Given that the city is interested in maintaining property value for tax revenue, workshop participants wondered how the city or other actors would take steps to preserve that

Manhattan Bridge and Pebble Beach in Brooklyn Bridge Park. Photo courtesy of Dan Gold on Unsplash.

Far right
Vertical view of Fifth Avenue, New York City. Photo courtesy of Stephan Guarch/Shutterstock.com.

value, and whether part of the financial support for pursuing retrofits could come from the insurance industry, through reduced premiums for resilient buildings. Private action is also heavily motivated by government financial support and quick returns on investment, which requires swift action from code review officials and others.

Positive messaging

Private efforts to retrofit properties do not enjoy the same reputational and promotional benefits as impressive new resilient buildings. Positive messaging around the benefits of retrofits to improve the public perception of private companies would potentially help motivate action. Similarly, positive messaging emphasizing how private actors can become part of a unified social effort to prepare for climate change would provide an alternative to fear-based messaging around the severity of climate risks and may be more effective to stimulate action.

b Evaluation of the ecosystem

New York City has made great strides on climate adaptation and has become a national leader in the U.S. resilience field, especially in the following areas:

- The opportunities for translating recovery momentum after paradigm-shifting events into permanent mechanisms for climate adaptation.
- The importance of proactive planning relative to climate change, and the integration of this infrastructure and policy planning with independent science-based climate analysis.
- The key role of partnerships in increasing the reach of resilience action, whether through national government funds, private approaches to real estate, or community organisations in building social equity. The diversity of actors in New York is an enormous resource for pursuing citywide adaptation.
- The opportunity for design precedents for climate resilience in large-scale redevelopments and signature parks to offer protective infrastructure and improve quality of life.



c Opportunities and way forward

The following are several key future directions to pursue in terms of resilient building retrofits.

Provide fine-grained risk assessment data to help property owners understand their vulnerability

Currently, data are not specific or widely available enough to guide adaptation. City government agencies and the private sector could coordinate on the creation of combined data sets and maps, and education on projected future climate scenarios, to allow individual property owners to better understand the likely medium and long-term risks and decide what options exist for on-site mitigation measures. New York City has begun developing future flood risk maps.

Link existing energy efficiency retrofit programmes, incentives, and regulations with resilience-related retrofits

City government should find ways to expand existing energy efficiency programmes to include resilience goals to avoid inefficient replication and missed opportunities for synergy. Local Law 97 would have been a useful opportunity for this integration, but there are other pathways as well.

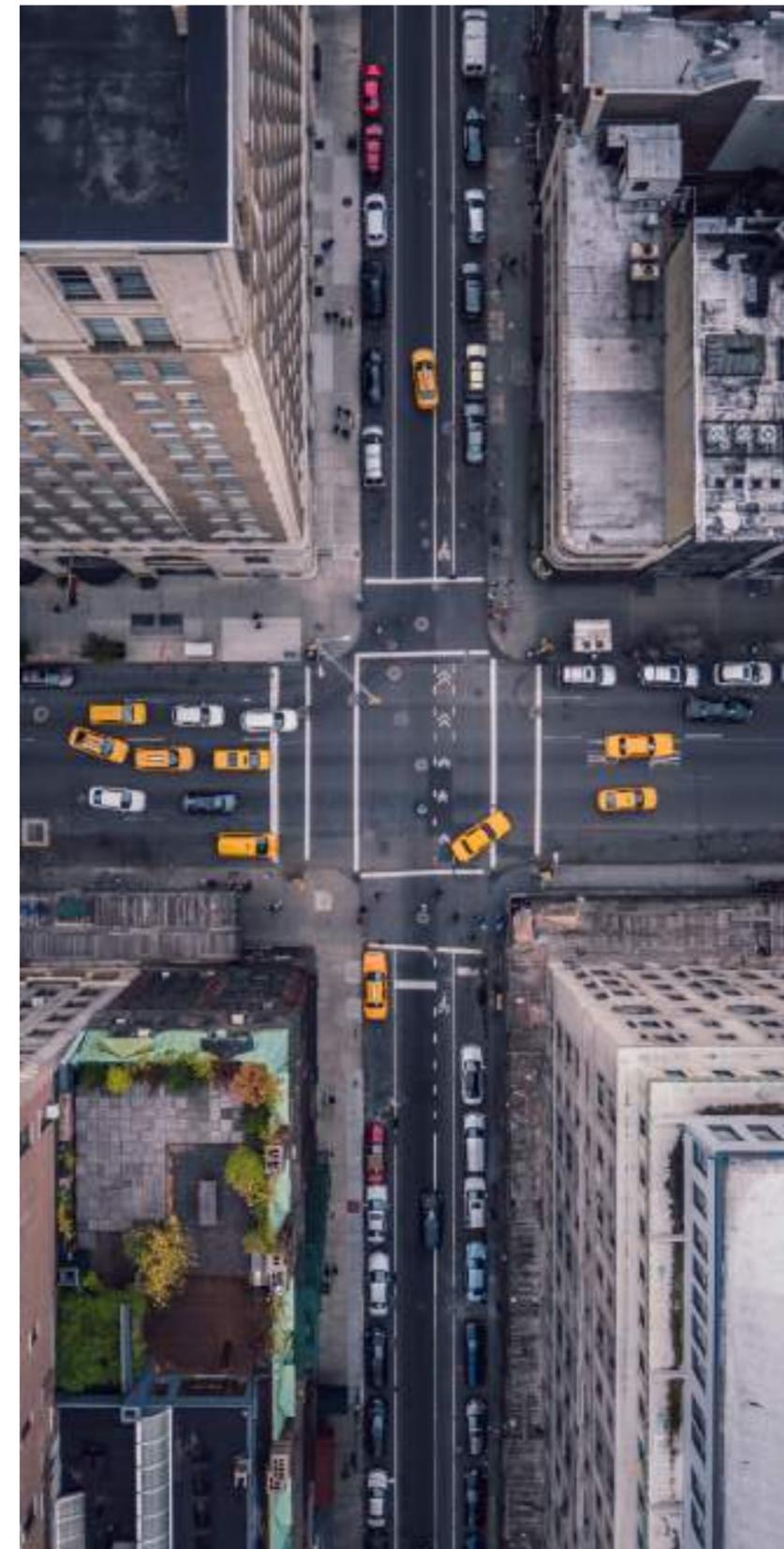
Support the creation of larger collectives to support private adaptation action

Property owners can only do so much on their own site; larger collectives are needed at the block, neighbourhood, and city scale to effectively reduce climate risk. There are existing entities that would be well suited for this role, such as block associations (a group of residents of a city block which organise to improve local quality of life) and business improvement districts, which collect additional taxes to fund local economic development projects. These groups could coordinate with individuals and small businesses to support resilience strategies beyond the scale of individual properties, to supplement the citywide resilience approaches managed by local government; however, effective funding approaches still need to be identified.

Develop communications and outreach materials that include success stories and positive social motivation

Education and outreach that emphasize the positive role of climate adaptation and retrofits may be necessary to better communicate the opportunities of climate action. The city can educate the private sector and the general public on the following:

- The action that can be taken by individuals, organisations and communities at multiple geographic scales;
- Clear strategies and options for retrofitting buildings that can be customized by building typology; and
- Examples of successful resilient retrofits, including the funding strategies. Pilot retrofit projects can be conducted within the highest-priority vulnerable communities.





MIAMI

CITY CHARACTERISTICS

Physical

Land area:

92.9 sq km

Proportion and metres of land above sea level:

Roughly 26% of land is less than 1.8 metres above sea level; highest point is along a limestone ridge at 7.3 metres¹

Coastline:

142 km²

Annual rainfall:

1,570 mm

Green cover:

7% of city land is used for parks³

Geography:

Porous limestone bedrock can exacerbate groundwater flooding and reduce effectiveness of seawalls

Social

Population:

467,963 (2019)⁴

Population density:

4,300 per sq km

Population proportion:

41.8% local, 58.2% foreign-born⁵

Infrastructure

Drainage infrastructure:

A complex system of storm drains, pipes, ditches, curbs, gutters, and culverts to collect stormwater and discharge it safely

Coastal defence infrastructure:

Miami and its neighbour and climate planning partner, the separate municipality of Miami Beach, have a patchwork of public and private seawalls. In Miami Beach, 95% of these are privately owned⁶

Economic

GDP:

US\$355 million (2019)⁷

GDP per capita:

US\$58,196

Median household income:

US\$41,818 (annual)⁸

Real estate indicators in Greater Downtown Miami:

Residential units: 53,000

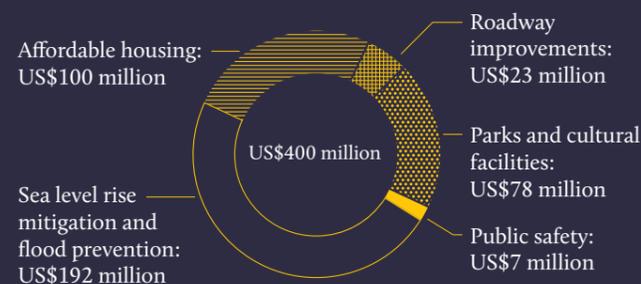
Office space: 2.3 million sq m (25 million sq ft)

Hotel rooms: 8,000⁹

City's budget:

Total proposed budget for FY 2019/20 is US\$1.13 billion.

New US\$400 million Miami Forever General Obligation Bond will invest in infrastructure projects to alleviate climate risks.¹⁰



Risk assessment

Temperature increase:

Roughly 180 days above 32.2°C by 2080, up from 130 days today¹¹

Infrastructure at risk:

US\$416 billion as of 2011, rising to US\$3.5 trillion by 2070¹⁶

Sea-level rise:

Up to 0.8 m (2.5 ft) by 2060

Up to 1.9 m (6.1 ft) by 2100¹²

Population proportion of vulnerable:

110,000 socially vulnerable people (23% of total current city population) will be living in 1% annual chance floodplain by 2050¹⁷

Flood-prone area:

600 ha of land under 1 m above sea level¹³

40% of homes could be flooded by a 1% annual chance event^{14, 15}

CLIMATE IMPACTS AND CHALLENGES

Miami faces a combination of water-related climate risks, including rising sea levels, increasing storms, and rising groundwater levels. In terms of property risks, it has been listed as the global city most vulnerable to sea level rise by the Organisation for Economic Co-operation and Development in terms of assets at risk, with over US\$400 billion in assets exposed to coastal flooding.¹⁸ However, its coastal location is a key economic, environmental, and cultural asset to the city, and the region has responded to risk by becoming a U.S. leader for resilience planning.

Founded officially in 1896, Miami has grown into playing an economic and cultural role larger than its population size — just under half a million — might suggest. Known for its swift growth and prominence of Cuban and other Latin American communities and international business headquarters¹⁹, the city is the second-largest international tourism hub in the U.S.²⁰ (behind only New York City) and the third-richest city in the U.S. in terms of purchasing power per capita.²¹

Miami has densely concentrated development along its waterfront, which continues to draw interest for its amenities despite climate risks.

The exact asset that has made it so attractive to tourists and residents, and so valuable to real estate — its coastal location and stunning beaches — is also its most at-risk resource, amplified by its geology. The flat, low-lying region averages an elevation of 1.8 metres (6 ft) above current sea level, with the only natural high ground a limestone ridge reaching an average of 3.6 metres and a maximum of 7.3 metres.²² Located on the Atlantic coast at the southern tip of the state of Florida, the city has limited ability to migrate inland to the west, as it already borders the vast wetlands known as the Everglades — an ecosystem so flat that Miami could potentially see flooding from it as well.

Compounding its threats, the city is built above porous limestone bedrock. This allows saltwater intrusion and pushes groundwater



up, overwhelming stormwater infrastructure and causing flooding from below while also contaminating drinking water. In addition, high-tide flooding already causes consistent threats to infrastructure and will worsen as sea levels rise.

The city is also subject to numerous hurricanes and tropical storms, having recorded 31 since 1851.²³ The most prominent of these in the past 30 years are Hurricanes Andrew in 1992, Wilma in 2005, and Irma in 2017. Andrew, in particular, became a cataclysmic event that reshaped Miami's (and later, the state's) approach towards climate events, especially through revised building codes and greater code enforcement. During Wilma and Irma, structures that were built or retrofitted according to the post-Andrew codes generally sustained much less damage than structures built to older codes. Only 25 percent of homes in Miami were built after 2000²⁴ to new codes first instituted in the mid-1990s, indicating that many structures may still be vulnerable.

Miami has densely concentrated development along its waterfront, which continues to draw interest for its amenities despite climate risks.

Miami cityscape.
Photo courtesy of
Robert Gomez on
Unsplash.



Sea-level rise presents a significant challenge for the city's future. With sea levels projected to rise by nearly a metre (2.5 ft) by 2060, which is equivalent to a third of the average land elevation, and a projected increase in the frequency and strength of hurricanes ahead, the city is adapting to a dual threat of inundation — by water and by the costs of damage and adaptation.

Miami is also at risk from rising temperatures. Located in a tropical climate with high humidity, Miami already experiences 130 days per year over 32.2°C (90°F), a critical threshold for health effects. This frequency could increase to 180 days per year by 2080; in fact, because of its high humidity, by 2050 the city will likely see more days that feel over 32.2°C than any other U.S. city.²⁵

RESPONSE TO CLIMATE CHANGE

a Governance structures

A gap in federally declared disasters and corresponding recovery funding from 2005 to 2017, alongside the state government's dismissal of climate change under its previous governor,^{26,27,28} led Miami to forge ahead with climate adaptation without the federal government — and until recently, without the state government. Most resilience efforts are largely self-funded by the city, rather than relying primarily on state or federal funding (in contrast to New York City, for example).

At the regional level, the local governments in Southeast Florida offer some of the best examples of intergovernmental coordination on climate change in the U.S.. In 2010, Miami and its adjacent governing areas (counties²⁹) established one of the only regional cooperative governance bodies on climate change in the United States, known as the Southeast Florida Regional Climate Change Compact. Composed

of Miami's surrounding county, Miami-Dade, and three other counties (Palm Beach, Monroe, and Broward), the compact was formed to increase South Florida's advocacy power with the federal government and coordinate climate mitigation and adaptation activities and resources at a larger scale, given the similar risks these areas face.³⁰ The compact released a Regional Climate Action Plan in 2012 (and released a one-time update in 2017), which identifies vulnerabilities, priority actions, and best practices that local governments can adopt to guide emissions reduction and resilience initiatives within their own jurisdictions.

Similarly, Miami's regional resilience strategy, Resilient305, is a collaboration among the city, its neighbouring city of Miami Beach, and their county government. This programme is funded principally by the budgets of its participating entities. Miami-Dade County, for example, has set aside US\$22 billion of its multi-year operating budget for resilience programmes under Resilient305.³¹

b Government-led strategies

For Miami, climate solutions are conducted on several scales, both regionally and locally.

Similar to the Southeast Florida Regional Climate Change Compact, Miami's participation in the Rockefeller Foundation's landmark 100 Resilient Cities initiative was also a collaboration — the city of Miami partnered with the city of Miami Beach and Miami-Dade County to form a partnership known as Greater Miami and the Beaches. Chief resilience officers from these three jurisdictions collaborated on their resilience strategy and regularly meet to coordinate on policy. In May 2019, the three entities released a joint resilience strategy, known as Resilient305, which looks at the issue regionally — a rarity for a resilience strategy.

Resilient305 includes more than 50 actions to increase resilience, organised in three main categories:

Places — location-based actions intended to reduce physical risk and enhance climate resilience through design and planning. The actions focus on using and improving natural systems such as coral reefs, beaches, and wetlands to reduce storm surge vulnerability; embedding resilience features into parks and open spaces; creating a sea-level rise adaptation strategy; and strengthening resilience planning, along with other actions like developing mobility hubs (locations that support multimodal transportation) and increasing connectivity and redeveloping public housing to mitigate climate risk.

People — actions that aim to improve social resilience and quality of life for residents. The actions are geared towards supporting job growth, empowering neighbourhoods and networks to prepare and better respond to climate change, creating volunteer emergency training programmes, and educating and engaging communities through public art to raise awareness and enhance social sustainability.

Pathways — focused on creating links among governments, businesses, community organisations, educational institutions, and others. Examples of actions include using a pre-planning for post-disaster toolkit, creating an Actionable Science Advisory Panel, and hosting workshops and convenings.

Much like other resilience strategies, Resilient305 will guide the broader region's approach to climate adaptation and integrate climate concerns with socioeconomic strategies to strive for broad resilience to shocks and stresses. Public, private, non-profit, and civic entities will partner on various initiatives to drive implementation.

In addition to its participation in the regional Resilient305 initiative, Miami has its own city-specific resilience strategy known as Miami Forever Climate Ready, released in January 2020. This plan explicitly aligns with Resilient305, sourcing some of its actions from the larger plan and elaborating further on Miami's resilience programmes and projects. Miami Forever Climate Ready also sets in motion recommendations from the climate compact's second *Regional Climate Action Plan*.

Because the plan builds off earlier work, some of the projects it contains have already begun. For example, in 2019 the city began executing its Stormwater Master Plan, a comprehensive guide to updating Miami's storm drainage system over the next 20 years. The system is outdated and frequently experiences inundation. This infrastructure upgrade process is designed to protect the city from rising flood risk over the next 40 to 50 years. The multi-phase plan involves a complete assessment of the city's roads, drainage infrastructure, and water management features; recommendations to reduce the frequency, severity, and duration of flood events; a consideration of multiple sea-level rise scenarios; resilient natural and built coastal features and infrastructure; and, significantly, updated design standards for developers and land use and building code recommendations.³²

Further evidence of locally derived funding for local projects is the Miami Forever General Obligation Bond, a US\$400 million investment approved by

voters in 2017 to construct new infrastructure projects that reduce current and future climate risks. A bond of this type is backed by the full credit of the municipality issuing the bond and allows the municipality to use any available funds, such as general funds, to repay the bond when it comes due. The US\$400 million in bond money will be used to invest in five categories of projects: sea-level rise and flood prevention; roadways; parks and cultural facilities; public safety; and affordable housing. The bulk will be invested in sea-level rise and affordable housing, to alleviate two of the city's most pressing resilience issues — constructing affordable housing, especially in low-income, higher-elevation neighbourhoods experiencing gentrification pressure, will help the city work towards equity outcomes and ensure that lower-income residents are not displaced from lower-risk neighbourhoods.

The bond structure allows the city to make investments without raising taxes, which enables the city to pursue major climate adaptation

ECONOMIC MODELLING AS A GUIDE FOR INVESTMENTS

To guide their investments, Miami, Miami-Dade County, and Miami Beach have all used innovative “business case” analyses for a variety of projects — in essence, cost-benefit analysis to estimate the feasibility of various adaptation measures. These analyses, conducted differently by each jurisdiction, examine factors such as the degree of risk reduction achieved by different solutions, cost comparisons of different approaches, or the co-benefits to environmental or quality-of-life goals for all residents.³⁴ This strategy, which often involves the use of economic modelling and external consultants, is worth highlighting for cities needing to make the case for why adaptation actions are financially advantageous and which ones maximize that advantage.

infrastructure without increasing the cost of living for residents. The bond has shown success so far, as some of the first projects subsidized through bond funding broke ground in 2019.³³

Building codes and preparedness

Hurricane Andrew made landfall a few miles south of Miami in 1992, destroying more than 63,500 houses, damaging more than 101,000 others, costing US\$26.5 billion in insured losses, and causing 65 deaths. It was, at the time, the costliest natural disaster for insured losses in global history.^{35,36}

The storm prompted the state to revise its building code and conduct greater code enforcement. Structures are required to withstand higher wind

Florida — and Miami, specifically — has one of the strongest building codes in the nation.



speeds, include impact-resistant glass to protect from windborne debris, and use cinderblock masonry construction reinforced with concrete pillars and hurricane-strapped roof trusses, rather than lightweight wood, or “stick” framing.³⁷ As a result, Florida — and Miami, specifically — has one of the strongest building codes in the nation.

Additionally, the city will be revising its code's standards for public and private seawalls, raising the required height, creating standards for natural waterfronts, and enacting rules for when owners will be required to bring waterfronts up to these new standards.³⁸ Miami is also in the process of updating its well-known form-based zoning code, Miami21, to include aspects that will address sea-level rise and climate change.³⁹

C Private-sector strategies

All new developments in Miami must comply with the state building code and city standards. Although many new developments stop at meeting minimum code requirements, some leading developers are beginning to take proactive steps to build “beyond

code” and focus on resilient design as a means of differentiating their product, securing lower flood insurance premiums, and offering better assurance for business continuity and preparedness for hurricanes and flooding.

For example, one prominent luxury apartment in Miami Beach, Monad Terrace, has a base that is elevated 3.7 metres (12 ft), with a landscaped ramp to help residents avoid floodwater; the basement is sealed to prevent water intrusion; the building has a large generator for power outages and flood pumps; and the building's glass is designed to withstand a Category 5 hurricane (the strongest designation).⁴⁰

Moreover, buildings must follow building code rules for development in federally designated floodplains. They must elevate the first residential floor up to 1.5 metres (five ft) above the base flood elevation and have open spaces under that floor for floodwater to move through without damaging the building.^{41,42} Some developments are going beyond these requirements and elevating homes even higher, sometimes by up to 4.6 metres (15 ft).⁴³

Other approaches include locating critical mechanical equipment on higher floors; installing flood doors, pump systems, or floodwater holding tanks; designing lower levels and basements to be easy to clean and resume service after flooding; and incorporating green infrastructure elements such as permeable paving, saltwater-tolerant planting, and berms to direct floodwaters away from building entrances.⁴⁴ Many private properties also construct their own seawalls to protect from coastal flooding; however, seawalls are less effective in this region because of the prevalence of groundwater flooding.

A review of Miami's resilience strategies by a panel of experts convened by the Urban Land Institute (ULI) in 2019 found that although the city has guidelines and regulations meant to support these design strategies, more could be done to encourage private sector participation through a combination of incentives and regulation.⁴⁵

Additionally, questions remain as to how flood-resilient features will be incorporated in low-to-moderate-income areas, which are also highly vulnerable to flooding, but whose residents cannot afford luxury flood-resilient homes.

Left
Seawalls are typical in Miami and nearby localities, though a greater variety of more naturalised waterfront edges (such as living shorelines) are being considered as a key new direction for greater resilience. Photo courtesy of ULI.



1450 Brickell, a 35-story office development in Miami completed in 2010, was built to withstand winds approaching 480 kilometers per hour (300 mph), and is one of Miami's most resilient buildings. Photo courtesy of 1450 Brickell, Miami, Florida.

d Non-profit-driven actions

Community-based organisations and non-profit organisations in Miami have been working to ensure that at-risk communities are included in the planning process for adaptation and are protected from both climate hazards and displacement. These organisations include:

- Catalyst Miami, an anti-poverty organisation that works to train and empower community leaders in climate resilience organising;
- The CLEO Institute, which works to expand climate change education, engagement, and advocacy; and
- The Miami Climate Alliance, a coalition organisation of more than 80 environmental and social justice member groups that provides coordination and works to prioritise equity within local climate adaptation.

These organisations play an essential role in expanding the reach of climate adaptation efforts across communities in Miami and work to prioritise the interests of community members with traditionally diminished political and socioeconomic influence. For example, Catalyst Miami works with the city to help inform city-led community outreach practices on climate planning projects like Miami Forever Climate Ready.

Similarly, Catalyst Miami and the city collaborate to ensure that the projects selected for funding under the Miami Forever Bond, and the process for selecting those funded projects, follow principles of equity, where funded projects are located in communities most at risk, and that diverse community members have the opportunity to participate in making funding decisions.⁴⁶

The Miami Climate Alliance notes that it successfully mobilised residents during Miami-Dade County's 2015 budget hearings to direct funds towards climate adaptation, eventually leading to creation of the county's Office of Resilience and hiring of the county's first Chief Resilience Officer.⁴⁷



Miami skyline. Photo courtesy of Alejandro Luengo on Unsplash.

LESSONS LEARNT

a Key insights from Miami

The city of Miami recently engaged ULI to convene a panel of national resilience experts from the public and private sectors who provided strategic recommendations on design, policy, and finance to increase resilience within downtown Miami's waterfront area. The panel briefly analysed Miami's progress on climate adaptation and created a roadmap for future directions. In their analysis, the panellists noted the following insights.

Base policy decisions on a comprehensive land use plan

To enhance overall resilience, many decisions must be made to boost overall resilience in areas such as zoning, transportation, open space, housing, sustainability, and public facilities. Although individual plans in each of these areas are helpful, a comprehensive development plan that considers all of them can provide the necessary unity to consider how resilience should apply citywide. Otherwise, cities can suffer from "over-planning" and find themselves acting in an uncoordinated fashion.

Include more than just financial returns in returns on investment

In addition to design and policy, the panel focused on how to finance investments in building climate resilience. Panellists noted that payback is different depending on the investor. "Traditional" investors are usually considered to be private institutions like developers, pension funds, and banks, who might invest in Miami by purchasing properties or bonds (such as the Miami Forever General Obligation Bond). These investors look to the government to protect their returns by mitigating physical risk to assets and drops in land and property value.

However, everyday Miami residents also invest time and money into their lives in the city and hope for a return through better quality of life. Quality of life will rise if investors (be they institutions, citizens, or even city governments) prepare for climate risks proactively, as a dollar invested today in resilience measures may generate significant savings tomorrow in repairing the damage incurred through inaction. More concretely, returns for resilient investment can include reduced insurance premiums and preservation of

property value, which in turn preserves property tax revenue for the city. They can also include the protection of affordable housing.

b Evaluation of the ecosystem

Miami's lessons to highlight include the following:

- In the absence of federal support, partnering with neighbouring governments to form regional collaborations to increase advocacy power, available funding, and impact of adaptation measures;
- Identifying cross-jurisdictional opportunities, such as interjurisdictional planning initiatives like Resilient305, and policy concepts like Adaptation Action Areas;
- Finding innovative local financing mechanisms, like bonds or impact fees, to fund adaptation actions;
- Backing investment decisions with economic analyses to demonstrate the value of a proactive approach; and
- At the state level, mobilising political will and momentum after a climate disaster to increase resilience by improving mandatory tools with broad application, like building codes. This is a key aspect of climate resilience work in the U.S., where widespread recognition of climate risk is still developing.

As noted, Miami has not received large-scale federal financial support for resilience-building in recent years (though the city has received funding to assist with hurricane clean-up costs after Hurricane Irma and is currently subject to a new U.S. Army Corps of Engineers project). Miami did not experience a major disaster between 2011 and 2013, which prevented the city from applying for the US\$1 billion National Disaster Resilience Competition⁴⁸ hosted by the federal Department of Housing and Urban Development in 2014. Increased federal funding, for example at the magnitude received by New York City after Hurricane Sandy but scaled proportionally to Miami's costs, could greatly accelerate capacity for infrastructural, social, and economic resilience investments.



Nonetheless, Miami has still made significant progress in its pursuit of climate adaptation. Continuing to scale up investments in resilient infrastructure and services by city government, advancing resilient building incentives and regulations for real estate, and including equity objectives and processes in adaptation planning through collaborations with community members will be key to ensuring that Miami remains a safe, attractive, and affordable place to live and invest in.

c Opportunities and way forward

Miami has taken significant action to address its climate risks, and the urgency and level of commitment must continue, given the extent of vulnerability the city faces.

As discussed in ULI's 2019 expert panel, a key strategy for the city will be to direct future development toward available high ground and less flood-prone neighbourhoods,⁴⁹ while simultaneously ensuring these safer zones contain room for residents of all income levels.

The panel also noted that focused development should be accompanied by improved design standards and strategies for waterfront edges along its bay- and river-facing urban zones. These strategies include slightly raising seawalls, expanding planting areas, and creating "living shorelines" (nature-based solutions mimicking the function of natural shorelines). These design standards would need to be continually adjusted to account for changes in sea level and storm projections. Resilient waterfront design has been a key focus of Greater Miami's resilience plan, Resilient305, which includes several future projects and policies to enhance the built and natural coastlines that protect the city.

Other select recommendations by the panel include:

- Updating building and zoning codes to include some of the advanced steps taken by the real estate market as minimums, to accelerate adoption of resilience principles;
- Updating the Downtown Miami Master Plan to bring cohesion to the numerous existing planning documents the city has put together, as previously discussed;
- Using a transfer of development density programme or tax increment financing programme to encourage development in high-ground areas and provide capital for buildings to invest in flood-proofing measures if elevation is not possible;
- Creating a place-based organisation or conservancy to generate and manage private investment for the city's waterfront areas; and
- Continuing to engage with residents and community organisations to connect climate adaptation steps with social and economic resilience needs like affordable housing or employment.

The city clearly has numerous opportunities to continue to scale up its resilience work citywide, while more can be done to address the resilience of existing buildings. However, its successes so far in establishing strong partnerships with local allies and generating new sources of funding place it in a strong position to continue expanding its adaptation work and remain an international centre of culture and climate resilience.

City of Miami and Miami Beach. Photo courtesy of Kent Wien licensed under CC BY-NC 2.0.



Chapter 5

APPLYING THE PRINCIPLES: GETTING STARTED IN YOUR CITY, COMPANY, OR COMMUNITY

THINKING GLOBALLY, ACTING LOCALLY: SPURRING YOUR ORGANISATION TO ACT

The five city case studies in the previous chapter reflect how the 10 principles for building climate resilience can be enacted by local governments and businesses. Although many of the principles focus on the organisational scale, individuals also have a major role to play, by influencing their organisations to make resilience a priority.

Far-sighted business leaders recognise the opportunity to incorporate resilience into their business models, while municipal leaders can prioritise resilience for all stakeholders in their communities and cultivate a more hospitable ecosystem that welcomes the private sector to join the work of resilience. This concluding chapter highlights key domains where individuals in any sector can get started in applying the 10 Principles, as they seek to make their cities more climate-resilient.

1 Build Awareness

Stay informed

Some risks associated with climate change may not be apparent or may arise unexpectedly — recall from Chapter 2 that there are both physical risks and transition risks. Make use of existing reports, data sets, and resources, and attend public forums and webinars (e.g., by the Centre for Liveable Cities, Urban Land Institute, C40, and Resilient Cities Network) to understand the risks faced by your region, business, property, or residence.

Know your resources and local landscape

Identify local government agencies and civic groups working on resilience. Recall Principle 1: Elevate resilience as a goal for all sectors and

stakeholders. Find out who is active in your vicinity, whether through citizen engagement, climate justice, conservation, policy or other angles. Search for location-specific resources, such as maps, design guidelines (e.g., Waterfront Edge Design Guidelines by the Waterfront Alliance), resilience toolkits (e.g., BlueLabel for home assessments or The Resilience Shift for life cycle analysis), and checklists of recommended actions (e.g., the National Fire Protection Association's safety checklist) to make your business or property more resilient.

For **governments and knowledge organisations**, identify the stakeholders in your district, and assess how they could be affected by climate risks. Are appropriate resources available to them? Have they been included in planning processes? Principle 4: Provide transparency through data and knowledge sharing is crucial in making it possible for more stakeholders to contribute.

2 Start a Conversation

Initiate a dialogue

Is there a resilience working group in your organisation, or a local advocacy group in your community? If so, join the conversation. Otherwise, seek out diverse individuals interested in resilience. Form a group to carry out activities such as assessing risks in your area and implementing resilience measures within your neighbourhood. Self-organised groups may eventually garner interest and participation from others.

Learn from peers

Look out for building features, organisational practices, and innovative actions by neighbours, industry peers, or other cities. Companies that

adopt Principle 3: Leverage opportunities to enhance liveability are worth emulating, as they present a clear business case that makes projects more attractive.

3 Take Action to Increase Resilience

Mainstream resilience thinking

Organisations can develop an internal resilience index or adapt one from public resources (e.g., Arup's City Resilience Index or the Task Force on Climate-related Financial Disclosures' reporting framework), and update internal operations plans, external contracts, and public-facing media to reflect resilience goals.

For **companies**, the goal is to make “resilience” the default mode of operating, much as “sustainability” has become a norm. This requires understanding climate risk exposures across supply chains and business processes, and how resilience investments add value. Inquire how your company is analysing and managing climate risks, or if it has not, determine who can do so. Many real estate companies have sustainability or risk management teams whose remit includes resilience.

For **governments**, many agencies or departments can participate in resilience efforts, often spearheaded by environmental or urban/regional planning offices. Find out whether other government bodies are working on a climate resilience or sustainability plan. Contribute by supporting relevant staff members or joining meetings in your jurisdiction; resilience is cross-cutting, and many agencies have a role to play. Some municipalities are adding resilience requirements into land use regulations or launching resilience design competitions as ways to encourage action and partner with the private sector.

Learning from past coastal storms, Partners HealthCare underwent a fundamental shift in its approach to the design of the Spaulding Rehabilitation Hospital. Besides sustainability, it focused on resilience, through careful planning using data and documented evidence. *Photo courtesy of Steinkamp Photography.*



Request action

For **tenants**, there may be local programs, often run by energy utilities, that help you engage with your landlord to make minor energy/weatherisation retrofits, saving energy and increasing resilience. Exemplifying Principle 9: Motivate the Market, Spur Innovation, these programmes (e.g., Mass Save in the U.S. state of Massachusetts) may provide rebates or financing for property owners to incentivise upgrades. Research local programmes and talk to your landlord about getting started.

For **owners/property managers**, can keep tenants informed about the building's vulnerabilities and actions taken to reduce risk. To promote sustainability among tenants, consider "green leases", which require residents to participate in sustainability and resilience efforts to achieve greener, safer buildings. These actions help address Principle 6: Spur united action through a common narrative.

For **property developers**, you can request that designers consult resilience/sustainability rating systems and design guidelines. Explore the use of green bonds, sustainability-linked loans, or other resilience-linked financing.

These are manifestations of Principle 2: Operate across space, time, and organisations and Principle 10: Normalise green finance to fund projects.

**4 Cultivate Alliances and Partnerships****Build a coalition to co-develop synergistic solutions**

Join a climate-related network that seeks interdisciplinary, collaborative climate solutions. Conduct outreach to stakeholders through local chambers of commerce, business improvement districts, or non-profit alliances. Support their work, and leverage their activities to drive implementation in your own organisation. Draw on Principle 7: Nurture a culture of collaboration in your coalition-building, which should amplify local voices to enact Principle 5: Strive for equity, access and inclusion. Inclusive approaches are likelier to be accepted, successful and beneficial to the broadest range of stakeholders.

Seek partners beyond city borders

Governments can look to neighbouring cities or regional groups (e.g., Southeast Florida Regional Climate Change Compact) or international networks (e.g., C40, GRCN, or ICLEI). Memorandums of Understanding (MOUs) on climate change (e.g., MOU between the United States, Canada, and Mexico) or multilateral collaborations such as Making Cities Resilient 2030 can also promote learning exchange.

5 Reassess and Recalibrate**Review risks and vulnerability regularly**

Uncertainty surrounds climate change impacts, globally and locally. As circumstances shift, re-evaluate your exposure and adjust assumptions, policies, and projects in line with updated climate science. Principle 8: Embody flexibility in approaches and solutions requires scrutinising outcomes, assessing effectiveness, and adapting risk management strategies.

Crescent Park in New Orleans was rebuilt by citizens and policymakers with a "build back better" approach post-Katrina. Besides boosting flood control, the redevelopment introduced access to the river yet preserved its industrial history. *Photo courtesy of Timothy Hursley.*



Diverse stakeholders gather to discuss resilience initiatives during a site visit in Bridgeport, Connecticut, for the Rebuild by Design competition. *Photo courtesy of Rebuild by Design.*

LESSONS FOR CITIES AND COMPANIES WORLDWIDE

This publication highlights how city governments, the private sector, and other stakeholders can benefit from greater cooperation, suggesting 10 principles to motivate action toward resilience. While our core workshops took place in five coastal cities, the research draws from many global contexts, and the distilled principles can be applied to cities of all kinds. Growing their collective strength to address the existential climate crisis requires cities to recognise shared responsibility and work across spatial scales.

Beyond city borders, knowledge sharing and support among municipalities builds upon their diverse experiences and complementary strengths. The many intergovernmental coalitions and specialist city networks cited in this publication are testament to the possibilities of global cooperation.

Above all, an integrated approach is key to climate resilience. Besides the physical and infrastructural dimensions of resilience, stakeholders must also consider economy, culture, ecology, and health. Efforts that take a systems lens will be more robust in building a city's capacity to adapt to climate change, among other trends and disruptions.

Advancing climate resilience in cities worldwide is a complex and difficult undertaking that requires forward-looking leadership, broad participation, and integrated planning. By drawing on a support network of governments, businesses, civic organisations, and individuals, it is not only possible to build a more sustainable and liveable future — in numerous cities, the process has already begun.

Notes

Chapter 1: Climate Change, Coastal Cities, and Resilience

- European Environment Agency, Data and maps, Indicators, Atmospheric greenhouse gas concentrations, 14 Oct. 2020, <https://www.eea.europa.eu/data-and-maps/indicators/atmospheric-greenhouse-gas-concentrations-6/assessment-1>.
- World Meteorological Organization (WMO), "WMO confirms 2019 as second hottest year on record", 15 Jan. 2020, <https://public.wmo.int/en/media/press-release/wmo-confirms-2019-second-hottest-year-record>
- National Oceanic and Atmospheric Administration, National Centers for Environmental Information, "Global Climate Report — Annual 2019", <https://www.ncdc.noaa.gov/sotc/global/201913>.
- Meteorological Service Singapore, Past Climate Trends, www.weather.gov.sg/climate-past-climate-trends/.
- WMO, "The State of the Global Climate in 2018", <https://wmo.maps.arcgis.com/apps/Cascade/index.html?appid=855267a7dd394825aa8e9025e024f163>.
- John A. Church and Peter U. Clark, et al., "Sea Level Change" in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK and New York: Cambridge University Press, 2013), https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf; IPCC, "Summary for Policymakers" in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (2019), <https://www.ipcc.ch/srocc/chapter/summary-for-policymakers/>.
- "Fact Sheet: People and Oceans", The Ocean Conference, United Nations, New York 5–9 June 2017, <https://www.un.org/sustainabledevelopment/wp-content/uploads/2017/05/Ocean-fact-sheet-package.pdf>.
- Centers for Disease Control and Prevention, Climate and Health, Temperature Extremes, 14 Oct. 2020, https://www.cdc.gov/climateandhealth/effects/temperature_extremes.htm.
- World Health Organization, Climate Change and Human Health, "Climate change and infectious disease", <https://www.who.int/globalchange/summary/en/index5.html>.
- Christina Nunez, "The jet stream, explained", *National Geographic*, 8 Mar. 2019, <https://www.nationalgeographic.com/environment/weather/reference/jet-stream/#:~:text=Rising%20global%20temperatures%20from%20global,%2C%20in%20turn%2C%20the%20weather.&text=Slower%2C%20weaker%20jet%20streams%20have,place%2C%20stalling%20them%20over%20regions>.
- Alejandra Borunda, "The science connecting wildfires to climate change", *National Geographic*, Sept. 2020, <https://www.nationalgeographic.com/science/2020/09/climate-change-increases-risk-fires-western-us/>.
- Petra Löw, "Hurricanes cause record losses in 2017 - The year in figures", Munich RE, 1 Apr. 2018, <https://www.munichre.com/topics-online/en/climate-change-and-natural-disasters/natural-disasters/2017-year-in-figures.html>.
- Congressional Budget Office, *Expected Costs of Damage from Hurricane Winds and Storm-Related Flooding* (CBO, April 2019), <https://www.cbo.gov/system/files/2019-04/55019-ExpectedCostsFromWindStorm.pdf>.
- Matthew Foley, "The High Cost of Wildfire in 2018", *NFPA Journal* (November/December 2019), <https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2019/November-December-2019/Features/Large-Loss/Wildfire-Sidebar>.
- United Nations (UN), Department of Economic and Social Affairs (DESA), "68% of the world population projected to live in urban areas by 2050, says UN", 16 May 2018, <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html>.
- UN, DESA.
- International Energy Agency and Global Alliance for Buildings and Construction, *2019 Global Status Report for Buildings and Construction* (UN Environment Programme, 2019), <https://wedocs.unep.org/bitstream/handle/20.500.11822/30950/2019GSR.pdf>.
- World Green Building Council, "New report: the building and construction sector can reach net zero carbon emissions by 2050", 23 Sept. 2019, <https://www.worldgbc.org/news-media/WorldGBC-embodied-carbon-report-published>.

- Louis Celliers and Cebile Ntombela, "Urbanisation, Coastal Development and Vulnerability, and Catchments" in *Regional State of the Coast Report: Western Indian Ocean* (UN Environment Programme, 2015), http://wedocs.unep.org/bitstream/handle/20.500.11822/11349/rsocr-printedition.compressed_Part29.pdf?sequence=30&isAllowed=y.
- Barbara Neumann, Athanasios Vafeidis, Juliane Zimmermann, and Robert J. Nicholls, "Future Coastal Population Growth and Exposure to Sea-Level Rise and an Coastal Flooding — A Global Assessment", *PLOS ONE* 10, no. 3 (11 Mar. 2015, correction 18 June 2015), <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0118571#sec001>.
- "Fact Sheet: People and Oceans", The Ocean Conference.
- IPCC, *Climate Change 2013: The Physical Science Basis*, https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_all_final.pdf.
- World Business Council for Sustainable Development (WBCSD), *Business Climate Resilience: Thriving through the Transformation* (Geneva, 2019), https://docs.wbcsd.org/2019/09/WBCSD_Business-Climate-Resilience.pdf.
- WBCSD, *Business Climate Resilience*.
- IPCC, Data Distribution Centre, Glossary, "Land use and Land use change", https://www.ipcc-data.org/guidelines/pages/glossary/glossary_.
- European Commission, Adaptation to climate change, https://ec.europa.eu/clima/policies/adaptation_en.
- ULI, Developing Urban Resilience, <https://developingresilience.uli.org/about-resilience/#:~:text=Resilience%20is%20%E2%80%9Cthe%20ability%20to,built%20environment%2C%20such%20as%20the>.
- IPCC, "Annex II: Glossary" in *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC, 2014), 117–130, https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-AnnexII_FINAL.pdf.
- Judith Rodin, "Cities in the Age of Crisis: Realising the Resilience Dividend", *Urban Solutions* 7 (June 2015), <https://www.clc.gov.sg/docs/default-source/urban-solutions/urb-sol-iss-7-pdfs/essay-cities-in-the-age-of-crisis.pdf>.

Chapter 2:

Partnering on Climate: The Business Case

- C40 and Arup, *Deadline 2020* <https://www.c40.org/researches/deadline-2020>.
- World Green Building Council, *Bringing Embodied Carbon Upfront*, https://www.worldgbc.org/news-media/WorldGBC-embodied-carbon-report-published#_ftn1.
- "1.2. Past and recent drivers of climate change" in IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC, 2014), https://ar5-syr.ipcc.ch/topic_observedchanges.php#section_1_2.
- Chapter 9: "Energy Efficiency in Building Renovation" in *Handbook of Energy Efficiency in Buildings* (Butterworth Heinemann, 2019), 675–810, <https://doi.org/10.1016/B978-0-12-812817-6.00042-5>.
- "Climate Risk, Real Estate, and the Bottom Line", 427 Geophy, Oct. 2018, http://427mt.com/wp-content/uploads/2018/10/ClimateRiskRealEstateBottomLine_427GeoPhy_Oct2018.pdf.
- Asaf Bernstein, Matthew Gustafson, and Ryan Lewis, "Disaster on the horizon: The price effect of sea level rise", *Journal of Financial Economics* 134, no. 2 (November 2019): 253–272, <https://doi.org/10.1016/j.jfineco.2019.03.013>.
- Urban Land Institute. The Business Case for Resilience in Southeast Florida: Regional Economic Benefits of Climate Adaptation. Washington, DC: Urban Land Institute, 2020
- Katharine Burgess and Elizabeth Foster, *Scorched: Extreme Heat and Real Estate* (Washington, DC: Urban Land Institute, 2019), <https://americas.uli.org/research/centers-initiatives/urban-resilience-program/extreme-heat/>.
- Urban Land Institute, *Returns on Resilience: The Business Case* (Washington, DC: ULI Center for Sustainability, 2015), <https://uli.org/wp-content/uploads/ULI-Documents/Returns-on-Resilience-The-Business-Case.pdf>.

[wp-content/uploads/ULI-Documents/Returns-on-Resilience-The-Business-Case.pdf](https://uli.org/wp-content/uploads/ULI-Documents/Returns-on-Resilience-The-Business-Case.pdf).

- ULI Asia Pacific, Mitsui Fudosan Nihonbashi Revitalisation Plan, 2020, <https://asia.uli.org/programs/awards-and-competition/awardsforexcellence/2020-winners/nihonbashi-muromachi-mitsui-tower/>.
- ULI Asia Pacific, EY Centre, 2020, <https://asia.uli.org/programs/awards-and-competition/awardsforexcellence/2020-winners/ey-centre/>.
- HafenCity Hamburg: Der Masterplan, new edition 2006, https://www.hafen-city.com/upload/files/files/z_en_broschueren_19_Masterplan_end.pdf.
- Urban Land Institute, *Returns on Resilience: The Business Case* (Washington, DC: ULI Center for Sustainability, 2015), <https://uli.org/wp-content/uploads/ULI-Documents/Returns-on-Resilience-The-Business-Case.pdf>.
- Economist Intelligence Unit, "Global economy will be 3 percent smaller by 2050 due to lack of climate resilience", EIU Update, 20 Nov. 2019, <https://www.eiu.com/n/global-economy-will-be-3-percent-smaller-by-2050-due-to-lack-of-climate-resilience/>.
- Aqil Haziq Mahmud, "S\$100b for climate change measures could come from borrowing, reserves and ministry budgets", CNA, 3 Sept. 2019, <https://www.channelnewsasia.com/news/singapore/100billion-climate-change-borrowing-reserves-budget-parliament-11867642>.

Chapter 3:

10 Principles for Building Climate-Resilient Cities

- Dirk Philipsen, "Private gain must no longer be allowed to elbow out the public good" (Aeon, 2020).
- Jalonne L. White-Newsome, "Rethink Resilience for the Era of COVID-19 and Climate Change", <https://nextcity.org/daily/entry/rethink-resilience-for-the-era-of-covid-19-and-climate-change>
- Paula Jarzabkowski, Konstantinos Chalkias, Daniel Clarke, Ekhosuehi Iyahan, Daniel Stadtmueller, and Astrid Zwick, "Insurance for Climate Adaptation: Opportunities and Limitations" (Background paper, CASS Business School, July 2019), https://cdn.gca.org/assets/2019-07/Insurance%20for%20climate%20adaptation_Opportunities%20and%20Limitations.pdf.
- Pieter Bloemen, Martijn Van Der Steen, and Zeger Van Der Wal, "Designing a century ahead: climate change adaptation in the Dutch Delta", *Policy and Society* 38, no. 1 (2019): 58–76, DOI: 10.1080/14494035.2018.1513731.
- The Sustainability Consortium, *Improving Supply Chain Resilience to Manage Climate Change Risks* (2020), <https://www.sustainablefinance.hsbc.com/-/media/gbm/sustainable/attachments/supply-chain-resilience-and-climate-change.pdf>.
- United Nations Office for Disaster Risk Reduction, Regional Office for Asia and Pacific, "Building back better with Sendai", 4 Feb. 2016, <https://www.undrr.org/news/building-back-better-sendai>.
- Judith Rodin, *The Resilience Dividend: Being Strong in a World Where Things Go Wrong* (Rockefeller Foundation, 2014).
- Carol Zabin et al., *Putting California on the High Road: A Jobs and Climate Action Plan for 2030* report prepared for the California Workforce Development Board, 2020, <https://www.documentcloud.org/documents/7197687-UC-Berkeley-report.html>.
- Kevin Hsu, Nicole Lum, and Augie, Williams-Eynon, "Joint Workshop on Climate Resilience" (Singapore: Centre for Liveable Cities, Urban Land Institute, New York City Mayor's Office of Recovery and Resilience, 2020), <https://drive.google.com/file/d/1fZUjOiwGzLxkPhYjYWrHlsxGaBSCbU4zE/view>.
- Urban Redevelopment Authority, "About BID", <https://www.ura.gov.sg/Corporate/Get-Involved/Enlive-Public-Spaces/Business-Improvement-District>.
- Burton Suedel et al., "Climate Change Benefits from the Horseshoe Bend Engineering with Nature Project", Engineering with Nature, https://doer.el.erdc.dren.mil/infographics/Suedel_WEDA_2017_Postor.pdf.

- Burton Suedel et al., "Creating Horseshoe Bend Island, Atchafalaya River, Louisiana", *Terra et Aqua*, September 2015, https://ewn.el.erdc.dren.mil/pub/Pub_2_Terra_et_Aqua_September2015.pdf.
- Centre for Liveable Cities, *The Active, Beautiful, Clean Waters Programme: Water as an Environmental Asset*, Urban System Studies, 2017, <https://www.clc.gov.sg/docs/default-source/urban-systems-studies/rb172978-mnd-abc-water.pdf>.
- European Union, "Climate Capture and Geological Storage", https://ec.europa.eu/clima/policies/innovation-fund/ccs_en.
- Joe Indvik, Robert Foley, and Mark Orlovski, *Green Revolving Funds: A Guide to Implementation & Management* (Cambridge MA: Sustainable Endowments Institute and the Association for the Advancement of Sustainability in Higher Education, 2013), http://greenbillion.org/wp-content/uploads/2015/07/GRF_Full_Implementation_Guide.pdf.

Chapter 4:

Case Studies: Singapore

- Singapore Land Authority, Total Land Area data set, 2019, <https://data.gov.sg/dataset/total-land-area-of-singapore>.
- National Climate Change Secretariat (NCCS), *Impact of Climate Change in Singapore*, 2019, <https://www.nccs.gov.sg/singapore-climate-action/impact-of-climate-change-in-singapore/>.
- Yearbook of Statistics Singapore, 2019*, https://www.singstat.gov.sg/-/media/files/publications/reference/yearbook_2019/yos2019.pdf.
- History SG, <https://eresources.nlb.gov.sg/history/events/1f669eff-bc82-49d1-a27c-2624e4c48c6>.
- Meteorological Service Singapore (MSS), *Annual Climate Assessment Report 2018 Singapore*, www.weather.gov.sg/wp-content/uploads/2019/03/Annual-Climate-Assessment-Report-2018.pdf.
- NCCS, *Impact of Climate Change in Singapore; MSS, Annual Climatological Report*, www.weather.gov.sg/wp-content/uploads/2019/03/Annual-Climatological-Report-2018.pdf.
- David E. Aldous, "Planning Green Open Spaces for South East Asian Capital Cities", 2010, https://www.nparks.gov.sg/-/media/cuge/ebook/citygreen/cg3/cg3_01.pdf?la=en&hash=1DB58BB7DFAB1AA5B0B00AEDA67BCD4B18903ED8.
- PUB, press release, 2016.
- MSS, *Annual Climate Assessment Report 2018 Singapore*.
- MSS, Past Climate Trends, 2017, www.weather.gov.sg/climate-past-climate-trends/.
- Yearbook of Statistics Singapore, 2019*.
- Yearbook of Statistics Singapore, 2019*.
- Yearbook of Statistics Singapore, 2019*.
- PUB, press release, "Drainage", 2019, <https://www.pub.gov.sg/drainage>.
- NCCS, Coastal Protection, 2019, <https://www.nccs.gov.sg/singapore-climate-action/coastal-protection/>.
- Yearbook of Statistics Singapore, 2019*.
- Yearbook of Statistics Singapore, 2019*.
- Department of Statistics Singapore, Household Income, <https://www.singstat.gov.sg/find-data/search-by-theme/households/household-income/latest-data>
- Ministry of Sustainability and the Environment, *Singapore's Climate Action Plan: A Climate-Resilient Singapore, for a Sustainable Future*, 2016, <https://www.nccs.gov.sg/docs/default-source/publications/a-climate-resilient-singapore-for-a-sustainable-future.pdf>.
- Ministry of Sustainability and the Environment, *Singapore's Climate Action Plan: A Climate-Resilient Singapore, for a Sustainable Future*, 2016, <https://www.nccs.gov.sg/docs/default-source/publications/a-climate-resilient-singapore-for-a-sustainable-future.pdf>.
- Prime Minister's Office Singapore, *National Day Rally NDR*, 2019, 18 August 2019, <https://www.pmo.gov.sg/Newsroom/National-Day-Rally-2019>.

- 22 Centre for Liveable Cities, *Living with Water: Lessons from Singapore and Rotterdam*, 2019, <https://www.clc.gov.sg/docs/default-source/books/living-with-water.pdf>.
- 23 Centre for Liveable Cities, *Living with Water*, 2019.
- 24 *Yearbook of Statistics Singapore*, 2019.
- 25 MOM, Foreign workforce numbers, 2019, <https://www.mom.gov.sg/documents-and-publications/foreign-workforce-numbers>.
- 26 MSS, Past Climate Trends, www.weather.gov.sg/climate-past-climate-trends/.
- 27 MSS, Climate of Singapore, 2010, www.weather.gov.sg/climate-climate-of-singapore/.
- 28 C. Choo, "The Big Read: As temperatures and urbanisation increase, fight against dengue will only get tougher", *Channel News Asia*, 25 June 2019, <https://www.channelnewsasia.com/news/singapore/dengue-deaths-signs-symptoms-treatable-cure-singapore-11655506>.
- 29 NCCS, "Climate Change Public Perception Survey 2019" infographic, <https://www.nccs.gov.sg/docs/default-source/publications/pps-infographic-final.pdf>.
- 30 NCCS, "Climate Change Public Perception Survey 2019", press release, 16 December 2019, <https://www.nccs.gov.sg/media/press-release/climate-change-public-perception-survey-2019>.
- 31 P. Stafford "Climate Change Colours Agenda for Singapore Investors", *Financial Times*, 27 June 2019, <https://www.ft.com/content/3f07f51a-78c3-11e9-b0ec-7dff87b9a4a2>.
- 32 NCCS, Inter-Ministerial Committee on Climate Change, <https://www.nccs.gov.sg/who-we-are/inter-ministerial-committee-on-climate-change/>.
- 33 Ministry of Sustainability and the Environment, *Singapore's Climate Action Plan*.
- 34 J. Lim, "Explainer: How Singapore will fund its \$5100b effort to mitigate climate change effects", *Today Singapore*, 21 August 2019, <https://www.todayonline.com/singapore/explainer-how-singapore-will-fund-its-s100-billion-effort-mitigate-climate-change-effects>.
- 35 National Environmental Agency, "The Environment Is Ours", 2012, <https://www.nea.gov.sg/docs/default-source/envision/chapter-6-the-environment-is-ours.pdf>.
- 36 NCCS, "Singapore's Long-Term Low-Emission Development Strategy", 1 April 2020, <https://unfccc.int/sites/default/files/resource/SingaporeLongtermLowemissionsdevelopmentstrategy.pdf>.
- 37 Prime Minister's Office Singapore, National Day Rally 2019 speech, <https://www.pmo.gov.sg/Newsroom/National-Day-Rally-2019>.
- 38 Centre for Liveable Cities, *The Active, Beautiful Clean Waters Programme* (Urban Systems Studies, 2017), <https://www.clc.gov.sg/docs/default-source/urban-systems-studies/rb172978-mnd-abc-water.pdf>.
- 39 Housing Development Board, "Homes at One with Nature", press release, 18 July 2018, <https://www.hdb.gov.sg/cs/infoweb/press-release/homes-at-one-with-nature1>.
- 40 PUB, Drainage, <https://www.pub.gov.sg/drainage>.
- 41 A. Tan, "Parliament: Only 2 of 9 flash flood locations on Jan 8 had history of flooding; not feasible to build drains for all extreme rainfall events", *The Straits Times*, 5 February 2018, <https://www.straitstimes.com/politics/parliament-only-2-of-9-flash-flood-locations-on-jan-8-had-history-of-flooding>.
- 42 PUB, 2 December 2019, <https://www.facebook.com/PUBsg/photos/flash-floods-occurred-at-two-reported-locations-in-jurong-east-street-32-and-cho/2560771844013481>.
- 43 National Parks Board, "NParks to work with the community to transform Singapore into a City in Nature", 4 March 2020, <https://www.nparks.gov.sg/news/2020/3/nparks-to-work-with-the-community-to-transform-singapore-into-a-city-in-nature>.
- 44 NCCS, "Singapore's Approach to Alternative Energy", 2020, <https://www.nccs.gov.sg/singapores-climate-action/singapore-approach-to-alternative-energy/>.
- 45 C. Li, et al., "Hidden Benefits of Electric Vehicles for Addressing Climate Change", *Scientific Reports* 5: 9213 (2015), <https://www.nature.com/articles/srep09213.pdf>.
- 46 Lea A. Ruefenacht and Juan A. Acero, eds., *Strategies for Cooling Singapore* (Cooling Singapore, 2017), https://static1.squarespace.com/static/586dfed8b3db2bba412a8919/t/5d33a948b5c4a100011cb82d/156366897377/CS_Catalogue_of_Strategies_online.pdf.
- 47 PUB, Drainage, <https://www.pub.gov.sg/drainage>.
- 48 PUB, Code of Practice, <https://www.pub.gov.sg/compliance/industry/codeofpractice>.
- 49 Public Utilities Board, *Managing Urban Runoff: Drainage Handbook* (2013), <https://www.pub.gov.sg/Documents/managingUrbanRunoff.pdf>.
- 50 Building and Construction Authority, *3rd Green Building Masterplan* (2014), https://www.bca.gov.sg/GreenMark/others/3rd_Green_Building_Masterplan.pdf.
- 51 MSS, *2019 Annual Climate Assessment Singapore*.
- 52 United Nations Framework Convention on Climate Change, 2020, <https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Singapore%20First/Singapore%27s%20Update%20of%201st%20NDC.pdf>.
- 53 N. Choy, "Singapore charts path on green finance", *Business Times*, 6 January 2020, <https://www.sgsme.sg/news/singapore-charts-path-green-finance>.
- 54 Monetary Authority of Singapore, *Singapore Corporate Debt Market Development* 2019, <https://www.mas.gov.sg/-/media/MAS/News-and-Publications/Surveys/Debts/Singapore-Corporate-Debt-Market-Development-2019.pdf?la=en&hash=B62FF66BD26D794562B5291D6693966C85F1DC55>.
- 55 Ministry of Finance, Speech by Ms Indraneel Rajah, Minister in the Prime Minister's Office, Second Minister for Finance and Education, at the Singapore Regional Infrastructure Summit 2019, Friday, 16 August 2019, at The Ritz-Carlton, Millenia Singapore, <https://www.mof.gov.sg/newsroom/speeches/speech-by-ms-indraneel-rajah-minister-in-the-prime-minister-s-office-second-minister-for-finance-and-education-at-the-singapore-regional-infrastructure-summit-2019-friday-16-august-2019-at-the-ritz-carlton-millenia-singapore>.
- 56 Prime Minister's Office, DPM Heng Swee Keat at the Singapore Perspectives Conference 2020, 20 January 2020, <https://www.pmo.gov.sg/Newsroom/DPM-Heng-Swee-Keat-at-the-Singapore-Perspectives-Conference-2020>.

Chapter 4: Case Studies: Hong Kong

- Government of the Hong Kong SAR, Census and Statistics Department (CenStatD), 2018.
- Wyss W.-S. Yim, "Coastal flooding in Hong Kong", PowerPoint, City University of Hong Kong, <https://www.cityu.edu.hk/gcacic/IGCP588Yim.pdf>.
- Environmental Protection Department (EPD), Marine Water Quality in Hong Kong, https://www.epd.gov.hk/epd/misc/marine_quality/1986-2005/eng/introduction_content.htm.
- 2016 Population By-census, "Snapshot of the Hong Kong Population", Housing Characteristics of Hong Kong Population, <https://www.bycensus2016.gov.hk/data/snapshotPDF/Snapshot05.pdf>.
- Government of the Hong Kong SAR, Drainage Services Department (DSD), Flooding Problems, https://www.dsd.gov.hk/EN/Flood_Prevention/Our_Flooding_Situation/Flooding_Problems/index.html.
- Hong Kong Agriculture, Fisheries and Conservation Department, "Hong Kong: The Facts — Country Parks and Conservation", https://www.afcd.gov.hk/english/country/cou_lea/the_facts.html.
- CenStatD, Population, <https://www.censtatd.gov.hk/hkstat/sub/so20.jsp>.
- CenStatD, Population Estimates Table E489, <https://www.censtatd.gov.hk/hkstat/sub/sp150.jsp?productCode=D5320189>.
- 2016 Population By-census, "Snapshot of the Hong Kong Population".
- DSD, Key Statistics and Data, Environmental Performance, https://www.dsd.gov.hk/Documents/SustainabilityReports/1819/en/key_statistics_and_data.html.
- CenStatD, National Income, <https://www.censtatd.gov.hk/hkstat/sub/sp250.jsp?tableID=030&ID=0&productType=8>.
- CenStatD, National Income.
- CenStatD, National Income.
- CenStatD, National Income, Gross Domestic Product (Yearly), 2019 ed., <https://www.censtatd.gov.hk/hkstat/sub/sp250.jsp?productCode=B1030002>.
- HKO, Climate Projections.
- Hong Kong Observatory (HKO), Climate Projections for Hong Kong, https://www.hko.gov.hk/en/climate_change/proj_hk_info.htm#msl.
- Medium scale: affecting area of more than 10 hectares or resulting in significant property damage or serious traffic disruption; small scale: affecting area of more than 0.25 hectares or resulting in some agricultural damage, isolated property damage, or traffic disruption; minor scale: affecting area of less than about 50 metres by 50 metres (area less than 0.25 hectare) or resulting in minor public nuisance and inconvenience.

- 18 DSD, Flooding Blackspots, https://www.dsd.gov.hk/EN/Flood_Prevention/Our_Flooding_Situation/Flooding_Blackspots/index.html.
- 19 Bloomberg.
- 20 Dharisha Mirando and Debra Tan, "CLSA Report: Thirsty and Underwater: Rising Risks in Greater Bay area", 20 September 2019, CWR, <https://www.chinawaterrisk.org/resources/analysis-reviews/thirsty-and-underwater-rising-risks-in-greater-bay-area/>.
- 21 Projected changes in the mean sea level in Hong Kong and its adjacent waters, HKO, https://www.hko.gov.hk/en/climate_change/proj_hk_info.htm.
- 22 Dharisha Mirando and Debra Tan, "No-Sense Climate Strategies: From DSD to HSBC", 20 September 2019, CWR, <https://www.chinawaterrisk.org/resources/analysis-reviews/no-sense-climate-strategies-from-dsd-to-hsbc/>.
- 23 Climate Change and Health, Collaborating Centre for Oxford University and Chinese University of Hong Kong (CUHK) for Disaster and Medical Humanitarian Response, 2016.
- 24 Emily YY Chan et al., "Policy Implication of Health Impacts of Climate Change in Hong Kong", Policy Brief, Collaborating Centre for Oxford University and the CUHK for Disaster and Medical Humanitarian Response, 2016, http://ccouc.org/_asset/file/policybrief-climatechangeandhumanhealthinhs-161020.pdf.
- 25 Chan et al., "Policy Implication of Health Impacts of Climate Change in Hong Kong", 2016.
- 26 Natural Terrain in Hong Kong, https://hkss.cedd.gov.hk/hkss/eng/natural_terrain.aspx.
- 27 Business Environment Council, Hong Kong Climate Resilience Roadmap for Business (2015).
- 28 Woody Chan and Debra Tan, "Hot, Thirsty, Sweaty & Wet: HK's Future Down the Drain?", 19 August 2019, CWR.
- 29 Civic Exchange, "People's Attitudes towards Climate Change Survey Results: Hong Kong Does Not Feel Climate Change Urgency", 14 January 2020, <https://civic-exchange.org/peoples-attitudes-towards-climate-change-survey-results/>.
- 30 Mirando and Tan, "No-Sense Climate Strategies: From DSD to HSBC".
- 31 Mirando and Tan, "No-Sense Climate Strategies: From DSD to HSBC".
- 32 "Steering Committee on Climate Change convenes its first meeting", press release, 7 April 2016, <https://www.info.gov.hk/gia/general/201604/07/P201604070814.html>.
- 33 Environment Bureau, *Hong Kong's Climate Action Plan 2030+* (January 2017), www.climateready.gov.hk/files/report/en/HK_Climate_Action_Plan_2030+_booklet_En.pdf.
- 34 Daphne Ngar-yin Mah and Peter Hills, "An International Review of Local Governance for Climate Change: Implications for Hong Kong", *Local Environment* 21, no. 1 (2016).
- 35 "Steering Committee on Climate Change convenes its first meeting", press release, 7 April 2016, <https://www.info.gov.hk/gia/general/201604/07/P201604070814.htm>.
- 36 Paris Watch, *Paris Watch Climate Action Report: Hong Kong's Contribution to the Paris Agreement Goals* (Hong Kong: Carbon Care InnoLab, 2018).
- 37 Annex 1, Membership of the Steering Committee on Climate Change, press release, 7 April 2016, <https://www.info.gov.hk/gia/general/201604/07/P201604070814.htm>.
- 38 DSD, Design and Construction of Hong Kong West Drainage Tunnel, 21 January 2013, <https://www.dsd.gov.hk/others/HKWDT/eng/background.html>.
- 39 Environment Bureau, Hong Kong's Climate Action Plan 2030+ (January 2017), www.climateready.gov.hk/files/report/en/HK_Climate_Action_Plan_2030+_booklet_En.pdf.
- 40 Government of Hong Kong SAR, *Total Water Management Strategy 2019: Strategy for Sustainable Water Supply in Hong Kong* (Development Bureau and Water Supplies Department, 2019).
- 41 Water Supplies Department, Additional Local Yield, 2019, <https://www.wsd.gov.hk/en/core-businesses/total-water-management-strategy/twm-review/additional-local-yield/index.html>.
- 42 Water Supplies Department, Additional Local Yield, 2019.
- 43 Environment Bureau, *Hong Kong Climate Change Report 2015*, <https://www.enb.gov.hk/sites/default/files/pdf/ClimateChangeEng.pdf>.
- 44 Legislative Council Panel on Development, "Government's Preparedness for Increasing Landslide Risk due to Climate Change", LC Paper No. CB(1)648/19-20(03), <https://www.legco.gov.hk/yr19-20/english/panels/dev/papers/dev20200526cb1-648-3-e.pdf>.
- 45 Survey and Mapping, Lands Department PowerPoint presentation, *Slope Maintenance Responsibility Information System (SMRIS)*, http://www.mnr.gov.cn/zt/ch/lhgcdlt_30142/tbg/201610/P020180727331287051006.

- pdf; Chengdu Forum (UN-GGIM) Global Map for Sustainable Development: Development and Applications in Urban Hazard Mapping, 15–17 October 2013.
- 46 Environment Bureau, *Hong Kong Climate Change Report 2015*.
- 47 "Hong Kong Planning Standards and Guidelines – A Summary. Chapter 11: Urban Design Guideline", https://www.pland.gov.hk/pland_en/tech_doc/hkpsg/sum/pdf/sum_ch11_en.pdf.
- 48 Hong Kong Green Building Council, "HKGBC BEAM Plus: Transform the Built Environment in Hong Kong", 2019, https://www.hkgbc.org.hk/eng/beam-plus/file/HKGBC_BEAMPlusOverview_Brochure_2019_Reduced.pdf.
- 49 Environment Bureau and Environmental Protection Department, *Environment Hong Kong 2017*, https://www.epd.gov.hk/epd/misc/ehk17/en/pdf1/web/EPD_AR_EHK2017.pdf.
- 50 *Hong Kong's Climate Action Plan 2030+*, chapter 5, "Energy and Carbon Efficiency in Buildings and Infrastructure", <https://www.climateready.gov.hk/files/report/en/S.pdf>.
- 51 IPCC Briefing in Hong Kong, 18 October 2019, *Business and the Climate Challenge*, <https://ienv.ust.hk/events/business-and-climate-change-challenge>; Post-COP25 Hong Kong Forum, 17 January 2020, <https://ienv.ust.hk/events/post-cop25-hong-kong-forum>.
- 52 Link Asset Management, Green Finance, 2020, <https://www.linkreit.com/en/sustainability/genericPage/greenfinanceV2/>.
- 53 Green Finance, Link Asset Management, 2020 <https://www.linkreit.com/en/sustainability/genericPage/greenfinanceV2/>.
- 54 Climate Bonds Initiative, Hong Kong Green Bond Market Briefing 2019, <https://www.climatebonds.net/resources/reports/hong-kong-green-bond-market-briefing-2019>.
- 55 Government Green Bond Programme, <https://www.hkma.gov.hk/eng/key-functions/international-financial-centre/bond-market-development/government-green-bond-programme/>.
- 56 Eric Ng, "Hong Kong listed firms get 'F' on ESG report card, put on notice as rules become mandatory in 2021", *South China Morning Post*, 1 January 2020, <https://www.scmp.com/business/article/3044106/hong-kong-listed-firms-get-f-esg-report-card-put-notice-rules-become>.
- 57 Mirando and Tan, "No-Sense Climate Strategies: From DSD to HSBC".
- 58 The CCRIF is the Caribbean Catastrophe Risk Insurance Facility supported by the World Bank, <http://projects.worldbank.org/P108058/caribbean-catastrophe-risk-insurance-facility?lang=en>.

Chapter 4: Case Studies: Rotterdam

- Centre for Liveable Cities, "Living with Water", November 2019, <https://www.clc.gov.sg/research-publications/publications/books/view/living-with-water>.
- Municipality of Rotterdam, "Rotterdam Weatherwise Urgency Document", 2019, <https://www.rotterdam.nl/wonen-leven/rotterdams-weerwoord/>.
- OECD, *Peer Learning Country Report: Netherlands* (2016), oecd.org/dac/peer-reviews/Peer-Learning-Country-Report-Netherlands.pdf.
- Municipality of Rotterdam.
- "Rotterdam Weatherwise Urgency Document", 2019.
- Mathijs Van Vliet and Jeroen Aerts, "Adaptation to Climate Change in Urban Water Management — Flood Management in the Rotterdam Rijnmond Area", in *Understanding and Managing Urban Water in Transition*, ed. Quentin Grafton, et al. (Dordrecht: Springer, 2014), 549–574.
- Philip Ward et al., "Governance of Flood Risk Management in a Time of Climate Change: The Cases of Jakarta and Rotterdam", *Environmental Politics* 22, no. 3 (2013): 518–536.
- Frauke Hoss, "A Comprehensive Assessment of Multilayered Safety (Meerlaagsveiligheid) in Flood Risk Management" (MSc. thesis, Delft University of Technology, 2010).
- Peter van Veelen, "Adaptive Strategies for the Rotterdam Un-Embanked Area: Synthesis Report" (Bussum: Knowledge for Climate Foundation, 2013): 17.
- Peiwen Lu and Dominic Stead, "Understanding the Notion of Resilience in Spatial Planning: A Case Study of Rotterdam, the Netherlands", *Cities* 35 (December 2013): 200–212.
- Herman Havekes et al., *Water Governance: The Dutch Water Authority Model* (The Hague: Dutch Water Authorities, 2017).

- 12 Municipality of Rotterdam, "Rotterdam Weatherwise Urgency Document", 2019, <https://www.rotterdam.nl/wonen-leven/rotterdams-weerwoord/>.
- 13 "Rotterdam Weatherwise Urgency Document", 2019.
- 14 "Rotterdam Weatherwise Urgency Document", 2019.
- 15 Waterplan Rotterdam, *Water Plan 2 - Working on Water for an Attractive City* (Municipality of Rotterdam, Hollandse Water Delta Board, Higher Water Board of Schieland and Krimpenerwaard, and Higher Water Board of Delfland, 2007).
- 16 Wilrik, "Urban Waterbuffer supplies water for Sparta stadium Rotterdam", *Field Factors*, 21 June 2018.
- 17 Rathenau Instituut, "Science Policy and Innovation Policy", 1 January 2018, <https://www.rathenau.nl/en/science-figures/policy-and-structure/infrastructure-knowledge/sciencepolicy-and-innovation-policy>.
- 18 Centre for Liveable Cities, "Living with Water".
- 19 Helen Mees and P.P.J. Driessen, "Adaptation to Climate Change in Urban Areas: ClimateGreening London, Rotterdam and Toronto", *Climate Law* 2, no. 2 (January 2011): 251–280.
- 20 De Urbanisten, *Climate-Proof ZOHO: a Work-in-Progress* (Rotterdam: De Urbanisten, 2016), https://www.urbanadapt.eu/wp-content/uploads/2016/01/URBANISTEN_climate_adaptive_ZOHO_lr-strippresentatie.pdf
- 21 "Rotterdam Weatherwise Urgency Document", 2019.
- 22 "Rotterdam Weatherwise Urgency Document", 2019.
- 23 Centre for Liveable Cities, "Living with Water".
- 24 Esther Wiense, *Rotterdam Rooftops: Taking Resilience to a Higher Level* (Rotterdam: NAI Publishing, 2018).
- 25 Arcadis Nederland and CE Delft, "LIFE@Urban Roofs: SCBA Multifunctional Roofs — General Report" (Arnhem: Arcadis Nederland, 25 May 2018), [https://www.rotterdam.nl/wonenleven/urban-roofs/LIFE@Urban-Roofs-Report-SCBA-General-\(English-Version\).pdf](https://www.rotterdam.nl/wonenleven/urban-roofs/LIFE@Urban-Roofs-Report-SCBA-General-(English-Version).pdf).
- 26 Tussentuin, 2019, <https://www.tussentuin.nl/>.
- 27 CLC-ULI Climate Resilience Workshop, November 2019.

Chapter 4: Case Studies: New York

- 1 Climate Central, Surging Seas Risk Finder, https://riskfinder.climatecentral.org/place/new-york.ny.us?comparisonType=city-neighborhood&eae-Variables=Roads&forecastType=NOAA2017_int_p50&impact=Land&impactGroup=Land&level=6&protection=unprotected&unit=ft.
- 2 NYC Department of City Planning, Open Data, Maps & Geography, <https://www1.nyc.gov/site/planning/data-maps/open-data/dwn-pluto-mappluto.page>.
- 3 NYC Department of Parks and Recreation, "About the New York City Department of Parks & Recreation", <https://www.nycgovparks.org/about>. Figure does not include land managed by other city, state, and federal agencies.
- 4 U.S. Census Bureau Population Estimates.
- 5 NYC Mayor's Office of Immigrant Affairs, *State of Our Immigrant City* (2018).
- 6 NYC Department of Environmental Protection.
- 7 City of New York, *A Stronger, More Resilient New York* (2013).
- 8 U.S. Bureau of Economic Analysis.
- 9 Statista.
- 10 NYC Housing Preservation & Development.
- 11 City of New York, *One City Built to Last* (2016).
- 12 NYC Office of Management and Budget, *The City of New York Executive Budget Fiscal Year 2019: Budget Summary*, <https://www1.nyc.gov/assets/omb/downloads/pdf/sum4-18.pdf>.
- 13 City of New York, *OneNYC 2050* (2019).
- 14 *NPCC 2015*.
- 15 *New York City Panel on Climate Change 2019 Report (NPCC3)*.
- 16 This figure does not include area at risk from stormwater or groundwater flooding. *New York City Panel on Climate Change 2015 Report (NPCC 2015)*.
- 17 This figure does not include assets at risk from stormwater or groundwater flooding. NYC Comptroller, *Safeguarding Our Shores* (2019).

- 18 Josh Barbabel, "Market Value of New York Real Estate Shows Signs of Weakening", *Wall Street Journal*, 19 January 2020, <https://www.wsj.com/articles/market-value-of-new-york-real-estate-shows-signs-of-weakening-11579442400>.
- 19 Office of the Mayor, "Mayor de Blasio Announces New York City Poverty Rate Hits Historic Low", NYC, 1 October 2019, <https://www1.nyc.gov/office-of-the-mayor/news/449-19/mayor-de-blasio-new-york-city-poverty-rate-hits-historic-low>.
- 20 U.S. Census Bureau Quick Facts, <https://www.census.gov/quickfacts/fact/table/newyorkcitynewyork#>.
- 21 NYC Mayor's Office of Resiliency, 2020.
- 22 City of New York, *OneNYC 2050* (2019).
- 23 Defined by the U.S. Federal Emergency Management Agency as the area with a 1 percent chance of flooding in any given year.
- 24 *OneNYC 2050* (2019).
- 25 *NPCC3* (2019).
- 26 NYC Department of City Planning (DCP), Flood Resilience Zoning Text, <https://www1.nyc.gov/site/planning/zoning/districts-tools/flood-text.page>.
- 27 NYC DCP, Zoning for Coastal Flood Resiliency, <https://www1.nyc.gov/site/planning/plans/flood-resilience-zoning-text-update/flood-resilience-zoning-text-update.page>.
- 28 NYC Parks, East Side Coastal Resiliency, <https://www.nycgovparks.org/planning-and-building/planning/neighborhood-development/east-side-coastal-resiliency>.
- 29 NYC, The East Side Coastal Resiliency Project, <https://www1.nyc.gov/site/escr/index.page>.
- 30 NYC, Lower Manhattan Coastal Resiliency, Progress, <https://www1.nyc.gov/site/lmcr/progress/progress.page>.
- 31 Bill de Blasio, "My New Plan to Climate-Proof Lower Manhattan", *New York Intelligencer*, 13 March 2019, <https://nymag.com/intelligencer/2019/03/bill-de-blasio-my-new-plan-to-climate-proof-lower-manchattan.html>.
- 32 "HUD Awards \$1 Billion through National Disaster Resilience Competition", press release, 21 January 2016, Rockefeller Foundation, <https://www.rockefellerfoundation.org/news/hud-awards-1-billion-through-national-disaster-resilience-competition/>.
- 33 NYC, Community Development Block Grant Disaster Recovery, National Disaster Resilience, <https://www1.nyc.gov/site/cdbgdr/action-plan/national-disaster-resilience.page>.
- 34 Mayor's Office of Long-Term Planning and Sustainability, *One City: Built to Last*, <https://www1.nyc.gov/assets/builttolast/downloads/OneCity.pdf>.
- 35 Joel Rose, "5 Years after Sandy, New York Rebuilds with the Next Flood in Mind", *NPR*, 28 October 2017, <https://www.npr.org/2017/10/28/560450423/5-years-after-sandy-new-york-rebuilds-with-the-next-flood-in-mind>.
- 36 Rose, "5 Years after Sandy, New York Rebuilds with the Next Flood in Mind".
- 37 WLA, "Domino Park Designed by James Corner Field Operations Opens in New York", 16 June 2018, <https://worldlandscapearchitect.com/domino-park-designed-by-james-corner-field-operations-opens-in-new-york/>.
- 38 James Corner Field Operations, Domino Park, <https://www.fieldoperations.net/project-details/project/domino-park.html>.
- 39 *NPCC3* (2019).

Chapter 4: Case Studies: Miami

- 1 Climate Central, Surging Seas Risk Finder, https://riskfinder.climatecentral.org/place/miami.fl.us?comparisonType=city-commission-district&forecastType=NOAA2017_int_p50&impact=Property&impactGroup=Land&level=6&protection=unprotected&unit=ft.
- 2 Miami Forever Climate Ready 2020.
- 3 Trust for Public Land.
- 4 U.S. Census Bureau July 2019 Population Estimates, <https://www.census.gov/quickfacts/fact/table/miamicityflorida,miamidadecountyflorida/PST045219>.
- 5 The foreign-born population includes anyone who was not a U.S. citizen or a U.S. national at birth. This includes respondents who indicated they were a U.S. citizen by naturalization or not a U.S. citizen. U.S. Census Bureau Quick Facts.

- 6 City of Miami, "City Initiates Process to Revise Seawall Standards and Elevations", 14 January 2020, <https://www.miamigov.com/Notices/News-Media/City-Initiates-Process-to-Revise-Seawall-Standards-and-Elevations>; City of Miami Beach, Miami Beach Rising Above, Seawalls, www.mbrisingabove.com/climate-adaptation/public-infrastructure/seawalls/; Alex Harris, "Feds Consider a Plan to Protect Miami-Dad from Storm Surge", *Miami Herald*, 7 February 2020, <https://www.miamiherald.com/news/local/environment/article239967808.html>.
- 7 Bureau of Economic Analysis.
- 8 Datausa.io.
- 9 City of Miami, "Uli Panel Shares Ideas for Strengthening Miami's Waterfront", 19 June 2019, <https://www.miamigov.com/Notices/News-Media/ULI-Panel-Shares-Ideas-for-Strengthening-Miami%E2%80%99s-Waterfront>.
- 10 City of Miami, *Proposed Budget in Brief, Fiscal Year 2019-20*.
- 11 Miami Forever Climate Ready 2020.
- 12 Southeast Florida Regional Climate Change Compact (2019), <https://southeastfloridaclimatecompact.org/compact-documents/>.
- 13 Climate Central, Surging Seas, Miami.
- 14 It is difficult to find an exact measurement of the extent of flood zone maps in Miami. Federal flood risk maps have been critiqued for underestimating flood risk, and areas outside mapped flood zones flood regularly. Groundwater flooding and tidal flooding also frequently flood large areas whose locations are not mapped.
- 15 "Irma Spared America, but Still Had a Big Effect on It", *The Economist*, 14 September 2017, <https://www.economist.com/united-states/2017/09/14/irma-spared-america-but-still-had-a-big-effect-on-it>.
- 16 S. Hanson et al., "A global ranking of port cities with high exposure to climate extremes", *Climatic Change* 104, 89–111 (2011), <https://doi.org/10.1007/s10584-010-9977-4>. These estimates are old data but are still cited in recent reports, such as Resources for the Future's *Florida Climate Outlook: Assessing Physical and Economic Impacts through 2040* (<https://www.rff.org/publications/reports/florida-climate-outlook/>).
- 17 Climate Central, Cities Most Vulnerable to Major Coastal Flooding and Sea Level Rise. Social vulnerability was determined using the Social Vulnerability Index developed by the Hazards and Vulnerability Research Institute, which evaluates ability of communities to respond to and recover from environmental hazards using 29 different socioeconomic variables, such as age, relative wealth, race, mobility, English-language proficiency, medical disabilities, etc. <https://www.climatecentral.org/news/us-cities-most-vulnerable-major-coastal-flooding-sea-level-rise-21748>.
- 18 S. Hanson et al., "A global ranking of port cities with high exposure to climate extremes".
- 19 Miami Forever Climate Ready (2020).
- 20 The Next Miami, Miami is the second most popular destination for international visitors (and growing fast), 18 June 2015, <https://www.thenextmiami.com/miami-is-the-second-most-popular-destination-for-international-visitors-and-growing-fast/>.
- 21 UBS, Miami, <https://www.ubs.com/minisites/prices-earnings/en/cities/miami/>.
- 22 Jeff Goodell, "Miami: How Rising Sea Levels Endanger South Florida", *Rolling Stone*, 30 August 2013, <https://www.rollingstone.com/politics/politics-news/miami-how-rising-sea-levels-endanger-south-florida-200956/>.
- 23 Miami Forever Climate Ready 2020.
- 24 U.S. Census Bureau, 2018 American Community Survey, Selected Housing Characteristics, <https://data.census.gov/cedsci/table?q=DP04&t=ACS&tid=ACSDPSY2018.DP04&hidePreview=true&g=1600000US1245000>.
- 25 Miami Forever Climate Ready 2020.
- 26 Former Governor Rick Scott famously forbade use of the phrase "climate change" by state officials.
- 27 Tristram Korten, "In Florida, Officials Ban Term 'Climate Change'", *Miami Herald*, 11 March 2015, <https://www.miamiherald.com/news/state/florida/article12983720.html>.
- 28 Amy Green, "In Florida, a New Governor Speaks the Words, 'Climate Change'", *WLRN*, 30 April 2019, <https://www.wlrn.org/post/florida-new-governor-speaks-words-climate-change#stream/0>.
- 29 In the United States, county governments are subdivisions of states that provide a variety of services to multiple municipalities and have differing levels of authority over smaller city/town governments.
- 30 Southeast Florida Regional Climate Change Compact, What Is the Compact?, <https://southeastfloridaclimatecompact.org/about-us/what-is-the-compact/>.

- 31 City of Miami, "Resilient 305 — 21st Century Model for Urban Resilience", 30 May 2019, <https://www.miamigov.com/Notices/News-Media/Resilient-305-21st-Century-Model-for-Urban-Resilience>.
- 32 City of Miami, Coastal and Stormwater Infrastructure, <https://www.miamigov.com/Government/ClimateReadyMiami/Coastal-and-Stormwater-Infrastructure>.
- 33 City of Miami, "Breaking Ground on First Miami Forever Bond Resilience Project", 22 February 2019, <https://www.miamigov.com/Notices/News-Media/Breaking-Ground-on-First-Miami-Forever-Bond-Resilience-Project>.
- 34 Resilient305 (2019).
- 35 Rob Lenihan, "Lasting Effects of Hurricane Andrew", *Business Insurance*, 22 August 2017, <https://www.businessinsurance.com/article/00010101/NEWS06/912315310/Lasting-effects-of-Hurricane-Andrew>.
- 36 Mike Tsikoudakis, "Hurricane Andrew Prompted Better Building Code Requirements", *Business Insurance*, 19 August 2012, <https://www.businessinsurance.com/article/00010101/NEWS06/308199985/Hurricane-Andrew-prompted-better-building-code-requirements>.
- 37 Tsikoudakis, "Hurricane Andrew Prompted Better Building Code Requirements".
- 38 City of Miami, "City Initiates Process to Revise Seawall Standards and Elevations".
- 39 John C. Robbins, "Miami OKs Its First Legislation to Protect from Sea Level Rise", *Miami Today*, 29 April 2019, <https://www.miamitodaynews.com/2019/04/02/miami-oks-its-first-legislation-to-protect-from-sea-level-rise/>.
- 40 Ian Stewart and Lulu Garcia-Navarro, "Building for an Uncertain Future: Miami Residents Adapt to the Changing Climate", *NPR*, 31 March 2019, <https://www.npr.org/2019/03/31/706940085/building-for-an-uncertain-future-miami-residents-adapt-to-the-changing-climate>.
- 41 Robbins, "Miami OKs Its First Legislation to Protect from Sea Level Rise".
- 42 Jonathan Hahn, "Can South Florida Adapt to Rising Sea Levels before It's Too Late?" *Sierra*, 21 December 2018, <https://www.sierraclub.org/sierra/2019-1-january-february/feature/can-south-florida-adapt-rising-sea-levels-its-too-late>.
- 43 Josh Baumgard, "Flood-proof Miami Beach Home Seeks \$4M", *Curbed*, 10 August 2017, <https://miami.curbed.com/2017/8/10/15971462/flood-proof-miami-beach-home>.
- 44 ULI Advisory Services Panel Report, *Waterfront Resilience, Miami, Florida* (2019).
- 45 ULI Advisory Services Panel Report, *Waterfront Resilience, Miami, Florida* (2019).
- 46 Loren Berlin, "How Catalyst Miami Is Working to Make a \$400 Million Municipal Bond a Model for Equitable Climate Adaptation", 3 June 2019, Urban Institute, <https://next50.urban.org/article/how-catalyst-miami-working-make-400-million-municipal-bond-model-equitable-climate>.
- 47 <http://miamiclimateteam.org/>. Chief Resilience Officers, a permanent position created by the Rockefeller 100 Resilient Cities Initiative, are city-funded government officials who have a broad mandate to work across departments to advance climate, economic, and social resilience programmes in their cities.
- 48 "HUD Awards \$1 Billion through National Disaster Resilience Competition", press release, 21 January 2016, Rockefeller Foundation, <https://www.rockefellerfoundation.org/news/hud-awards-1-billion-through-national-disaster-resilience-competition/>.
- 49 ULI Advisory Services Panel Report, *Waterfront Resilience, Miami, Florida* (2019).

Chapter 5: Applying the Principles: Getting Started in your City, Company, or Community

- 1 *Cities and Climate Change: An Urgent Agenda*, Urban Development Series Knowledge Papers, vol. 10 (Washington, DC: International Bank for Reconstruction and Development/The World Bank, 2010), <https://openknowledge.worldbank.org/bitstream/handle/10986/17381/637040WP0Citie00Box0361524B0PUBLIC0.pdf?sequence=1&isAllowed=y>.

Contributors

CLC and ULI would like to extend their deepest gratitude to those who have contributed to the research one way or another, whether it is through their participation at the workshops, interviews and site visits, or providing an expert review of the content.

Singapore

Adele Tan, Urban Redevelopment Authority
 Alvin Lee, IHS Markit
 Andrew Buay, Singtel
 Angelene Chan, DP Architects
 Ankit Joshi, NUS Deltares
 Cesar Rocha, AECOM
 Chan Eu Jin, National Climate Change Secretariat
 Chua Boon Bee, Singtel
 Diana Chin, Urban Redevelopment Authority
 Esther An, City Developments Limited
 Govinda Singh, Colliers International
 Ho Chai Teck, Building and Construction Authority
 Ira Martina Drupady, Energy Studies Institute
 Jen Teo, Singapore Environment Council
 Jeremy Ng, Singapore Youth for Climate Action
 Jonathan Denis-Jacob, Colliers International
 Khoo Teng Chye, CLC
 Lauren Sorkin, Resilient Cities Network
 Lee Ai Ling, Keppel Urban Solutions
 Lee Gek Lang, PGIM Real Estate
 Lynette Leong, CapitaLand Group
 Miak Aw, City Developments Limited
 Ong Choon Fah, Edmund Tie
 Pang Chin Hong, Frasers Property Limited
 Poh Wei Shin, City Developments Limited
 Rachel See, City Developments Limited
 Sam Kernaghan, 100 Resilient Cities
 Scott Dunn, AECOM
 Serena Toh, Keppel Land
 Shakura Bashir, Temasek Holdings
 Tang Wei Leng, Colliers International
 Tony Chan, Arup
 Wong Heang Fine, Surbana Jurong

Rotterdam

Arnoud Molenaar, City of Rotterdam
 Eva Gaaff, Delft University of Technology

Femke Feenstra, Gortemaker Algra Feenstra
 Greg Lowe, Aon
 Henk Ovink, Embassy of the Netherlands
 Jan Willem Roel, FlexBase
 Jannes Willems, University of Amsterdam
 Jeroen Rijdsdijk, Municipality of Rotterdam
 Job Hogewoning, Ernst & Young
 Jeroen Dirckx, KCAP Architects&Planners
 Michaela Winter-Taylor, Gensler
 Nora Prins, APPM Management
 Piet Dircke, Arcadis
 Pieter Roozenboom, CBRE
 Richard Hamilton-Grey, Nuveen
 Robert Dijksterhuis, Ministry of the Interior and Kingdom Relations
 Tanja Lina, Tussentuin Foundation
 Wouter Dijkman, CBRE

New York

Aaron Ordower, Mayor's Office of Sustainability
 Amy Leitch, Arup
 Amy Chester, Rebuild by Design
 Andrew Salkin, Resilient Cities Catalyst
 BJ Jones, Battery Park City Authority
 Breanna Gribble, STV Inc.
 Brian Geller, The Durst Organisation
 Christian Braneon, New York City Panel on Climate Change
 Dan Egan, Vornado Realty Trust
 Dana Getman, SHoP Architects
 Dana Kochnower, Mayor's Office of Resiliency
 Dana Schneider, Empire State Realty Trust
 Daniel McPhee, Urban Design Forum
 David Briefel, Gensler
 Despo Thoma, SCAPE Studio
 Elijah Hutchinson, Economic Development Corporation
 Eri Furusawa, HR&A Advisors
 Eric Klinenburg, New York University

Eric Wilson, Mayor's Office of Resiliency
 Gonzalo Cruz, AECOM
 Hannah Glosser, HR&A Advisors
 Janice Barnes, Climate Adaptation Partners
 Joel Towers, New York Panel on Climate Change
 Jonathan Flaherty, Tishman Speyer
 Joy Sinderbrand, New York City Housing Authority
 Julia Bontempo, NYC Mayor's Office of Resiliency
 Kate Boicourt, Waterfront Alliance
 Konstantina Tzemou, Arup
 Lauren Zullo, Jonathan Rose
 Laurian Farrell, Resilient Cities Network
 Mallory Taub, Gensler
 Michael Izzo, Hines
 Michelle de la Uz, Fifth Avenue Committee
 Oliver Schaper, Gensler
 Peter Adams, Mayor's Office of Resiliency
 Peter Skevas, New York University
 Ranjini Venkatesan, Moody's
 Roger Platt, Green Business Certification Inc.
 Sanjay Seth, HR&A Advisors
 Sarah Dougherty, Waterfront Alliance
 Stephanie Margolis, HR&A Advisors
 Thomas Balsley, SWA/Balsley
 Thomas Jost, Sherwood Engineers
 Vincent Lee, Arup
 Xiaomei Lee, Gensler

Hong Kong

Albert Lee, Hong Kong Civil Engineering and Development Department
 Ashley Hegland, Swire Properties
 Calvin Kwan, Link REIT
 Colin Galloway, ULI
 Ellie Tang, New World Development
 Elvis Au, Hong Kong Environmental Protection Department
 Ir. Cary Chan, Hong Kong Green Building Council
 Ivan Chung, Hong Kong Planning Department
 Kristy Wong, Bank of America
 Margaret Kam, Hong Kong Green Building Council
 Nicholas Brooke, Professional Property Services Limited
 Professor KK Ling, Jockey Club Design Institute of Social Innovation
 Raymond Lee, Hong Kong Planning Department

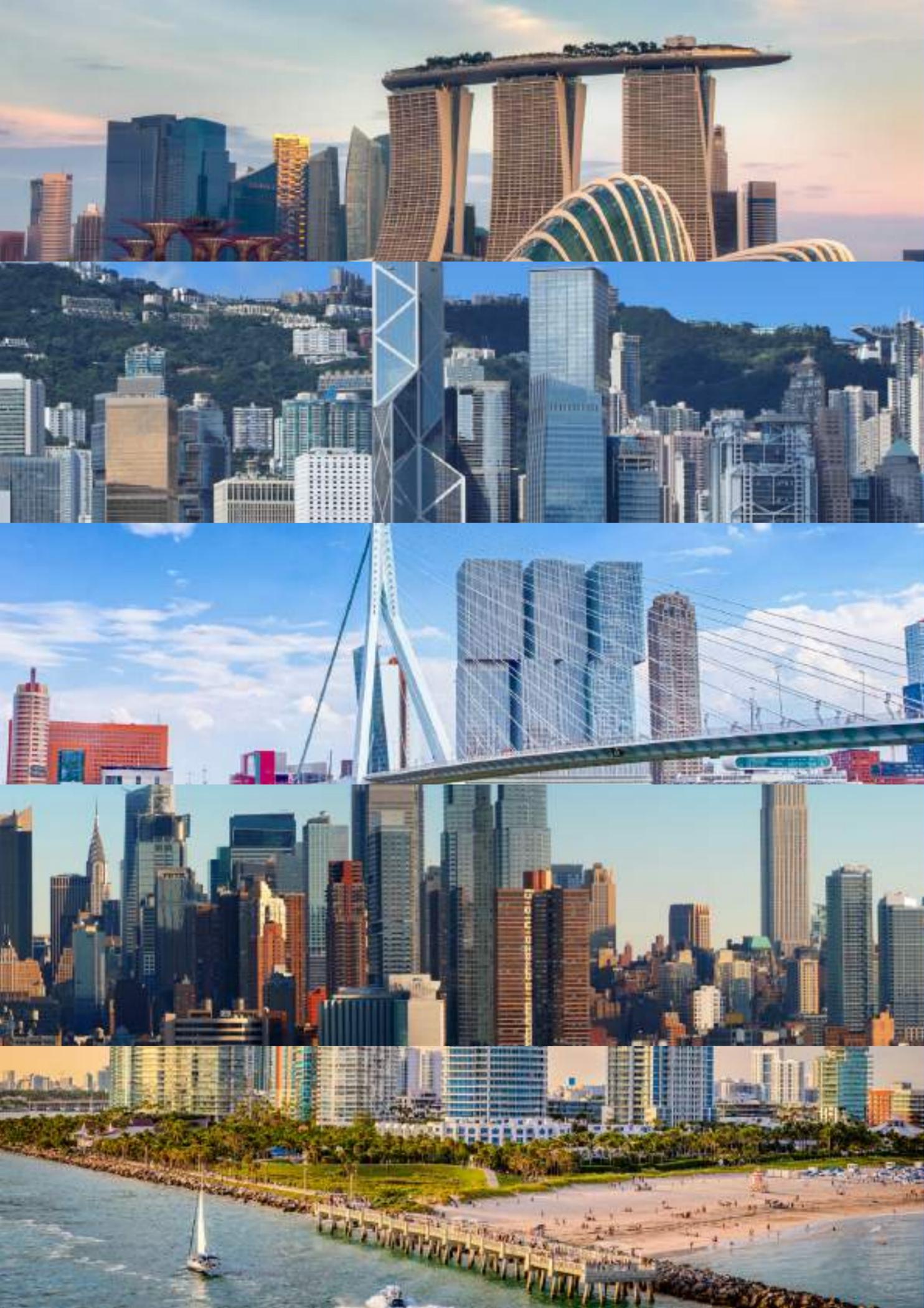
Tiffany Lau, ULI
 Tom Miller, LaSalle Investment
 Winnie Ho, Hong Kong Architectural Services Department

Miami

Albert Slap, Coastal Risk Consulting
 Chi Chi Truong, Schwebke-Shiskin & Associates
 Esteban Biondi, Applied Technology & Management
 Jacqueline Gonzalez Touzet, Touzet Studio
 Leonard Berry, Coastal Risk Consulting
 Michael Laas, Sustainable Futures Group
 Patrice Gillespie Smith, The Underline

Staff

Andre Kwok, CLC
 Christopher Kho, CLC
 David Ee, CLC
 Elyssa Ludher, CLC
 Eugene Tay, CLC
 Ken Lee, CLC
 Michelle Zhu, CLC
 Norio Sim, CLC
 Shaivi Herur, CLC
 Rex Chan, CLC
 Rachel Bok, CLC
 Raynold Toh, CLC
 Pearlwin Koh, CLC
 Lisette van Doorn, ULI
 Michelle Wong, ULI
 Colin Galloway, ULI
 Monika Henn, ULI
 Sofia Guerrero, ULI
 Tiffany Lau, ULI
 Ryan Chiao, ULI
 Emma, TU Delft
 Jisu, TU Delft
 Sienna, TU Delft
 Tessa, TU Delft





Building Climate Resilience in Cities Worldwide

This publication provides a framework and practical guide for cities to enhance their climate resilience in cooperation with the private sector. It draws examples of coastal city strategies and investments in the United States, Europe, and Asia to document international best practices, propose principles for stronger public-private cooperation, and evaluate approaches that are transferable based on a city's context or risk profile.

Covering both municipal and business perspectives, with a focus on the built environment, real estate, finance, and insurance sectors, the research carries an eye toward mobilising funding and governance structures to effectively support climate resilience. A series of workshops in the case study cities with stakeholders from the government, industry, academia, and the non-profit sectors, as well as interviews with businesses on climate resilience strategies, were conducted to gather the insights.