

PREPARING FOR A CLIMATE RESILIENT SINGAPORE

This Urban Systems Study documents Singapore's efforts to address climate change. Since its independence, Singapore has sought to balance economic development with concern for a clean and sustainable environment. As the seriousness of climate change becomes clearer, efforts have been stepped up to mitigate carbon emissions and adapt to projected changes. Working domestically and cooperating internationally, Singapore has adopted innovative, forward-looking and integrative solutions to address this existential challenge, recognising that ultimately, a liveable city must be a climate resilient one. This book highlights Singapore's past and ongoing efforts to reach this goal.

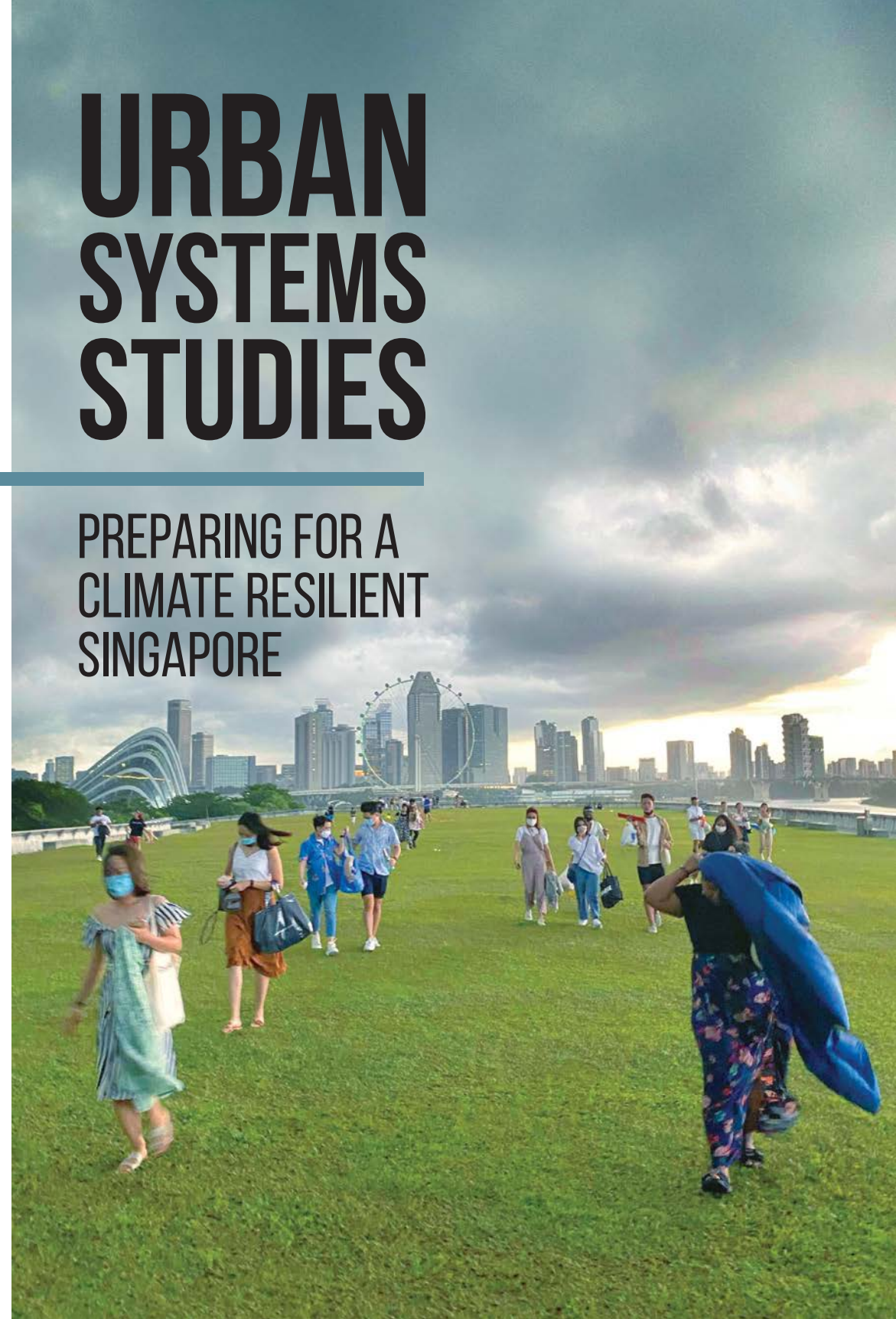
"We only have our small precious island nation, so it is all the more important that we look after it well, not just for this generation but for future generations of Singaporeans. Let us also work with friends around the world to protect our precious planet."

Teo Chee Hean, Senior Minister and Coordinating Minister for National Security
Chair of the Inter-Ministerial Committee on Climate Change (2011-Present)



URBAN SYSTEMS STUDIES

PREPARING FOR A CLIMATE RESILIENT SINGAPORE



**PREPARING FOR A
CLIMATE RESILIENT
SINGAPORE**

Urban Systems Studies Books

Water: From Scarce Resource to National Asset
Transport: Overcoming Constraints, Sustaining Mobility
Industrial Infrastructure: Growing in Tandem with the Economy
Sustainable Environment: Balancing Growth with the Environment
Housing: Turning Squatters into Stakeholders
Biodiversity: Nature Conservation in the Greening of Singapore
Financing a City: Developing Foundations for Sustainable Growth
Land Acquisition and Resettlement: Securing Resources for Development
Built by Singapore: From Slums to a Sustainable Built Environment
Planning for Tourism: Creating a Vibrant Singapore
Cleaning a Nation: Cultivating a Healthy Living Environment
Urban Redevelopment: From Urban Squalor to Global City
Port and the City: Balancing Growth and Liveability
The Active, Beautiful, Clean Waters Programme: Water as an Environmental Asset
Working with Markets: Harnessing Market Forces and Private Sector for Development
A City of Culture: Planning for the Arts
Sino-Singapore Guangzhou Knowledge City: A New Paradigm in Collaboration
Land Framework of Singapore: Building a Sound Land Administration and Management System
Integrating Land Use & Mobility: Supporting Sustainable Growth
Engaging Well, Forging Bonds: The Community as Stakeholders in Urban Development
Food and The City: Overcoming Challenges for Food Security
Technology and the City: Foundation for a Smart Nation
Energising Singapore: Balancing Liveability and Growth
one-north: Fostering Research, Innovation and Entrepreneurship
Planning for a Secure City
The Rule of Law and Urban Development
Past, Present and Future: Conserving the Nation's Built Heritage
Integrating the Planning of Airports and the City: The Singapore Story
Resettling Communities: Creating Space for Nation-Building
Religious Harmony in Singapore: Spaces, Practices and Communities
Enhancing Liveability, Fostering Communities: Estate Management for Singapore's Public Housing
Towards Ageing Well: Planning a Future-Ready Singapore



PREPARING FOR A CLIMATE RESILIENT SINGAPORE

For product information, visit



**URBAN SYSTEMS
STUDIES SERIES**

[www.clc.gov.sg/research-
publications/publications/
urban-systems-studies](https://www.clc.gov.sg/research-publications/publications/urban-systems-studies)



CLC PUBLICATIONS

[https://www.clc.gov.sg/
research-publications/
publications/books](https://www.clc.gov.sg/research-publications/publications/books)

CENTRE for
LiveableCities
SINGAPORE

Singapore, 2021

Editorial Team

Writers:	Elyssa Kaur Ludher, Kevin Fan Hsu, Norio Sim
Research Supervisor:	Elaine Tan
Research Advisor:	Loh Ah Tuan
Editor:	Brooklyn-media Pte Ltd
Production Supervisor:	Gregory Lee
Design and Production:	Epigram

© 2021 Centre for Liveable Cities, Singapore. All rights reserved.

CENTRE for
LiveableCities
SINGAPORE

CLC is a division of  MND
SINGAPORE

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) has as its mission 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, please visit www.clc.gov.sg.

Research Advisors for CLC's Urban Systems Studies are experts who have generously provided their guidance and advice. However, they are not responsible for any remaining errors or omissions, which remain the responsibility of the author(s) and CLC.

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

For queries, please contact:

CLC Publications
45 Maxwell Road #07-01
The URA Centre
Singapore 069118
T: +65 6645 9560
E: mnd_clc_publications@mnd.gov.sg

ISBN 978-981-14-8685-2 (print)

ISBN 978-981-14-8686-9 (e-version)

All rights reserved. No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, including photocopying, recording, or other electronic or mechanical methods, without the prior 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 will ensure that full credit is given at the earliest opportunity.

Cover photo:
People leaving Marina Barrage as an impending storm approaches.
Image courtesy of Kevin Fan Hsu.

CONTENTS

List of Illustrations and Exhibits	ix
Foreword	xiii
Preface	xv
Acknowledgements	xvii
The Singapore Liveability Framework	xviii
OVERVIEW	1
CHAPTER 1	5
SINGAPORE AND ITS VULNERABILITY TO CLIMATE CHANGE	
• Climate Change and its Impact on Singapore	7
- Rising Sea Levels	8
- Changing Rainfall Patterns	8
- Heat Stress	10
• Charting Singapore's Low-Carbon Future	11
CHAPTER 2	13
BEFORE THE 1990s: ESTABLISHING THE FOUNDATION FOR ENVIRONMENTALLY CONSCIOUS DEVELOPMENT	
• From Squalid Slum to a Garden City	15
• <i>Greening From the Top, Greening Everywhere: The Garden City Action Committee</i>	16
• Conserving Biodiversity	17
• Creating a Clean Environment for the People	18
• <i>Jurong Town—A Clean and Green “Garden Industrial Town”</i>	20
• Developing Water Infrastructure to Address Potable Demand, Sanitation and Flooding	22
• <i>Swimming Out of Danger: Addressing Flood-prone Singapore</i>	24
• Protecting the Coastline	26
• Charging up for Growth	26
• Planning a High-Density, Transit-Oriented City	27
• <i>Sustainable Living Through High-Density, Self-Contained Towns</i>	30

CHAPTER 3	33
1990s–2000s: UNDERSTANDING CLIMATE CHANGE AND ITS IMPACT	
• Understanding the Challenge of Climate Change	34
• Earth Summit and the United Nations Framework Convention on Climate Change (UNFCCC): Singapore on the International Stage	34
• The Kyoto Protocol: Global Efforts to Take Action on Climate Change	36
• Mindset Shift from Environmental Performance to Sustainable Outcomes	37
• National Commitment to a Sustainable Environment	39
• From a Garden City to City in a Garden	39
• Waste Management for a Cleaner Environment	41
• <i>Shifting Mindsets Through Tables on Buses</i>	44
• Enhancing the Nation’s Water Resources: Singapore’s Four National Taps	45
• Electricity Supply: Fuel-Switching to Natural Gas and Improving Efficiency	49
• Demand-side Management: Taking a Serious Step Towards Energy Efficiency	51
- Industry	51
- Buildings	52
- Transport	53
• <i>Improving Standards for Diesel Vehicles</i>	54
• Advancing Through 3P Partnerships	55
• <i>Rallying Support to Conserve Chek Jawa</i>	56
CHAPTER 4	59
2007–19: INSTITUTIONALISING EFFORTS TO RESPOND TO CLIMATE CHANGE	
• Establishment of the IMCCC	60
• Changing Minds: Climate Awareness Permeates the Civil Service	64
• Long Road to Paris: Singapore’s Contributions to International Negotiations	65
• <i>An Important Innovation: Nationally Determined Contributions</i>	68
• Understanding Climate Change Impact: From Macro to Micro	71
• What is Singapore’s Emissions Contribution to Climate Change?	73

• Improving the Industrial Sector’s Energy Efficiency	74
• Improving the Building Sector’s Energy Efficiency	76
• Transport Sector: Low-Carbon Mode Choice and Improving Efficiency	80
• Improving Households’ Conservation and Energy Efficiency	83
• The Power Sector and Four Switches	84
• <i>Capturing the Sun: Adopting Solar Power in Singapore</i>	86
• Prudent Adoption of Clean Technologies	89
• <i>Falling for Timber: Innovating for Carbon Positive Building Material</i>	90
• Implementing a Carbon Tax	92
• <i>Carbon Pricing</i>	94
• Widening the Scope of Climate Action: Beyond Emissions Mitigation Strategies	96
• Adaptation: Demystifying the Impact of Sea Level Rise	97
• Protecting the Coast and Infrastructure	98
• Preparing for Flooding	100
• Keeping Singapore’s Taps Flowing	101
• <i>Preparing for Drought</i>	102
• Cooling Down in a Heating Singapore	103
• Planning for Food Security	106
• Climate Change and Public Health	107
• Raising Internal Capacity for Continued Climate Action	108
• Innovating with the Private Sector	111
• <i>Public-Private Partnership: Singapore Green Building Council (SGBC)</i>	112
• <i>Today’s Limitations are Tomorrow’s Opportunities: Adopting New Practices in Green Buildings</i>	114
• Raising Awareness and People’s Action	116
• My Backyard is Your Front Yard, My Side Gate is Your Side Gate: Regional Engagement	118
• <i>Avoiding Socialising Pain, Privatising Gain: Regional Cooperation on Haze</i>	120
CHAPTER 5	123
BUILDING A CLIMATE RESILIENT FUTURE	
• A Rallying Call	124
• Understand: Planning for a Climate-Unstable Future	125
• Mitigate: Towards a Low-Carbon Future	126
- Thrust 1: Transforming Industry, Economy and Society	127
• <i>Racing for Zero Internal Combustion Engines</i>	128
• <i>Reducing Food Waste: Whole-of-Industry Approach</i>	129
- Thrust 2: Adopting Advanced Low-Carbon Technologies	132

- Thrust 3: Effective International Collaboration	132
• <i>A Stalwart Defender of the Paris Agreement and Multilateralism</i>	134
• Looking Ahead to Net-Zero Emissions	136
• Adapt: Preparing for the Worst with Clear-Eyed Realism	136
- Addressing Sea Level Rise	137
- Climate Proofing the City Against Heat	138
- Ensuring Availability of Food and Water	140
• <i>Our Singapore Food Story: The 3 Food Baskets</i>	142
• Adopting Science and Technology in a Time of Dynamic Change	144
• Engaging the Community in Building Resilience	145
• <i>Learning About Resilience by Doing</i>	146
• Individual and Collective Action Needed for Climate Action	148
• Cities at the Forefront of Global Climate Action	149
• Growing Expectations from Future Generations	150
Post-script	152
Timeline	154
Appendix	160
Endnotes	164
Bibliography	176
Image Credits	185

LIST OF ILLUSTRATIONS AND EXHIBITS

Illustrations

1. From an often-flooded squalid city, Singapore has developed into a liveable city.
2. As part of the Garden City movement, Singapore planted thousands of trees along roadsides and in estates.
3. Fullerton Road before and after planting.
4. The Singapore River clean-up was a whole-of-government effort.
5. Jurong Town was planned to be a Garden City industrial town.
6. The Jurong Bird Park served as an efficient bioindicator of pollution levels.
7. The Rochor Canal was regulated and expanded to control flooding issues in the neighbourhood.
8. Flooding was commonplace in the early years of independence.
9. Seawalls protect Singapore's main island and its surrounding islands.
10. Over the decades, Singapore's Concept Plans have consistently built on previous iterations.
11. The completion of the first MRT line.
12. Tampines, which began occupancy in 1983, is a town with a population of over 230,000 in just over 1,200 ha (12 km²).
13. Our Tampines Hub integrates various facilities to meet the needs of the residents.
14. Ambassador Koh chairing the Preparatory Committee of the Earth Summit in 1992.
15. There was concerted effort to increase vegetation cover across Singapore.
16. Incineration ash is buried at purpose-built lagoons in Semakau Landfill.
17. The DTSS network and co-location of NEWater plants with water reclamation contributed to Singapore's water security.
18. Today, two-thirds of Singapore's land area is a water catchment area.
19. The HDB flats were built with windows that orient north-south to promote cross ventilation and have void decks to draw wind onto the ground and improve wind flow.
20. The Singapore Green Building Council adopts a 3P approach to engage in outreach activities.
21. Chek Jawa became such a popular spot for marine life that a boardwalk was built to minimise adverse impact on the biodiversity.
22. The CCRS conducts climatic studies that impact Singapore and Southeast Asia.
23. The BCA Green Mark Scheme covers energy and resource efficiency, smart and healthy buildings, climatic responsive design and other green efforts.
24. The BCA's Zero Energy building is a prototype that is a model for developers and builders to learn from.
25. Over the decades, the number of MRT lines and stations has increased to improve access across Singapore.
26. The Energy Label Scheme helps consumers make informed choices when purchasing appliances.
27. Singapore's plans to develop its "Four Switches" to create a sustainable energy future.
28. In 2016, the PUB and EDB launched a 1 MWp testbed at Tengeh Reservoir to study the feasibility of floating solar PV deployment on reservoirs.
29. The Wave at NTU is one of the first large-scale buildings in Southeast Asia built using MET.

30. The carbon tax was introduced in 2019 at S\$5 per tCO₂e, with plans to increase it to between S\$10 and S\$15 per tCO₂e by 2030.
31. An illustration of the areas with higher risk of flooding.
32. Since 2011, the PUB has raised minimum platform levels and minimum reclamation levels by 1 m to cater to projected sea level rise.
33. Beyond localised measures, Singapore's coast has been divided into eight segments to improve coastal defences.
34. Entrances of MRT stations are elevated to reduce flood risk in times of intense rainstorms.
35. Simulation of the rise of average temperature due to climate change and heat island effect.
36. The Floating Wetlands System is an innovative solution to introduce pockets of greenery on the waterway which helps to attract biodiversity and cleanse the water.
37. Singapore is looking to improve thermal comfort in urban areas through vertical and rooftop greenery.
38. The Eco-Link@BKE was built across an expressway to re-connect the Bukit Timah Nature Reserve with the Central Catchment Nature Reserve.
39. Singapore is opening up new spaces to farming, including the rooftops of multi-storey carparks.
40. Evolution of sustainability and climate change plans from 2002-20.
41. The SGBC promotes public-private partnership on greening the built environment.
42. The PPVC moulds are completed in factories, allowing better quality control.
43. The SAMCA was initiated and hosted by the Government of Singapore on 10 July 2018.
44. The site of Tianjin Eco-City was once a saline wasteland.
45. PM Lee highlighting the impact of climate change on Singapore at the National Day Rally 2019.
46. All public buses will run on cleaner energy by 2040.
47. The Tuas Nexus generates energy from sludge and solid waste to be fully energy self-sufficient.
48. Studies are underway to explore new energy options, including solar power from other countries.
49. At the invitation of the Polish COP 24 President, Michal Kurtyka, Minister Zulkifli co-facilitated with Norway the ministerial negotiations on the mitigation track.
50. At the request of the Chilean COP 25 Presidency, Singapore co-facilitated with Spain the key overarching conference decisions.
51. The HDB is experimenting with polder technologies more suitable for the Singapore context.
52. The HDB Green Towns Programme aims to reduce energy consumption, recycle rainwater and cool the HDB towns.
53. Nature Ways enhance the streetscape while allowing biodiversity to flourish amidst the urban landscape.
54. The three "food baskets" to safeguard Singapore's food security, one of which entails ramping up local food production.
55. Community gardening initiatives strengthen social resilience amongst Singaporeans by encouraging community bonding and bringing people closer to nature.
56. The Centre organised community engagement events to not only raise awareness to spur local climate action, but it also walked the ground with residents to understand the impact.
57. Climate action events will become more frequent as more residents' concerns are raised.
58. More extreme weather events are expected as a result of climate change.

Exhibits

1. Annual total rainfall in Singapore (1980–2019).
2. Flood-prone areas (1970s–2019).
3. Annual average temperature (1948–2019).
4. Charting Singapore's low-carbon future.
5. National blueprints on environmental sustainability and mitigation (1992–2006).
6. Water loop.
7. Fuel mix for electricity generation by percentage.
8. Committees, working groups and members under the IMCCC.
9. Singapore greenhouse gas emissions profile 2017.
10. Green Mark building projects in Singapore.
11. Public transport operation and ridership.
12. Entities and their relationship under the SolarNova programme.
13. Carbon tax vs. emissions trading.
14. Technology roadmaps for energy and climate challenges.
15. Public awareness of climate change.

FOREWORD

Singapore has focused on sustainable development long before the words “sustainability” and “climate action” entered the global discourse. As early as 1967, then Prime Minister Lee Kuan Yew had introduced the vision of a “Garden City” into our development strategy, to ensure that Singaporeans can enjoy abundant greenery and a clean environment even as we pursued economic growth. As a small city-state with limited land and natural resources, we have always emphasised the need to preserve and protect our environment and make the most of what we have, as we have no option to retreat anywhere else.

Today, we must continue to prioritise sustainable growth in the face of climate change, which represents an existential challenge for Singapore. If current global warming trends continue, unprecedented climate impact could bring dire consequences to Singapore. As a low-lying island, Singapore is particularly vulnerable to the threat of rising sea levels and extreme weather events. In recent years, we have seen more episodes of unusually intense rainfall while 2010–19 was our nation’s warmest decade.¹ Such extreme conditions could become the norm in the future if global warming is not addressed.

Singapore is committed to supporting the global call for enhanced climate action. Given the multi-faceted nature of climate change, we established the Inter-Ministerial Committee on Climate Change in 2007 to coordinate a whole-of-government response. As a signatory of the Paris Agreement, Singapore has committed to peak our emissions at 65 million tonnes of carbon dioxide-equivalent (MtCO₂e) around 2030. In 2020, we released our long-term Low-Emissions Development Strategy, which aims to halve national emissions to 33 MtCO₂e by 2050 and achieve net-zero emissions as soon as viable, in the second half of the century. These targets will guide our efforts across all sectors to achieve economy-wide decarbonisation.

Apart from improving energy efficiency, we will leverage low-carbon technologies such as hydrogen, carbon capture, utilisation and storage, and renewable energy. We will also continue to promote international collaboration to build capabilities and develop cross-border solutions, such as well-functioning carbon markets and regional electricity grids. While the actions of our nation alone may be insufficient, a collective effort by all countries will bring us much closer to a global low-carbon future.

This book presents Singapore's sustainability journey since our independence. It outlines our vision to create a greener environment for Singapore, and our strategies to achieve a low-carbon future. We must build upon the legacy of our pioneers to make Singapore a liveable city for generations to come.

Teo Chee Hean

Senior Minister and Coordinating Minister for National Security
Chair of the Inter-Ministerial Committee on Climate Change (2011–Present)

PREFACE

The Centre for Liveable Cities' research in urban systems unpacks the systematic components that make up the city of Singapore, capturing knowledge not only within each of these systems, but also the threads that link these systems and how they make sense as a whole. The studies are scoped to venture deep into the key domain areas the Centre has identified under the Singapore Liveability Framework, attempting to answer two key questions: how Singapore has transformed itself into a highly liveable city over the last five decades, and how Singapore can build on our urban development experience to create knowledge and urban solutions for current and future challenges relevant to Singapore and other cities through applied research. *Preparing for a Climate Resilient Singapore* is the latest publication from the Urban Systems Studies (USS) series.

The research process involves close and rigorous engagement of the Centre's researchers with our stakeholder agencies, and oral history interviews with Singapore's urban pioneers and leaders to gain insights into development processes and distil tacit knowledge that has been gleaned from planning and implementation, as well as the governance of Singapore. As a body of knowledge, the USS—which covers aspects such as water, transport, housing, industrial infrastructure and sustainable environment—describes not only the visible outcomes of Singapore's development, but reveals the complex support structures of our urban achievements.

In this book, we have sought to include key policies, actions and decisions to document the evolution of policy-making strategies and its impact over time. However, in providing a picture of the key actions and lessons, not everything that Singapore has done in relation to climate change is covered, as activities to combat climate change are far-reaching and require concerted efforts across all sectors of society.

The Centre would like to thank the National Climate Change Secretariat, Ministry of Sustainability and the Environment and all who have contributed their knowledge, expertise and time to make this publication possible. I wish you an enjoyable read.

Khoo Teng Chye

Executive Director
Centre for Liveable Cities

ACKNOWLEDGEMENTS

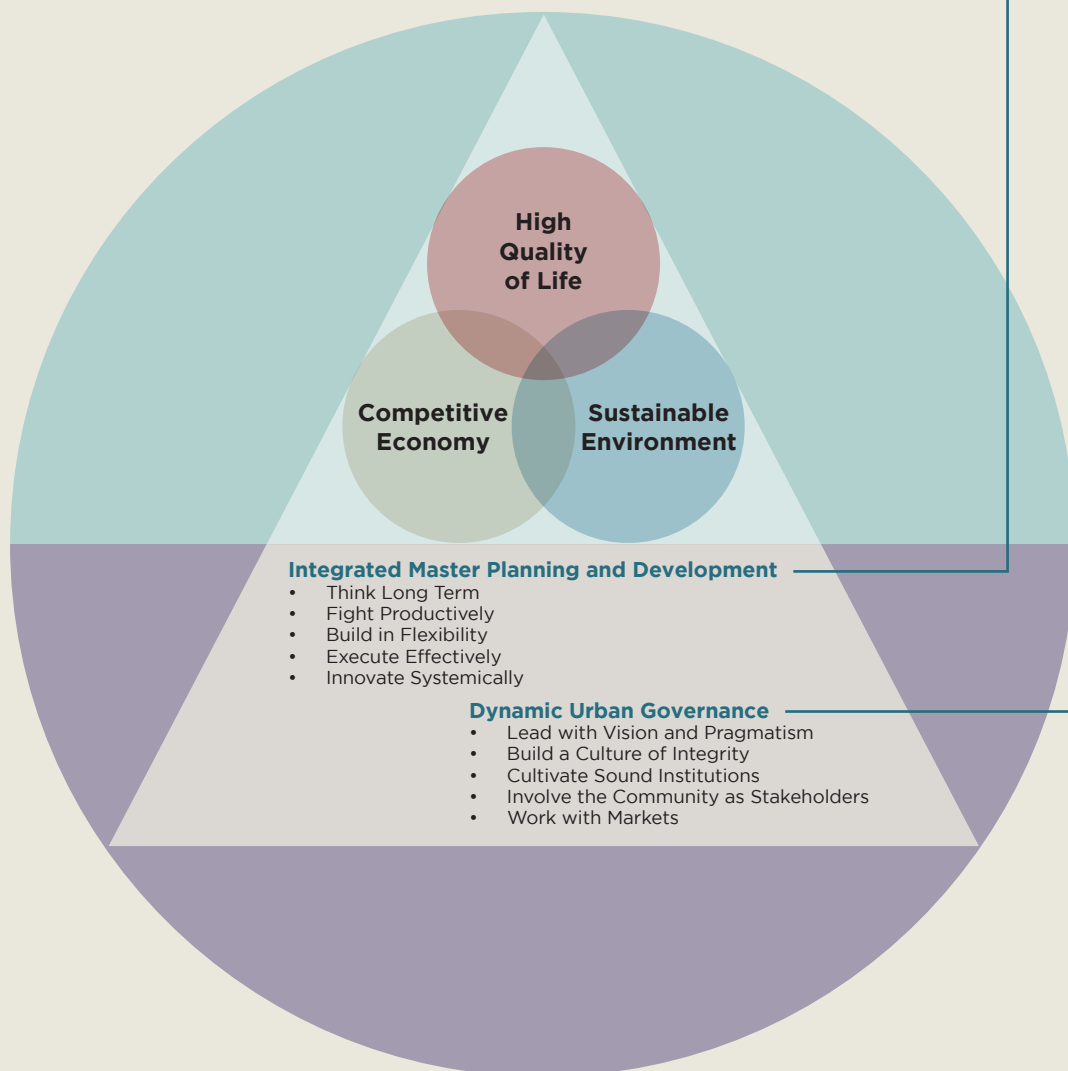
The Centre for Liveable Cities gratefully acknowledges the National Climate Change Secretariat, Ministry of Sustainability and the Environment, and advisors, Elaine Tan and Loh Ah Tuan, for their assistance in preparing this book.

The Centre also extends special thanks to the following interviewees and partners for their contributions (in alphabetical order): Benedict Chia, Ambassador Burhan Gafoor, Choi Shing Kwok, Esther An, Dr John Keung, Joseph Hui, Joseph Teo, Khoo Teng Chye, Ambassador Kwok Fook Seng, Lee Chuan Seng, Lim Swee Say, Prof Liong Shie-Yui, Loh Ah Tuan, Minister Masagos Zulkifli, Pamela Lee, Tan Yong Soon, Senior Minister Teo Chee Hean, Teo Eng Dih, Ambassador-at-Large Tommy Koh, Minister Vivian Balakrishnan and Assoc Prof Winston Chow.

The researchers, Elyssa Kaur Ludher, Kevin Fan Hsu and Norio Sim would like to thank the following for their time, guidance and support: Elly Chiu, Eugene Tay, Lim Wei Da, Melissa Grace Tan, Michelle Chng, Naufal Khan Surattee and Nicole Lum.

THE SINGAPORE LIVEABILITY FRAMEWORK

The Singapore Liveability Framework is derived from Singapore's urban development experience and is a useful guide for developing sustainable and liveable cities. The general principles under Integrated Master Planning and Development and Dynamic Urban Governance are reflected in the themes found in *Preparing for a Climate Resilient Singapore*.



Integrated Master Planning and Development

Think Long Term

The 1971 Concept Plan laid the foundation for a multicentric settlement form and provisions for future transport infrastructure development. Bus services and Mass Rapid Transit (MRT) lines connect homes to jobs, amenities and services. Today, bus services have grown to more than 300—serving 3.6 million people—and the MRT system has expanded to over 200 km across 6 lines. To reduce private car congestion and minimise vehicle growth rate, demand management programmes such as the Area Licensing Scheme (later Electronic Road Pricing) and an Additional Registration Fee (later Certificate of Entitlement) were introduced. Vehicular emission standards were also gradually improved to Euro VI today. Together, these have contributed to much lower vehicular carbon emissions, lowering Singapore's greenhouse gas growth. See pages 27, 53 and 80.

Execute Effectively

The Building and Construction Authority (BCA) introduced the Green Mark Scheme in 2005 under its first Green Building Masterplan to incentivise greater efficiencies in energy, water, waste reduction and indoor air quality. Additional gross floor area is provided for higher certification levels. The BCA has also streamlined the Green Mark certification process for builders to seamlessly report design plans and seek clarity. Development guidelines are also in the works for low-energy, zero-energy and positive-energy buildings. To build up local capacity, the BCA runs courses to award licences to those who have acquired green building skills, and is continuously pushing research and development. Today, all new buildings must be Green Mark certified, and the target is for 80% of all buildings to be certified by 2030. See pages 52 and 76.

Dynamic Urban Governance

Cultivate Sound Institutions

As whole-of-government efforts were needed for climate action, the Inter-Ministerial Committee on Climate Change (IMCCC) was established in 2007. It established three cross-agency working groups to address mitigation, resilience, and international negotiations. As coordination was required, the National Climate Change Secretariat was set up under the Prime Minister's Office. Singapore also invested in climate modelling research to provide scaled down projections on the impact of climate change. The establishment of the Centre for Climate Research Singapore was part of these efforts. Together, these institutions continue to enhance Singapore's capability to mitigate and adapt to climate change through sound policymaking and rigorous research. See pages 60 and 71.

Involve the Community as Stakeholders

Effective climate action requires action by all. Social (software) resilience is just as vital as infrastructural (hardware) resilience to deal with shocks and stresses. Aside from sustained community engagement on climate issues, Singapore designated 2018 as the Year of Climate Action to galvanise communities and the private sector as partners for climate action. Government agencies, such as the Centre for Liveable Cities, undertook the “Building Community Resilience” project to strengthen the community’s capacity to adapt and grow in the face of climate stresses. Residents crowdsourced and collaborated on localised solutions targeting climate impact and were educated on the value of their efforts on a national scale. Such partnerships fostered greater community trust and ownership, to building up the adaptive capacity for long-term action. See page 145.

OVERVIEW

Climate change is an existential threat to Singapore. At just 722 km² and lying close to the equator, Singapore is vulnerable to rising sea levels, drought, floods, and prolonged heat stress due to higher daily temperatures. Already, 8 of the 10 warmest years that Singapore has experienced to-date occurred after 2000. The warmest years on record are 2016 and 2019.

Singapore adopted environmentally-conscious measures early due to the foresight of the country’s leaders. Since the first years of independence, Singapore realised that it could not afford to pollute its own backyard. This led to long-term planning for development and adopting policies that minimised adverse impact on the environment across various domains. Higher densities were adopted to promote resource efficiency, thereby limiting sprawl into green spaces. Policies were laid down to promote clean air and water as well.

As the science behind the impact of greenhouse gases on our environment and climate became clearer, Singapore recognised the need for effective governance structures to address these impacts. A whole-of-government approach was taken—with the establishment of the Inter-Ministerial Committee on Climate Change in 2007, and subsequently, the National Climate Change Secretariat in 2010—to better coordinate efforts between agencies.

Concurrently, Singapore also set up research facilities to understand how climate change will affect the country. Early climate models lacked granularity for Singapore’s needs. To address this, Singapore scientists worked with international bodies to enhance the resolution of the climate models, thus providing greater clarity on the potential impact. The Centre for Climate Research Singapore was instituted in 2013 and is now one of the most advanced climate research centres in Southeast Asia.

Greater awareness of the magnitude of the impact of climate change triggered further action. Some of these are summarised below and elaborated in greater detail in the chapters of this book.

Lower Carbon Emissions Through Energy Efficiency

Having no local resources for power generation, Singapore established the need for energy security early. Power generation initially relied on fuel oil but was gradually replaced with natural gas from 1992.

Public transport was prioritised while private transport growth was constrained. Vehicles were also subject to stringent standards, which were further tightened periodically as technology improved. Energy efficiency was another key part of this plan. Early efforts sought to incorporate energy conservation into building codes.

In 1998, focus was placed on curbing rising energy consumption, which also promoted cost competitiveness. Regulatory approaches and assistance schemes were adopted to improve energy efficiency in industry, buildings, transportation, and consumer sectors. Schemes and regulations were supported by clear monitoring and enforcement frameworks. Incentive programmes spurred the construction of buildings that used less energy and resources. Later, the government led the deployment of solar photovoltaic panels, which scaled up and drove growth of the industry.

Singapore is adopting several other energy reducing strategies, such as phasing out internal combustion engines by 2040, encouraging regional grids to buy cleaner energy from other nations, and exploring carbon capture, utilisation and storage infrastructure.

Enhancing Sustainability Through Nature

Since the early years of independence, Singapore has sought to distinguish itself as a clean and green city—a garden city. A nationwide greening programme was introduced in the 1960s to avoid the monotony of concrete jungles. This has since evolved to a City in a Garden concept, which aims to bring people closer to greenery.

Vertical greenery was later introduced to integrate greenery into buildings and rooftops. Concurrently, Singapore recognised the intricate interconnection between flora and fauna, and worked to strengthen biodiversity. This then led to the City in Nature vision, with plans to expand nature parks and plant a million trees by 2030. These greening efforts have been vital to improving thermal comfort and reducing heat stress.

Managing Destructive and Life-giving Water

Climate change is expected to exacerbate drought and flooding, as well as cause sea level rise. Singapore has long recognised the scarcity of its water supply and has worked to “capture every drop” through water catchments and reservoirs. Drainage and water infrastructure were developed to reduce flooding and improve storage capacity.

Today, the water catchment has expanded to two thirds of the island. As membrane technology improved, Singapore leveraged water recycling and desalination techniques to bolster water security. It is preparing for sea level rise, coastal protection and flooding, through a S\$5 billion Coastal and Flood Protection Fund.

Adapting to the Wider Impacts of Climate Change: On Food and Health

With 90% of food being imported, Singapore is vulnerable to food supply disruptions. As such, comprehensive food security measures have been adopted through diversifying food import sources and increasing local food production. Efforts have also been made to address public health issues such as safeguarding against potential exacerbation of foodborne diseases due to higher temperatures, and the controlled releasing of male Wolbachia-Aedes mosquitoes to naturally suppress the population of the Aedes mosquito in order to reduce incidences of dengue, which also tends to rise as temperatures increase.

Climate Action, Together

Climate action can only be successful through a whole-of-society effort. While public education on water and environmental issues has been the norm since the early years, focused, whole-of-nation conversations were facilitated recently through the Year of Climate Action in 2018 and Year Towards Zero Waste in 2019. Activities were organised by youth, businesses, and civil society organisations to highlight the need for individual action to address climate change.

Being a Responsible Global Citizen

Singapore has actively participated in climate change fora, including the annual Conferences of the Parties. Being a natural interlocuter, Singapore has played a unifying role helping parties to arrive at a global consensus in the shape of the Paris Agreement and its Nationally Determined Contributions, which set the baseline for global carbon emission reductions. Recognising the need to play its part in reducing carbon emissions, Singapore has now committed to an absolute peak in emissions, of 65 million tonnes of carbon dioxide-equivalent (MtCO₂e) by 2030 and halving emissions to 33 MtCO₂e by 2050.

These are just some of the comprehensive efforts made by Singapore to address the threat of climate change. This Urban System Study shares how these policies and efforts evolved over time and provides some of the lessons learnt in charting the path to a more carbon neutral future. The need to re-orient policies and spaces to account for the diverse impact of climate change remains paramount and urgent. Understanding the past can help us tread carefully into the future. It is hoped that this book will provide the reader with the context, and thus confidence, to run fast and galvanise ambitious climate action.



CHAPTER 1

SINGAPORE AND ITS VULNERABILITY TO CLIMATE CHANGE

“

The ultimate threat to human survival is global warming and climate change.²

”

LEE KUAN YEW
Prime Minister (1959–90)

The world is grappling with the unprecedented effects of climate change. The momentous Paris Agreement, adopted in 2015, marks an important first step in a new and ambitious direction to tackle the climate challenge. Under the Paris Agreement, the Parties have agreed to strengthen the global response to the threat of climate change, with the aim of halting the increase in the global average temperature to “well below 2°C above pre-industrial levels” while pursuing efforts to “limit the temperature increase to 1.5°C above pre-industrial levels”.

While nations have pledged to act through the “Nationally Determined Contributions” (NDCs) as part of the Paris Agreement, the world is not yet on track to meet its long-term goals to slow warming. Even with current pledges, the Intergovernmental Panel on Climate Change (IPCC), the international body of scholars that provides assessments on climate science, has projected a global average temperature increase of between 3°C and 5°C.³ This will have devastating effects as 90% of coastal areas, where many of the world’s cities lie, are at varying levels of risk from sea level rise and extreme weather events.⁴ In 2018, the IPCC’s “Special Report on Global Warming of 1.5°C” found that 570 cities—home to 800 million people—are likely to be under water by 2100. Clearly, climate change will significantly impact the liveability of cities.

Singapore, too, will be affected. Sea level rise represents an existential threat for Singapore as Teo Chee Hean, Senior Minister and Chair of the Inter-Ministerial Committee on Climate Change (2011–Present) highlighted:

If no action is taken, and the world maintains its current emissions trajectory, we could face an increase in mean daily temperature of around 4.6°C by 2100, compared to 1980–2009 levels. This is a serious situation. This scenario—referred to as the Representative Concentration Pathway (or RCP) 8.5—will mean global sea level rise of up to about 1 m by 2100 compared to 1986–2005 sea levels for Singapore.⁵

Singapore currently produces only 0.11% of global emissions but is committed to playing its part to support the global effort to address climate change. Given its urgency, Singapore has enhanced its NDC this year to peak its emissions at 65 million tonnes of carbon dioxide-equivalent (MtCO₂e) around 2030. In order to achieve this, long-term Low-Emissions Development Strategies have to be developed. The aspiration is to halve 2030 emissions, to reach 33 MtCO₂e by 2050, with a view to achieve net-zero emissions as soon as viable in the second half of the century.⁶



1. From an often-flooded squalid city, Singapore has developed into a liveable city through environmentally sustainable policies in greening, biodiversity, water and air quality management.⁷

Climate Change and its Impact on Singapore

“Singapore, being near the equator, is more vulnerable to climate change than the global model suggests.”⁸

—Lee Hsien Loong,
Prime Minister (2004–Present)

Although there is little seasonal variation in Singapore’s climatic conditions, an increase in the frequency and magnitude of extreme weather events due to changes in global climate patterns is predicted. As a small island city-state with a highly urbanised landscape, limited natural resources, and the lack of a hinterland, the impact of climate change represent an existential threat to Singapore.

Climate change can affect Singapore on multiple fronts. Sea level rise could erode coastal regions. Prolonged periods without rain can affect water resources while extreme rainfall could cause flash floods. Rising temperatures can contribute to increasing prevalence of heat stress and vector-borne diseases; it can also affect natural biodiversity. Singapore’s food supply could also be disrupted if episodes of extreme weather events occur, given the high import of food. Of these, rising sea levels, changing rainfall patterns and higher temperatures are recognised as key focus areas.

Rising Sea Levels

Since the 1970s, long-term tide gauge records indicate rates between 2.12 mm/year and 3.55 mm/year, leading to an average sea level of 140 mm above pre-1970 levels today.⁹ As a low-lying island, the impact of sea level rise is acute. In Singapore, mean sea level is projected to rise up to 1 m by 2100, according to the Second National Climate Change Study.¹⁰ However, co-occurrence of extreme events under rising emissions could give rise to even more challenging scenarios such as high tides, and changes in waves and surges.

Much of Singapore's land is less than 15 m above the mean sea level, with a generally flat coast.¹¹ One-third of the island—including the central business district and Marina Bay—are less than 5 m above the mean sea level. Other vulnerable areas include the major aviation hub of Changi Airport, industrial towns like Jurong and Tuas, and the Southern Islands.

Beyond the inundation of key business districts and tourism zones, sea level rise could also exacerbate coastal erosion, resulting in shifting coastlines.¹² Loss or damage to coastal land area for land-scarce Singapore has severe implications. The increased risk of flooding during storm surges and rainstorms, and of seawater intrusion into coastal reservoirs also affect long-term water security and the stability of critical infrastructure.

Changing Rainfall Patterns

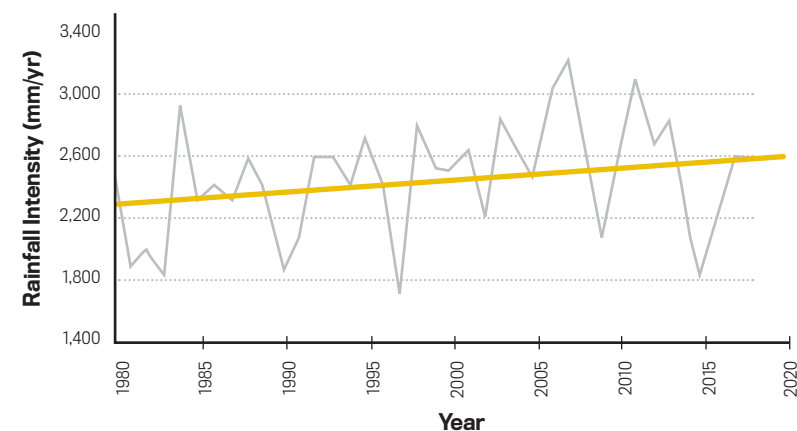
Singapore has an equatorial climate that experiences ample rainfall, high and uniform temperatures, and high humidity all year round. Maximum daily temperature rises to 31–33°C during the day, while minimum temperature cools to 23–25°C at night. The long-term (1981–2010) average annual rainfall is 216.59 cm,¹³ and it rains an average of 167 days in a year.¹⁴

The local climate is characterised by two monsoon seasons—the Northeast Monsoon from December to early March, and the Southwest Monsoon from June to September—separated by the inter-monsoonal periods (late March to May, and October to November). There is no distinct wet or dry season, but monthly variations do occur. Monsoon surges bring widespread moderate to heavy rain during the first half of the Northeast Monsoon season, while short duration showers and thunderstorms occur during the Southwest Monsoon season. The mean annual relative humidity is around 84%, and frequently reaches 100% during prolonged periods of rainfall.

Over the past 30 years, rainfall has intensified in Singapore. The maximum hourly rainfall has been increasing yearly by 9.8 mm and the number of days of large storms¹⁵ has risen by 1.8 days per decade.¹⁶ This has contributed to an upward trend of average annual rainfall from 219.2 cm in 1980 to 272.7 cm in 2014.¹⁷

EXHIBIT 1

ANNUAL TOTAL RAINFALL IN SINGAPORE (1980–2019).



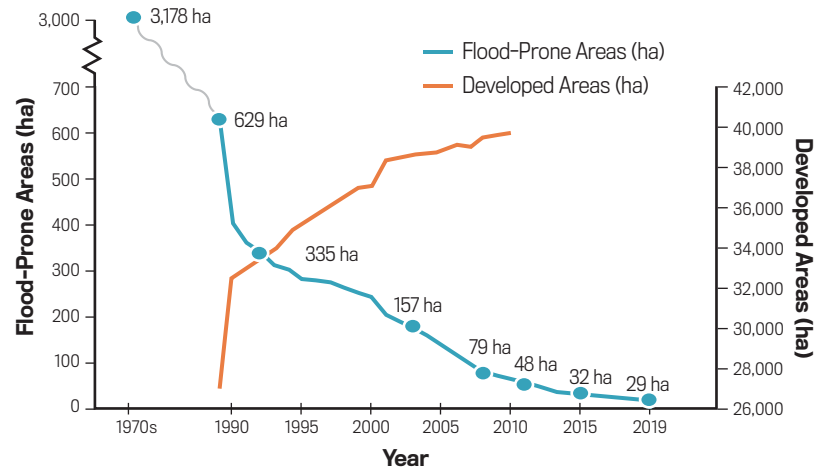
Average annual rainfall has increased over the years, a trend that is likely to continue.

Source: Centre for Climate Research Singapore, Meteorological Service Singapore.

Extreme downpours, coinciding with incoming high tides, can contribute to flooding. Singapore has experienced several major flooding events in its history, with the worst flood recorded in 1978. As Singapore continues to urbanise, extreme rainfall events have overwhelmed the capacity of drainage systems, resulting in flash floods—localised flooding which typically subsides within an hour.¹⁸ Intense rainfall has resulted in a rise of flash floods occurring.¹⁹ The location of flash floods are highly unpredictable, and can result in severe or minor damage. Flooding along Orchard Road in 2010 and 2011 are examples of flash flood events that resulted in damages of more than S\$23 million—based on 868 insurance claims—due to business interruptions, property damage and motor vehicle claims.²⁰

The government has enhanced the urban system to alleviate widespread flooding, and flood-prone areas have decreased from 3,200 ha (32 km²) in the 1970s to 29 ha (0.29 km²) in 2019.²¹ However, with climate change, weather uncertainties and more intense rainfalls are expected.²² As Singapore continues to develop, urban density has increased impervious surfaces, such as asphalt. This increases the risk of storm water exceeding drainage capacity during heavy rainfall events, resulting in localised flash floods.

EXHIBIT 2 FLOOD-PRONE AREAS (1970s–2019).



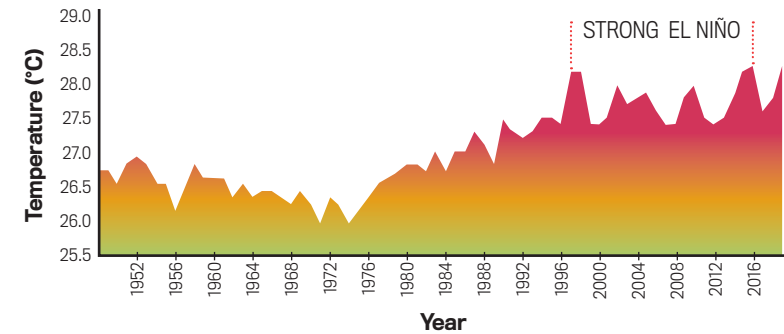
Reduction in flood-prone areas despite increasing urbanisation over the last decades in Singapore.
Source: PUB, Singapore's National Water Agency.

Climate change has made the contrast between wet and dry months more pronounced, with wet months (November to January) getting wetter and dry months (February and June to September) getting drier. Between January and March in 2014, Singapore experienced two severe dry spells, each lasting a record-breaking 27 days.²³ February 2014 was the driest month on record since official recording began in 1869: a mere 0.2 mm of rainfall was observed, in contrast to the monthly average of 112.8 mm.²⁴ The most recent dry spell was during a prolonged rainfall deficit period between July and September 2019, when rainfall was more than 40% below normal for each of the months.²⁵ Such low rainfall patterns affect upstream water sources, necessitating actions to ensure that Singapore's long-term water security is not threatened.

Heat Stress

Outdoor weather and climate conditions—namely temperature, humidity and winds—have a heavy impact on the liveability in urban areas. Although the variability of temperature from month to month is low, they have been steadily increasing. The mean annual temperature for the last 10 years from 2010–19 was 27.94°C, surpassing the previous warmest decade's 27.89°C from 2009–18. Eight of the 10 warmest years that Singapore has experienced occurred after 2000, with the warmest years on record a tie between 2016 and 2019 at a mean annual temperature of 28.4°C.²⁶

EXHIBIT 3 ANNUAL AVERAGE TEMPERATURE (1948–2019).



Each of the last four decades had warmer average temperatures compared to the decade before.
Source: Centre for Climate Research Singapore, Meteorological Service Singapore.

The Second National Climate Change Study has identified robust projections of near surface temperatures. By the end of the century, daily mean temperatures are projected to increase by 2°C to 4°C (depending on the future trajectory of greenhouse gas concentrations in the atmosphere), resulting in warmer days and nights. Under the “high-emissions” RCP8.5 greenhouse gas trajectory, Singapore could experience far higher average temperatures of above 34°C during the day and up to 26°C at night.²⁷

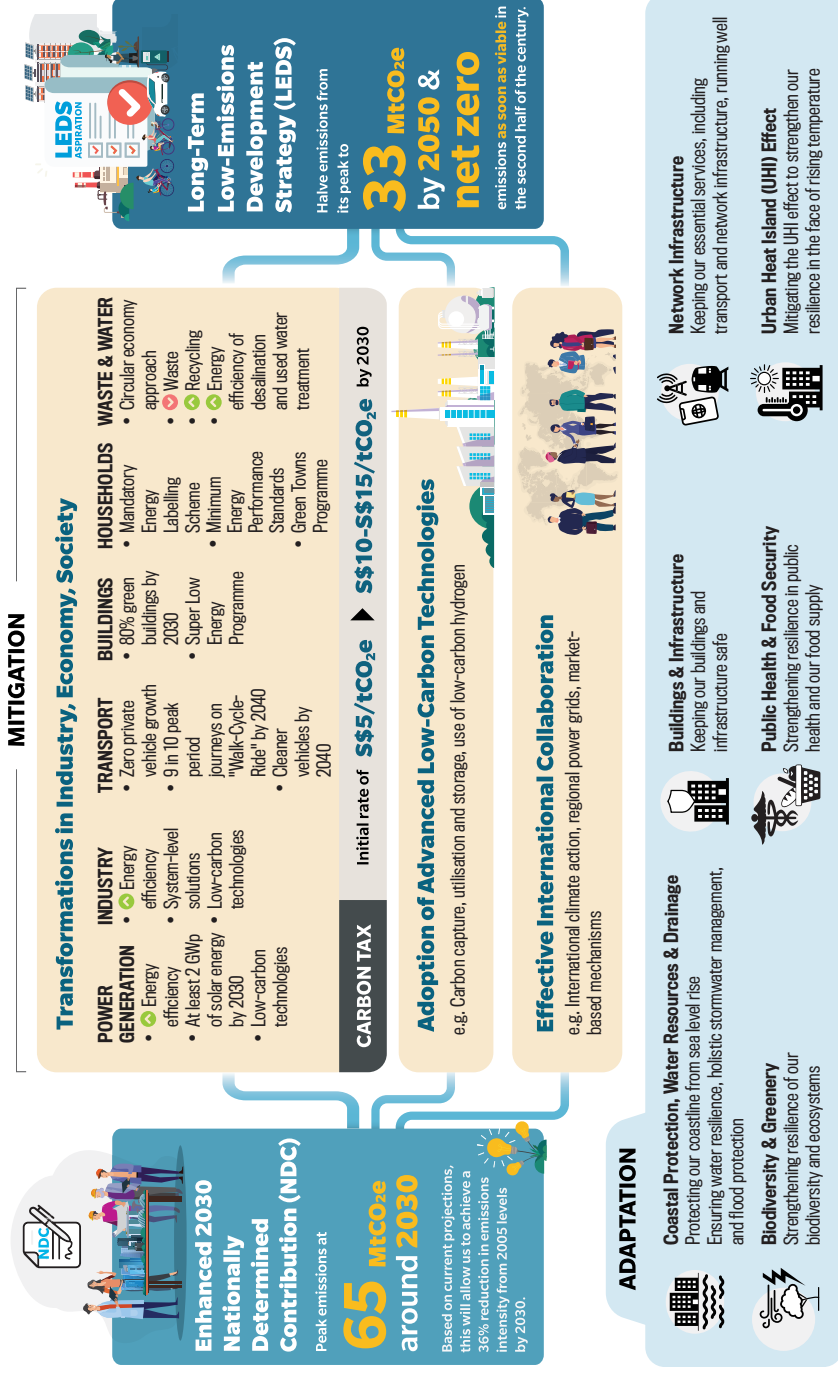
Higher temperatures can contribute to heat stress and discomfort amongst vulnerable populations, such as infants, the elderly and the infirm. This phenomenon is exacerbated by the opposing thermal comfort impact of urban heat island²⁸ effect and increased use of air-conditioners. Hotter conditions also enhance the risk of the spread of vector-borne diseases like dengue, already prevalent in warmer months. A temperature increase of 1.5°C–2.5°C could threaten Singapore's natural biodiversity, impacting the functioning of natural ecosystems.²⁹

Charting Singapore's Low-Carbon Future

Singapore started its low-carbon actions in the 1960s. Since then, it has ramped up its low-carbon actions and the impact from those actions have become clearer. Chapters 2–5 share some of the major decisions, policies and actions taken to address climate change.

In 2020, Singapore announced its actions for the succeeding decades, in line with its Paris Agreement commitments. These mitigation and adaptation measures are illustrated on the next page:

EXHIBIT 4
CHARTING SINGAPORE'S LOW-CARBON FUTURE.



CHAPTER 2

**BEFORE THE 1990s:
ESTABLISHING THE
FOUNDATION FOR
ENVIRONMENTALLY
CONSCIOUS
DEVELOPMENT**

“

After independence, I searched for some dramatic way to distinguish ourselves from other Third World countries. I settled for a clean and green Singapore. One arm of my strategy was to make Singapore into an oasis in Southeast Asia; for if we had First World standards, then businessmen and tourists would make us a base for their business and tours of the region.³⁰

”

LEE KUAN YEW
Prime Minister (1959–90)

Since independence in 1965, Singapore has recognised the importance of balancing economic development with a clean, green and good quality living environment—an approach that enhances quality of life, and attracts investors, talent, and visitors. In the short span of a few decades, Singapore has transformed from a backwater country to one of the most liveable cities in the world. In spite of rapid industrialisation and urbanisation, Singaporeans today breathe clean air, drink clean water direct from the tap, live on clean land, and enjoy high standards of environmental public health. Few cities in the world have achieved this same feat.

There was a great need for new industries and employment, but Singapore's pioneer leaders were aware that the nation could not afford a “pollute now, clean up later” approach. As Dr John Keung, Chief Executive Officer (CEO) of the Building and Construction Authority (BCA) (2006–17), shared:

It was a matter of survival for Singapore. Planning a city-state is very different from planning a city. In other cities even if you mess up a location or a district, you can always go further out of the city to meet the land demand, and then you'll be okay. You can come back later and redo things. But in Singapore it is extremely difficult, if not impossible, given our small city-state. Sustainable development is not a luxury; it's a necessity.³¹

To realise the vision of “clean, green and good-quality living environment”, Singapore adopted six core environmental strategies: 1) control pollution at the source; 2) force the polluter to pay; 3) pre-empt by taking early action; 4) develop innovations and technologies; 5) conserve resources and enhance efficiency; and 6) promote environmental stewardship and a sense of ownership. Singapore's later climate commitments were no accident as they would reflect these approaches.³²

From Squalid Slum to a Garden City

In the early years after independence, a large portion of Singapore's population was housed in squalid slums. Streets, back lanes and public areas were strewn with litter and garbage. Rivers were open sewers and residents regularly used them as rubbish “conveyers”. Residents knew they were nearing the central business district because of the stench of the Singapore River in the tropical heat.

In 1967, then Prime Minister Lee Kuan Yew launched the Garden City vision. Its purpose was to transform Singapore into a city with abundant greenery and a clean environment.³³ The effort built upon the first nationwide intensive tree planting campaign in 1963.³⁴ Committed to cloaking Singapore with a green mantle, the Public Works Department (PWD) set up the Parks and Trees Unit in 1967.³⁵ The Parliament also declared greening a national policy during the second reading of the Environmental Public Health Bill of 1968.

By 1970, some 55,000 new trees had been planted along roads. Ornamental plants, creepers and climbers were also added to retaining walls, overhead bridges and concrete structures to soften their appearance. That year, a multi-agency Garden City Action Committee (GCAC) was set up to ensure a whole-of-government commitment to oversee greening policies and campaigns aligned with the Garden City vision (see Box Story). A key outcome was the incorporation of this vision into Singapore's first Concept Plan in 1971.

GREENING FROM THE TOP, GREENING EVERYWHERE: THE GARDEN CITY ACTION COMMITTEE

Prime Minister Lee Kuan Yew's commitment to creating a green, beautiful, and well-organised Singapore was apparent when he chaired the GCAC at its formation in 1970.³⁶ Set up within the Ministry of National Development (MND), the committee's leadership comprised senior representatives from the infrastructural, planning and environmental agencies. These included the PWD and its Parks and Trees Unit—later the Parks and Recreation Department (PRD); the Housing and Development Board (HDB); the Primary Production Department; the Jurong Town Corporation (JTC);³⁷ and the Urban Renewal Department (URD)—later renamed the Urban Redevelopment Authority (URA).³⁸

Under the committee, the HDB, JTC and URD/A were responsible for planning and implementation of tree planting and greening within their respective domains. The HDB took care of public housing neighbourhoods, while the JTC managed industrial estates. Greening for the rest of Singapore would be undertaken by the PRD. Such inter-agency cooperation allowed for a concerted greening effort across different domains, a big step in realising the Garden City vision.



2. As part of the Garden City movement, Singapore planted thousands of trees along roadsides and in estates to develop a lush and green environment.

In 1971, Tree Planting Day was re-introduced as an annual event, involving students, residents and leaders throughout Singapore. Its purpose was to include citizens in the efforts to keep Singapore clean, green and beautiful.³⁹ Trees were planted intensively along major roads and streets in the city. Tall, large crown shaped trees like the Rain Tree and the Angsana not only provided aesthetic enhancements but also shade from the blazing sun and relief from urban infrastructure.



3. Fullerton Road before⁴⁰ and after planting.

The Singapore Botanic Gardens provided much expertise and plant materials for the greening programmes, and in 1973 merged with the Parks and Trees Unit. In 1975, the Parks and Trees Unit was redesignated the PRD under the MND. That same year, Singapore enacted the Parks and Trees Act that set out guidelines for promoting and maintaining trees and greenery.

Conserving Biodiversity

Before independence, the 1951 Nature Reserves Ordinance had been introduced to protect the remaining primary forests, as 90% of forests had already been lost to agriculture, housing, industry, roads and other uses.⁴¹ The law protected areas such as Bukit Timah, Kranji, Pandan, Labrador and the Central Catchment area as nature reserves.⁴² Conserving and protecting biodiversity promotes healthy ecosystems that contribute to long-term human well-being and economic development.

By the 1980s, the provision of open spaces was part of the comprehensive planning process. With rising economic affluence, there was increased demand for a physical environment that could improve people's quality of life. This included the need for access to nature: places that could uplift the spirits of the people and contribute to the liveability of the city.

Creating a Clean Environment for the People

"It has always been that social and economic aspects must be considered when we address the environment: environmental infrastructure, environmental protection, environmental management and environmental ownership."⁴³

—Loh Ah Tuan, Deputy CEO (DCEO),⁴⁴
National Environment Agency (NEA) (2004–07)

A clean environment has always been Singapore's national priority. In 1970, the Anti-Pollution Unit (APU) was set up directly under the Prime Minister's Office (PMO) to combat air pollution. Placing the APU under the PMO underscored the importance of the environment. The Parliament passed the Clean Air Act in 1971 and the Clean Air (Standards) Regulations in 1972. These regulations provided the "teeth" needed to control polluters and stipulate emission standards for industries.

There is no plan B for Singapore. Mr Lee Kuan Yew witnessed the issues of industrialised countries which grew so rapidly that they neglected the environment and people had to suffer the consequences. [He] was determined that Singapore should not develop at the expense of the environment and hence enacted policies that were guided by that principle.⁴⁵

—Joseph Hui, DCEO, NEA (2011–14)

The UN Conference on the Human Environment held in Stockholm in June 1972 was the first international forum aimed at addressing global environmental challenges. Following the conference, Singapore set up the Ministry of the Environment (ENV)—one of the first countries in the world to do so. The new ministry included departments that dealt with pollution control, sewerage, drainage and solid waste, as well as environmental public health.⁴⁶ The new ENV launched a campaign in 1973 to "Keep Our Water Clean", aiming to raise awareness of water pollution and how to prevent it.⁴⁷

One significant problem in the centre of the city was the Singapore River, which former DCEO of the NEA, Loh Ah Tuan, described as "black, smelly, and devoid of fish and aquatic life—the river was dead."⁴⁸ Years of pollution discharge by the shipping industry and factories, and runoff from nearby farms had choked the waterway. With office towers and hotels being built in the newly created central business district, there was a pressing need to

clean up the river. The nation's few reservoirs were also insufficient to store the water needed for growing industries and an expanding population.

In 1977, then Prime Minister Lee challenged the ENV to clean up the Singapore River in 10 years. Farms and factories were relocated, itinerant hawkers were rehoused in food centres, and drainage and sewage systems were separated to reduce loads. Rubbish in and around the river was cleared away while new landscaping enhanced the environment. The measures provided the basis for future environmental governance while helping to protect water as a scarce resource.

Singapore's heat and humidity necessitate removing waste in a timely and hygienic manner. However, as the population boomed, so did their waste. Landfills filled quickly; scarce land meant little space for new ones. The government decided on incineration as the most suitable approach for waste management. The Ulu Pandan Incineration Plant was commissioned as the city's first incineration facility in 1979. Handling more than 15% of Singapore's total waste, incineration at the Ulu Pandan plant reduced the volume of waste ultimately sent to the landfill.⁴⁹

The public was involved through environmental campaigns. The "Keep Singapore Clean" campaign, first launched in 1968 used mass media and public education to exercise social pressure on Singaporeans. Fines were imposed on errant behaviour with the aim of raising hygiene standards and keeping Singapore litter-free.

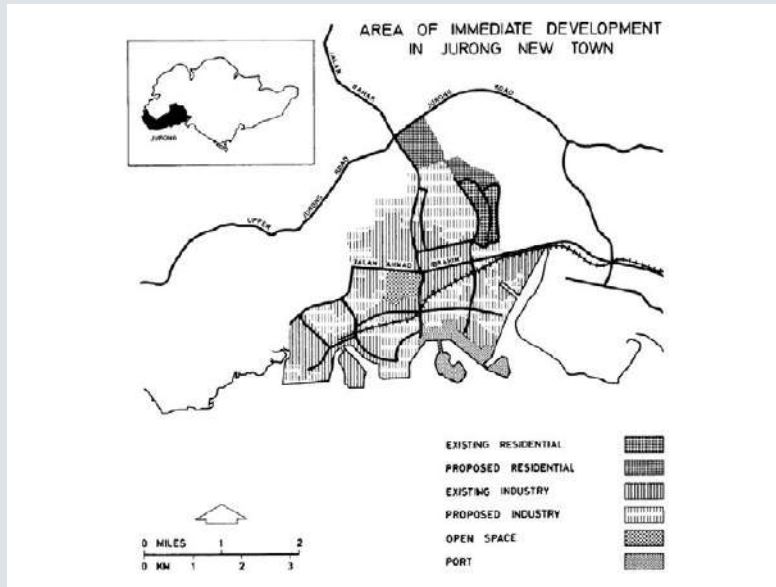
Cleaning campaigns were expanded to cover public and workplace health, including programmes to keep Singapore mosquito-free, and to keep factories and toilets clean. Much of the cleaning effort was tied back to the greening campaign, as "Singapore [is] one home, one garden, for all of us".⁵⁰



4. Hawkers dominated the riverside and much of the waste flowed into the river. The Singapore River clean-up, which began in 1977 and ended in 1987, required hundreds of businesses and industries to be relocated and the river itself to be dredged. It was a whole-of-government effort.

JURONG TOWN—A CLEAN AND GREEN “GARDEN INDUSTRIAL TOWN”

Jurong Town, developed in the 1960s from swampland and marshes, was planned as Singapore’s first and largest industrial estate. The vision was a Garden City town connected by ports and railways and surrounded by green spaces and natural beauty.



5. Jurong Town was planned to be a Garden City industrial town.⁵¹

The JTC worked with the APU to advise polluting industries to comply with the emission standards under the Clean Air Act. Industries were carefully sited away from residential estates. A green belt of trees, shrubs and grassy fields was preserved in the surroundings of the Upper Jurong River as a buffer between industrial and residential areas.

Keeping in line with the ongoing tree-planting campaign, the JTC planted trees along roads and streets around the industrial estates. Manicured frontage and landscaping ameliorated the harsh façades of industrial buildings and created aesthetically attractive working environments.

The JTC ensured greenery was a key component of the new town. With the assistance of the PRD, swamps and ponds were transformed into 283 ha (2.83 km²) of parks and gardens. The showpieces were the Chinese and Japanese Gardens, which served as major recreational facilities and a

“green lung” for the budding industrial town. Sungei Jurong was dammed to form Jurong Lake, surrounding these gardens. The lake helped to break the unrelenting steel and concrete face of the new town, but more importantly, rendered easier provision of water for the industrial estate. Jurong Hill was developed into a park with a lookout tower, garden and waterfall. At the foot of the hill, the 20 ha (0.2 km²) Jurong Bird Park was built. The success of the park was a testament to the clean and green environment that Jurong Town had developed into, allowing the birds to thrive and flourish.



6. The Jurong Bird Park served as an efficient bioindicator of pollution levels.

Within the housing estates of Taman Jurong and Boon Lay, the HDB also provided open green spaces between the blocks of flats. These recreational spaces, together with the planting of more than 37,000 trees, shrubs, plants and hedges, provided a cooler living environment and improved air quality for enhanced liveability, fulfilling the vision of a clean and green “garden industrial town”.

[Other than being an industrial complex, Jurong Town] is a town with an equal emphasis on enriching the lives of workers. It is fast becoming a “must” for tourists and visitors...to see a town teeming with life and happiness.⁵²

—Woon Wah Siang, Chairman, JTC (1968-77)

Developing Water Infrastructure to Address Potable Demand, Sanitation and Flooding

Since independence, ensuring water security has remained a critical concern for Singapore's growing population, especially when much of its water is imported from Malaysia. The two Water Agreements governing the import of water from the southern state of Johor of the Malay Peninsula were subject to potential disruptions; and their validity dates—to end in 2011 and subsequently in 2061—were also in doubt at times. Faced with limited natural resources and the lack of a hinterland, the government recognised the importance of achieving sustainable and resilient water supply.

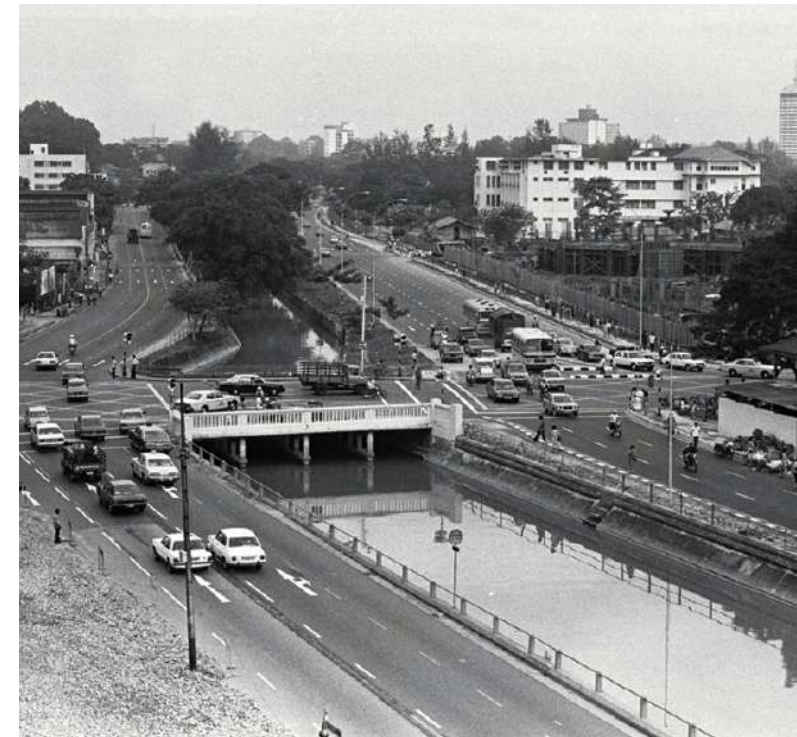
Strong leadership was necessary to advance this agenda. The government thus drew up plans to boost domestically-sourced water supply. In 1971, the Water Planning Unit was set up in the PMO, to oversee water issues and policies. The unit drew up Singapore's first Water Master Plan in 1972. The plan highlighted the need for sustainability, while exploring alternative sources to increase water supply. In 1969 and 1975, the capacities of Seletar and Pierce Reservoirs were expanded while dams were constructed in the 1970s and 1980s to form new reservoirs. The clean-up of the Singapore River, which began in 1977, also paved the way for the Marina Reservoir, which receives water from one-sixth of Singapore's total land area.

The Sewerage Master Plan (later renamed the Used Water Master Plan) was also developed in the late 1960s to address the lack of sanitation. It facilitated the provision of a used water network and treatment services for the whole island. Under the Used Water Master Plan, Singapore was divided into six used water catchment zones. Each zone was served by a water reclamation plant where used water was treated to meet the international trade effluent standards before it was discharged into the sea. All industries were required to comply with controls on trade effluent stipulated by regulations before they were allowed to discharge treated effluent into the public sewers. Other regulative mechanisms were also implemented under the Water Pollution Control and Drainage Act to prevent water pollution in public sewers and water courses.

For the earlier generation of Singaporeans, widespread flooding was commonplace, especially during the monsoon seasons. Financial limitations during the initial years after independence prevented planning and construction projects associated with water management.⁵³ Despite these limitations, numerous concrete drains and canals were built in the 1970s under the Drainage Master Plan to convey storm water away more

quickly. Flood alleviation measures were also planned for developments in flood-risk areas. The Road Drainage Improvement Task Force was formed in 1984 to seek engineering solutions to flood-prone roads, such as removing drain blockages and raising of roads.

Planning for water security included managing water demand, through pricing, regulation and public education. In 1972, the "Water is Precious" campaign was launched and sustained through subsequent years to promote water conservation. To discourage excessive household water consumption, tiered domestic water tariffs were introduced in 1973, with higher tariffs for every 25 m³ of water used per month (up to 75 m³). As industrialisation accelerated, the Water Conservation Plan was introduced in 1981 to further encourage and incentivise the reduction of water wastage and the use of recycled water and non-potable water. For example, to reduce water wastage in non-domestic premises, the installation of self-closing delayed taps was made compulsory.



7. The Rochor Canal was regulated and expanded to control flooding issues in the neighbourhood.

SWIMMING OUT OF DANGER: ADDRESSING FLOOD-PRONE SINGAPORE

Flooding was an issue that the government had to grapple with in the early years of nationhood. Singapore was prone to flooding due to a combination of factors—namely, intense rainfall, many low-lying areas and inadequate drainage.

One of the worst flooding events occurred in 1969, when more than 450 mm of rain fell within a 17-hour period. Flood waters reached over 2 m. Five people lost their lives and more than S\$4 million of damage was incurred. More than 3,000 people lost their homes.



8. Flooding was commonplace in the early years of independence.

Agencies worked urgently to implement adequate drainage infrastructure:

It was a real sense of emergency. We saw for ourselves the suffering of the people because of the floods. Possessions were destroyed, people had to be evacuated and worse of all, we saw people dying.⁵⁴

—Yap Kheng Guan, who was involved in developing Singapore's drainage infrastructure since 1975 and later Senior Consultant, PUB, Singapore's National Water Agency (2012–14)

This led to the implementation of a number of flood alleviation schemes such as the Phase 1 of the Bukit Timah Flood Alleviation Scheme in 1972, where S\$7 million was spent to divert water from the rapidly urbanising low-lying Bukit Timah area as the old Bukit Timah canal was increasingly incapable of holding in storm water runoff. A new canal was constructed and that reduced overflows of floodwater by 60–70%.

More, however, needed to be done. In 1978, Singapore was hit with another flood more devastating than the one in 1969. More than 500 mm of rain fell within a 24-hour period, which was almost a quarter of the annual rainfall of 1978. The intense rainfall also coincided with a very high tide. The police and army were called in to assist with relief efforts.

There was greater urgency and commitment after the 1978 flooding to improve Singapore's drainage systems. Working together with other government agencies like the HDB, JTC and URA, the drainage department poured in more resources to implement the Drainage Master Plan. These efforts were continued through the decades and have resulted in the provision of a comprehensive drainage network throughout the country and a significant reduction in flood-prone areas.

Today, the size of flood-prone areas in Singapore has been reduced from about 3,200 ha (32 km²) in the 1970s to 29 ha (0.29 km²) currently. Unlike the scale of floods witnessed in the early days, floods today are localised and usually subside within 30 minutes. However with climate change, more frequent and heavier rainfall can be expected. Given land constraints and the massive cost required, it would not be feasible to build bigger drains to cater to every extreme rainfall event, meaning flash floods cannot be entirely eliminated.

Protecting the Coastline

Singapore's low-lying coasts are vulnerable to erosion. Engineering—such as constructing seawalls that extends 1.8 m south of the Singapore River—was introduced in the early 1900s to shelter ships from the Northeast Monsoon.⁵⁵ Additional seawalls were later built to protect coastal assets in areas such as Bedok, Katong and Pasir Panjang.

In 1968, Singapore introduced the East Coast Reclamation Scheme to expand into the sea.⁵⁶ Breakwaters were built along the south-eastern coast to shield the newly reclaimed land. The success of the headland breakwater concept provided a precedent for future land reclamation projects in Pasir Ris and Pasir Panjang.⁵⁷

The growing maritime industry also prompted the need for breakwaters to protect ships and their crews from rough sea conditions. The Port Authority of Singapore built a breakwater off the Pasir Panjang Berths in 1976 in response to extreme conditions, which provided for a safer working environment.⁵⁸ These measures ensured that critical coastal infrastructure was protected, while economic activities flourished. Today, over 70% of the coastline is protected from coastal erosion through hard structures and stone embankments.



9. Seawalls protect Singapore's main island and its surrounding islands.⁵⁹

Charging up for Growth

The oil crisis in the 1970s prompted nations worldwide to embark on long-term energy security plans. In Singapore, rapid industrialisation and rising home ownership meant increased demand for an efficient and reliable supply of electricity. In the early years, the PUB, which oversaw the supply of water, electricity and gas, worked with economic and planning agencies like the JTC, HDB and Economic Development Board (EDB) to develop a long-term transmission and distribution network.

In terms of electricity generation, demand forecasts based on projections of future growth necessitated the construction of new power stations⁶⁰ that relied heavily on the burning of fuel oil. Senoko Power Station, built in stages between 1973 and 1983, was one of the largest power plants in the region when completed. Capable of generating 1,610 MW of electricity, its oil-fired steam turbines helped to relieve the pressure on electricity supply. Across the island, pollution controls ensured energy infrastructure complied with environmental considerations, while smokestacks were sited away from residential areas.

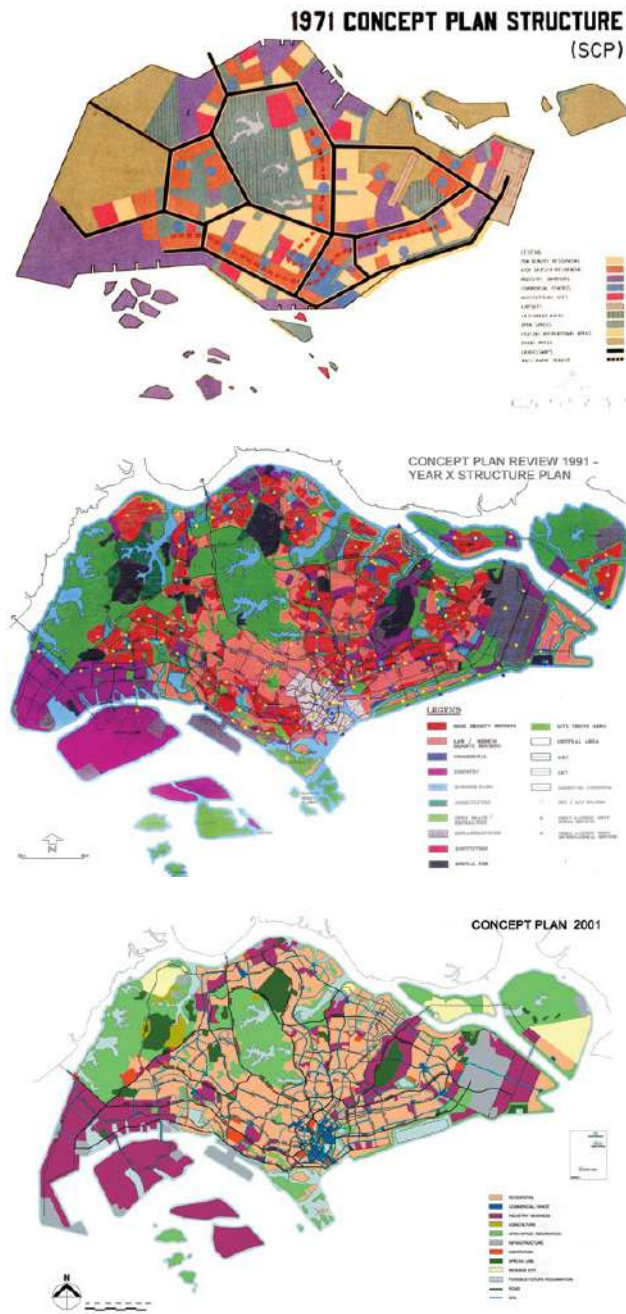
To boost domestic energy supplies, waste incineration was leveraged to produce electricity. Heat from incineration generated steam turbines which powered generators, thus completing the waste-to-energy (WTE) loop. The Ulu Pandan WTE plant, completed in 1979, was able to generate 5,800 MWh of energy every month, sufficient to power 16,000 4-room HDB flats.⁶¹ Well-planned maintenance programmes, good operating procedures and a group of dedicated staff maintained the lifespan of the plant, until it was finally decommissioned in 2009.

Early energy efficiency policies were introduced through the Energy Conservation Standards, first incorporated into Building Code Regulations in 1979 that specified requirements on temperature control for air-conditioned spaces and automatic lighting in hotel rooms. Public awareness and education programmes supplemented these policies, an echo of the water campaigns that encouraged Singaporeans to value energy conservation, while providing advice on more efficient energy use.

Planning a High-Density, Transit-Oriented City

Acutely aware of Singapore's land constraints, the first generation of leaders planned for a high-density city to maximise land use, while ensuring a high quality of life. Singapore embarked on resettlement programmes to move residents into new HDB towns equipped with running water, electricity and modern sanitation systems. Transport systems were required to serve and connect these residential areas with the rest of the country.

The 1971 Concept Plan marked the beginning of long-term strategic planning, providing Singapore's first comprehensive, integrated land-use and transportation plan. High-density satellite towns were connected via road and rail networks. Mass Rapid Transit (MRT) lines were constructed in 1983 to connect HDB towns with the city centre and industrial developments and became the backbone of the transport system. Buses connected destinations within towns and to transport hubs.



10. Over the decades, Singapore's Concept Plans have consistently built on previous iterations.

With public transport infrastructure in place, steps were taken to manage the environmental impact of private vehicles. One concern was exhaust pollution from motor vehicles. In 1979, new motor vehicles were required to install a crankcase recirculation device to cut down on black smoke emissions.⁶² In 1982, it became compulsory for private vehicles to undergo regular inspections and maintenance, thus raising vehicular standards and reducing pollution. Fuel quality was gradually improved, such as limiting the sulphur content of diesel, according to standards set by the United States, Japan and European countries.

Urban transportation is a major source of carbon emissions. We have prioritised initiatives that improve public transport and move Singapore towards a car-lite city. Unlike other countries that subsidise transport fuel, we levy additional taxes on transport fuel so that the user internalises the negative impact of emissions on society.⁶³

—Teo Chee Hean, Senior Minister and Chair of the Inter-Ministerial Committee on Climate Change (2011–Present)

To slow overall demand for car ownership, the government imposed an Additional Registration Fee—a vehicle ownership tax—to discourage the purchase of new vehicles. To manage congestion within the Central Business District, motorists had to pay a fixed entry fee under the Area Licensing Scheme of 1975.



11. The completion of the first MRT line was an important milestone for the public transport system.

SUSTAINABLE LIVING THROUGH HIGH-DENSITY, SELF-CONTAINED TOWNS

A United Nations-supported process gave rise to the 1971 Concept Plan, which recommended Singapore develop along a “ring-shaped” plan that anticipated future land-use and transport needs.

The ring plan set aside land for various uses such as housing, commercial, industrial, parks and recreational, airports and utilities. A network of roads and public transport lines facilitated connectivity in a growing city and new towns were connected by major and minor transport corridors.



12. Tampines, which began occupancy in 1983, is a town with a population of over 230,000 in just over 1,200 ha (12 km²). It is self-sufficient with its own commercial centre, schools, higher education facilities, parks and other amenities.



13. Our Tampines Hub integrates various civic, community, cultural, lifestyle and sports facilities to meet the needs of the residents.

The HDB worked to develop self-contained new towns of high-rise, high-density nature which freed up valuable space for other neighbourhood facilities such as schools, commercial centres, parks and recreational uses as well as industrial estates. Each town had a town park of 5–10 ha (0.05–0.1 km²), neighbourhood parks of 1–1.5 ha (0.01–0.015 km²) and many smaller precinct gardens.⁶⁴ People were able to live, work, and play within their towns, reducing the need to travel to the city centre for work or leisure. Each town is served by the MRT and public buses. Encouraging the use of public transport as the mode of choice aided to reduce congestion.

In the first three decades after independence, Singapore underwent intense industrialisation and urbanisation, yet it avoided the pitfalls of “develop first and clean up later”.⁶⁵ Long-term planning and strong governance tempered economic goals with social and environmental priorities. By planting greenery, controlling air and water pollution, and securing potable water and electricity supplies, Singapore established a firm foundation for its development that did not compromise the city’s environmental quality. Regulations were introduced step by step, pragmatically but decisively. These principles underpinning the vision of a “clean and green” Garden City would be called upon when confronting a new environmental challenge: human-induced climate change.

CHAPTER 3

1990s–2000s: UNDERSTANDING CLIMATE CHANGE AND ITS IMPACT

“

Climate change was one among many issues in the 2000s. Don’t forget, Singapore had experienced a recession between 1997 and 2001, then there was [the] SARS outbreak in 2002–03, and the Iraq war started in 2003. Attention was on the economic and social front, and even on the environment front, there were many issues such as water, dengue, haze, etc. These were all happening while the world was still in the process of better understanding climate change and how to deal with it. To Singapore’s credit, we have always taken the long view. Environmental sustainability is all about taking the long view—it is about how the choices we make now do not compromise the future of the next generation.⁶⁶

”

TAN YONG SOON

Permanent Secretary, National Climate Change Secretariat (2010–12)
and Ministry of the Environment and Water Resources (MEWR)
(2004–10)

Understanding the Challenge of Climate Change

Scientific discourse on the greenhouse effect was first recorded in 1896,⁶⁷ with sporadic studies on the topic until the 1960s. By the 1980s, scientists were increasingly worried about signs of “anthropogenic” or human-caused global warming through increased emissions of greenhouse gases (GHGs) such as carbon dioxide.

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme to “assess climate change based on the latest science”.⁶⁸ The IPCC released its First Assessment Report in 1990 and a follow-up Second Assessment Report in 1995.⁶⁹ These offered the best state of scientific knowledge on climate change at that time. With the release of these reports, climate change gradually became a topic of public interest.

Earth Summit and the United Nations Framework Convention on Climate Change (UNFCCC): Singapore on the International Stage

In 1992, the United Nations (UN) convened a UN Conference on Environment and Development in Rio de Janeiro, Brazil—later dubbed the “Earth Summit”. Tommy Koh, Singapore’s Ambassador-at-Large (1990–Present) was invited to chair the summit’s Preparatory Committee since he had previously had positive interactions with the summit organisers. The Preparatory Committee, which began its work in 1990, forged consensus on a key document adopted at the Earth Summit, the Rio Declaration on Environment and Development. Due to his leadership in the preparatory process, Ambassador Koh was asked to continue on as the chair of the main negotiating committee at Rio itself. Discussions still needed to be completed on Agenda 21, an action plan for how national governments and international organisations could work together on sustainable development, and to decide on a set of principles on forestry.

The agreements at Rio affirmed key principles of sustainable development—“soft laws” that became environmental best practice over time. These included the “precautionary principle” to prevent unintended harm with new technologies or innovations and the “polluter pays” principle.

As Ambassador Koh shared of his experience:

We wanted to play a small but positive role in convincing developing countries that it’s not a dichotomy—that you don’t have to choose either development or environment but you should try to do both. It’s not true that you should get rich first and then clean up later. We also wanted to make the point that yes, you may have sovereignty over your resources, but if you cause harm to your neighbour, you are liable.

We just wanted to be viewed by the world as a helpful interlocutor and sort of neutral chairman. We want to play a bridging role between North and South, East and West. So that’s a role that Singapore diplomats try to aspire to—to be used by the world as somebody playing a bridging role.⁷⁰



14. Ambassador Koh (front row, centre) chairing the Preparatory Committee of the Earth Summit in 1992.

The UNFCCC was established in 1992, with the goal of stabilising GHG concentrations in the atmosphere at a level that could “prevent dangerous anthropogenic interference with the climate system”.⁷¹ This seminal treaty has guided international climate negotiations ever since.

Representatives from Singapore participated in the 1991 talks to negotiate the UNFCCC, and many nations, including Singapore, signed it at the Earth Summit. The Parliament of Singapore eventually ratified the agreement in 1997.

Singapore participated in these talks, but there was not a widespread understanding of climate change at home [in the early 1990s]. The issue was not a major motivation for us until the 2000s, when we became more interested. [Nonetheless], Singaporean diplomats have been present at these meetings, even when climate change was not a priority.⁷²

—Dr Vivian Balakrishnan, Minister for Foreign Affairs (2015–Present) and Minister for the Environment and Water Resources (2011–15)

The Kyoto Protocol: Global Efforts to Take Action on Climate Change

Once the UNFCCC began functioning in 1994, countries began meeting through an annual Conference of the Parties (COP) to negotiate next steps, first in Berlin in 1995 and then Geneva in 1996. The third COP, hosted in Kyoto, Japan in 1997, introduced legally binding emissions targets.

The efforts at Kyoto took inspiration from the 1987 Montreal Protocol, which was seen as a successful example of international environmental cooperation. The Montreal Protocol had successfully galvanised nations to ban the use of chlorofluorocarbons (CFCs)—a class of chemicals used in aerosol sprays and Styrofoam production, and as refrigerants and solvents—that damaged the Earth’s ozone layer. As CFC emissions dropped, the ozone layer showed marked improvements.

But while CFCs could be substituted with other chemicals, the GHGs responsible for climate change were not as easy to reduce—almost all human activities consume energy or emit greenhouse gases through land-use change.

The UNFCCC had categorised the world into Annex I countries (developed nations, including the United States, European Union, Japan and former Soviet states) and non-Annex I countries (all others), who were understood to have “common but differentiated responsibilities” in responding to climate change. Many developing countries felt that major emitters—the wealthier, industrialised nations—should be taking on the bulk of the burden, as they had been responsible for the bulk of historical emissions and could afford to act. Furthermore, emerging economies did not want to have limits imposed on their growth. The Kyoto Protocol followed the same approach: 37 developed countries (plus the European Union as a whole) committed to reduce “their overall emissions of such gases by at least 5% below 1990 levels in the commitment period 2008 to 2012”. Developing countries, such as Singapore, were not required to act.

Though the Kyoto Protocol entailed no legal obligations to limit emissions for developing countries, Singapore elected not to sign the Kyoto Protocol.

At the point of Kyoto, we did not yet see a lot of climate change impacts, and we didn’t prioritise the issue. As a non-Annex I country under the UNFCCC, an agreement like Kyoto was non-binding on us. At home, there was a sense of comfort that we were not forced to act.⁷³

—Ambassador Kwok Fook Seng,
Chief Negotiator for Climate Change (2014-16)

Singapore’s Parliament ratified the UNFCCC in 1997 which obligated the country to report its emissions regularly. Singapore submitted its first National Communication in 2000, with details on Singapore’s national GHG inventory and its climate actions. Some years later in 2006, Singapore acceded to the Kyoto Protocol.⁷⁴

Mindset Shift from Environmental Performance to Sustainable Outcomes

In the pursuit of a clean and green island-nation, policies and initiatives put out by the government had emphasised environmental performance. The greening efforts had allowed Singapore to achieve total green cover of 47% by 2007. Air quality was in the “good” range of the Pollutant Standards Index (PSI) for 96% of the year and the overall waste-recycling rate rose from 40% in 2000 to 56% in 2008.

However, the 2001 Environmental Sustainability Index highlighted that Singapore was in the middle of the pack, likely to be hit by environmental disaster in the long run.

Our performance was good, but how can we be happy to be in the middle in terms of sustainability? We can use it as a starting point and ask ourselves what we need to do differently so that we can stay away from environmental disaster. Hopefully, we can not only be amongst the top in terms of performance in the short term, but also in the long term. Otherwise, our environmental performance will not be sustainable in the long term.⁷⁵

—Lim Swee Say, Minister for the Environment (2000-04)

That sparked the impetus to pursue policies that had a greater emphasis on sustainable environment outcomes, as Minister Lim added:

It was a turning point for the ministry. We agreed from top to bottom that sustainability was our new mission, a new focus that we should work on.⁷⁶

**EXHIBIT 5
NATIONAL BLUEPRINTS ON ENVIRONMENTAL SUSTAINABILITY
AND MITIGATION (1992–2006).**



National Commitment to a Sustainable Environment

Singapore's early efforts to include environmental sustainability in long-term planning was evident in the first formal environmental plan, the 1992 Singapore Green Plan (SGP). Presented at the Earth Summit in Rio de Janeiro, it documented the conscious effort and intent of the small island-nation as a responsible global citizen.

In the early 2000s, burgeoning concerns on climate change, along with the changing nature of regional transboundary air pollution, prompted a review of the SGP. Multiple agencies were involved in this effort. In 2002, new performance targets were established under the SGP 2012, with six key areas (air and climate change, water, waste management, conserving nature, public health and international environment relations) to guide sustainable development. These included maintaining within a "good" range of the PSI for 85% of the year and increasing the overall recycling rate to 60%. Further revisions were made in 2006 to account for new changes to moderate carbon emissions growth and the recognition of a whole-of-society effort to achieve long-term sustainability.

Exhibit 5 shows the evolution of the objective and focus of national plans from 1992 to 2006. While few initiatives were explicitly motivated solely by climate change, many of them had important co-benefits that improved Singapore's carbon emissions profile, by protecting carbon sinks and limiting or reducing carbon sources.

From a Garden City to City in a Garden

To further the Garden City vision, in 1990 the National Parks Board (NParks) was established as a statutory board under the Ministry of National Development; in 1996 the Parks and Recreation Department (PRD) merged with the NParks. The National Parks Board Act was enacted to reconstitute the NParks and provide for the transfer of property, rights and liabilities of the PRD to NParks. The percentage of land demarcated for nature conservation was to be raised from 3% to 5% under the SGP 1992. This is important as "Singapore considers nature conservation to be a pragmatic investment of time, effort and finance that is providing benefits every day to the people at large and to business, industry, health and education."⁷⁷

The continual provision of green spaces played a role in reducing the urban heat island (UHI) effect, absorbing airborne particulate matter, and creating a cooler and liveable urban environment. The Park Connector Network was implemented in 1995 as a network of walking, running and cycling paths. This was done through activating underutilised spaces along canals and open spaces to enhance connectivity between parks and green spaces. This was undertaken with the understanding that connectivity to nature is key to enhancing psychological well-being. To instil Singaporeans with a sense of “green consciousness”, the Community in Bloom initiative was launched in 2005 as a national gardening movement, to foster a community spirit and bring residents together. Over the following years, Singapore transitioned toward becoming a City in a Garden, with increased community stewardship in nature conservation and further integration of greenery into the urban landscape.



15. There was concerted effort to increase vegetation cover across Singapore.

Waste Management for a Cleaner Environment

“You can’t be on [the] moral [high] ground and tell people not to throw rubbish indiscriminately if you do not provide a prompt, efficient and reliable waste collection service.”⁷⁸

—Loh Ah Tuan, Deputy CEO (DCEO),
National Environment Agency (NEA) (2004–07)

Singapore’s waste management challenge is exacerbated by its tropical climate: waste putrefies quickly in the hot, humid weather. In the early years, waste collection was rudimentary: residents deposited waste into open bin points along the roadside. Waste collection was irregular, inefficient, and unreliable. Accumulated refuse along roads, back lanes and other public areas led to foul odours, flies, rodents and water pollution.

In 1972, collection of waste was centralised under the Environmental Health Department of the newly formed Ministry of the Environment (ENV). Daily waste collection service was adopted. The rapidly growing number of high-rise apartments were designed with a refuse throw-point in the kitchen, connected to a common vertical chute, which removed the need for door-to-door collection. After the late 1980s, public high-rise apartments were fitted with centralised chutes. The early 2000s saw the introduction of pneumatic waste conveyance systems (PWCSs), which used a vacuum to convey refuse directly into a compactor located some distance away from the apartment. Besides improving efficiency and hygiene standards, the PWCS reduced manpower requirements and mileage of waste collection vehicles.

Population growth and the ease of waste disposal led to a new challenge: the volume of waste grew by more than seven-fold.⁷⁹ Singapore could not afford to set aside large tracts of land for landfill, as sanitary landfills cannot be put to other land use for many decades, even after they have been filled up and closed. This drove Singapore to adopt mass-burn incineration technology, which reduces the volume of waste by about 90%. The electricity generated from waste incineration covers the energy needs of operating the waste incineration plant, with surplus exported to the electricity grid.

One question we asked was, “Are we contributing to more CO₂ emissions by burning our rubbish?” We did a study then which showed that if we did not burn our rubbish, and allowed it to simply ferment in landfills, it would substantially increase methane emissions. Methane is a more powerful global warming agent than CO₂, which would have resulted in higher nett greenhouse gas emissions!⁸⁰

—Joseph Hui, DCEO, NEA (2011-14)

After inaugurating the first waste incineration plant in 1979, three more were built in the next two decades. This strategy of volume reduction by incineration helped to extend the lifespan of landfills.

In 1999, the last landfill on Singapore’s main island, at Lorong Halus, became full and had to close. In preparation for this, the ENV constructed an offshore sanitary landfill at Pulau Semakau by enclosing a 350 ha (3.5 km²) of sea space between Pulau Sakeng and Pulau Semakau with a 7 km perimeter bund. Operations at Pulau Semakau landfill commenced on 1 April 1999—one day after the Lorong Halus landfill was closed.

Great care was taken during the construction and operation of Semakau Landfill to ensure that the landfill was environmentally compatible with eco-systems and did not pollute the surrounding seawater. Landfills are typically stereotyped as dirty and smelly; Semakau is neither. It is scenic and a popular spot for bird watching and exploring the marine eco-systems around it. It is thus often used to educate the public on sustainable waste management. It was even featured in science magazine *New Scientists* and dubbed the “Garbage of Eden”.⁸¹

Beyond efficient collection and disposal, the government recognised the need to reduce, reuse and recycle waste. The solid waste management system introduced two additional initiatives: recycling and waste management. Former DCEO of the NEA, Joseph Hui rationalised:

The main reason we pushed for recycling was for the pressing issue of reducing the amount of waste sent to Semakau, to try to extend its lifespan as long as possible by minimising the generation of incineration ash. The less rubbish we burn, the less ash we generate and the less CO₂ we emit. Climate change was one of the reasons, but the main reason was really for sustainability.⁸²

The National Recycling Programme was subsequently launched in 2001. Bins were placed around the country for the collection of paper, plastic and metal recyclables. Recycling bags were distributed to residences and collected fortnightly from the doorsteps. Garden waste such as grass, leaves and small branches were also collected from landed properties. This approach raised Singapore’s overall recycling rate from a low of 15% in the 1990s to 59% in 2019.⁸³



16. Incineration ash is buried at purpose-built lagoons in Semakau Landfill. Adjacent wetlands and reefs serve as bioindicators of pollution.

SHIFTING MINDSETS THROUGH TABLES ON BUSES

Two issues which the ENV wanted to address in the early 2000s were the rising solid waste production and the low rate of recycling. In 2001, the ENV planned for a study trip to the Netherlands and Germany to learn about their solid waste recycling measures as they had performed well in this domain. However, for the solutions to be effective, the ENV needed the support from industries—the waste and recycling companies. Then Minister for the Environment Lim Swee Say explained:

We go there and see what they do, but when we come back, who is going to make it happen? Yes, we are the [Ministry] but we need the industry to support recycling and actually undertake the new initiative.⁸⁴

With that in mind, Minister Lim proposed a novel idea that involved mind-set changes to the operations of partnership between the government and the industries.

I said, why don't we bring the industry along? This is something that has never happened in the ENV. But if we bring them along, we can learn and change our mindsets together.⁸⁵

This proposal to bring the industries along was approved, but Minister Lim had one more request to ensure partnership objectives were met:

I [suggested that I] go into the coach together with my staff and the industry representatives. Because if you talk about partnership, we should learn together, and the minister will be part of the coach. But I had one [other] request, I wanted a coach with a meeting table so that in-between visits, when we have three to four hours on the coach, I could brainstorm with everyone while things were still fresh on our minds.⁸⁶

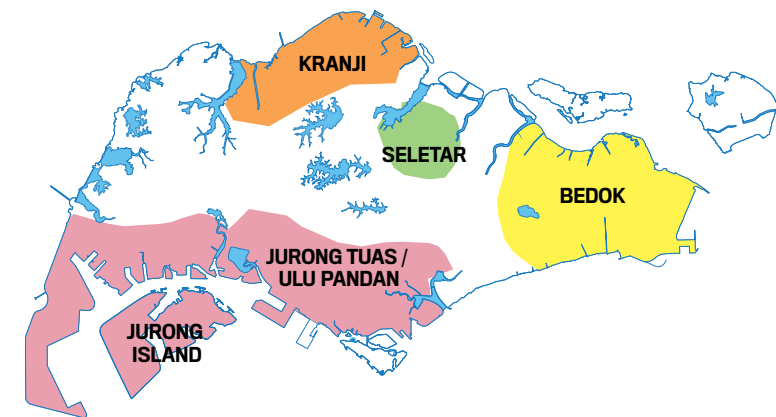
One key outcome of the trip was the formation of the Waste Management & Recycling Association of Singapore, a key partner of the ENV to oversee the waste management and recycling industry, which helped pushed the recycling agenda forward.

Enhancing the Nation's Water Resources: Singapore's Four National Taps

By 1997, 100% of Singapore was served by a modern sanitation system.⁸⁷ To ensure greater long-term sustainability and cost effectiveness, the PUB, Singapore's National Water Agency, completed the first phase of the Deep Tunnel Sewerage System (DTSS) in 2008, where used water is conveyed by gravity to two of three centralised water reclamation plants in Changi and Kranji. The goal was to gradually replace the current used water collection and treatment system, which consisted of numerous reclamation plants, sewage treatment plans and pumping stations. The new system reduced the risk of contaminating its freshwater sources due to pipe damage and degradation, and freed up large land uptake of existing plants and stations.



NEWATER CLUSTER MAP



17. The DTSS network and co-location of NEWater plants with water reclamation contributed to Singapore's water security. The DTSS (top) conveys used water to be treated at water reclamation plants; treated water is further purified into NEWater or discharged to the sea.

This effective management of used water also bolstered water supply through facilitating reclamation and reuse. The co-location of water reclamation plants with NEWater factories enabled efficient reclamation of treated used water to ultra-clean, high-grade reclaimed NEWater which meets the World Health Organization's Guidelines for drinking-water quality. The launch of NEWater in 2003 marked a significant milestone for water security.

In addition to NEWater, Singapore developed its capabilities in desalinating seawater. In 2005, using reverse osmosis membrane technology, SingSpring, Singapore's first water desalination plant became operational and Singapore's fourth national tap was turned on. Together, NEWater and desalination are important weather-resilient sources of water supply.

Domestic water supply was also increased through the creation of new reservoirs, such as the iconic Marina Reservoir. It was created in the heart of the city upon the completion of the Marina Barrage in 2008. Like many other reservoirs, it doubles as a lifestyle venue for a range of water-based activities. Today, there are 17 reservoirs collecting water from up to two-thirds of Singapore's land area. The PUB also has plans to increase the catchment to 90% by 2060.⁸⁸

The "Four National Taps"—local catchment water, imported water from Malaysia, NEWater and desalinated water—increased and diversified Singapore's water sources to further enhance water security and sustainability. They enabled Singapore to overcome its lack of natural water sources to meet the needs of a growing nation.

18. Today, two-thirds of Singapore's land area is a water catchment area where rainfall is channelled through its networks of drains and canals to form the local catchment water supply.

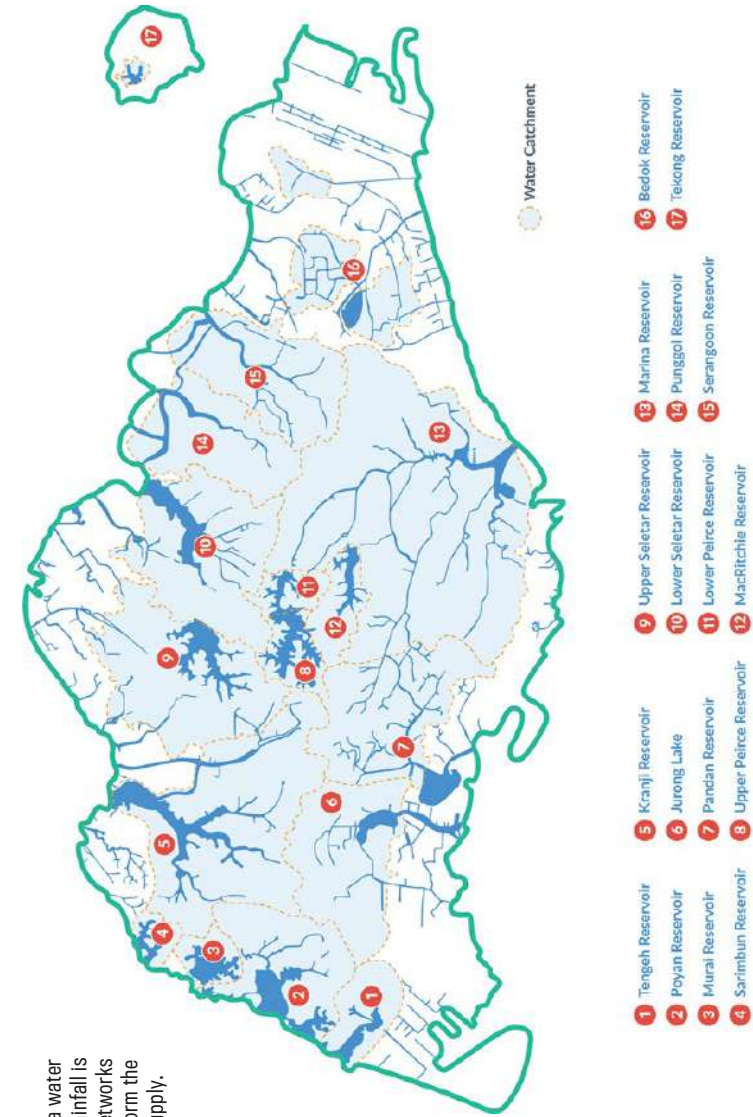
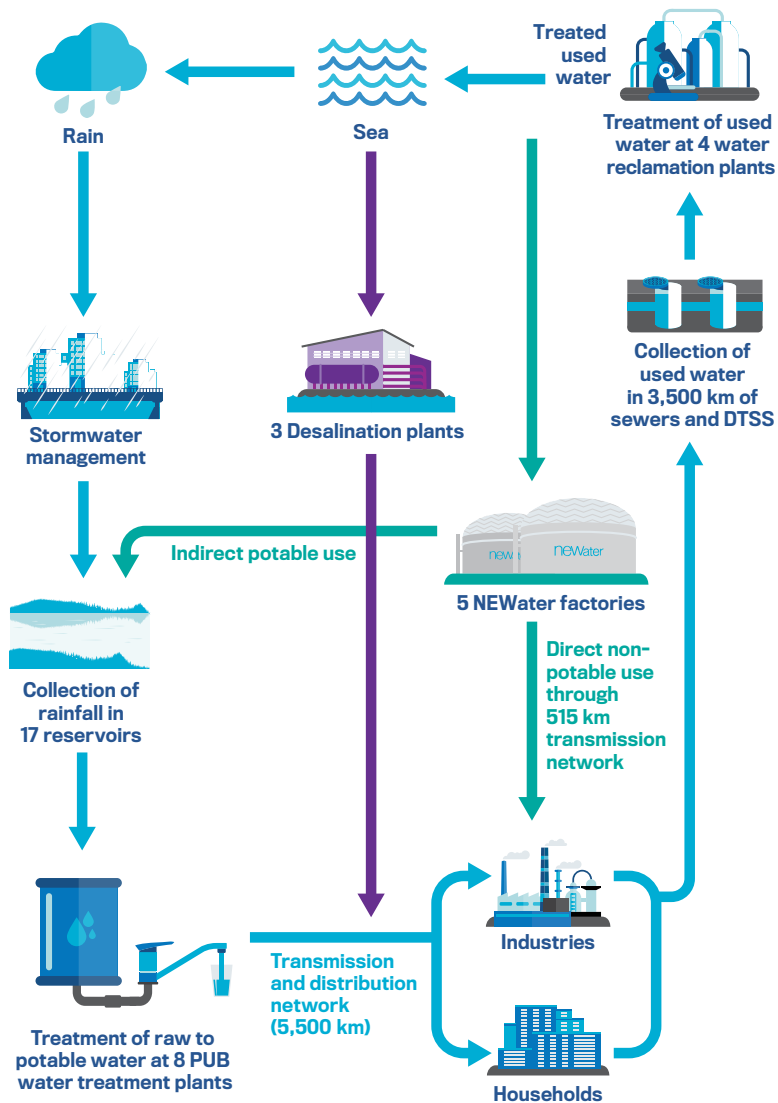


EXHIBIT 6 WATER LOOP.



Singapore has closed the water loop to maximise the collection and reclamation of every drop of water.
Source: PUB, Singapore's National Water Agency.

Electricity Supply: Fuel-Switching to Natural Gas and Improving Efficiency

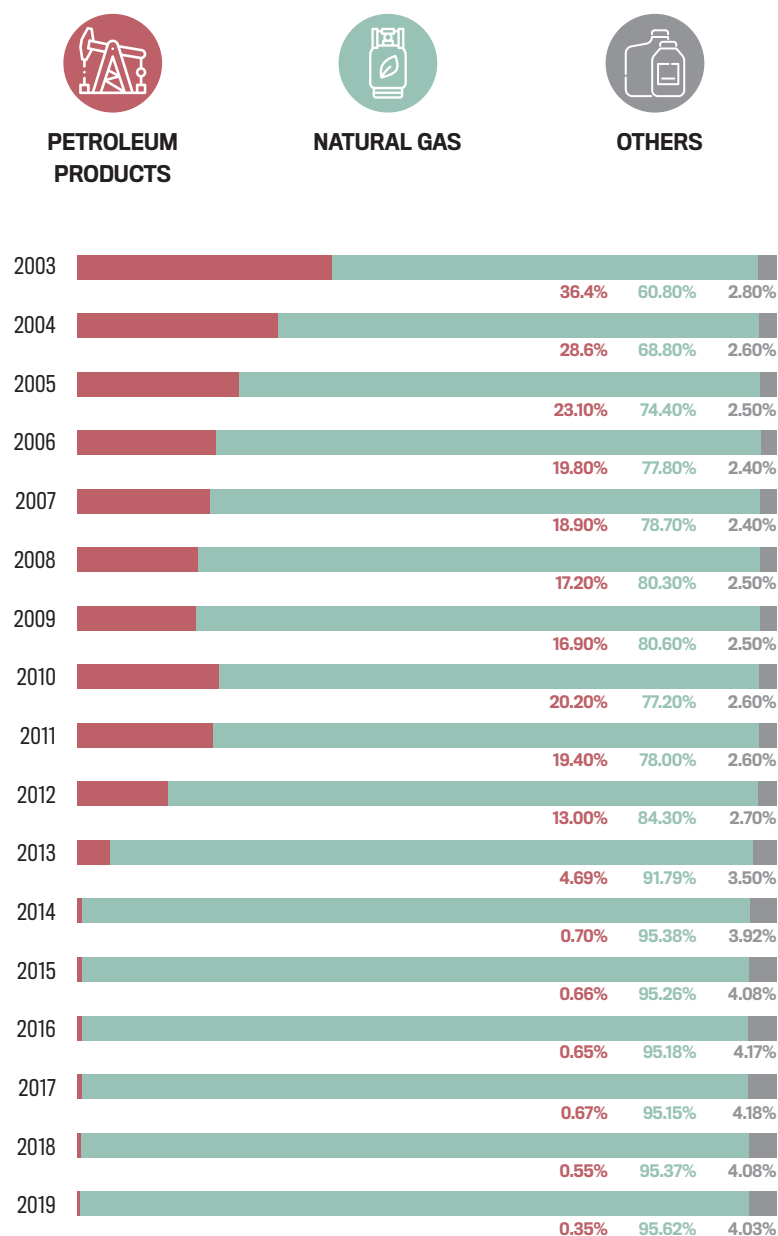
Prior to the 1990s, Singapore largely relied on oil-fired electricity generation. Though coal was a cheaper fuel, it was dirtier and more polluting. Following the recommendation of founding Prime Minister Lee Kuan Yew, Singapore did not build coal-fired power plants for 25 years.^{89,90} After careful deliberation, natural gas was promoted as an alternative fuel, and in 1992, the Senoko Power Station began to use natural gas piped from Malaysia to generate electricity.⁹¹

As natural gas was cleaner than burning fuel oil or diesel, it yielded better air quality. Through the 2000s, natural gas gradually displaced petroleum products in the power sector's fuel mix, until it accounted for over 95% of electricity generation by 2019 (see Exhibit 7). Natural gas is a cleaner, less emissions intensive fossil fuel and will continue to be a key fuel for Singapore's electricity production in the near future to ensure that energy supply remains reliable and affordable.

The capital investment involved in switching to natural gas prompted a search for more efficient power generation systems. Senoko Power Station installed combined-cycle natural gas turbine technology in 1997, which was 45-50% more efficient than conventional gas turbines. Other power plants followed suit. However, in a departure from earlier policy, a new coal-fired power plant—the Tuas Power Tembusu Multi-Utilities Complex—began operating in 2013⁹² to diversify fuel sources and take advantage of a “cheaper fuel option”.⁹³

Learning from overseas experiences, the government decided to liberalise the energy sector in 1995. The electricity and gas departments of the PUB were corporatised to become Singapore Power. Competition was legalised in contestable segments of the market, such as generation and retail sales while regulations on transmission and distribution were strengthened. The Energy Market Authority and Energy Market Company were formed in 2001 to regulate multiple new entrants. Competition between independent power producers and co-generators enabled wholesale trading of electricity.

EXHIBIT 7
FUEL MIX FOR ELECTRICITY GENERATION BY PERCENTAGE.



Source: Energy Market Authority.⁹⁴

Demand-side Management: Taking a Serious Step Towards Energy Efficiency

In 1998, an Inter-Agency Committee on Energy Efficiency (IACEE) was formed to identify strategies to curb rising energy consumption. The 11-agency body included government ministries, statutory boards and academic institutions.⁹⁵ The IACEE's report on Energy Efficiency in Singapore was released in 2000 and suggested that energy efficiency could enhance cost competitiveness while contributing to Singapore's international obligations on carbon emissions.⁹⁶

In 2001, the MEWR restructured the IACEE, renaming it the National Energy Efficiency Committee (NEEC), and expanding its scope to address energy efficiency in the industry, building, transportation and consumer sectors; promote cleaner energy sources and renewable energy, and promote Singapore as a location for test-bedding pioneering clean technologies. In 2006, the NEEC was renamed once more, becoming the National Climate Change Committee to tie the energy efficiency agenda to the nation's non-binding Kyoto commitment to reduce carbon intensity. Workgroups on electronics, pharmaceuticals and chemicals, and research and development were roped in to support these efforts.

The Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative was started in 2006 to promote energy efficiency, water efficiency and recycling in government buildings, as well as promote green procurement practices. Future updates to PSTLES would see public agencies continue to take the lead in design and operations.

Industry

On the industrial front, regulatory approaches and assistance schemes drove energy efficiency improvements. To encourage industries to replace energy-consuming equipment, the Economic Development Board introduced the Accelerated Depreciation Allowance for Energy Efficient Equipment Technology scheme in 1996, which permitted early write-off or depreciation of capital expenditure on energy-saving equipment. Manufacturers were encouraged to seek certification under the Voluntary Green Label scheme and to adopt best practices in energy efficiency. The scheme endorsed industrial and consumer products that had been produced by manufacturers with lower energy consumption, giving them a competitive advantage of branding over non-certified products. Meeting stringent standards also yielded long-run cost savings by reducing water and waste management fees.

In the early 2000s, the NEA implemented the Energy Audit Scheme to encourage industries and commercial buildings to conduct audits of their air-conditioning equipment in order to improve their efficiency, thereby saving on electricity bills and more importantly, shrinking their carbon footprint.

Buildings

The building sector began gradually to improve energy efficiency in the early 2000s. The Housing and Development Board (HDB) continued to incorporate many passive designs to reduce energy demand, such as orienting buildings in the north-south direction instead of east-west as much as possible to minimise direct exposure to sunlight. The HDB blocks were designed to promote cross-ventilation to reduce the need for air-conditioning. The HDB adopted environmental modelling tools to simulate urban climatic conditions to refine the placement of blocks and units which help to create cooler and more conducive living environment through sustainable design. As multi-storey carparks replaced surface carparks, the reduction of exposed surfaces helped stem the rise in ambient temperature due to UHI effects. The HDB also improved mechanical and electrical services by installing energy saving lamps in lifts.

The Building and Construction Authority (BCA) launched the Green Mark Scheme in January 2005 to rate buildings on environmental performance. The programme was meant to drive the construction industry towards creating buildings that would use less energy, water and materials.⁹⁷ In 2006, the BCA released a Green Building Masterplan expounding the progressive adoption of new standards over time. The Green Mark Scheme would become extremely influential in making Singapore's built environment more energy efficient (see Chapter 4).



19. The HDB flats were built with windows that orient north-south to promote cross ventilation and have void decks to draw wind onto the ground and improve wind flow.⁹⁸

Transport

As Singapore's population increased, the transport sector grew to be a substantial user of energy and contributor to carbon emissions, at 15% of total emissions in 2000.⁹⁹ The *1996 Transport White Paper* highlighted the need for continual expansion of public transport routes, with the vision of achieving 75% of daily trips made by public transport.¹⁰⁰ By 2005, there were more than 3,100 buses and 128 km of Mass Rapid Transit (MRT) lines, serving more than 4 million trips per day to seamlessly connect housing with commercial and industrial developments.¹⁰¹ The MRT North-East Line was opened in 2003 to link the city centre to the north-eastern regions of Singapore, while the East-West Line was extended to serve the Singapore Expo and Changi Airport. Light Rail Transit (LRT) was built in new towns like Bukit Panjang, Punggol and Sengkang to facilitate mobility and provide feeder services to the MRT network. For example, pedestrians in the newly developed town of Punggol could better access the town centre on foot or by the LRT instead of by car.

To curb air pollution emissions, new vehicle emissions standards were introduced in 1991. As diesel vehicles and motorcycles were more polluting, they were prioritised for regulation under the new standards, followed by petrol vehicles in 1994. Fuel quality standards were also raised: the maximum sulphur content in diesel was reduced from 0.5% by weight in 1976 to 0.005% in 2005. Unleaded petrol was introduced in 1991, and by 1998, leaded petrol was completely phased out. To manage congestion, vehicular ownership regulation was further tightened. Additional vehicle import taxes evolved into the Certificate of Entitlement under the Vehicle Quota System in 1990 to control the vehicle growth rate. The 1975 Area Licensing Scheme was also updated and replaced with Electronic Road Pricing in the late 1990s. The new mechanism leveraged on technology to impose a flexible road levy based on time and congestion levels. This dissuaded the use of private transport in favour of public transport.

After the Kyoto accession, the NEA partnered with the Singapore Environment Council, an environmental non-governmental organisation, to launch a public awareness campaign about energy consumption.¹⁰²

IMPROVING STANDARDS FOR DIESEL VEHICLES

Since the 1990s, diesel vehicles and two-stroke motorcycles were recognised as major sources of air pollution, accounting for 50% of pollutants. Concerned, the ENV initiated measures to combat air pollution and improve Singapore's standards.

The conversion of diesel vehicles to natural gas was considered, but, the cost of conversion made the option unviable. Former DCEO of the NEA, Loh Ah Tuan, shared:

At that time, Singapore had just started to import natural gas from the Natuna gas fields in Indonesia. We felt the timing was right to push for natural gas vehicles to replace diesel vehicles. Unfortunately, the plan did not work owing to the high cost of natural gas vehicles against diesel vehicles, and there were only a few natural gas stations.¹⁰³

The ENV was determined to find a solution by raising the vehicle tailpipe emission standards for diesel vehicles from Euro II to Euro III. But economic agencies objected to the compromise solution as well, as Loh further explained:

Diesel vehicles in Singapore are mainly commercial vehicles like the taxis, public and tour buses, and pick-up trucks. If we were to introduce higher emission standards for diesel vehicles, what will happen is that the cost of business will increase.¹⁰⁴

Notwithstanding, the NEA tabled a memo to the Cabinet to raise the emission standard for diesel vehicles from Euro II to Euro III. To their surprise, the Cabinet took the bold step to bypass Euro III for the more stringent Euro IV standard. Weighing air quality against the cost of implementing a cleaner standard, the Cabinet deemed this a necessary trade-off and took decisive action, which Loh described:

If we didn't do that, what will happen is that air quality would have deteriorated. If you looked at our air-monitoring results [at that time], we hadn't hit the unhealthy level yet. But the trend was moving upwards and we needed to do something.¹⁰⁵

Euro IV standards were eventually adopted in 2007. To facilitate the transition for commercial transport companies, the mandatory use-life of taxis and public buses was extended to alleviate the costs of transition.

Advancing Through 3P Partnerships

Improving the environment relied on not only government initiatives, but also active involvement of the private and non-profit sectors. To spur greater commitment, extensive consultations with the 3Ps (public, private and people) provided impetus for innovation and community partnerships. The revision of the SGP 2012 in 2006 endorsed this strategy.

To achieve the first "P" (public) was to shift from performance to sustainability. Then as we got the industries to come together, involve them in the joint formulation of the vision and help them through industry and manpower development, we achieve "2P" (public and private). Finally, when we went out and engaged the people through national programmes, we become "3P" (public, private and people).¹⁰⁶

—Lim Swee Say, Minister for the Environment (2000–04)



20. The Singapore Green Building Council adopts a 3P approach to engage in outreach activities such as sharing knowledge about green homes at the Clean & Green Singapore Carnival 2019.

RALLYING SUPPORT TO CONSERVE CHEK JAWA

Chek Jawa, a roughly 100 ha (1 km²) wetland in Pulau Ubin, is home to a rich biodiversity of creatures, rare plants and local and migratory birds. However, under the 1991 Concept Plan, Chek Jawa was earmarked for reclamation for future developments. The reclamation would effectively enlarge Pulau Ubin by 274 ha (2.74 km²).

When news of the upcoming reclamation works surfaced in 2000, the Nature Society and marine biologists from the National University of Singapore mobilised volunteers and nature supporters to bring awareness to the considerable natural heritage that was to be lost, in the hopes of saving it. Over months, they collected marine samples, carried out a survey to establish the biodiversity value of the area, conducted tours to the island and held public education events to raise awareness of the area's rich biodiversity. They were successful in attracting more than 1,000 people to attend the tours.

The research culminated in a detailed report sent to the Ministry of National Development. Members of the public also sent in their personal appeals in various mediums, such as CD-ROMS of field data trip reports to convince the government on the value of conservation. The Minister for National Development, Mah Bow Tan (1999–2011), together with chief executives from the URA, HDB, NParks and Ministry of Defence considered the plea and explored the possibility of alternative reclamation profiles that would not affect the biodiversity. After extensive deliberation and onsite surveys, the eventual decision was a cause for celebration. Minister Mah said:

Land in Singapore is scarce. There will always be competing needs for land for development and national security needs. The decision not to reclaim Pulau Ubin at the moment has been made only after we have weighed the trade-offs and carefully considered the land use implications.¹⁰⁷

This strong interest from nature enthusiasts and the public contributed to the decision to put off the reclamation. In fact, Minister Mah requested for greater partnership between the people and the government to continue to furnish the ministry with feedback and ideas to protect the biodiversity.

This exemplified the broad-based public support and constructive relationship that can be forged between the government and the public, as Minister Mah added:

This episode is a positive example of consultation and collaboration between the ministry and the stakeholders which has resulted in a win-win situation. The government will continue to take a balanced and pragmatic approach to land use planning.¹⁰⁸



21. Chek Jawa became such a popular spot for marine life that a boardwalk was built to minimise adverse impact on the biodiversity.¹⁰⁹

Today, the conservation of biodiversity is motivated by the understanding that healthy eco-systems contribute to human well-being and provide the foundation for development in the long run because "conservation of these resources depends on maintenance of their habitats and is closely related to land use and environmental quality. Biodiversity conservation in Singapore is therefore dependent on the efforts of many government agencies, and these efforts also reply on participation by non-governmental organisations and support from the private sector."¹¹⁰



CHAPTER 4

2007–19: INSTITUTIONALISING EFFORTS TO RESPOND TO CLIMATE CHANGE

“

The Singapore Government adopts a realistic and practical approach towards climate change—you can call us ‘climate realists’. We will continue to encourage constructive discussions, based on facts and the best available science and technology, and consider the larger context of the entire range of challenges we face in our national policy framework.¹¹¹

”

TEO CHEE HEAN

Senior Minister (SM) and Chair of the Inter-Ministerial Committee on Climate Change (IMCCC) (2011–Present)

Establishment of the IMCCC

After Singapore acceded to the Kyoto Protocol in 2006, there was a need to coordinate climate action across government—not only to put in place policies, plans and actions for Singapore to achieve its commitments, but also to coordinate reporting and to develop a unified position for Singapore in international climate negotiations.

In 2007, the IMCCC was formed for these purposes, under the chairmanship of then Deputy Prime Minister (DPM) S. Jayakumar, comprising ministers from the Ministry of Foreign Affairs (MFA), Ministry of Trade and Industry (MTI), Ministry of National Development (MND), Ministry of the Environment and Water Resources (MEWR), Ministry of Finance (MOF) and Ministry of Transport. The IMCCC's executive committee includes the permanent secretaries (PSs) of the same ministries plus the PS of National Research and Development and the Chair of the Economic Development Board (EDB), chaired by the PS of the Prime Minister's Office (PMO).

As SM and Chair of the IMCCC Teo Chee Hean said:

Environmental issues frequently involve externalities. The consequences of the emission are not necessarily borne by the emitter. If you pollute a waterway, you will not be affected by it, but someone downstream will be affected by it. If you tell the person he must do more to mitigate the impact of his actions, he doesn't feel the benefits. So, what does the IMCCC do? It tries to make these trade-offs and consequences visible. We must understand how these affect us as a whole and reconcile all the costs. We do what makes sense on a national level, rather than looking at things only at a sectoral level.¹¹²

Singapore appointed its first Chief Negotiator for Climate Change, Ambassador Chew Tai Soo, in 2007 to take a more active role in international negotiations. In 2010, the National Climate Change Secretariat (NCCS) was set up, initially based in MFA, and subsequently strengthened and repositioned under the PMO to facilitate tighter inter-agency coordination and to support the IMCCC.¹¹³

Climate change is better coordinated at [the] PMO. They drove the national initiative to comply once we ratified [the Kyoto Protocol].¹¹⁴

—Joseph Hui, Deputy Chief Executive Officer (DCEO),
National Environment Agency (NEA) (2011–2014)

Even with the PMO leading, and a secretariat formed, not everything fell into place, as Tan Yong Soon, who was the PS of NCCS (2010–12) shared:

It doesn't mean that once the NCCS was created, a PS appointed, and an SM overseeing it, that the ministries will take orders from you. That is not how it works. Agencies had to see how addressing climate change aligned with their own sector priorities. It should advance, not impede their policy agendas.

I had a skeletal staff. Very knowledgeable in climate change issues and brilliant thinkers—but they could not do everything! I had to create a structure. I decided that I would need to create an executive committee to oversee climate change and have separate working groups looking into mitigation, adaptation and negotiation. These groups would need to be headed at [the] PS-level to get their buy-in as well as lean on their authorities to drive [the] ministries and statutory boards (SBs) to work on solutions.

How to persuade the PSs to agree? The then PS (MTI), Ravi Menon, was very positive when I discussed with him. We then met with the PS (MOF) Peter Ong and persuaded him to chair a small breakfast meeting with the relevant PSs. Once the executive committee and working groups were agreed upon, I sought the minister's agreement on the Ministerial Committee.

Mitigation and Long-Term Emissions will be under both me as [the] PS (NCCS) and PS (MTI). [The] MTI is critical as the most challenging part of mitigation is from industry. Adaptation or resilience would be under [the] PS (MEWR) and PS (MND) as flood prevention and protection, and infrastructure, fall mainly under them. Negotiation would be under [the] PS (MFA). The executive committee to be chaired by me would coordinate all 3 working groups; it would report to a Ministerial Committee headed by the SM/DPM with all the ministers of ministries involved in working groups. [The] MOF was in the Ministerial Committee and Executive Committee as finance resources are important.

That was the organisation that was set up in late 2010. We had to make sure that there was a process to work on all the needed areas and certain targets were accepted for people to work towards. The NCCS officers would staff the meetings. The fact that [the] NCCS existed and the PSs agreed to head the working groups, helped to

move things along. Many ministry and SB officers worked very hard to achieve the targets and they came up with many innovative and effective solutions. The skeletal NCCS staff played a key role behind the scenes. It was truly a whole-of-government effort.¹¹⁵

In this way, the whole of government works together to undertake climate actions. The structure is explained in the diagram on the right (Exhibit 8).

The following describes the roles of the working groups:

- The Long-Term Emissions and Mitigation Working Group studies how Singapore can stabilise its long-term emissions, examines options for emission reduction, and identifies the capabilities, infrastructure and policies needed for long-term mitigation.
- The International Negotiations Working Group develops Singapore's international climate change negotiations strategy.
- The Resilience Working Group recommends long-term plans to ensure Singapore's adaptation to future environmental changes.¹¹⁶

EXHIBIT 8 COMMITTEES, WORKING GROUPS AND MEMBERS UNDER THE IMCCC.



Source: National Climate Change Secretariat.¹¹⁷

Changing Minds: Climate Awareness Permeates the Civil Service

Singapore has always sought to grow sustainably through long-term integrated planning. The government has pursued economic and environmental objectives concurrently, not one at the expense of the other. As global urgency surrounding climate change picked up in the 2000s, Singapore monitored the ongoing trend. Civil servants attended international meetings, such as the annual Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and brought back lessons and insights.

The release of the Oscar-winning documentary *An Inconvenient Truth* in 2006, featuring former United States Vice President Al Gore explaining climate change with accessible language and indelible images, helped to further galvanize discussion internationally and in Singapore. The 2007 Nobel Prize, jointly awarded to the Intergovernmental Panel on Climate Change (IPCC) and to Gore, further bolstered attention to the issue.

In 2007, former PS of the NCCS and MEWR Tan Yong Soon attended the COP 13 in Bali. After his return, he gave a presentation on climate change at the annual Public Service Conference for civil servants from all ministries. This was one of the first examples of addressing the entire civil service on the topic and draw attention to an issue many have not heard of. For government officers who were already aware of climate change and passionate about doing something, it smoothed the path for acting in their respective agencies; as Tan illustrated:

There were differing views on how quickly it was happening. Timeframes, priority of action, allocation of resources...between solving current ills and longer-term issues of climate change, the answers were not clear. One can understand why some individuals and agencies did not buy into the effort too wholeheartedly, but you have to work on the people who are more open to taking action.¹¹⁸

Long Road to Paris: Singapore's Contributions to International Negotiations

With the idea of climate action starting to take root at home, Singapore shifted its approach in international negotiations. As a non-Annex I country under the UNFCCC and the Kyoto Protocol, Singapore still had few international obligations on carbon emissions, and so had remained on the fringe of the issue.

We used to be a single-issue delegation. Bunkering¹¹⁹ is a big part of our role in Southeast Asia, as we are a maritime hub and refining centre. That used to be our main focus during these climate conferences, and it formed an impression among other delegations that we were only active on that issue.¹²⁰

—Ambassador Kwok Fook Seng,
Chief Negotiator for Climate Change (2014-16)

Many developing countries, including Singapore, worried that future climate agreements might unduly limit their ability to emit carbon, and thus affect them economically. These countries then lobbied that the developed nations agree to share this responsibility among all nations. By the late 2000s, it was clear that the international community was moving towards this more universal approach to climate action, made evident in the Bali Action Plan that called for finalising such an agreement at the 2009 COP in Copenhagen. As S. Jayakumar, SM and Chair of IMCCC (2007-11) observed, if Singapore was “not at the table, it was on the menu”.¹²¹

Before, climate change was largely a defensive issue [for Singapore]. Then we realised Copenhagen was coming and we needed to get our act together.¹²²

—Ambassador Burhan Gafoor,
Chief Negotiator for Climate Change (2010-14)

In 2009, there was strong momentum towards a climate agreement driven by the United States and the European Union. They favoured science-based targets and emissions quotas assigned to countries and, unlike Kyoto, sought to secure legally-binding action from all participants, not just wealthy countries. This was met with resistance from emerging economies, who were still concerned that limits on their emissions would

impact their growth. At the COP 15 in Copenhagen, major players such as the United States, European Union, Japan, China, India and Brazil, entered tough negotiations without the participation of smaller countries. As Ambassador Gafoor reflected:

We were not on the inside track of negotiations. We realised that a deal was being cooked without us, which really spooked us. Had there been a global agreement, we would have been excluded from shaping the outcome. As it turned out, the negotiations in Copenhagen collapsed. Ambitions were too high and there was not enough buy-in from many countries.

In the lead up to Copenhagen, we worked hard to put in place an inter-agency process and prepare our positions. But there was no avenue for us to present them during international negotiations. After Copenhagen, we knew we could not let this happen again.¹²³

This presented an opportunity for the negotiating team to self-reflect. Instead of being defensive and harping on Singapore's disadvantages in energy and land, the diplomats recognised there was an opportunity for Singapore to take a more "offensive" posture and constructively shape future negotiations. After the failure at Copenhagen to secure a global agreement, there was major uncertainty about how future negotiations would unfold. The old approach, where only a few nations negotiated among themselves, could no longer prevail. Ambassador Gafoor explained:

The system was now extremely fragmented and dysfunctional, with high levels of distrust and very low levels of communication. The top-down architecture had collapsed. This presented an incredible opportunity for smaller countries—and especially for Singapore—to reimagine the process.

What we essentially did was to play a bridge-building role to rebuild consensus around certain issues. We had to take it a step at a time, going from COP to COP. Between 2010 and 2014, we worked with other like-minded countries to build the bottom-up architecture of climate negotiations.¹²⁴

Singapore decided to proactively engage with other countries, bring useful ideas to the table, and support the global process. A key opportunity presented itself in 2010, when the UNFCCC asked Singapore to chair the

Ad Hoc Working Group on Long-term Cooperative Action on climate finance, which Singapore agreed to. Ambassador Gafoor mused that he did not fully recognise what agreeing to this would entail. However, he noted that it was a crucial move to establish Singapore as a friend to all:

We were not just at the table highlighting our concerns and defending our own issues. We used each of the meetings to comment on all issues on the agenda, to raise questions and to suggest solutions. We tried to propose solutions that were not inimical to any country's interest.¹²⁵

This led to Singapore being invited to participate in other pre-COP consultations, including the annual Japan-Brazil Informal Meeting on Further Actions against Climate Change in Tokyo—Singapore has been invited every year since 2011¹²⁶—and the Petersburg Climate Dialogue in Germany. Singapore also became a member of the International Partnership on Mitigation and Measurement, Reporting and Verification (MRV), as transparency was seen as an important principle.¹²⁷ The insistence on transparency and support for MRV enabled Singapore to gain the trust of the United States.

Another critical arena in which Singapore became involved was the Major Economies Forum on Energy and Climate. The Americans had originally initiated this as a dialogue of the Group of Twenty (G20) countries.¹²⁸ After Singapore gained a reputation for being a useful participant in international negotiations, it too was invited as an observer to Rome in 2010, at the Seventh Meeting of the Leaders' Representatives of the Major Economies Forum on Energy and Climate. Then SM S. Jayakumar headed the Singaporean delegation, initiating Singapore's participation alongside the G20 countries.

At the pre-COP in Mexico City in November 2010, Mexico asked SM Jayakumar to chair one of the three working groups, on finance, technology and capacity-building.¹²⁹ In the eyes of the international community, Singapore was now coming across as a country that had ambitious targets, acted constructively, and could speak to many countries.

One of the key ideas developed in this rebuilding period was that of "Nationally Determined Contributions" (NDCs)—statements of climate action that each country committed to and could be made legally binding. These are independently set by each country instead of mandated by the international community.

AN IMPORTANT INNOVATION: NATIONALLY DETERMINED CONTRIBUTIONS

The top-down Kyoto approach of assigning targets to countries had failed. Nations were against restrictive emissions targets. The Singapore delegation thus floated an alternative option, as Ambassador Gafoor recounted:

We floated the idea that targets must be nationally determined. We can take some pride in inspiring that phrase; I recalled I made an intervention emphasising that all actions and targets must be nationally determined. One of our key goals was to get an agreement with universal participation and we knew that we can only get everyone onboard if they could each determine their own contribution.¹³⁰

Ambassador Kwok added:

The concept recognised that the mitigation effort that every country would pledge as part of an agreement was a sovereign decision they would make for themselves. It was not something that a select group of major economies could divide up and decide which countries would take on what obligations. The idea of the NDC was qualitatively different from what had come before.¹³¹

The concept gained traction and Singapore continued to advocate the need for NDCs. Major players, such as the United States, thought in the same vein and began to put their considerable weight behind the concept, as did many developing countries. This was eventually formalised in Warsaw in 2013, when all countries were asked to declare their *intended* NDCs, paving the way for the same approach in the 2015 Paris Agreement. This way, all countries could participate in the global agreement and legally commit to limit their emissions, leading to a truly universal treaty.

While the Paris Agreement is only the beginning of the road, not the end of it, most agree it is a step in the right direction:

A lot of us scientists were saying that what was promised in Paris isn't sufficient. But putting on my policy hat, getting 195 nations to agree on 31 pages of documentation is a massive achievement. Do not underestimate or downplay the magnitude of getting that agreement done.¹³²

—Associate Prof Winston Chow,
Singapore Management University (2019–Present)

Ambassador Gafoor reflected on the evolution of Singapore's stance over time:

Before Copenhagen, we were locked in a defensive posture—constantly talking about Singapore being “alternative energy disadvantaged”. That phrase had been a mantra. It had become a security blanket for us, because saying this reassured us internally—but it did not help us communicate with others. People inside the Singaporean government understood what we meant, but no one outside understood our position.

[Yet] there was no reason for Singapore to be defensive. We had a good record of building a nation that was clean, green and sustainable, though we had some specific concerns and the best way to defend our position was by being proactive and constructive. If you build bridges, you can gain friends. That helps us better guard our interests. By going on the offensive and adopting a progressive approach—by constructively engaging in the multilateral process—we could serve the nation far more effectively than being on the defensive. Singapore can be an advocate for ambition, an advocate for transparency. People saw us as constructive and they also saw us as credible.

Once the idea of [the] NDCs began to gain traction, we also began to push for universal participation and greater transparency. We realised that an agreement with ambition and transparency was aligned with Singapore's interest of securing universal participation.¹³³

The road from Warsaw to Paris was not easy, but Singapore was gaining ground as an “honest broker”.

A lot of negotiations were bifurcated between developed and developing nations. We were a bridge between them—Singapore is a developing country, but we also understand the position of the developed countries well. That allowed us to engage all different parties.¹³⁴

—Dr Vivian Balakrishnan, Minister for Foreign Affairs (2015–Present)
and Minister for the Environment and Water Resources (2011–15)

Singapore's approach is to engage, to speak to every single stakeholder. It is very resource intensive. But especially for those delegations you do not agree with, if you don't meet with them, you will never find a space to agree.¹³⁵

—Ambassador Kwok Fook Seng,
Chief Negotiator for Climate Change (2014-16)

While countries agreed in principle to the idea of the NDCs, not all understood what this meant. Much of the work during the Peruvian COP presidency in 2014 was to clarify the concept, and to protect it from backsliding and “buyer’s remorse”. Singapore was requested to serve as one of the “Friends of the Chair” who would reach out to countries. Its first task was to bring all parties to the table and listen to their concerns, either in small groups or on one-on-one basis. As Dr Balakrishnan shared:

That gave us a chance to find out where the red lines are, and where there are grey zones—where things are possible. It lets you exercise imagination to find a formulation that works. One thing most countries hate is to feel that everything has been decided by a small clique of countries—that feeling when you know there are decisions being made in a small group, but because you’re not there, you don’t know what is happening.

For Singapore, what this means is that I meet with everybody, every small group. Sometimes at the COP, there will be people banging at the door because not everyone can get into the room. I would promise them, “If I can get a bigger room, I will do so. If I can’t, I promise I will meet you after this.” And we always did. That gave us credibility and trust. We are not a superpower, but we can be honest brokers.¹³⁶

To prevent others from questioning if Singapore was only acting in its own interest, the negotiating team, which Ambassador Kwok had led, took care that their actions were above-board and in good faith:

How you conduct yourself matters—we never took advantage of our role as facilitators to put in something Singapore wanted. Our Chief Negotiators and Ministers were invited to facilitate sessions because Singapore was seen as acceptable, not viewed as a threat to other parties.¹³⁷

When the Paris Agreement was finalised in 2015, Singapore had played a significant role in rebuilding the comity and consensus of international negotiations. Singapore’s capacity to be ambidextrous and speak to both developed and developing countries, had helped bring countries to the table, to agree on action by all.

It helped that Singapore had credibility: it could back up its words in negotiations with concrete actions. Because agencies could coordinate through the IMCCC, Singapore could be sure-footed in international negotiations, knowing that what its representatives promised on the global stage had the backing of other ministries at home.

Conversely, the IMCCC process was strengthened by the COP delegations that include officers from all major ministries, who brought back new ideas that contribute to a robust discussion of options in the IMCCC, and share global trends in climate mitigation and adaptation.

Understanding Climate Change Impact: From Macro to Micro

Among the IMCCC’s first tasks was to commission reports to understand exactly how Singapore was likely to be impacted by climate change. However, in 2007, climate models were at a global level at a 200 km by 200 km resolution and thus of insufficient resolution to project the impact crucial for sound decision-making to safeguard the population, environment and infrastructure; Singapore is only approximately 50 km by 27 km.¹³⁸

The first study on climate change was commissioned by the NEA in 2007 and completed in 2009. It was the first nationwide study looking into the long-term effects of the impact of climate change on Singapore. Singapore scientists worked with a team of international climate experts to understand the impact, relying on data from the IPCC’s Fourth Assessment Report. The study managed to bring down the modelling resolution to 45 km by 45 km.¹³⁹

The first study, which had improved local capabilities, formed the basis for the Second National Climate Change Study. Commissioned by the NEA, and completed in 2014, this second study team comprised mainly local scientists, coordinated by the Meteorological Service Singapore (MSS), partnering the Met Office Hadley Centre in the United Kingdom. The study further downscaled the global model for climate and sea level change to a higher resolution of 20 km by 20 km and made projections up to 2100.¹⁴⁰ This provided further confidence in findings on rainfall extremes and temperature variability. The results formed the basis of several vulnerability

studies that produced climate risk maps looking at coastal protection, water resources and drainage, biodiversity and greenery, public health and infrastructure.

In 2013, the MSS set up the Centre for Climate Research Singapore (CCRS) which specialises in climate science and climate modelling. The CCRS is guided by the International Scientific Advisory Panel on Climate Science and taps on relevant experts and institutions through the Climate Science Experts Network to steer climate-related research in Singapore. The CCRS is one of the most advanced climate research centres in Southeast Asia, and focuses particularly in tropical climate science.¹⁴¹ In 2020, it was announced that a new Climate Science Research Programme Office will be set up to drive and lead efforts to develop and implement the National Climate Science Research Masterplan.¹⁴²

Singapore concurrently improved its computing capabilities. Whereas the first two downscaled climate models used supercomputers located in China's Tianjin University (Tianhe-1 and 2), the CCRS now works with the National Supercomputing Centre on more accurate climate modelling, and has created its own climate model, SINGV.



22. The CCRS conducts climatic studies that impact Singapore and all of Southeast Asia.

In 2014, the Building and Construction Authority (BCA) commissioned another study, using the global climate model of the IPCC's Fifth Assessment Report as well as the Regional Climate Projection models. The study was undertaken by the CCRS, Tropical Marine Science Institute (TMSI) under the National University of Singapore, and Monash University's Cooperative Research Centres.

Besides climate modelling, Singapore has a growing range of institutions that have joined in climate-related research efforts. A partial list includes:

1. Earth Observatory of Singapore
2. Institute of Catastrophe Risk Management
3. Maritime Research Centre
4. NTU-JTC Industrial Infrastructure Innovation Centre
5. Singapore-Berkeley Building Energy Efficiency and Sustainability in the Tropics Programme
6. Solar Energy Research Institute Singapore (SERIS)
7. EcoLabs Centre of Innovation for Energy
8. Singapore Energy Centre
9. NUS-Deltares Alliance

Singapore also hosts the World Meteorological Organization's Regional Office for Asia and the South-West Pacific, which has made climate change a priority.

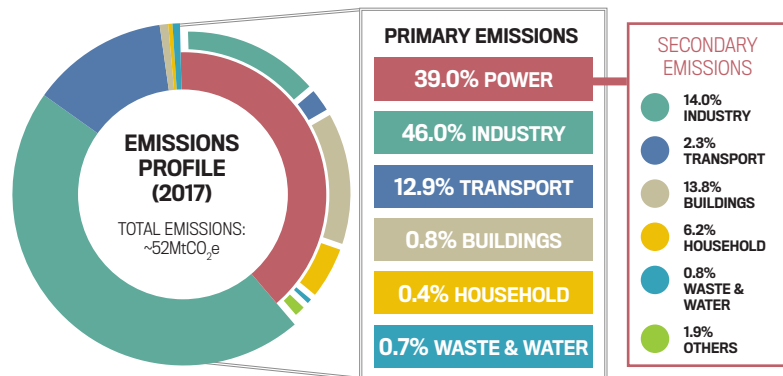
What is Singapore's Emissions Contribution to Climate Change?

Currently, Singapore contributes around 0.11% of global emissions, equating to approximately 52 million tonnes of carbon dioxide-equivalent (MtCO₂e) (2017 data)¹⁴³ In terms of emissions intensity, i.e. emissions per dollar of gross domestic product (GDP)—Singapore compares favourably and remains among the 20 best-performing countries.¹⁴⁴ This reflects Singapore's efforts to mitigate greenhouse gas (GHG) emissions by improving the energy efficiency of its economic activities.

Emissions from Singapore's industry sector accounted for about 60% of its total emissions in 2017. The industry sector is a key engine of Singapore's economic growth, producing not only for Singapore but also to meet the needs of the global market. Energy efficiency improvements remain a key strategy to reduce the industry sector's emissions. Over the years, Singapore has implemented regulations, incentives and capability-building programmes to encourage industries to implement energy efficiency

projects and improve their energy management practices. Singapore will also continue to study how advances in technology can help drive decarbonisation in industrial processes in the longer term.

EXHIBIT 9 SINGAPORE GREENHOUSE GAS EMISSIONS PROFILE 2017.



Source: National Climate Change Secretariat.¹⁴⁵

Singapore's first National Climate Change Strategy of 2008 "identified improving energy efficiency as Singapore's key strategy for mitigating greenhouse gas emissions".¹⁴⁶ It highlighted several types of "low-hanging fruit"—easily implementable actions that would reduce emissions and save costs.

Over time, addressing energy efficiency has grown into a more comprehensive effort. As Tan Yong Soon, former PS of the NCCS and MEWR shared, "Start with the little things, celebrate the little successes, then move on to bigger things."¹⁴⁷ Areas of activity include improving energy efficiency in industry, promoting better building designs, reducing emissions in transport, and addressing household consumption.

Improving the Industrial Sector's Energy Efficiency

As industry is the largest energy-consuming sector in Singapore, improving industrial energy efficiency is a key strategy to reducing business cost and GHG emissions. The year 2007 saw the creation of a multi-agency Energy Efficiency Programme Office (E²PO), spearheaded by the NEA and Energy

Market Authority (EMA); and the Energy Innovation Programme Office (EIPO) led by the EDB, EMA and the National Research Foundation (NRF). E²PO aims to promote and facilitate the adoption of energy efficiency and conservation in Singapore and has a one-stop portal for information on energy efficiency and conservation in Singapore.¹⁴⁸ The EIPO addresses growing a cleaner energy sector in Singapore, for example awarding grants related to materials and the manufacture of solar energy and to improve the operations of conventional power plants and gas supply.¹⁴⁹

The same year, the NRF set aside S\$170 million for research into clean energy and to "encourage more firms and organisations to use renewable energies and environmentally friendly technologies" with the ultimate aim of "offer[ing] Singapore as a global testbed and site for early adoption", as described by former Minister for the Environment and Water Resources (2004-11), Yaacob Ibrahim.¹⁵⁰ This would eventually be expanded to S\$300 million from 2011 to 2015 to "harness Singapore's R&D base to increase energy efficiency, reduce carbon emissions and increase energy options".¹⁵¹ In addition, to support energy efficiency efforts of industrial facility owners, a suite of incentive schemes is available throughout the lifecycle of their facilities, from the efficient design of new facilities, to the identification of energy efficiency gaps and implementation of energy-efficient technologies in existing facilities.

In 2010, the NEA launched an industry-focused Energy Efficiency National Partnership, a voluntary partnership for companies aiming to improve their energy efficiency and reduce their carbon footprint through networking activities, energy efficiency related resources and recognition. As energy efficiency measures started to take root, the Energy Conservation Act was introduced in 2012. Its purpose was to mandate energy efficiency requirements and energy management practices that would promote energy conservation, improve energy efficiency and reduce environmental impact. The Act provided regulators the ability to enforce energy conservation in transport, by households, and by industry. As Dr Balakrishnan, who was then leading the MEWR (2011-15) shared:

Given that we import all our energy, and that energy has an environmental impact, it makes sense to [save energy]. Yet why wasn't it happening quickly? Unlike in many countries, we do not subsidise energy; but even so, things were progressing slowly. The Energy Conservation Act, by providing transparency, monitoring and incentives, [was able to] speed up what was sensible anyway. The lesson is that even things that make sense do not necessarily get done. Sometimes, you still need to push. The Energy Conservation Act was a push.¹⁵²

Improving the Building Sector's Energy Efficiency

Another major category of “low-hanging fruit” is the building sector.

There are three types of government intervention, in order of how forceful they are—information/education, incentives/dis-incentives and regulation/legislation. Many of our early moves focused on the “softer” end of the spectrum, such as education and energy efficiency labelling, before moving on to more muscular approaches like the Energy Conservation Act. Policy change often happens over time, and in “salami slices”. Efforts must be sustained. You must play the long game. You need different agencies and ministries to take ownership. Build a coalition: those moving faster can lead the way.¹⁵³

—Tan Yong Soon, PS, NCCS (2010–12) and MEWR (2004–10)

The BCA was one of the agencies that led the way. Buildings account for more than 20% of Singapore’s emissions. Adopting green building standards was a key mitigation strategy to significantly reduce the sector’s impact.

There was LEED [Leadership in Energy and Environmental Design] in United States, BREEAM [Building Research Establishment Environmental Assessment Method] in the United Kingdom. Green Star is in Australia and other similar standards in New Zealand and South Africa, Korea, Japan and so on. All these standards are however meant for temperate countries with, for example, design for insulation to keep the heat in; but in tropical climates, like ours, we want to keep the heat out. Our design philosophy is different.¹⁵⁴

—Dr John Keung, CEO, BCA (2006–17)

The BCA thus pulled together its own Green Mark Scheme, a green building rating tool for the tropics with a focus on energy efficiency, in 2005 under the first Green Building Masterplan. There were five key criteria for green buildings at that time: energy efficiency, water efficiency, environmental protection, indoor environmental quality, and other green and innovative features that improve building performance. Over the years, the BCA Green Mark Scheme has undergone rounds of review to update the criteria and standards to be more relevant with technological advancements and green building capability in Singapore. In the latest

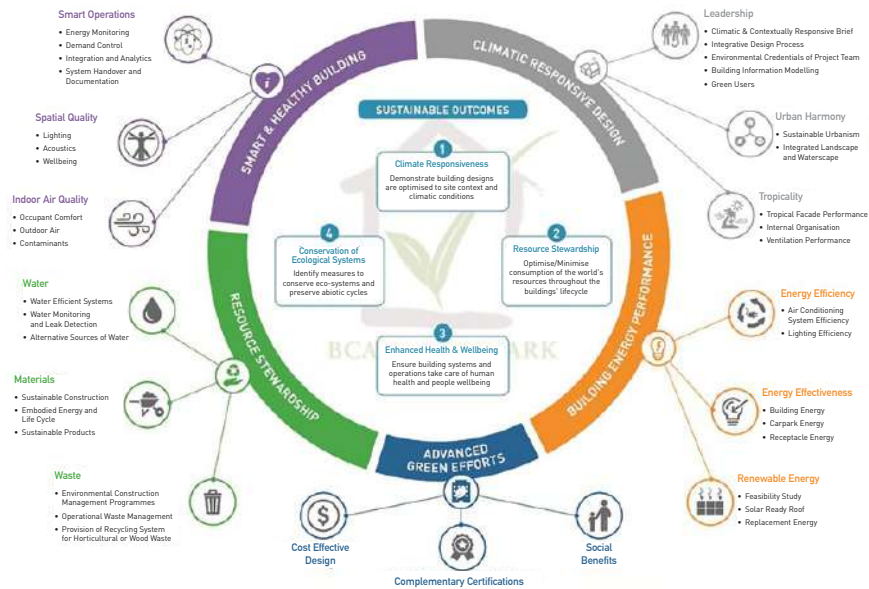
version of the Green Mark Scheme, buildings are assessed based on climatic responsive design, building energy performance, resource stewardship, features for a smart and healthy building, and other advanced green efforts. Depending on a building’s performance in these areas, the green building can achieve any of the four levels: the basic minimum certified level, Gold, Gold Plus or Platinum. For example, a Green Mark Platinum building would have performed well in all the areas and would be at least 30% more energy efficient than a standard building.

However, few private developers or government agencies felt incentivised to “go green” under this scheme. Dr Keung recounted:

Before 2005, support was lukewarm. People acknowledged it was a good thing, but there was no urgency nor incentive funding to kick-start green building development. “If [the] BCA wants to do it, you go do yourself”. In the early days, [the] BCA tried very hard to convince other agencies to allow bonus plot ratio to encourage private developers to go green, as there is a cost premium, which could be 5 or 10% over the construction costs. When you start from the beginning, few architects and engineers were experienced in designing and building a green building, so of course the cost premium was higher than today. It took us at least two or three years to persuade and secure support for incentive funding and other measures such as bonus plot ratio to get the green building movement going.¹⁵⁵

By 2007–08, the idea had gained traction, as Dr Keung expressed:

I recalled a discussion then with Minister Mah Bow Tan who was very concerned about air pollution in cities if development were left unchecked. “Can we make sure that we continue to see blue sky in Singapore?” he asked when we were discussing the need to push ahead with green building development under [the] BCA’s Green Mark programme. With his support, we managed to secure significant funding for the various stakeholders in the built environment sector from developers to consultants and contractors to kick-start the movement. But the big break came when [the] BCA’s proposal of giving bonus plot ratio to green building projects was given the green light to proceed. Other than the public sector taking the lead to go green, the bonus plot ratio scheme was probably the single most important incentive to energise the entire built environment sector to embark on the green building journey in a big way.¹⁵⁶



23. The BCA Green Mark Scheme covers energy and resource efficiency, smart and healthy buildings, climatic responsive design and other green efforts. The illustration shows the overview of the latest Green Mark Non-Residential Building criteria (GM NRB: 2015).

In 2009, the BCA launched the second Green Building Masterplan and set an ambitious target to green at least 80% of Singapore's buildings by 2030.¹⁵⁷ In the same year, the Green Mark Gross Floor Area (GM GFA) Incentive Scheme was launched to motivate the private sector developers. While all new buildings were required by legislation to meet minimum environmental sustainability legislative standards, bonus GFA was awarded to those who achieved the higher Gold Plus or Platinum tiers—1% and 2% additional GFA respectively. The second Green Building Masterplan also looked into bringing existing buildings on board the greening journey. The Green Mark Incentive Scheme for Existing Buildings, launched in 2009, supports the greening of existing buildings by co-funding the retrofit costs for energy-efficient equipment and legislation for existing buildings was subsequently launched in 2014 for buildings to meet the minimum legislative requirements upon retrofit.¹⁵⁸ The existing buildings that have undergone retrofits after 2014 will also be required to undergo energy audits every three years.¹⁵⁹

The BCA further expanded its scope in greening buildings in the third Green Building Masterplan, released in 2014. This master plan looked deeper into engaging the end-user of green buildings with a focus on

healthier indoor environments. The same year, the BCA also constructed its first zero energy, retrofitted low-rise (up to five storeys) building—the first in Southeast Asia—proving that it was possible to build a net-zero energy building in the tropics. The 4,500 m² building serves as a testbed and hub for practitioners. It is estimated to save S\$84,000 a year in energy costs, compared to typical offices, based on an electricity tariff of S\$0.22 cents/kWh.¹⁶⁰

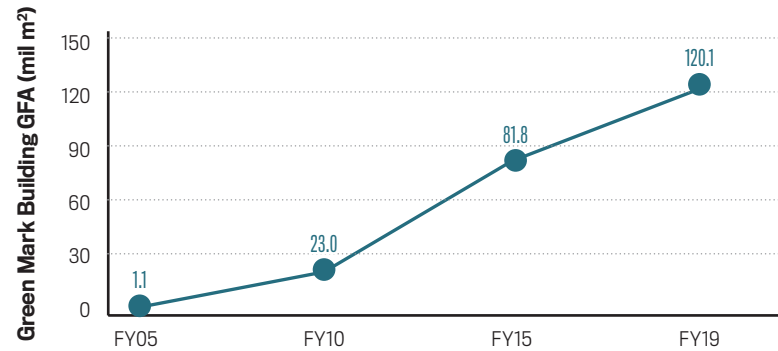


24. The BCA's Zero Energy building is a prototype that is a model for developers and builders to learn from.

The BCA continues to strive for greater environmental sustainability across buildings in Singapore. Beyond the existing requirements for building owners to submit their energy consumption yearly, the BCA plans to publish energy performance data in the coming years to facilitate benchmarking and increase the transparency of building performance data. In 2020, the BCA is co-creating the next Singapore Green Building Masterplan with the Singapore Green Building Council, industry stakeholders and the wider community. One of the key initiatives is to support the push towards more energy-efficient buildings by raising the minimum energy performance standards for both new and existing buildings.

District cooling, first introduced in 2006, has contributed to reducing the use of energy consumed through air-conditioning in office buildings by lowering aggregate installed plant capacities due to economies of scale, greater energy efficiencies, and better guaranteeing supply quality and reliability.¹⁶¹ District cooling has been implemented in Marina Bay, one-north and Changi Business Park, and soon in Housing and Development Board (HDB) residences in Tengah.

**EXHIBIT 10
GREEN MARK BUILDING PROJECTS IN SINGAPORE.**



Spurred by the Green Mark Certification programme, the GFA currently under Green Mark certification has risen significantly over time.
Source: Building and Construction Authority.

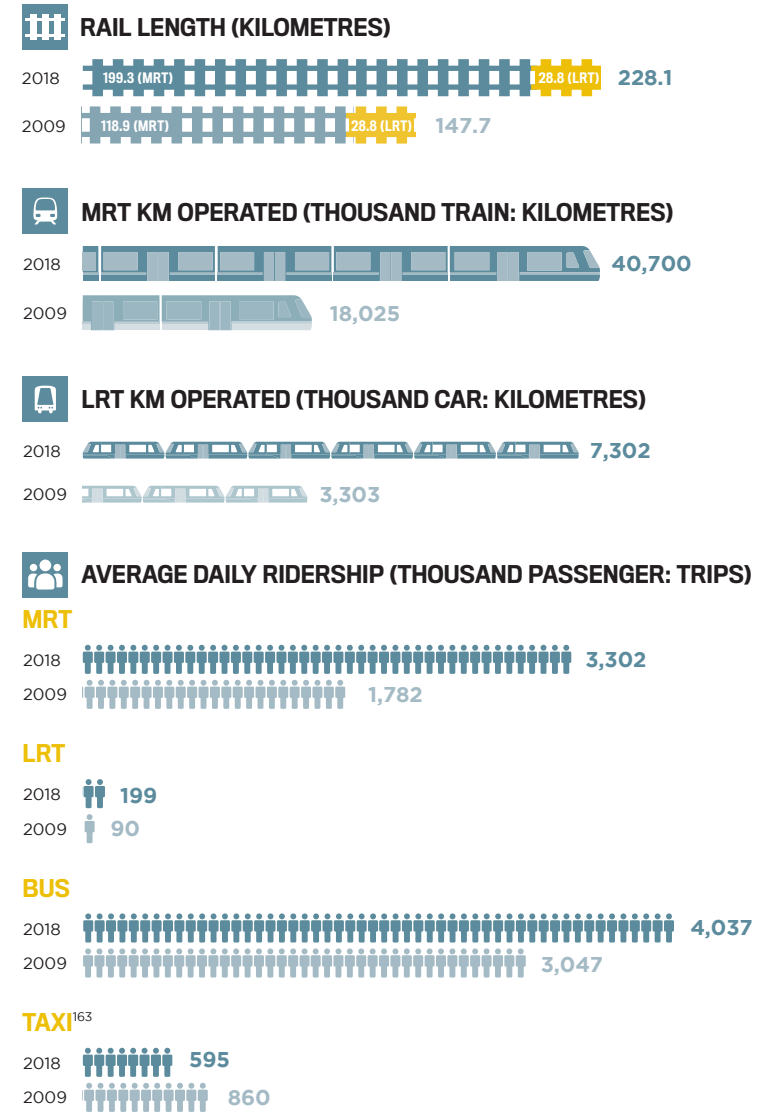
Transport Sector: Low-Carbon Mode Choice and Improving Efficiency

A holistic approach has been taken to reduce carbon emissions associated with transportation—around 12.9% of total emissions in 2017.¹⁶² In addition to improving the efficiency of the vehicle fleet and moving toward electrification, Singapore has prioritised mass transit, while committing to a zero-growth vehicle policy. These came together in the Land Transport Master Plan 2040 which promises that towns can be traversed in 20 minutes, and an island connected by trips no longer than 45 minutes.

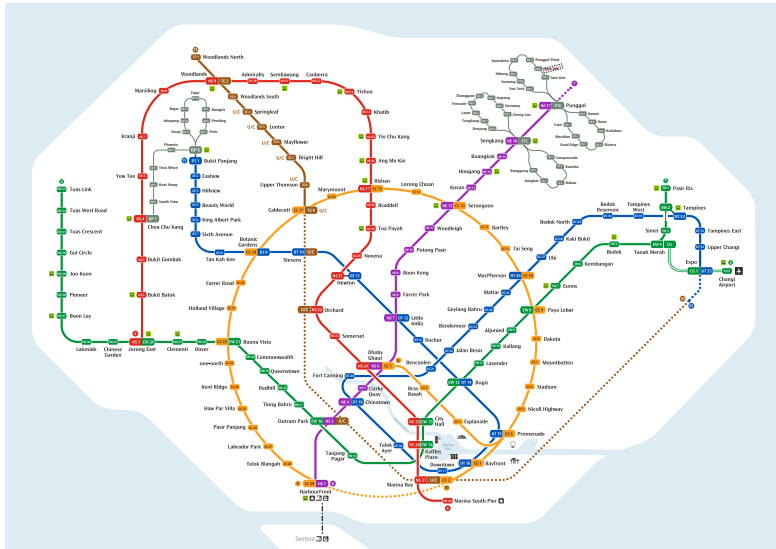
Overall, reducing carbon emissions aligns with the Land Transport Authority’s (LTA) goals of prioritising public transport. In recent years, the LTA has set strong targets for public transport modal share improvement, by improving bus and Mass Rapid Transit (MRT) service. Two new MRT lines (Circle and Downtown) opened with 64 new stations, with the first stage of another line (Thomson-East Coast) opened in January 2020. By 2017, 67% of all peak-period journeys were on public transportation.

In 2015, a Carbon Emission-Based Vehicle Scheme (CEVS) provided rebates and imposed surcharges on all new cars, taxis and imported used cars, to encourage consumers to purchase those with lower CO₂ emissions. In 2018, this was replaced by an enhanced Vehicular Emissions Scheme (VES) that factored in additional emissions of hydrocarbons, carbon monoxide, nitrogen oxides and particulate matter. Under the VES, owners of cleaner car models will be granted Additional Registration Fees (ARF)

**EXHIBIT 11
PUBLIC TRANSPORT OPERATION AND RIDERSHIP.**



Public transport usage has steadily increased as services expanded.
Source: Department of Statistics.¹⁶⁴



25. Over the decades, the number of MRT lines and stations has increased to improve access across Singapore.

rebates of up to S\$20,000 while owners of cars with higher emissions will be imposed surcharges of up to S\$20,000. As of 2018, all new petrol and diesel vehicles must also comply with the Euro VI emission standard to reduce particulate emissions.¹⁶⁵

There has also been a broader push for electrification, with the vision to phase out internal combustion engine (ICE) vehicles and have all vehicles run on cleaner energy by 2040. A new electric vehicle (EV) Early Adoption Incentive will be launched from 1 January 2021 to encourage EV adoption. Owners who register fully electric cars will receive a rebate of 45% off the ARF, capped at S\$20,000. The Government will also expand the EV charging infrastructure significantly from 1,600 points currently to 28,000 by 2030. This will be in conjunction with the BlueSG electric car-sharing programme, supported by the LTA and EDB. By the end of 2019, BlueSG had approximately 500 cars¹⁶⁶ and 300 charging stations¹⁶⁷ islandwide, of which 60 charging stations have been open for public charging.

For commercial vehicles that burn diesel, the Early Turnover Scheme (ETS) was first introduced in 2013 to encourage the removal of older, more polluting models. Beyond the ETS, a Commercial Vehicle Emission Scheme (CVES)¹⁶⁸ will be introduced from 1 April 2021 to 31 March 2023 for all new and used imported light goods vehicles, goods-cum-passenger vehicles and small buses, all with maximum laden weight not exceeding 3,500 kg. The CVES provides rebates for vehicles with low emissions, while imposing a surcharge on high-emission vehicles.

Significantly, in 2018, Singapore became the first country in the world to commit to having zero-vehicle ownership growth for private cars and motorcycles.¹⁶⁹ This goes in hand in hand with improving public transport while greening the private fleet to collectively slow growth in transportation-related emissions.

Improving Households' Conservation and Energy Efficiency

Households account for about one-sixth of the total electricity consumption in Singapore. Households can reduce their electricity consumption by using energy-efficient appliances. The NEA introduced the Mandatory Energy Labelling Scheme (MELS) in 2008 which requires energy-consuming appliances to be affixed with energy labels so that consumers can make informed decisions and choose greener options. To date, the MELS covers air-conditioners, refrigerators, TVs, clothes dryers and lamps. Regulations on Minimum Energy Performance Standards (MEPS) was introduced in 2011 to raise the average energy efficiency of household appliances by removing energy-inefficient models from the market. As only appliances that meet the MEPS are allowed for sale, consumers are protected from being locked into the high energy costs of operating energy-inefficient appliances. Energy efficiency funds, financing and training grants incentivise the industry to increase efficiency and transition to better equipment.



26. The Energy Label Scheme helps consumers make informed choices when purchasing appliances.

The Power Sector and Four Switches

The power generation sector is another significant contributor to Singapore's emissions and we are taking active steps to decarbonise our power grid. In 2019, Minister for Trade and Industry (2018–Present), Chan Chun Sing, spoke on the need to create Singapore's Energy Story together:

Our Singapore Energy Story will depend on four Switches for the next 50 years. So our plan for the next 50 years is that we will develop four Switches, and make sure that we reduce and manage our energy consumption in order to balance our budget constraints in terms of carbon and energy.¹⁷⁰

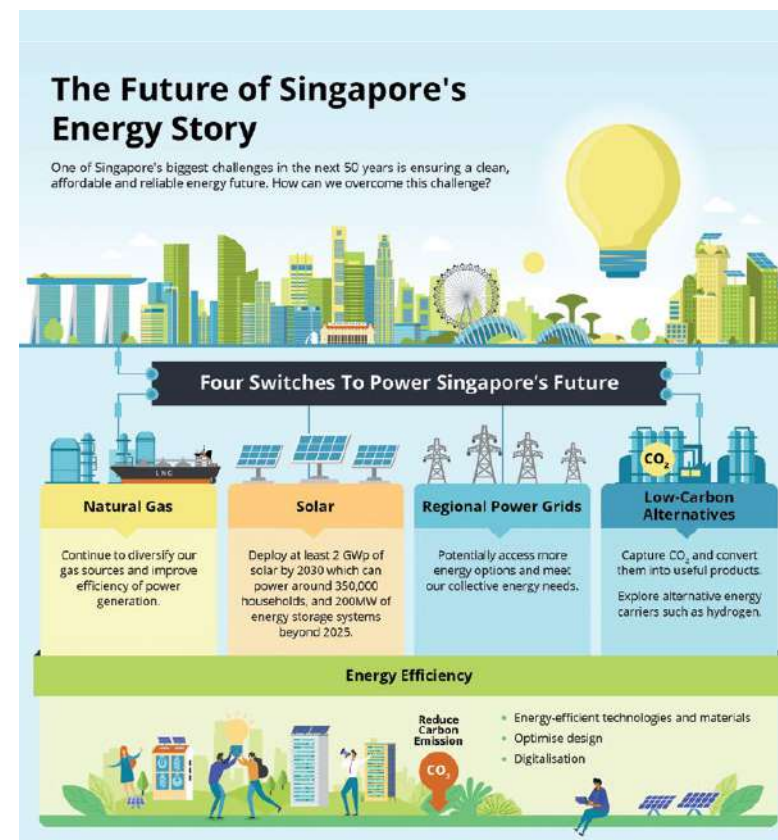
The Energy Story harnesses “Four Switches” to create a more sustainable, affordable and reliable energy future for Singapore. The “Four Switches” comprise natural gas, solar, regional power grids and other emerging low-carbon alternatives (such as carbon capture, utilisation, storage technologies and hydrogen). To make this vision a reality, the Government will work hand-in-hand with all stakeholders, including researchers, industry and individuals.

As a small and highly urbanised city state with low wind speeds, relatively flat land and lack of geothermal resources, there exists limited access to alternative clean energy options, such as geothermal, wind and tidal power. Solar is Singapore's most viable renewable energy source.

To address the intermittency of solar energy output, Singapore is exploring various mitigation measures such as enhancing its solar forecasting system and leveraging technologies such as energy storage systems (ESS) and demand response management systems. The EMA is working with the MSS and SERIS to develop a more accurate multi-timescale solar irradiance forecasting model for Singapore. This will allow the power system operator to better manage the impact of intermittency of solar power. In addition, Singapore has set a target to deploy 200 MW of ESS beyond 2025 to support the increased deployment of solar photovoltaic (PV). To achieve this, Singapore will need close collaboration between the government, industry and academia to develop solutions for the safe deployment of ESS in Singapore.

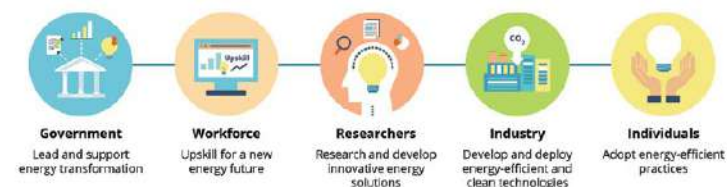
The SERIS also updated its Solar Energy Roadmap for Singapore in 2020.¹⁷¹ It projects that Singapore could potentially achieve 22% midday solar power contribution to electric power demand by 2030 at the very best-case scenario of technological improvements, including imported solar, floating PV, vertical PV and others.

With the increasing electrification of vehicles in Singapore in the longer term, there is potential to introduce vehicles to grid services. This provides greater optionality to tap on ESS resources to further stabilise the power grid and support the nation's longer-term solar ambitions.



Co-creating our Energy Story

The Government will work hand-in-hand with our workforce, researchers, industries and consumers to co-create our Energy Story.



27. Singapore's plans to develop its “Four Switches” to create a sustainable energy future for the country.

CAPTURING THE SUN: ADOPTING SOLAR POWER IN SINGAPORE

To overcome land constraints, Singapore is investing in innovative solar technologies, such as floating solar PV systems on its reservoirs and offshore spaces and integrating solar PV across the urban landscape. In 2014, a whole-of-government programme, led by the EDB and HDB, called SolarNova was launched. Its purpose was to accelerate the deployment of PV systems by promoting aggregate demand for PV across government facilities, achieve economies of scale and drive growth of the industry.

The programme has increased the adoption of solar energy by enabling those with smaller solar energy demand to enjoy it at a lower cost due to economies of scale:

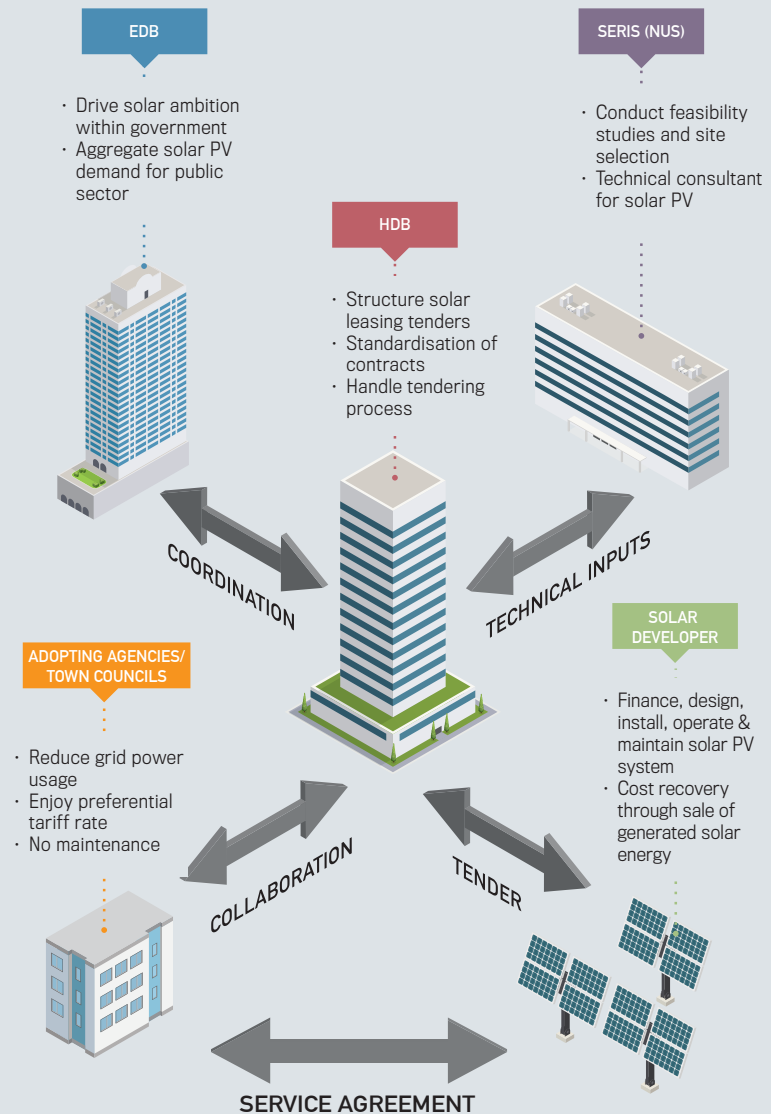
We found that [the] HDB was a real market mover. When [the] HDB went in [for solar panels], the price dropped 45% in a few years.¹⁷²

—Dr John Keung, CEO, BCA (2006–17)

In the first quarter of 2020, the SolarNova programme achieved its 2020 target of 350 megawatt-peak (MWp). With the success of SolarNova, the next national solar PV target would be to achieve at least 2 gigawatt-peak (GWp) by 2030, which is about six times more than today's installed capacity, and will power about 350,000 households per year. This will be achieved through deploying solar panels for approximately 70% of HDB blocks' rooftops. The HDB will continue to aggregate whole-of-government demand and implement solar PV installations on the rooftops of public buildings including schools and government offices under the SolarNova programme.

The PUB is also deploying floating PV systems in several reservoirs. A large-scale 60 MWp floating PV system will be operational at Tengeh Reservoir by 2021. When completed, it will be one of the largest single floating PV systems in the world. The PUB has awarded the contract for two other floating solar PV systems to be installed at Bedok and Lower Seletar Reservoirs to contribute to the national target.

EXHIBIT 12 ENTITIES AND THEIR RELATIONSHIP UNDER THE SOLARNOVA PROGRAMME.



Source: Housing and Development Board.

Even then, 2 GWp will only meet 4% of current annual electricity needs and approximately 10% of peak daily electricity demand. To surpass this, the government is exploring innovative deployment technologies on vertical and horizontal surfaces. The HDB is studying the use of its floating modular system to hold solar panels in coastal marine conditions to further harvest Singapore's solar energy under a Research Collaboration Agreement with ISO Landscape Pte Ltd. It aims to study the viability under harsh coastal marine conditions.

With these measures, Singapore will have one of the highest solar deployments per square kilometre in the world.



28. In 2016, the PUB and EDB launched a 1 MWp testbed at Tengeh Reservoir to study the feasibility of floating solar PV deployment on reservoirs.

Prudent Adoption of Clean Technologies

Technology and innovation are often suggested as the solution to climate change. However, choosing among options can be fraught with challenges. Investing in infrastructure is costly, and technology could become obsolete or a vendor might fail before the desired outcome is achieved. On the other hand, too many options may lead to over-analysis and inaction. The key is to rely on sound principles in encouraging appropriate technologies while keeping an eye on long-term outcomes, and continually evaluating progress.

The LTA experienced this challenge when it first offered incentives for low-carbon vehicles. The initial Green Vehicle Rebate scheme focused on incentives for vehicles with hybrid engines, which are generally more efficient than regular ICEs. However, the scheme did not work out as anticipated as some Singaporeans purchased high-end hybrid vehicles with larger engines, even though these were not necessarily as efficient as smaller engine vehicles. This was later replaced with the CEVS, where performance-based outcomes were favoured.¹⁷³

A prudent policymaker should not insist on being technology agnostic, as technologies can be more harmful or beneficial. A “hands-off” approach to new technology can lock in the status quo to the detriment of new innovations. At times, it can be in the nation's interest to promote environmentally-benign technologies in order to level the playing field for industry newcomers against polluting incumbents. One example is renewable energy, where cleaner technologies have both environmental and health benefits, compared to fossil fuels. Another is in the construction industry (see Box Story).

FALLING FOR TIMBER: INNOVATING FOR CARBON POSITIVE BUILDING MATERIAL

Cement and steel are widely used as construction materials in Singapore but they are responsible for 8% and 5% of global GHG emissions respectively; half a tonne of CO₂ is emitted to manufacture one tonne of concrete.¹⁷⁴

To reduce these emissions, Singapore has facilitated the adoption of Prefabricated Prefinished Volumetric Construction (PPVC) methods—reducing wastage, time on site, and allowing for greater automation. Another innovation is Mass Engineered Timber (MET), which is counter-intuitive for Singapore due to historical fires, high humidity and presence of termites. MET is treated wood. It is lighter, durable and weight bearing. It only burns a fractional surface level in a fire and can be treated for humidity warping and termites. Aesthetically, it is also pleasing. Allowing it as a construction material in Singapore, however, took some convincing:

Way back in 2007/08 when Minister Mah Bow Tan came back from Europe, telling me that he had seen 4-, 5-storey buildings made entirely in timber. He asked why we couldn't do the same in Singapore. I did not have the full answer offhand but thought it had to be due to fire safety concerns.

So, I asked the Singapore Civil Defence Force (SCDF). The answer was short, one word to the effect: No. But I couldn't give up! I asked, if we wanted timber building, what the fire safety conditions would be. The full reply came back quite a while later but the conditions to be met would make it very expensive to build such a timber building!

We didn't give up and by chance we learned about Cross Laminated Timber (CLT) buildings in Australia and Europe through an international development. Coincidentally, [then] CEO of the Urban Redevelopment Authority (URA) Ng Lang was also interested in such buildings which is lighter compared to concrete structures. We did more investigative work together with [the] SCDF and other private sector professionals who were more familiar with timber engineering and practices in Europe and Australia and developed a better understanding of CLT, which like other building materials, can be treated to meet the various fire ratings in these advanced countries. Indeed, we found out that CLT does not burn like wood. It burns to a maximum of 7 or 8 cm—a sacrificial layer—and it will stop burning. Of course, we were sceptical initially and needed to see for ourselves with engineers from both the public and private sector in the overseas test labs and true enough, it stopped burning.

Towards the end of our review, we invited the commissioner of the SCDF to join us in a fact-finding learning journey and arranged for him to talk to the Austrian and London Fire Chiefs, to have in-depth discussions on likely issues and concerns. To top it all, we even stayed in a modular (in our parlance PPVC) CLT hotel for a night in Austria—5 storeys, the bottom 2 were normal concrete, the top 3 storeys—120 hotel rooms—all in CLT, even the bathrooms. And it took the builders 20 days to stack up and build the top 3 storeys! Besides CLT to use as slab and wall, we also explored Glued Laminated Wood (glulam) to use as beam and column, which collectively called them MET.

As the saying goes, the rest is history. The SCDF decided to allow the use of MET up to 24 m—that's around 6 or 7 storeys—for non-healthcare buildings. So that's how the Nanyang Technological University (NTU) Wave was built. Of course, they had to provide sprinklers in critical locations. Subsequently for non-healthcare projects, the SCDF further allowed building of any height, except that performance-based approach is required if [the] height is more than 12 m. [The] BCA too, to walk our talk, we are building a 7-storey MET building with a multipurpose hall, classrooms, office, library, food centre and so on, right in the BCA Academy at Braddell road. Indeed, the requirement on height has been further relaxed, as long as the performance criteria are met. So, this to me a good outcome for the use of a sustainable material like timber. It will probably not replace concrete, but at least it's another option we have. And architects love the choice of timber.¹⁷⁵

—Dr John Keung, CEO, BCA (2006–17)



29. The Wave at NTU is one of the first large-scale buildings in Southeast Asia built using MET; the large roof did not require any internal columns, leaving a cavernous 3-storey space.

Implementing a Carbon Tax

Prime Minister Lee Hsien Loong highlighted that carbon pricing was a key approach to reduce emissions in 2010. The pricing of carbon, through either a tax or cap-and-trade system, was debated. Singapore ultimately adopted the principle that all polluters must pay, and it should be called a tax to clarify its intent—as a measure against pollution.

By 2012, the initial thinking on a carbon tax started to take form. Australia was quite advanced in carbon tax thinking, so they did quite a few workshops and our officers went there to learn and start building up our own tax model. We wanted to be in time for the future, should we decide to go ahead with the tax.¹⁷⁶

—Tan Yong Soon, PS, NCCS (2010–12) and MEWR (2004–10)

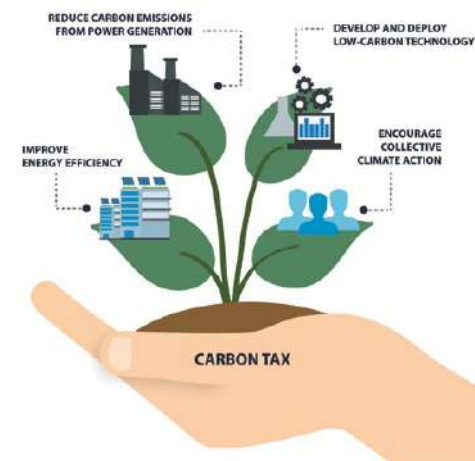
A key principle was that the tax had to be applied transparently and uniformly, without exemptions for any industry. The strategy could then accelerate the transition towards a low-carbon economy and the adoption of low-carbon technologies. Pushing through the carbon tax was not easy, as shared by former DCEO of the NEA, Joseph Hui:

It took a long time to come. We could not get it through all agencies. However, it is a good market-based system to encourage industries to adopt policies that will be most suitable for their own makeup. It will catalyse them to think up innovative ways of trying to meet the target.¹⁷⁷

In 2019, Singapore implemented a carbon tax with the Carbon Pricing Act, becoming the first country in Southeast Asia to put a price on carbon, at S\$5 per tonne of carbon dioxide-equivalent (tCO₂e). Singapore will review the carbon tax by 2023, with plans to increase it to between S\$10 and S\$15 per tCO₂e by 2030. In doing so, it will take into account international developments, the progress of its mitigation efforts and economic competitiveness. The tax is applied to all facilities emitting 25,000 tCO₂e or more per annum, without exception.

The carbon tax was set after consulting with industries, including Singapore's energy and chemical companies, a strategically important sector and sizeable contributor to the nation's GDP.

SINGAPORE'S CLIMATE ACTION PLAN



HOW A CARBON TAX WORKS

- 1 INTRODUCE A TAX ON EMISSIONS**
 - Carbon tax will generally be applied upstream, for example, on power stations and other large direct emitters.
 - Businesses can choose to reduce emissions or pay a carbon tax.
- 2 ENCOURAGE ENERGY EFFICIENCY & SUPPORT MORE GREEN ACTIONS**
 - Businesses are motivated to improve their energy efficiency.
 - Consumers are encouraged to use less electricity and save energy.
 - Carbon tax revenue will help to fund measures by industry to reduce emissions and provide appropriate measures to ease the transition.
- 3 LOWER CARBON, GREENER ECONOMY**
 - Lower emissions lead to a greener planet.
 - Businesses become more resource-efficient and sustainable.
 - More opportunities in green growth sectors, such as clean technology.

30. The carbon tax was introduced in 2019 at S\$5 per tCO₂e, with plans to increase it to between S\$10 and S\$15 per tCO₂e by 2030.

For example, the petrochemical industry is a vital sector, not just for Singapore, but for the whole world. Besides fuel, the industry supplies many other products that are needed for our daily lives. The sector also provides high-paying jobs with good career progression for Singaporeans and creates significant spin-offs to the rest of the economy in areas such as logistics and oil trading. The government works closely with our businesses so that our petrochemical plants are among the best-in-class globally in energy and carbon efficiency.¹⁷⁸

—Teo Chee Hean, SM and Chair of the IMCCC (2011–Present)

Stakeholder engagement on the carbon tax thus started in the early 2010s, so that all sectors could prepare. A highly punitive tax might have resulted in companies shifting their operations to other countries with even fewer safeguards, potentially resulting in greater emissions. It is hoped that the carbon tax will spur innovations to reduce GHGs in numerous industrial sectors.

CARBON PRICING

Singapore considered two options to set a price on carbon.¹⁷⁹

Emissions Trading System (ETS), often called “Cap-and-Trade”

The government sets a cap on total allowed GHG emissions each year and issues an equivalent number of permits. Emitters covered under the system must purchase and surrender permits to the government, equivalent to the units of GHGs emitted. The market determines the price for permits. It is similar to Singapore’s Certificate of Entitlement system to regulate vehicle population.

Carbon Tax

The government sets a price that polluters must pay for each unit of GHG they emit. The tax can be levied “upstream” based on the carbon content of fuels, or “downstream” based on direct GHG emissions. Singapore’s tax is levied on “upstream” activities.

As of 2020, the World Bank has documented 61 carbon pricing initiatives, either already operating or scheduled for implementation. There are 31 ETSs and 30 carbon taxes.¹⁸⁰ Some countries mix systems or only apply carbon prices to certain sectors.

A carbon tax is an economically efficient way to achieve GHG emission reduction while sending a transparent, fair and consistent price signal across the economy to incentivise emissions reductions. In a small domestic market like Singapore, implementing a carbon tax was seen as being more practical in the near term. Singapore remains open to linking its carbon tax framework with other carbon pricing jurisdictions with high environmental integrity.

Economy-wide, a carbon tax could:

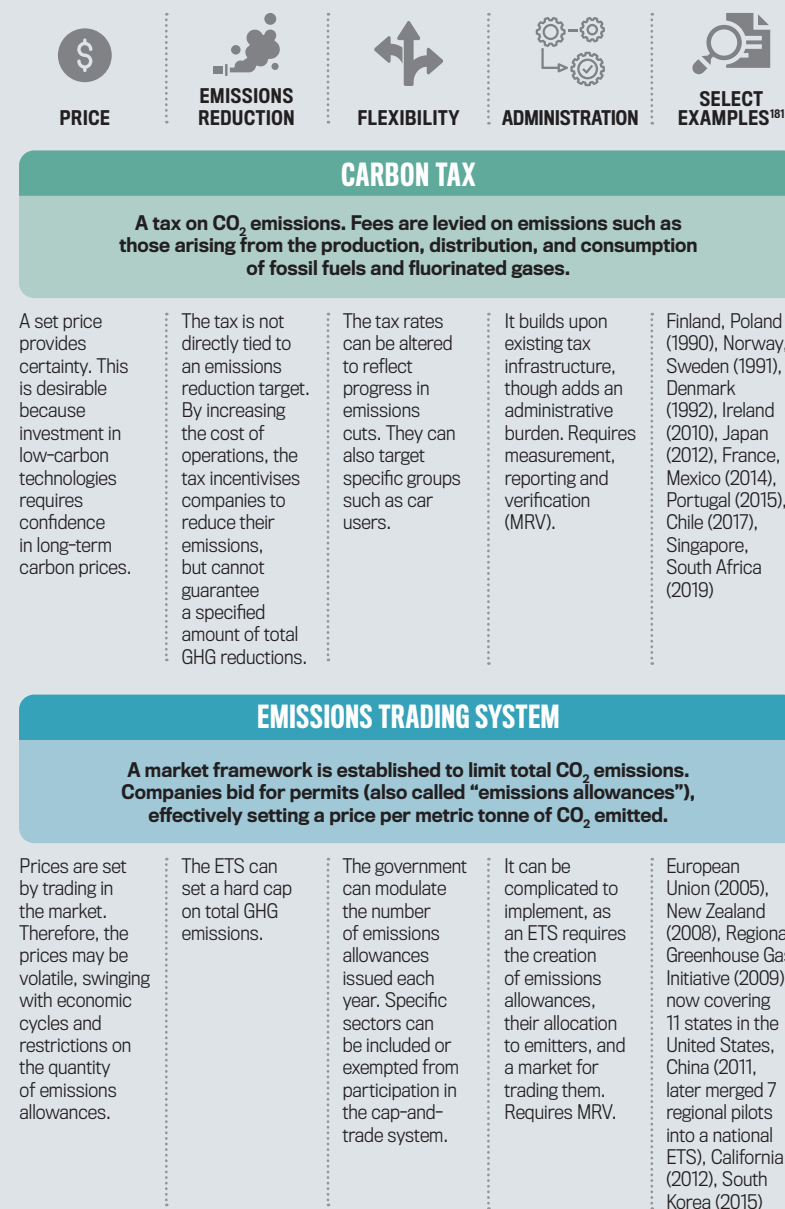
- enhance mitigation efforts under Singapore’s Climate Action Plan;
- stimulate the development of clean technologies and spur market innovation; and/or
- raise revenue, which could potentially be used to fund additional mitigation actions.

For companies, a carbon tax would send a price signal, incentivising emitters to:

- factor the costs of emitting GHG into their business decisions;
- innovate and improve the energy efficiency of their operations; and/or
- invest in low-carbon technologies to avoid paying the carbon tax.

Without a carbon tax, Singapore might need to rely on command-and-control regulations to reduce emissions, which some companies would find costlier and more disruptive.

EXHIBIT 13 CARBON TAX VS. EMISSIONS TRADING.



Widening the Scope of Climate Action: Beyond Emissions Mitigation Strategies

While mitigation efforts were crucial for climate action, the government took an expanded view of climate action—it needed to be part of every ministry and agency.

When [the] NCCS first got going, [climate action] was driven more at the top. But it takes some time for it to become part and parcel of what every ministry is aligned in doing.¹⁸²

—Choi Shing Kwok, PS, MEWR (2012–17)

The NCCS, backed by the IMCCC, led the efforts by publishing its plans in the National Climate Change Strategy 2012, entitled *Climate Change and Singapore: Challenges, Opportunities and Partnerships*. As former PS of the NCCS and MEWR Tan Yong Soon described, “It laid the foundation to everything.”¹⁸³ The strategies widened the scope beyond the first plan from 2008. The second plan sought to enhance research, envisioned whole-of-government mitigation and adaptation measures, and identified opportunities for economic development together with environmental sustainability.

The National Climate Change Strategy 2012 was aligned with the Sustainable Singapore Blueprint (SSB), released in 2009. The strategy’s vision was a “lively and liveable Singapore, one that Singaporeans love and are proud to call home”. It was a continuation of the 10-year plans introduced in the Green Plans of 1992 and 2002. The SSB covered sustainable buildings and towns, sustainable transport, green and blue spaces, public cleanliness, energy use, water use, waste and recycling, and air quality.

Sustainability has always been part of Singapore’s DNA, and integral to our development since our independence. We have always sought to balance our economic development with environmental protection and social inclusion.

With climate change, it is more important than ever that we put sustainability at the centre of everything we do. We must undertake a paradigm shift and build up three types of resilience: climate resilience, resource resilience and economic resilience.¹⁸⁴

—Masagos Zulkifli, Minister for the Environment and Water Resources (2015–20)

Once the baseline was clear, the NCCS also pushed for stretch targets in areas that could have wide mitigation impact.

The important thing is not to be too rigid and limited by existing constraints. You don’t [force] an immediate target that you must meet, but push in that direction, try to create the conditions such that solutions to achieve targets towards that direction can be found, that makes sense. So that it will not meet too much resistance.

And after a while, the agencies will be persuaded to test out what they can do. And sometimes they may come back and say, “Oh, this thing is just impossible.” Or sometimes they may say, “Eh, actually it is quite do-able.” And so that is how we move up. Of course, at least at my time, I did not experience one where we had someone on top to say, “No, no, no, you just achieve that target and that’s it.” But I think we have a good system and people, and people who are sincere in wanting to do their job and see each other’s views and then we just try to get things done.¹⁸⁵

—Tan Yong Soon, PS, NCCS (2010–12) and MEWR (2004–10)

Adaptation: Demystifying the Impact of Sea Level Rise

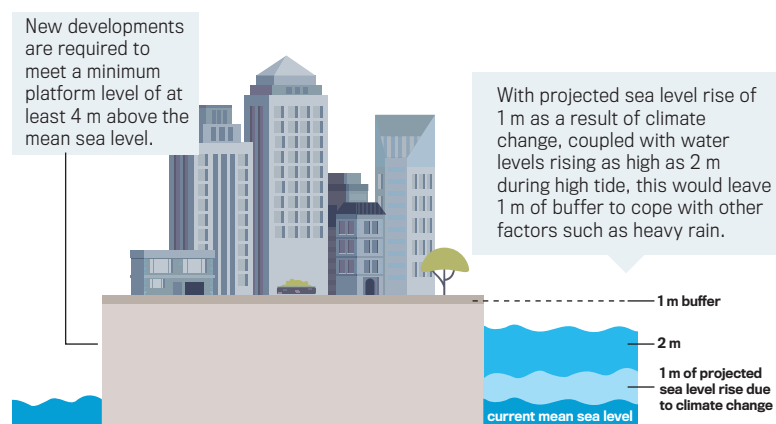


31. An illustration of the areas with higher risk of flooding (indicated in red).

Rising sea levels is a primary concern for low-lying countries like Singapore. Some 30% of the country is less than 5 m above the current mean sea levels. Downscaled climate models projected that sea levels may rise by

approximately 1 m by 2100. To address this, the PUB decided in 2011 to raise the minimum reclamation levels for newly reclaimed land by 1 m.¹⁸⁶ This effectively ensured that all newly reclaimed land was 4 m above the Singapore Height Datum (SHD). The highest high tide ever recorded was approximately 2 m above the SHD. The change provides an additional 1 m of clearance, providing an additional metre buffer in case of sea level rise of 1 m.¹⁸⁷

Sea level rise can affect Singapore's potable water reservoirs, due to possible salination contamination. Aside from the Central Water Catchment, the rest of Singapore's catchments are estuarial catchments—created by damming up rivers at river mouths, which are usually barely above sea level. There are concerns of “overtopping” the dams, which will result in saltwater intruding into reservoirs. As dams are built for a hundred years, the PUB's engineers had to ensure the heights can withstand sea level rise. Sea level rise data is thus a key concern to the PUB's water engineers.¹⁸⁸



32. Since 2011, the PUB has raised minimum platform levels and minimum reclamation levels by 1 m to cater to projected sea level rise.¹⁸⁹

Protecting the Coast and Infrastructure

The BCA was directed to conduct a study on potential impact of coastal inundation under climate change scenarios and identify site specific measures and long-term adaptation strategies. The Coastal Adaptation Study (CAS) was completed in 2019, and provided the BCA with the opportunity to expand its capabilities in this field:

The IMCCC broadened our coverage, beyond just buildings. [The] BCA was additionally tasked to lead a study [on coastal protection]. We worked through an inter-agency workgroup, with [the] HDB, PUB, URA and other agencies. It was extremely useful as it helped us understand the problem beyond building structures, and how to tackle the longer-term problems. Climate change is fast gaining pace and going to intensify in 10, 20, 50, 100 years, so how do we work out a strategy to handle the resulting impact of rising sea level problems as the bulk of our land is low-lying?

Under the severe climatic conditions projected with climate change, we needed to understand if our existing and new buildings could withstand the changes such as heavy rainfalls, strong wind, storm surges and others that may come our way. It was found that the current codes were reasonably resilient.¹⁹⁰

—Dr John Keung, CEO, BCA (2006–17)

The CAS divided Singapore's coast into eight segments to study options for each area. Detailed plans will be developed to phase in coastal protection measures.¹⁹¹ With the Public Utilities Amendment Bill that took effect from April 2020, the PUB has been designated the National Coastal Protection Agency, responsible for coordinating policies on land use, development and safeguarding the coastline from rising sea levels.



33. Beyond localised measures, Singapore's coast has been divided into eight segments to improve coastal defences, with areas like City-East Coast and Jurong Island identified as more vulnerable than others to flooding.

Preparing for Flooding

For inland flooding, the PUB adopts the “source-pathway-receptor” approach to better manage urban runoff. Water is detained at source, directed to drains and canals (pathways) and managed at its reception point. Developers are encouraged to install source solutions (such as detention tanks and ponds, rain gardens, etc.) and receptor solutions so storm water runoff can be better managed and developments are better protected from floods.

To monitor this closely, the PUB operates a network of closed-circuit televisions (CCTVs) and water level sensors. Data from selected CCTVs and water level sensors have been made available to the public in real time, as drain sensors monitor if water levels reach significant points during heavy rain. A free Short Message System alert is available for subscription and provides warnings on rising water levels in drains and canals.

The PUB’s drainage codes have already been set up to address flooding and were upgraded in 2011 with an additional metre of clearance. For example, MRT stations are built with elevated entrances, and passengers must walk up a few steps before descending to the station. Land reclamation



34. Entrances of MRT stations are elevated to reduce flood risk in times of intense rainstorms.

has always been built above sea level, and for critical infrastructures like Changi Airport Terminal 5 and the future Tuas Port, these are at least 5 m above sea level. Buildings with basements are required to have a crest that prevents ingress of water into basements and carparks. Older buildings and low-lying areas are still prone to flooding, but new infrastructure has to be built with flooding in mind.

Keeping Singapore’s Taps Flowing

Singapore has also had to grapple with the other effect of climate change: drought, which was not often talked about. Khoo Teng Chye, CEO, PUB (2003–11) explained:

It’s a two-edged sword. If you keep on telling people “We don’t have enough water”, it becomes a scary thing. Then the population loses confidence and more importantly, the investors lose confidence.¹⁹²

The PUB has since developed comprehensive strategies to manage drought (see Box Story).

To ensure residents use water carefully, demand management strategies are also employed. Water tariffs, used water charges and water conservation taxes continue to reinforce the message that water is a finite resource. For businesses, mandatory Water Efficiency Management Practices (WEMP) was introduced in 2015 for large water users consuming at least 60,000 m³ a year. This ensures that companies are aware of water usage breakdown at their premises, which helps them identify ways to reduce consumption. The PUB studies WEMP by these large water users to develop water efficiency benchmarks and good practice guidelines for different sectors. Companies can also tap on the Water Efficiency Fund for water efficiency studies and projects.

PREPARING FOR DROUGHT

By the early 2010s, it became clear that there is an increasing frequency of prolonged months without rain which can impact Singapore's reservoirs, as well as the Linggiu Reservoir in neighbouring Malaysia that provides water to Singapore.

Tan Gee Paw was paranoid about drought, and we should all feel very lucky that he is. He saw things happening way before all of us. Around 2011, he told us to watch the reservoir levels in Linggiu. He looks at the reservoir level every single day. At first, I was dubious, but now I understand why, because it's our lifeline! Gee Paw saw that the level was coming down quickly. It was the beginning of several occurrences of the kind of drought we've never seen before.¹⁹³

—Khuo Teng Chye, CEO, PUB (2003–11)

Water levels in the Linggiu Reservoir were then falling by approximately 10% each month. The fall in levels would endanger water supplies. As Khuo shared:

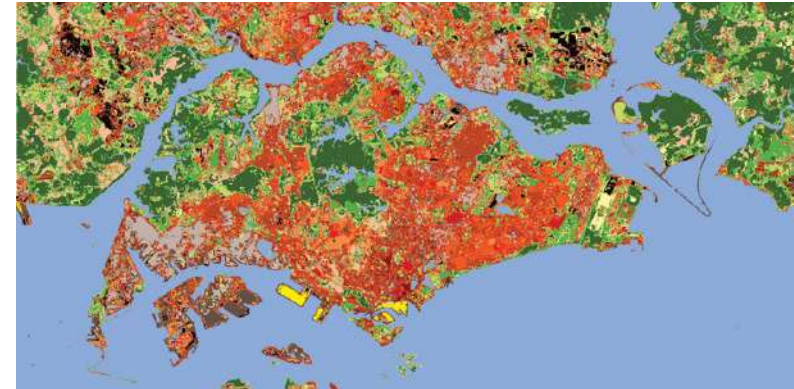
We did a lot of calculations, scenario planning. It is a risk management exercise....The problem is that we do not always have perfect [scientific] evidence, but it does not mean you wait until the science is right and then you make the decision. That creates analysis paralysis—people are doing these wonderful diagrams, coming up with all these studies, but what policies are they coming up with?

We concluded that we needed a desalination plant. We already had one, but we concluded that we needed to double or triple up.

[The Cabinet] agreed with [the] PUB that it is an important insurance against prolonged drought. We did not use climate change as a reason, but it was at the back of our minds. So, we received PM's approval, and we had to build it very quickly, because what if it happens in the next dry season and we're not ready?¹⁹⁴

The PUB subsequently commissioned the Tuaspring Desalination Plant in 2013, which was timely because when the next major drought happened in 2014, there was no interruption in water supply.

Cooling Down in a Heating Singapore



35. Simulation of the rise of average temperature due to climate change and heat island effect—the darker the red, the greater the temperature rise.¹⁹⁵

Without additional efforts to reduce GHG emissions, temperatures could continue to rise to between 3.7°C and 4.8°C above pre-industrial levels by 2100.¹⁹⁶ This equates to a maximum daily temperature of 35°C and 37°C in Singapore by 2100. The impact is calculated to be more pronounced in urban areas which may be several degrees higher. This will impact lifestyles and productivity.

Several initiatives have been introduced to improve greenery and concurrently address the expected increase in temperature. These include:

- The HDB's Biophilic Town Framework which aims to develop townships that are nature centric, focusing on optimising the performance of neighbourhood landscapes. It outlines strategies and considerations in five key areas of residential landscape planning and design—soil, flora and fauna, outdoor comfort, water and people.¹⁹⁷ The concept was first applied to Punggol Northshore District in 2015. The HDB has also improved greenery provisions since 2016 to require at least 4.5 Green Plot Ratio and 45% to 60% green cover in new residential developments. Developments can achieve this through ground level landscape and planting spaces as well as rooftop and vertical greenery on residential and carpark blocks. In promoting skyrise greening for existing estates, the HDB developed the Prefabricated Extensive Green Roof Tray System, a lightweight and low-maintenance system in 2006 to add greenery into existing rooftop spaces. The system comprises modular lightweight green roof trays that enables off-site plant propagation and easy

installation on the roof. The system requires minimal maintenance as it is equipped with water storage capabilities to help the carefully selected plant species weather through dry spells. The system has been deployed to existing buildings, such as multi-storey carparks with excess parking lots. Extensive greening can help reduce surface temperature by up to 15°C and cut down the amount of glare to surrounding blocks.

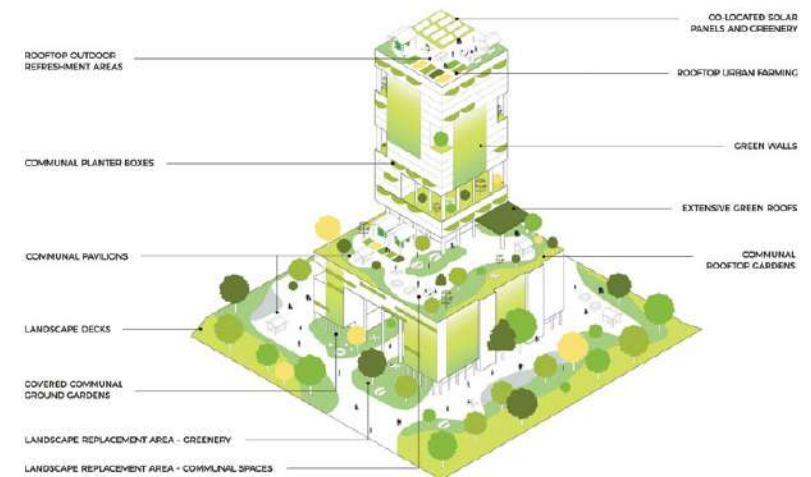


36. The Floating Wetlands System is an innovative solution to introduce pockets of greenery on the waterway which helps to attract biodiversity and cleanse the water.

- The Floating Wetlands System, also developed and patented by the HDB, has improved biodiversity and water quality, intensified greenery and brought nature closer to the doorstep of residents living along My Waterway@Punggol. The design of the system was inspired by the strong and lightweight organic structure of honeycombs, and the hexagonal modules can be snugly joined together to form “floating spaces” on water bodies. The HDB is working with the National Parks Board (NParks) to scale up the implementation of a large scale unique floating wetlands of around 4,000 m² in Pekan Quarry of Pulau Ubin to attract native fauna.
- The URA’s Landscaping Urban Spaces and High-Rises programme, which encourages vertical greenery, green roofs, and net replacement of vegetation. This was first introduced in 2009 and was subsequently expanded in 2014 and 2017.
- The NParks established the Centre for Urban Greenery and Ecology in 2007 to advance expertise on urban greenery and ecology. It also

released the “City in a Garden” Framework in 2011 to guide greening efforts. It introduced the Forest Restoration Action Plan, which aims to restore 8 nature parks—approximately 4% of Singapore’s land area and home to 40% of Singapore’s native flora and fauna—by 2030.¹⁹⁸ The Park Connector programme also ensures that there are greenways connecting the city to the regional and town parks. A bridge, the Eco-Link@BKE, was built across the Bukit Timah Expressway to allow animal crossings over two nature reserves.

- The PUB’s Active, Beautiful, Clean Waters programme, which integrates water drainage and cleaning spaces with green recreational spaces.



37. Singapore is looking to improve thermal comfort in urban areas through vertical and rooftop greenery.



38. The Eco-Link@BKE was built across an expressway to re-connect the Bukit Timah Nature Reserve with the Central Catchment Nature Reserve.

Planning for Food Security

Climate change is expected to alter global food production patterns directly and result in a drop in crop productivity.¹⁹⁹ Indirectly, the impact of climate change is expected to cause conflict and migration, which may further disrupt trade and supply.

Since the 1980s, up to 90% of Singapore's food supply has been imported. The global food crisis in 2007–08 triggered a need to review food security in Singapore. Warming neighbouring sea waters had also resulted in plankton blooms. Erratic rainfall patterns had made an impact on yields in the region.

In 2010, an Inter-Ministerial Committee for Food Security was formed, and in 2012, a Food Security Roadmap was unveiled to strategically plan for how to address Singapore's food security. The roadmap identified diversification of imports as the focus. Since then, Singapore has increased its food sources to more than 200 countries and reduced reliance of any major food product from any one source. This also addresses the challenges of price fluctuations at times of disruption. Diversification of food imports was one way to build some resilience against the impact of climate change.

We have a mission to achieve that is as crucial as water—and that is to strengthen our food security in an era of global food uncertainty.²⁰⁰

—Dr Koh Poh Koon, Minister of State,
Ministry of National Development (2016–17)

Beyond that, Singapore identified local food production for perishables such as fish, chicken eggs and leafy greens to be particularly vulnerable, and worked with local farmers to increase production and facilitate new farms. The Agrifood and Veterinary Authority (AVA)²⁰¹ unveiled the Farm Transformation Map in 2017, to maximise the 1% of land currently available for food production. It comprised four key thrusts: “Space”—to make more efficient use of available space; “Innovation”—to spur R&D and translate research to commercially viable farming solutions and help farmers adopt technology; “People”—to build a future relevant workforce; and “Ecosystem”—to create an enabling environment for the agriculture sector to thrive. Each farm and food producer was assigned an account manager to advise on business development, technology adoption and financial assistance options available.

In 2019, the Singapore Food Agency was formed specifically to oversee food safety and security in response to challenges posed by the vulnerable global food landscape and climate change. The new agency centralised the

food related functions which previously were with the AVA, NEA and Health Sciences Authority. The new agency had enhanced regulatory oversight from farm to fork. Among its first policies was to enhance Singapore's three food baskets—namely import diversification, helping companies establish presence overseas, and increasing local food production to 30% of nutritional needs by 2030 (see Chapter 5).



39. Singapore is opening up new spaces to farming, including the rooftops of multi-storey carparks, such as the Citiponics Farm in Ang Mo Kio.

Climate Change and Public Health

To mitigate the risk of foodborne diseases in public hawker centres, the NEA has continued its efforts in providing conducive and sanitary environment for hawkers to conduct their trade and for patrons to dine in. The focus is paced on infrastructural enhancement and maintenance, improving cleaning standards and raising awareness on public health and hygiene. The BCA is also looking at workplace health guidelines and information systems to address heat stress.

As a complementary tool to combat dengue, Zika and chikungunya transmission, the NEA has since 2016 been carrying out phased field trials to pilot releases of male *Wolbachia*-*Aedes* mosquitoes to reduce the urban *Aedes aegypti* populations. The study sites in the public housing estates of Tampines and Yishun have yielded promising results; releases have brought

down the *Aedes aegypti* population to levels that pose low dengue risk, with some positive results. With that, the NEA is now gradually expanding the coverage to the entire towns of Tampines and Yishun. This expansion is supported by a new mosquito production facility to allow the NEA to scale up production capacity for mass-rearing and sorting.²⁰² Since 2015, Singapore has also used drones to facilitate the detection of mosquito larval habitats at heights that cannot be safely accessed by inspectors.

Raising Internal Capacity for Continued Climate Action

It is important that domestic capabilities are improved to address complex issues such as climate change. By having to develop sustainability plans over the last few decades, agencies built competency in identifying opportunities for climate action over time. Plans include the Sustainable Singapore Blueprint 2015, the Singapore Climate Action Plan of 2016, and the Low-Emissions Development Strategy “Charting Singapore’s Low-Carbon and Climate Resilient Future” established in 2020.

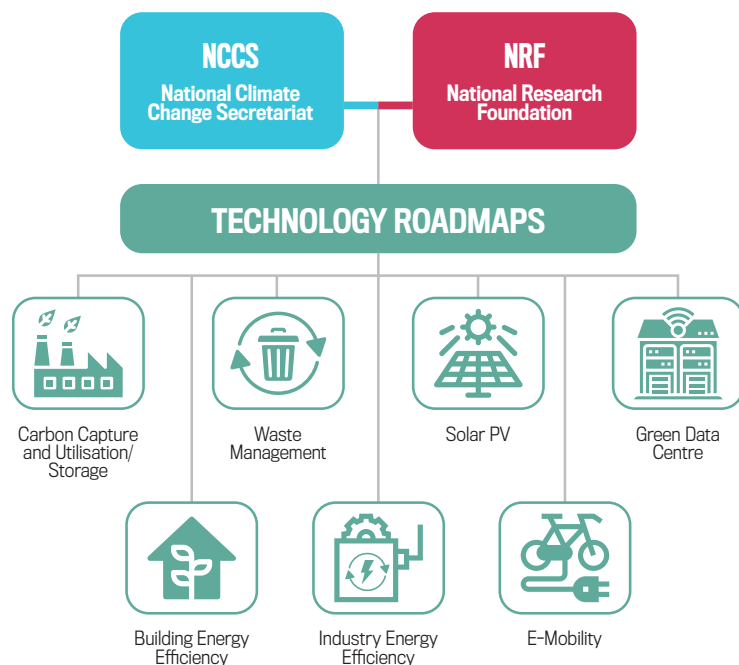
Building capacities to understand climate science was crucial to greater competency in understanding localised impact, and research centres within the TMSI and CCRS have been crucial in improving local capabilities. Singaporean scientists have been involved in contributing to IPCC’s Assessment Reports, such as Professor Wong Poh Poh of the National University of Singapore, Associate Professor Winston Chow of the Singapore Management University and Professor Lynette Cheah of the Singapore University of Technology and Design, so as to increase capacities in climate science.

The NCCS and NRF worked with industrial sectors to create seven technology roadmaps: carbon capture, utilisation and storage, solar, green data centres, building energy efficiency, industry energy efficiency, waste management and EVs. This helped agencies and industries understand options to reduce carbon emissions, advised on R&D funding options and guided emissions reduction plans, thereby raising overall capacity. The exercise was crucial to calculate potential realistic reductions for Singapore’s international carbon reduction pledge.



40. Evolution of sustainability and climate change plans from 2002–20. Each builds on its predecessor.

EXHIBIT 14 TECHNOLOGY ROADMAPS FOR ENERGY AND CLIMATE CHALLENGES.



Each technology roadmap is led by relevant government agency(s) to formulate master plans and funding initiatives to reduce carbon emissions and increase energy efficiency.
Source: National Climate Change Secretariat.

Formalised capacity building is crucial. The BCA Academy is a good example of moving the industry forward in adopting more sustainable technologies and ensuring building excellence:

A constant argument is the industry is not ready, especially in the early stage[s] of innovation adoption. Taking green buildings as an example, I recalled many CEOs of private companies and public agencies telling me: “We want to go green, but my consultants don’t know what to do! Then how?” So that’s why [the] BCA has the academy for the built environment sector to build up such capabilities. We train thousands and thousands of people: architects, engineers, contractors, and supervisors on how to design, build and maintain green buildings. Without this, it’s very hard to move forward in such speed and reach.²⁰³

—Dr John Keung, CEO, BCA (2006–17)

To continue capability development and solutions, the Research, Innovation and Enterprise 2020 plan announced a S\$1 billion investment for urban solutions and sustainability projects. It establishes Singapore as a “living lab” to testbed innovative solutions, which may be eventually exported globally.

Innovating with the Private Sector

The government has an important role to play in facilitating the adoption of climate-friendly actions on a larger scale by the private sector.

The government needs to 1) ensure the proper distribution of costs and benefits between emitters and society; 2) make sure that regulations encourage rather than inhibit responsible action; and 3) resolve potential bottlenecks in implementing climate-friendly practices. If you need to build infrastructure before a particular technology can be deployed, then the government has to play a role. The private sector may not be able to do so on its own.

The approach that we have taken is to move with the market, rather than lean against it. For example, electric and hydrogen vehicles require new charging and fuelling infrastructure, and new regulations. Government has to play a role.²⁰⁴

—Teo Chee Hean, SM and Chair of the IMCCC (2011–Present)

Various government agencies are working with the private and non-government sectors for this purpose. Others, like the EDB, has also facilitated the establishment of Centres of Excellence for companies to encourage R&D and sharing. Partnerships between the various sectors are crucial to achieve this. Dr Balakrishnan shared:

Another value that will underpin our future is that of partnership. The solutions for our challenges tomorrow will be at the boundaries of different disciplines and different groups. It will not be just government; but it will be government, non-governmental organisations and businesses working together. Because, at the end of the day, we need to generate solutions which are ecologically sound, economically viable and socially and politically fair.²⁰⁵

PUBLIC-PRIVATE PARTNERSHIP: SINGAPORE GREEN BUILDING COUNCIL (SGBC)

The BCA's key partner in promoting energy efficiency and sustainability in buildings is the SGBC. Formed in 2009, the SGBC's goal was to promote green building design, practices and technologies and drive environmental sustainability in the building and construction sector. The SGBC is a public-private partnership, whose members include developers, architects, engineers, facilities managers and product suppliers. They represent the whole value chain for building development.

The government can only push so much, it cannot do everything ourselves. The industry must come in, get buy-in support and be a co-leader. So, the SGBC is very important and can play a much bigger role to drive the movement here and in the region.²⁰⁶

—Dr John Keung, CEO, BCA (2006–17)

The BCA provided some seed funding as well as some administrative support for the establishment of the SGBC. With this set-up and the presence of the Green Mark certification scheme, the SGBC was accepted in the World Green Building Council in record time—in six months.

After one decade, the SGBC is assisting in the certification of buildings under the Green Mark certification programme. Dr Keung added:

I feared that if we privatise [the Green Mark] too fast, things that we do not want to see may happen, and we would lose credibility. Green Mark is really a unique system—we not only look at design, but we check how you build, operate and function after the building is completed.²⁰⁷

The Green Mark Scheme has now expanded beyond Singapore to 71 cities in 15 countries.²⁰⁸

One example such partnerships forged was the establishment of the SGBC (see Box Story on facing page) and companies that pushed ahead with their initiatives often saw dividends:

A lot of architects and engineers who went through green building [certification] and constructability ended up with real substantive differentiators that allowed us to compete in the other regions.²⁰⁹

—Lee Chuan Seng, Member of Committee of Government Scientific Advisors (2019–Present) and Founding President, SGBC (2009–11)

Private and non-governmental sectors also have responsibilities to support low-carbon actions. For example, the Singapore Environment Council (SEC) suspended the green label of Asia Pulp and Paper's (APP) exclusive distributor in Singapore in 2015, due to their link to regional forest fires. Consequently, larger supermarket chains removed all APP products from their shelves (NTUC FairPrice, Sheng Siong and Prime) and the Dairy Farm Group stopped all purchase of APP products.²¹⁰

Companies can also adopt climate-friendly policies. Temasek Holdings, for example, aims to be carbon neutral before the end of 2020.²¹¹ It also aims to halve the carbon emissions in its portfolio by 2030. Others can implement zero waste practices, even applying for the Towards Zero Waste Grant and 3R Fund to support new initiatives.



41. The SGBC promotes public-private partnership on greening the built environment. It supported the Garden on the Move initiative to study possible energy and costs savings for bus operators.

TODAY'S LIMITATIONS ARE TOMORROW'S OPPORTUNITIES: ADOPTING NEW PRACTICES IN GREEN BUILDINGS

The private sector can also take the lead in introducing low-carbon technologies, such as City Developments Limited (CDL) who built Singapore's first timber building.

Among Singapore's limitations are the high cost of labour and the lack of space. Furthermore, traditional construction methods require much concrete and steel, both high carbon emitters.

In 2014, CDL decided to build Singapore's first large-scale Prefabricated Prefinished Volumetric Construction (PPVC) building using CLT.²¹² It was a 638-unit Executive Condominium, a type of public housing called The Brownstone. The development set the benchmark and a world record of engaging 4,098 modules, which were prefabricated off-site and assembled on-site.²¹³

At that time, PPVC was a new technology that required adopting smarter building techniques that were completely different from traditional building methods. It promised game-changing improvements in both construction productivity and the worksite environment. Precision cutting and fabrication also ensured quality control and reduction in waste.

Every new technology will require upfront investment as well as trial and error, especially when it is not tested in such a large scale. For the long-term benefit of raising construction productivity and best industry practices in Singapore, CDL was fully committed to support and invest much resources, over and above the BCA's grant. The success was a result of unwavering commitment and joint effort.²¹⁴

—Esther An, Chief Sustainability Officer, CDL (2014–Present)

Apart from the commitment and strong collaboration between the BCA, CDL and CDL's builders and consultants, the construction of The Brownstone also required the support of relevant agencies. The PPVC structures were large and needed to be transported over distances on roads, which required path identification and clearance. Timings for transport had to be well coordinated. All these contributed to the complexity of the PPVC implementation. In short, various construction protocols had to be adapted due to the different construction methods.

The collaborative efforts to pilot PPVC on a record large scale eventually proved to achieve the objectives of raising productivity, health and safety performance on-site. An explained:

It helped us to raise productivity by about 40% and saved us 55,000 man-days over three years. The project was completed three months ahead of schedule. The technology was also able to achieve better worksite environment, health and safety performance.²¹⁵



42. The PPVC moulds are completed in factories, allowing better quality control. After the building modules are formed, finishings such as flooring, wall tiles, paint and window frames are applied. The completed modules are then securely wrapped and transported to the site. The modules are assembled like "Lego" blocks on-site to form whole apartments seamlessly.

Raising Awareness and People's Action

The SEC's Climate Change Awareness Programme was set up in 2006, and since 2009, the Ministry of Education has collaborated with agencies to include water and climate change in the curriculum.

2018 was designated the Year of Climate Action (YOCA) to rally businesses, households and individuals to take collective action for a sustainable future.²¹⁶ This garnered strong response from the community, including corporations, non-governmental organisations and schools, with many organising climate-change themed events to raise awareness.²¹⁷ Many of these were coordinated through the Climate Action SG Alliance, formed in 2018 by corporate and civil society leaders. Communities wishing to hold activities could also apply for grants of up to S\$5,000 to organise climate action activities. In total, more than 800 activities, equivalent to more than two activities per day, were held to create awareness on climate change. In all, 350,000 people committed to a climate pledge.

The YOCA was followed by Year Towards Zero Waste (YTZW) in 2019. More activities were held to shed light on the challenges of waste, encourage residents to treasure resources and make it a habit to reduce, reuse and recycle. Policies were also adopted to nudge businesses to adopt a circular economy approach and engage in sustainable production and consumption. Two youth-led movements—ZeroWasteSG and LepakInSG—helped to facilitate focus group discussions on the inaugural zero waste masterplan, which was released later that year.

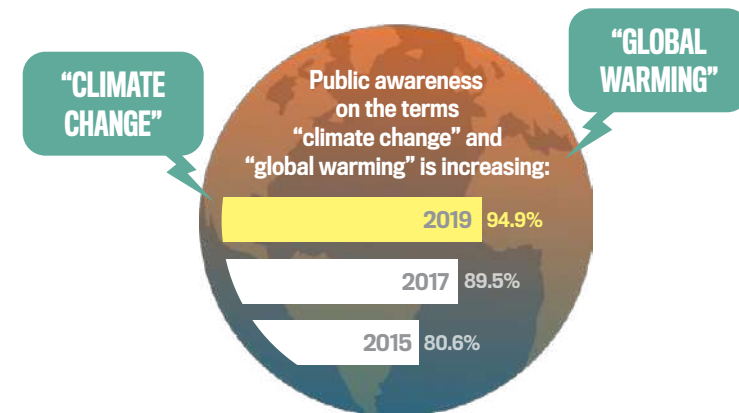
I had initiated thematic years for the MEWR Family, starting from the YOCA in 2018, to make climate change and sustainability relatable and salient for Singaporeans in everyday life. The yearly themes have helped people to understand the broad-ranging impact that climate change has on our lives, and at the same time, how each one of us can make a difference. For instance, in the YTZW in 2019, we made a deliberate effort to link how efforts to recycle and reduce waste can help in fighting climate change by reducing consumption and waste incineration.

When people are more aware of how their choices and lifestyles impact the environment, they are more willing to make environmentally-friendly lifestyle changes. This will in turn spur organisations to be more sustainable, as consumers increasingly demand responsible and sustainable products.²¹⁸

—Masagos Zulkifli, Minister for the Environment and Water Resources (2015–20)

The NCCS also held public consultations on how Singapore could be a low-carbon global city-state. In 2019, a survey revealed that 90% of Singapore residents were aware of climate change, higher than the years before. Respondents were aware of the impact of climate change, such as disrupting ecosystems (95.3%), increased vulnerability to heat stress and diseases (93.7%), and problems caused by rising sea levels (93.4%). More importantly, 95.4% supported Singapore making a shift to a low-carbon economy.

EXHIBIT 15 PUBLIC AWARENESS OF CLIMATE CHANGE.



The biennial Climate Change Public Perception Surveys by the NCCS reveal greater awareness of climate change over time.

Source: National Climate Change Secretariat.²¹⁹

As former Minister for the Environment and Water Resources, Masagos Zulkifli remarked:

This is an important first step. When people are convinced of the importance and necessity of climate action, they will be more willing to make a change in their lifestyle and behaviours to help mitigate climate change.²²⁰

My Backyard is Your Front Yard, My Side Gate is Your Side Gate:²²¹ Regional Engagement

Southeast Asia has been identified as one of the most vulnerable to climate change.²²² Its 640 million population live mainly along low-lying coastlines, exposed to sea level rise.²²³ The region is a major food producer for the world, vulnerable to drought, mega storms and heat waves. According to the Asian Development Bank, climate change could reduce the region's GDP by 11% by the end of the century due to its impact on tourism, agriculture, fishing, human health and labour productivity.²²⁴ Continued deforestation and land degradation in the region are likely to further exacerbate the impact of climate change.

Aside from extensive economic ties, Singapore has strong social and cultural ties to the region. To this end, Singapore has led efforts among the Association of Southeast Asian Nations (ASEAN) for collective climate action. In 2007, it led the endorsement of the Singapore Declaration on Climate Change, Energy and Environment, with ASEAN+6.²²⁵ The ASEAN Working Group on Climate Change was established in 2009 to oversee implementation of the relevant action lines in the ASEAN Socio-Cultural Community Blueprint 2009-15.²²⁶

In 2018, Singapore, as the ASEAN chair, convened the first Special ASEAN Ministerial Meeting on Climate Action (SAMCA) and Expanded-SAMCA. It was at this meeting that Singapore introduced its commitment to a "Climate Action Package" to provide capacity building programmes in disaster risk reduction, climate science, flood management and long-term mitigation and adaptation strategies.

Southeast Asia's challenges with climate change are complex, many of which are cross-border issues. One common pain point has been the annual haze caused by burning forests, which creates intense regional air pollution, releases stored carbon, and damages carbon sinks. Singapore has been working with its neighbours and the private sector to address this.



43. The SAMCA was initiated and hosted by the Government of Singapore on 10 July 2018.

Singapore is also actively working with its neighbours to reduce energy intensity and increase the use of renewable energy through the ASEAN Plan of Action for Energy Cooperation, 2016-25.²²⁷ Among the goals are reducing energy intensity in the ASEAN region by 20% from 2005 levels by 2020.²²⁸ Singapore also houses the first Southeast Asia Disaster Risk Insurance Facility, which was set up in December 2018.²²⁹

We are a small country, but sometimes we can punch above our weight. People may listen to us if we have done scientific studies and analyses, and we can influence the setting [of] international standards.²³⁰

—Khoo Teng Chye, CEO, PUB (2003-11)

AVOIDING SOCIALISING PAIN, PRIVATISING GAIN: REGIONAL COOPERATION ON HAZE

Forests fires can be a major source of carbon emissions in Southeast Asia. Under certain conditions, they also produce a thick haze that blankets cities across the region, affecting respiratory health.

The haze is a classic textbook example of socialising the pain and privatising the gain. The people who gain from burning forests are the few owners of plantations, who privatise the profits. The pain, the pollution and health impact, are going to be suffered by the people on the ground living there.²³¹

—Dr Vivian Balakrishnan, Minister for Foreign Affairs (2015–Present) and Minister for the Environment and Water Resources (2011–15)

Singapore is working with the region to address this. In 2002, ASEAN members signed the ASEAN Agreement on Transboundary Haze Pollution, a legally binding environmental agreement. This was ratified by all ASEAN countries by 2014. It recognised that transboundary haze pollution resulting from forests fires and land clearing should be mitigated through concerted national efforts and international cooperation. Dr Balakrishnan explained:

There are precedents in international law which do indicate that what you do—if it affects the health or impacts the interests of your neighbours—you can be held to account.²³²

In 2014, Singapore further enacted the Transboundary Haze Pollution Act, which criminalises conduct which causes or contributes to haze pollution in Singapore. This penalised companies based in Singapore which were causing or linked to the burning of forests in the region as Dr Balakrishnan emphasised:

With the Act, we can put pressure on errant companies. We are putting the spotlight on them. We also exercise thought leadership and offer potential legal and business solutions to these challenges.²³³

The COP 24 President, Michal Kurtyka, Secretary of State of Poland's Ministry of Energy and Environment, observed that Singapore "played a catalytic role in galvanising regional climate action as Chair of ASEAN, including hosting a meeting between ASEAN and Plus Three Ministers in July 2018 to discuss ways to increase regional action to address climate change".²³⁴

Beyond ASEAN, Singapore has also developed global partnerships. Singapore joined the C40 Cities Climate Leadership Group, a consortium of cities working to reduce their carbon emissions, as an observer in 2012. Singapore also worked closely with China to develop the Sino-Singapore Tianjin Eco-City, which turned a saline wasteland into a low-carbon, liveable and sustainable city of more than 100,000 inhabitants.

While Singapore's efforts to reduce emissions on our own may be modest, our collective efforts with all nations can be substantial.²³⁵

—Teo Chee Hean, SM and Chair of the IMCCC (2011–Present)



44. The site of Tianjin Eco-City was once a saline wasteland.



CHAPTER 5

BUILDING A CLIMATE RESILIENT FUTURE

“

We should treat climate change defences like we treat the SAF [Singapore Armed Forces]—with utmost seriousness. Work steadily at it, maintain a stable budget year after year, keep your eye on the target and do it over many years and several generations....Everything else must bend at the knee to safeguard the existence of our island nation. We must make this effort...otherwise one day, our children and grandchildren will be ashamed of what our generation did not do.²³⁶

”

LEE HSIEN LOONG

Prime Minister (2004–Present)

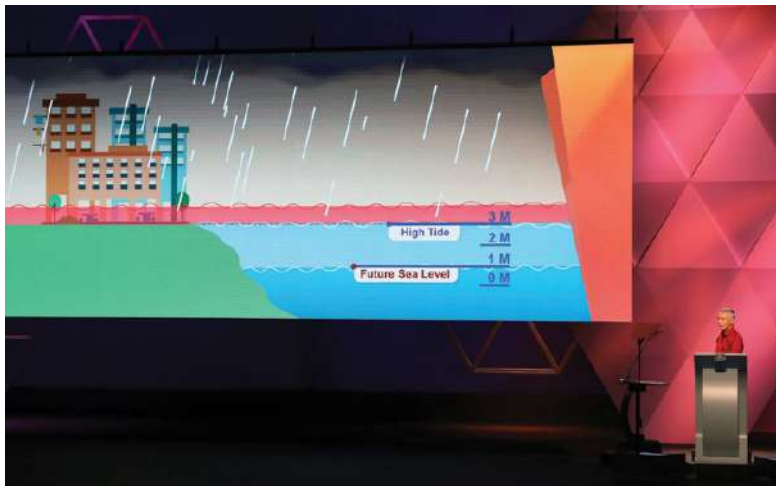
A Rallying Call

At the National Day Rally in 2019, Prime Minister Lee Hsien Loong highlighted the existential threat of climate change:

A recent Swiss study found that by 2050, just 30 years from now, several cities in the world will experience unprecedented climate shifts. And it found that one of them will be Singapore. We must prepare for the impact of climate change on Singapore. There are many risks and consequences. New diseases, more frequent pandemics, food shortages, forced migration of displaced populations, and even wars.²³⁷

The speech socialised an expanding circle of Singaporeans to the dangers of climate change. It dispelled misconceptions, opened up spaces to talk about the dangers of climate change and encouraged more ambitious goals. Each generation must contribute its fair share without burdening future generations.

Singapore's next steps are to further **understand**, **mitigate** and **adapt** to climate change.



45. PM Lee highlighting the impact of climate change on Singapore at the National Day Rally 2019.

Understand: Planning for a Climate-Unstable Future

Knowledge is important for wise decision-making. Singapore will continue to drill down on the impact of climate change, starting with a 1 km by 1 km downscaled model of potential impact from climate change.²³⁸ Under the Centre for Climate Research Singapore, a new Climate Science Research Programme Office will be set up to lead efforts and implement the National Climate Science Research Masterplan.²³⁹

As science suggests that climate change is accelerating, one must undertake plans recognising the uncertainty.

Where we have not started to really grapple is additional changes—because when the climate system changes, you have all these freak weather events, and you have changes to what you've historically experienced that you're not able to forecast based on the past. How do you take all that into account in your adaptation plans? It's difficult to make that kind of judgement.²⁴⁰

—Choi Shing Kwok, Permanent Secretary, Ministry of the Environment and Water Resources (MEWR) (2012–17)

Efforts to project sea level rise are a case in point as "sea level rise is a complex, multi-disciplinary issue which involves many areas of domain expertise—in atmospheric science (storm surges), cryosphere (ice-sheet dynamics), oceanography (circulation and thermal expansion of ocean) and geoscience (vertical land movements). The science in this field is also constantly and rapidly evolving".²⁴¹

To understand its impact on sea level rise, the MEWR launched a five-year National Sea Level Research Programme in 2019 to build local research capabilities to project and adapt to risks posed by long-term sea level rise. This, and others, will contribute to Singapore's Third National Climate Change Study, which is due in 2022.

Mitigate: Towards a Low-Carbon Future

"We are an incubator for possibilities. Through technology and innovation, we can find development pathways with a lower carbon footprint. Every time we succeed with one of these experiments, we prove something can be done for sustainability. We prove things can be done in a climate-friendly way, without deteriorating the quality of life."²⁴²

—Ambassador Kwok Fook Seng, Chief Negotiator for Climate Change (2014–16)

Beyond its 2015 commitment to reduce emission intensity in 2030 by 36% from 2005 levels, Singapore has now committed to an absolute peak in emissions of 65 million tonnes of carbon dioxide-equivalent (MtCO₂e) by 2030. It has also committed to halve this amount to 33 MtCO₂e by 2050, and to achieve net-zero emissions as soon as viable in the second half of the century. It will also commit to reporting the seventh greenhouse gas (GHG), nitrogen trifluoride, by 2024.

There are three thrusts in our [mitigation] strategy. First, we need transformations in our industry, economy and society. Second, we will have to draw on technologies, which are not yet mature such as carbon capture, utilisation, and storage (CCUS), and low-carbon fuels. Third, we will need international collaboration in areas such as well-functioning carbon markets and regional electricity grids.

Each thrust will contribute to the halving of our emissions. We will pursue all three vigorously to achieve our aspiration. The extent to which potential emission reductions from each thrust can be realised will become clearer in the coming years as we gain experience from implementing our programmes, as technology evolves, and as the modalities for international cooperation and collaboration become formalised. If the actual reductions from each thrust are larger than we now assess, or are available sooner, then we can realise our aspiration earlier. On the other hand, if the potential reductions turn out to be less promising, we will still strive to meet our Low-Emissions Development Strategy (LEDS) aspiration to the best of our ability even though the task becomes more difficult.²⁴³

—Teo Chee Hean, Senior Minister (SM) and Chair of the Inter-Ministerial Committee on Climate Change (2011–Present)

These thrusts are explained in further detail below:

Thrust 1: Transforming Industry, Economy and Society

Singapore's carbon tax rate is planned to rise to S\$10–15 by 2030, which will motivate greater efficiencies in power generation, buildings, households and industry. Singapore will also expand its solar power, targeting at least 2 gigawatt-peak of solar deployment by 2030 and explore efficient, vertical, and transparent photovoltaic (PV) panels. Additionally, smart grids may be deployed now, given that testing in Semakau Island has proven viability. To reduce carbon emissions in transport, Singapore is targeting that 9 in 10 peak-hour journeys will consist of "walk-cycle-ride" options by 2040. All public buses and taxis will run on cleaner energy by 2040.²⁴⁴ All new public bus purchases from now on will be cleaner energy buses, including electric or hybrid buses. Since March 2019, the Land Transport Authority has deployed 50 diesel hybrid buses on the roads and also bought 60 fully electric buses that will be deployed progressively. New bus depots will be designed to support electric buses. With the gradual replacement of existing diesel buses with cleaner energy ones, Singaporeans will enjoy quieter commutes and cleaner air.



46. All public buses will run on cleaner energy by 2040.

Singapore will continue its net-zero private vehicle growth policy and by 2040, all internal combustion engines (ICE) will be phased out and replaced with cleaner vehicles.

RACING FOR ZERO INTERNAL COMBUSTION ENGINES

While Singapore's vehicle population is moderate, most vehicles have ICE that burn gasoline or diesel. Electric vehicles (EVs) are fuelled by the power grid, but their emissions are concentrated in one location allowing for better pollution control, whereas ICE vehicles represent multi non-point sources distributed across the island, with high concentration of pollution near roadways. Furthermore, even accounting for transmission and distribution losses on the grid, EVs are still more energy efficient than their ICE counterparts:

Motor vehicles are constantly accelerating and decelerating, so combustion efficiency is poor. You use more fuel, and you emit more pollution and CO₂ as a result. In a power station, conditions are always defined within very narrow realms, and you can control your combustion to almost 100%. So, electricity produced by the power station will always require less fuel than [regular] motor vehicles.²⁴⁵

—Joseph Hui, Deputy Chief Executive Officer,
National Environment Agency (NEA) (2011-14)

As part of its commitment to halve 2030 emissions by 2050, Singapore will aim to phase out ICE in favour of cleaner energy alternatives, such as electric, hybrid, hydrogen or other options.

Both electric and hydrogen fuel cell vehicles offer pros and cons that could change the urban landscape. Battery-operated EVs are readily available, but the availability of charging stations and length of time taken to charge have deterred some adopters, though both are improving. Metals used in the batteries also contribute to an embodied carbon footprint.²⁴⁶ Hydrogen fuel cell electric vehicles (FCEVs) are still in the prototyping stage, and refuelling infrastructure is very expensive, requiring stringent safety measures. Moreover, for FCEVs, the majority of the world's hydrogen production comes from steam methane reforming of natural gas, which contributes to a higher carbon footprint. It can be replaced by "green" hydrogen from electrolysis, powered by renewable energy. Technological breakthroughs and system-wide infrastructure deployment will be needed for both solutions.²⁴⁷

REDUCING FOOD WASTE: WHOLE-OF-INDUSTRY APPROACH

The key to addressing food waste is to engage industry and stakeholders. Accordingly, an industry steering committee for circular economy in food was formed. It includes agencies such as the Singapore Food Agency (SFA), National Parks Board (NParks), JTC Corporation (JTC), Enterprise Singapore, Agency for Science, Technology and Research and NEA. From the private sector, it includes the Singapore Manufacturers' Federation, Singapore Food Manufacturers' Association, Singapore Agro-Food Enterprises Federation Limited, Singapore Hotels Association, and chief sustainability officers from various large companies.

Taking a point from the construction industry, the first challenge was to find off-takers, which requires some understanding of the materials and lateral thinking. Lee Chuan Seng, Member of Committee of Government Scientific Advisors (CGSA) (2019-Present) and Founding President, Singapore Green Building Council (SGBC) (2009-11) illustrated:

For instance, [the] NParks says they have 500,000–600,000 tonnes of horticultural waste. The question is, what percentage is leaves and what percentage is wood? Leaves are easily decomposed, however when they are mixed with wood, the compost quality is actually not good, full of millipedes and can smell because it turns anaerobic. However, if 60% is wood, then you have 300,000 tonnes of timber! We need timber for making packing cases, pallets, and particleboard and so on. So now you potentially have industrial off-takers!

With the reduction of biomass then the compost supply drops, and so there could be need for more compost which can come from food waste composting. So, things like black soldier flies where the larvae can provide protein for feedstock, and the waste fertiliser—that is actually better than compost because there's actually nitrates, phosphorus, potassium inside. Others can be sent to the new integrated waste management facility in Tuas (Tuas Nexus) where waste is mixed with sludge from the wastewater treatments plant, and actually get an increase of 50% in biogas generation!

So, then we say to people to start sorting waste, introduce mandatory regulation. We're working through a 2 to 3-year timeline.²⁴⁸

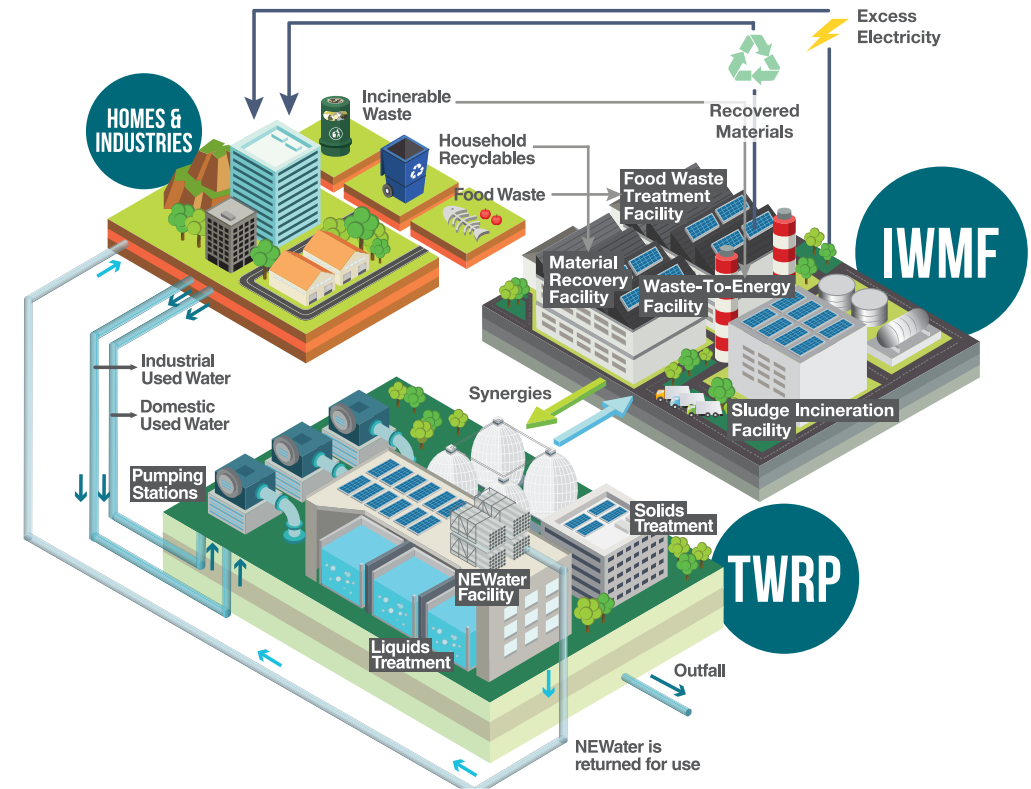
Singapore's cities, towns, neighbourhoods and homes will become "greener" through optimising natural ventilation in design, the use of low-carbon materials and incentivising sustainable technologies through the mandatory energy labelling scheme and minimum energy performance standards. The Housing and Development Board's (HDB) newly launched Green Town seeks to reduce energy usage by 15% before 2030.

To maximise resources, Singapore will move towards a circular economy. It introduced the Resource Sustainability Bill in 2019 to target electronic, packaging and food waste. Part of this is the Extended Producer Responsibility (EPR) framework, which will be launched in 2021. Items such as phones, computers, batteries, lamps, large appliances and solar panels sold in Singapore will require responsible collection and recycling plans by producers—including free take-back services for all end-of-life equipment upon request. The EPR framework will be extended to packaging waste by 2025. From 2021, it will also be mandatory for large food waste generators to segregate and treat food waste.²⁴⁹

Projects to maximise resources will be taken from a systems-based, integrated approach. One example is the proposal for the Tuas Nexus plant, which integrates the PUB, Singapore National Water Agency's Tuas Water Reclamation Plant with the NEA's Integrated Waste Management Facility. It will be completed in 2027, saving more than 200,000 tonnes of carbon emissions annually:

The Tuas Nexus will maximise energy and resource efficiencies by employing the latest technologies to harness the synergies of the water-energy-waste nexus from used water and solid waste. Tuas Nexus will not only achieve full energy self-sufficiency, but also generate excess electricity capable of powering up to 300,000 HDB four-room apartments annually.²⁵⁰

—Masagos Zulkifli, Minister for the Environment and Water Resources (2015–20)



47. The Tuas Nexus generates energy from sludge and solid waste to be fully energy self-sufficient.

Thrust 2: Adopting Advanced Low-Carbon Technologies

Technology is a key enabler for achieving Singapore's LEEDS aspirations. The second thrust relates to adopting emerging low-carbon technologies such as CCUS and low-carbon fuels such as hydrogen to drive deep decarbonisation. The government has commissioned feasibility studies to better understand the potential of deploying CCUS and low-carbon hydrogen in Singapore. The CCUS study was completed in 2019 and a hydrogen study was commissioned that same year. Singapore is also working with local and international partners in government, industry and academia to explore demonstration and pilot projects to commercialise these emerging technologies.

Singapore will continue to invest in research, development and demonstration to develop cost-effective low-carbon technological solutions. Complete transition depends on global advances in technology and effective international cooperation. However, instead of succumbing to the belief that it is merely a small country with limited market power, some leaders suggest that Singapore's soft power among the world's cities lends it influence, and allows it to be a living laboratory for solutions:

It's a slightly belated realisation that we are more useful than what we had thought. What we once thought were limitations are tomorrow's opportunities. Because we organise our environmental protection policies on economically and scientifically sound principles, it dawned on us that the solutions we are creating to deal with our own challenges actually presented opportunities to be laboratories to the world and show how city states could deal with existential challenge.²⁵¹

—Dr Vivian Balakrishnan, Minister for Foreign Affairs (2015–Present) and Minister for the Environment and Water Resources (2011–15)

Thrust 3: Effective International Collaboration

Singapore will continue to play a role in multilateral efforts to tackle climate change. One possibility suggested by Dr Balakrishnan is an international carbon tax:

What [we] need is a global, comprehensive, universal, levelised, revenue-neutral carbon tax. I have chosen each adjective carefully. That means it is global, it is uniform. No exemptions, no arbitrage opportunities, no unfairness. Set it at a level high enough to account

for the externalities caused by carbon, and to incentivise the use and development of the appropriate technologies. All the technologies for a low-carbon future are already available.²⁵²

Another approach is working with regional neighbours to address climate change. Singapore is studying ways to leverage on regional power grids for cost-competitive energy that will help to decarbonise its power grid and overcome land constraints. This could be realised through bilateral cooperational or regional initiatives to collaborate on a regional power grid to allow broader deployment of renewable energy. The Energy Market Authority has launched a technical study to assess the feasibility of electricity imports as a supply option while maintaining the security and reliability of the power system. Australia's Northern Territory government has backed a S\$19 billion plan to connect Australian solar farms to Singapore and Southeast Asia through an underwater direct current cable.²⁵³ A proposed array of 2 million panels spanning 15,000 ha (150 km²) in northern Australia is projected to generate 10 GW of power, making it the world's biggest solar farm. From this farm, 3 GW could be transmitted to Singapore, potentially meeting 20% of Singapore's energy needs.²⁵⁴ Construction is due to start in 2023 and transmission could begin as early as 2027.



48. Studies are underway to explore new energy options for Singapore, including solar power from other countries.²⁵⁵

A STALWART DEFENDER OF THE PARIS AGREEMENT AND MULTILATERALISM

Much work remains in international climate negotiations to push towards more ambitious climate action:

While admittedly not perfect, the Paris Agreement is our best bet to address climate change. It would not be in anyone's interest to throw the baby out with the bathwater. This is why Singapore participates actively in the climate negotiations: to support a multilateral rules-based approach to addressing climate change, one where every country plays its part to faithfully implement the Paris Agreement.²⁵⁶

—Joseph Teo, Chief Negotiator for Climate Change (2016–Present)

Singapore hopes to continue to play the role of honest broker, constructive and trusted interlocuter to help forge solutions at international climate negotiations. At the Conference of the Parties (COP) 24 in 2018, then Minister for the Environment and Water Resources, Masagos Zulkifli, played a key role in co-facilitating the topic of mitigation, which was ultimately adopted in the Katowice Climate Package.



49. At the invitation of the Polish COP 24 President, Michal Kurtyka (right), Minister Zulkifli co-facilitated with Norway the ministerial negotiations on the mitigation track, which contributed to the successful adoption of the Katowice Climate Package at COP 24.



50. At the request of the Chilean COP 25 Presidency, Singapore co-facilitated with Spain the key overarching conference decisions. In 2020, SM Teo Chee Hean expressed Singapore's desire to work closely with the United Kingdom, host of COP 26, which has been rescheduled for November 2021.

Singapore's efforts have won friends. The United Nations Framework Convention on Climate Change (UNFCCC) Executive-Secretary Patricia Espinosa observes, "Singapore has a very strong credibility and I would say well-deserved high stature in these negotiations because of their diplomacy. Their representatives have consistently been looking for solutions, being constructive, making a contribution to the process."²⁵⁷ To be actively engaging in multilateral climate processes and supporting "strong outcomes" as Minister Zulkifli puts it, "is critical to Singapore's well-being, by upholding a rules-based system, earning international respect, and contributing to a better world".²⁵⁸

Looking Ahead to Net-Zero Emissions

As stated in the 2020 LEDS, Singapore aims to reach net-zero emissions as soon as viable in the second half of the century. In the meantime, it will pursue all avenues for a carbon neutral future, including through improved solar photovoltaic, imported renewable energy, low-carbon technologies, and transforming Singapore for enhanced energy efficiencies.

There is a need for accelerated efforts as called for by the UN Secretary-General António Guterres, exhorting the world to achieve “net-zero emissions by mid-century” to avoid dangerous warming.²⁵⁹ At the COP 25 in Madrid, Spain, more than 70 countries signalled their intention to achieve carbon neutrality by 2050. However the world is still far from achieving the goal of capping global average temperature rise at under 2°C.²⁶⁰ The task is urgent.

Adapt: Preparing for the Worst with Clear-Eyed Realism

The National Day Rally 2019 raised the reality and dangers of climate change and set the stage for greater action. As an article in Bloomberg highlights, “Singapore has a reputation for planning ahead. When it comes to climate change, it is planning for the worst.”²⁶¹ Dr Balakrishnan added:

You can see what we are doing through carbon tax; through environmental regulations, air quality, energy conservation and incentivising our companies to do the right thing for the long term. [But] we know or we expect that the world will not make these decisions quickly enough...we are also setting up our ability to adapt to what is going to be a very uncomfortable 50 years, or century ahead of us.

This will give Singaporeans both the reassurance that we will survive, but also the hope that we will play a leading role as a problem-solver and a solution for the future. It is a combination of clear-eyed realism, sensible economics, and a coordinated long-term approach to converting a threat into an opportunity [that] we can give both hope and reassurance to our people.²⁶²

Addressing Sea Level Rise

“With climate change, we know for sure sea levels will rise. The only uncertainty is whether they rise a few decades earlier, or a few decades later. Therefore, we will implement our climate change plans progressively, and keep them flexible. But we must start now and sustain the effort.”²⁶³

—Lee Hsien Loong, Prime Minister (2004–Present)

Prime Minister Lee stated that S\$100 billion or more may be needed over 100 years to protect Singapore against rising sea levels caused by climate change. A new Coastal and Flood Protection Fund was announced in 2020 by the Deputy Prime Minister and Minister for Finance Heng Swee Keat. The fund will be topped up whenever the fiscal situation allows.

Singapore is exploring the options of building polders, dykes and seawalls to manage sea level rise. One possibility is a series of offshore islands connected with barrages that would not only protect the coast but provide new water reservoirs and recreational spaces.²⁶⁴ Hopefully, these measures will be implemented with a strong regime of public engagement to consider human communities, biodiversity, heritage and local businesses. Beyond “hard” infrastructure solutions, nature-based solutions can also be considered:

We will preserve our green carbon sinks and identify nature-based solutions. For example, planting mangroves can both stabilise our coastline by reducing erosion, while preserving our green lungs and supporting biodiversity.²⁶⁵

—Masagos Zulkifli, Minister for the Environment and Water Resources (2015–20)



51. The HDB is experimenting with polder technologies more suitable for the Singapore context.

Climate Proofing the City Against Heat

The urban heat island effect due to climate change can affect thermal comfort for residents. The HDB Green Towns Programme is an ambitious 10-year plan to bring sustainable living to all existing HDB towns, with large-scale implementation of green features. The programme will focus on three areas: reducing energy consumption, recycling rainwater and cooling HDB towns. The HDB will also introduce greenery to the top decks of existing multi-storey carparks for urban farming, skyrise greenery or community gardening. Cool coatings can be applied on rooftops, building facades and pavements to reflect the heat of the sun. Cool-coated surfaces absorb less heat during the day and emit less heat at night, therefore leading to a cooler environment. The HDB will also introduce urban water harvesting system to HDB towns to reduce the use of potable water for common area washing and irrigation, and mitigate flood risk.



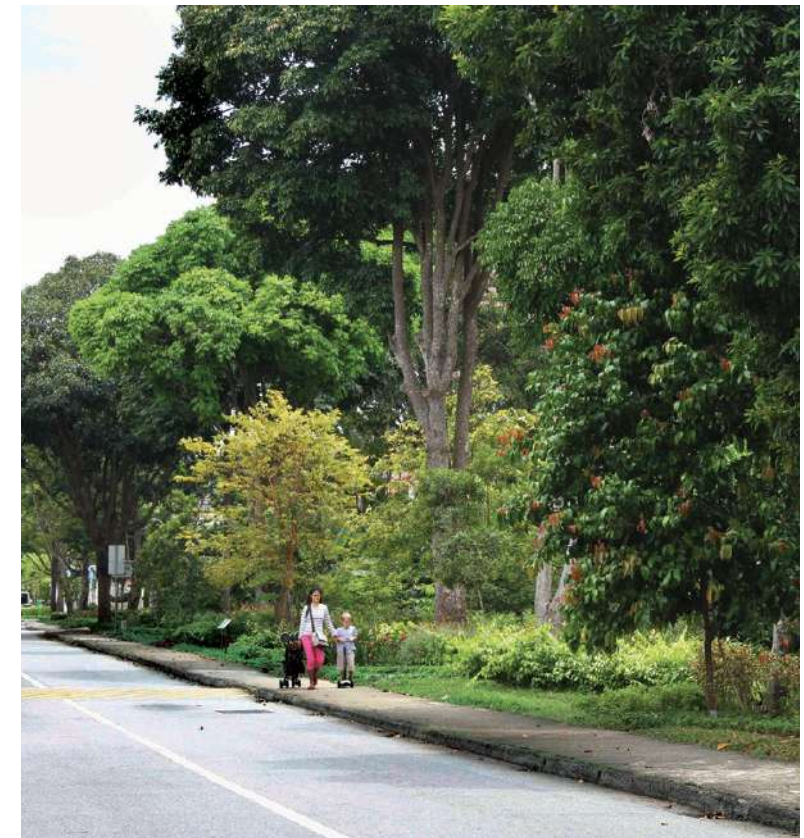
52. The HDB Green Towns Programme aims to reduce energy consumption, recycle rainwater and cool the HDB towns.

In 2020, Singapore launched its intention to transform to a City in Nature.²⁶⁶ This builds on previous efforts to achieve a biophilic City in a Garden. The aim is to further integrate nature into the city, thereby mitigating the impact of climate change. The transformation will be guided by four key strategies: 1) extending the nature park network; 2) intensifying nature in gardens and parks; 3) restoring nature into the built environment; and 4) strengthening connectivity between green spaces.

Under these strategies, the NParks will extend the nature park network by 200 ha (2 km²); intensify nature by recreating the look and feel of 140 ha (1.4 km²) of Singapore's natural forests; establish 30 therapeutic gardens

and conserve more than 70 native plant and animal species. It will also restore nature by developing 300 km of Nature Ways with multi-tiered planting along roadsides; integrate 200 ha (2 km²) of skyrise greenery by 2030, up from the current 120 ha (1.2 km²); and extend the Park Connector Network by 500 km (up from 340 km today). Every household will be within a 10-minute walk of a park or garden.²⁶⁷

Furthermore, Singapore has also committed to plant a million trees by 2030. More than a hundred groups, as well as various companies, such as Keppel Corporation, JTC Corporation, Oversea-Chinese Banking Corporation Limited and others, have pledged their support to plant trees or donate to the cause.²⁶⁸ The National University of Singapore (NUS) alone has pledged to plant 80,000 trees over the next 10 years.²⁶⁹ The new Centre for Nature-based Climate Solutions, housed in the NUS, has also been set up by the university to maximise carbon sequestration through cost effective nature-based solutions.



53. Nature Ways enhance the streetscape while allowing biodiversity to flourish amidst the urban landscape.

Ensuring Availability of Food and Water

As of 2017, Singaporeans consume approximately 143 litres of water per person per day.²⁷⁰ Singapore targets to reduce this to 130 litres by 2030, through smart meters, water-saving appliances and education. Further research and development (R&D) will be conducted to reduce the amount of energy required for recycling or desalination of water. One example is learning from biomimicry, which involves the development of biomimetic membranes from aquaporins and transmembrane proteins found in living organisms.

As over 90% of Singapore's food is currently imported, it is vulnerable to food disruptions. The Singapore Food Agency (SFA) has been preparing for the possibility of food supply disruptions, whether due to global pandemics, climate change or geopolitical developments. While the COVID-19 pandemic had highlighted some vulnerabilities in Singapore's systems in food availability, supply chains and resilience—some source countries have locked down or banned exports to cater to their domestic needs—the overall impact on Singapore's food import was minimal and supply remained stable. This was in part because of Singapore's focus on managing food supply through diversification of food import sources, supporting Singaporean food-related companies to grow overseas, and increasing local production of food:

Our “30 by 30” goal is ambitious as we are aiming to meet these needs using less than 1% of our land area in Singapore. To achieve this goal, we will have to leverage R&D and new technology to grow more food with less resources and overcome our land constraints by utilising alternative urban farming spaces. If successful, the “30 by 30” goal also means that we will own technologies and unique processes that will become the value-add our companies can bring to growing food overseas.

One critical factor to make this 3 Food Basket strategy work is the role of consumers, who can do their part by supporting local produce. There are in fact many benefits to consuming local produce—it is fresher, easily traceable and safe. As the produce does not need to travel far to reach the consumer, it will also mean a lower carbon footprint to bring food to our tables.²⁷¹

—Masagos Zulkifli, Minister for the Environment
and Water Resources (2015–20)

The SFA has been actively supporting local farmers to achieve the “30 by 30” goal through technology. For example, the S\$63 million Agriculture Productivity Fund (APF) was introduced in 2014 to co-fund high-tech, high-productivity farming systems—up to 70% of the cost, at S\$2 million per project—that can raise local production.²⁷² As of end March 2020, S\$38 million has been committed from the APF to support 110 farms.²⁷³ The need to reinforce local production witnessed a push to achieve “30 by 30” earlier to ensure food resilience. In 2020, the SFA launched a new S\$30 million “30x30 Express” grant for industry players who can expand production of eggs, leafy vegetables and fish within the next two years.²⁷⁴ This new grant will co-fund up to 85% of the qualifying project costs. At the same time, to continue pushing the boundaries of technology into food-related research, including sustainable urban food production, future foods, and food safety science and innovation, S\$144 million of research funding has been made available under the Singapore Food Story R&D Programme.²⁷⁵

To enable local production, the development of farming spaces is crucial. Since 2017, the SFA has been tendering agricultural land to agri-food companies who compete based on technology, productivity and track record. There are also plans to redevelop the larger Lim Chu Kang area, taking into consideration feedback from farmers for centralised facilities and services, to reduce the cost of food production. Additionally, the SFA has been looking to unlock alternative spaces locally, such as vacant interim state properties and rooftops. A tender of nine rooftop spaces on the HDB multi-storey carparks across the island for urban rooftop farming was launched in May 2020.²⁷⁶

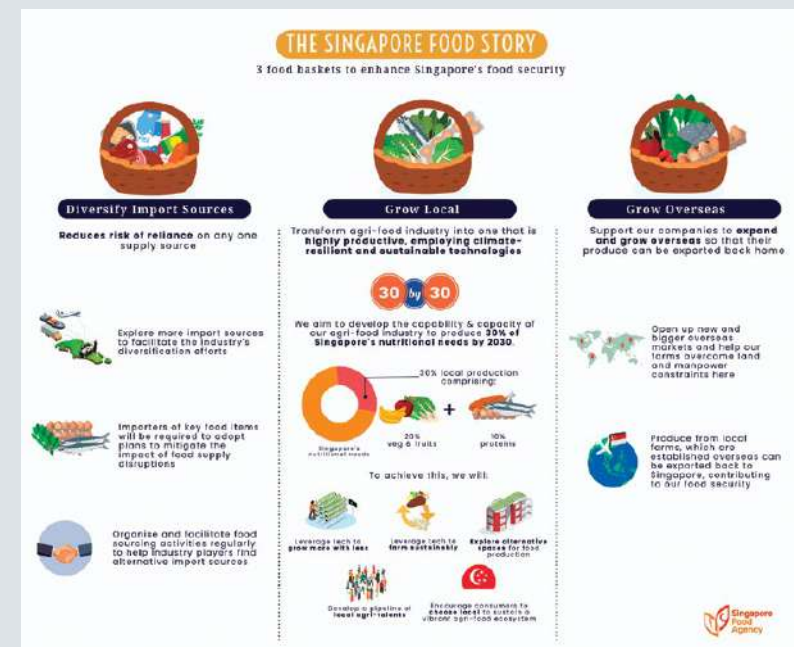
OUR SINGAPORE FOOD STORY: THE 3 FOOD BASKETS

In 2019, the SFA introduced the 3 Food Baskets strategy to bolster Singapore's food resilience. The first strategy—import source diversification—is one of Singapore's main food supply resilience strategy. By diversifying import sources, Singapore avoids being overly reliant on any single source country and spreads the risk of food supply disruption across as many sources as possible. This way, if supply from any source country is disrupted, the impact would be minimised. Having more import sources also enables importers to ramp up supply from other sources when there are supply disruptions. Diversification of imports sources is done by working with importers to organise overseas sourcing trips and business matching sessions. Singapore also works with overseas authorities to accredit as many farms and countries to export to Singapore as possible, as long as food safety requirements are met.

Since early 2019, Singapore has required importers of key food items to adopt plans, including preventive strategies, to mitigate the impact of potential supply disruptions. For example, egg importers are required to have business continuity plans to mitigate disruptions. To support this, the SFA has actively accredited new egg sources that meet Singapore's food safety standards. Since December 2018, over 65 additional overseas eggs farms have been accredited. The number of approved countries for eggs has increased from 7 in 2016 to 14 in August 2020.

Second, local production provides a buffer supply in the event of import sources disruption. Singapore-based farms currently produce around a quarter of the necessary egg supply, 14% of leafy vegetables and around 10% of fish supply.²⁷⁷ To reduce the reliance on imports and buffer against the impact of overseas supply disruptions, the “30 by 30” goal for local production was set. The goal is to produce 30% of Singapore's nutritional needs locally by 2030. This is an ambitious goal that required the agri-food industry to transform into one that is highly productive and employs climate-resilient and sustainable technologies to enable Singapore to overcome its land, water, energy and manpower constraints. Singapore envisages farming to become more like manufacturing—where production takes place within a controlled environment with a defined input. The result is an assured and consistent output and a predictable way to address the effects of climate change and extreme weather.

Third, the SFA, together with Enterprise Singapore, supports local companies to expand and grow overseas. These overseas-based Singaporean companies will be able to overcome land and manpower constraints, access new and bigger overseas markets, and export back to Singapore to strengthen food security.



54. The three “food baskets” to safeguard Singapore's food security, one of which entails ramping up local food production.

Adopting Science and Technology in a Time of Dynamic Change

The actions to mitigate and adapt to climate change can be complex and costly. As Singapore races ahead on climate action, it must leverage on learning as a whole to avoid duplication, mismatch and redundancies. The government has thus set up the CGSA to help address this, modelled after the British, Israeli and American systems. Member of the CGSA, Lee Chuan Seng elucidated:

There is a feeling that we have been [doing] so much research, but where is the outcome? Where's the commercialisation? Where's the payback? Where are the overlaps? What are the gaps? Are we spending it in the right way? The best way? Biotech, bio-medical diseases, and climate change...are going to create new environments that behave differently, and our systems that previously performed well now will not. And we still don't know what we don't know. We need to start focusing people's minds to say, "What are the things that would be of concern to us that we don't know?"²⁷⁸

The first step was to understand resources used by each branch and agency of government as Lee added:

We set up a framework to help map out all the Science and Technology (S&T) Plans for the relevant government agencies. The S&T Plans were based on: Are you a smart user? A smart buyer? A smart ecosystem builder? Or are you a smart innovator (producing your own science and technology)? Do you do it big or small?

Once you have all the mapping, you can share best practices across agencies, have centres of excellence for government. We can learn from each other.²⁷⁹

The greatest value in the science advisory committee, as Lee highlighted, is the opportunity to find solutions that solve more than one challenge.

This is something that we need to encourage, the greater interaction between the different sciences and areas of work because that's where the innovation will come. If we just do our own sweet, old things, and stay in our own silos...then there will be no fire.²⁸⁰

Engaging the Community in Building Resilience

Climate action requires a whole-of-society effort. With extreme and unpredictable weather patterns, it is crucial for Singapore to integrate the physical and social infrastructures to afford greater flexibility to the urban system to build resilience towards climate risks.

Communities are being galvanised for action from all sectors, raising awareness and suggesting practicable steps to be more carbon neutral. Multi-sectoral partnerships are crucial to collective action (see Box Story for example). These ensure that the public, private and people sectors cross-pollinate ideas to understand how to tackle climate change together, thereby bringing about resilience. For example, as part of the City in Nature vision, the NParks launched the Gardening with Edibles initiative to motivate households to garden together and bring nature indoors. Free seeds of edible plants were distributed alongside gardening materials to impart knowledge and skills in growing edibles. Gardeners are also encouraged to join the Community in Bloom and allotment gardens to further the gardening movement.

Collaboration across sectors will spur local, citizen-led adaptation that can build community resilience to cope with future challenges. In doing so, it strengthens the partnership between government and the public. It would be a whole-of-society effort—one that combines strategic government-led public policies and infrastructure investments as well as citizen-initiated community-owned programmes and initiatives.



55. Community gardening initiatives strengthen social resilience amongst Singaporeans by encouraging community bonding in growing one's food and bringing people closer to nature for health and well-being.

LEARNING ABOUT RESILIENCE BY DOING

The Cambridge Road neighbourhood, located close to the oldest settled areas in Singapore, is a low-lying area with public and private housing, schools and community amenities. In the past, the area had experienced frequent flooding.

In 2019, the Centre for Liveable Cities (CLC) brought together relevant agencies, community partners and academics to pilot a participatory planning and design process to address climate risk at the neighbourhood. The purpose was to examine how Singaporeans could develop and enhance community resilience to climate risks by fostering stronger social cohesion, a sense of ownership and a level of preparedness.

The Centre, together with agency, research and community partners conducted various means of engagement such as walking conversations, focus group discussions and pop-up booths. Together, they crowd-sourced ideas and potential initiatives. Proposed ideas included increasing greening initiatives in the neighbourhood to enhance thermal comfort and raise awareness of the impact of climate change through conversations.

The conversations were not only about involving residents as part of the process, but to encourage self-organisation. A group of 25 local champions (“Our Green Pek Kio”) took the lead to rally community effort to build a more resilient Cambridge Road. People began joining the group through existing social networks and by word-of-mouth. Two local community partners, the Youth Executive Committee and an art gallery joined the group to play their part for the community. Rexlee, a local champion juggling a part-time job at a nearby hospital and a mother of two, summarised:

We want to get them [the Youth Executive Committee members] involved in planning because it is for the community. I think what we really want is to do something for the community by residents like ourselves and hopefully over time we can get more people to join.²⁸¹

Residents have a deeper understanding of local conditions, existing resources and place-based assets, which fosters a sense of commitment and ownership amongst the community. Residents have also recognised the value of building social capital and strong community network to create an environment of trust and understanding. The process hopes to

encourage mutual assistance and preparedness, especially in time of need, a sentiment shared by Sim, a resident of Cambridge Road:

As neighbours, we should be closer than just friends because our relatives may be living far away. The immediate help is actually from neighbours and the community.²⁸²

Through weekly meetings, the local champions discussed the visions and key outcomes of the projects. Simultaneously, the Centre has partnered agencies to aid. For a start, the NParks, PUB and People’s Association have been active in providing guidance on the feasibility of proposed blue-green efforts. Through technical consultations, the community understood the implementation and long-term maintenance considerations.

Through the iterative process, residents understood the value of local adaptations and appreciate how community efforts complement nationwide strategies to reduce the perceived gap between community actions and climate risks. Policymakers also understood how communities prioritise problems and solutions. Involving communities as collaborators therefore allowed the forging and strengthening of community resilience.

The community has strengthened social ties through the process. During the COVID-19 pandemic, the community took their consultations online to sustain collaborative efforts to address environmental issues in their neighbourhood.



56. The Centre organised community engagement events to not only raise awareness to spur local climate action, but it also walked the ground with residents to understand the impact.

Individual and Collective Action Needed for Climate Action



57. Climate action events will become more frequent as more residents' concerns are raised.²⁸³

The climate crisis, compounded by the global pandemic, will be the defining challenge of the 21st century. The need to build resilience, especially for the most vulnerable of our communities, in the face of these current and future challenges cannot be understated. We are the first generation to recognise the full impact of climate change, and the last capable of doing something to prevent it. That is our responsibility and our great opportunity.²⁸⁴

—Mark Watts, Executive Director, C40 Cities (2013–Present)

Over the decades, it is individuals in the public, private and people spheres who have taken courageous decisions that set Singapore on a socially equitable, environmentally sustainable and economically competitive path. There were naysayers, deniers and sceptics, but over time, the climate agenda has taken root in Singapore due to visionaries, the environmentally conscious and pragmatists.

When the Prime Minister made that statement about climate change at the National Day Rally last year [2019], it was for me a great source of satisfaction, personally and professionally. It was also to some extent a vindication that what we were doing was the right thing.²⁸⁵

—Ambassador Burhan Gafoor,
Chief Negotiator for Climate Change (2010–14)

This is an encouraging lesson that civil servants can take to heart. Across many government agencies, both leaders in high positions and passionate officers persisted and gradually gained ground. As more and more individuals came to share the same principles and vision, they created conditions whereby Singapore was able to set up the required governance structures, policies, scientific modelling capabilities, and action in every relevant sphere, joining in global efforts to mitigate and adapt to climate change.

A growing number of pro-environmental voices have emerged among private firms and within the civil sector. And now the youth, who organised the Singapore Climate Rally in 2019, are also expressing their concerns. Minister Zulkifli reminds us:

Every effort counts. Though climate change cannot be solved by a single individual, do not discount the cumulative impact of small actions.²⁸⁶

Cities at the Forefront of Global Climate Action

"No single country will be able to address the challenges of climate change on its own. To effectively address a global problem like climate change and its impact, we need a strong, collective global response."²⁸⁷

—Masagos Zulkifli, Minister for the Environment
and Water Resources (2015–20)

According to the United Nations Environment Programme, cities are responsible for three-quarters of global energy consumption and two-thirds of GHG emissions.²⁸⁸ Therefore, urban development must next be transformed into low carbon development.

We used to think of city-state status as a congenital defect. Now we are realising that this is not so. The solutions lie in cities. Strategies that cities formulate will ultimately have an impact globally. As more than half of humanity lives in cities, what we do in cities matters.

Singapore demonstrates that dense, well-planned cities that take into account externalities, and are organised on economically sensible grounds...are the solution. We can be a useful living laboratory, a role model, for what a green, living, sustainable future for all of humanity could look like.²⁸⁹

—Dr Vivian Balakrishnan, Minister for Foreign Affairs (2015–Present) and Minister for the Environment and Water Resources (2011–15)

Successful implementation of ambitious initiatives at home will also transform the economy and propel Singapore to become a leader in low-carbon development. As the UNFCCC Executive Secretary Patricia Espinosa shares, “Singapore’s experience in managing its economy and emissions, despite its limited natural resources, [is] an example to other nations.”²⁹⁰

Growing Expectations from Future Generations

Support at home for climate action continues to grow as Dr Balakrishnan shared:

When we first dropped hints that Prime Minister Lee would talk about climate change at the National Day Rally, some criticised and asked why we were looking at the long term. He delivered the speech anyway, especially to reach out to the younger generation, asking Singaporeans to do more, not less.²⁹¹

Ambassador Gafoor added:

Young Singaporeans expect the government and the public service to be ambitious and proactive in dealing with climate change. I think many young people are seized with this issue. The positive reaction after the 2019 National Day Rally is a recognition that this is an important issue for Singaporeans.²⁹²

Business as usual cannot go on. Governments and leaders in every nation have a duty to respond. At the Intergovernmental Panel on Climate Change Scoping Meeting for the Sixth Assessment Report Synthesis Report Opening Ceremony hosted in Singapore on 21 October 2019, then Minister for the Environment and Water Resources Masagos Zulkifli cautioned that the world must live up to its responsibilities and take decisive action as “young people are rightly concerned about climate change and how this impacts their future. We have to give them the confidence that we are taking their concerns seriously. It is our responsibility to work together with them to address this challenge.”²⁹³



58. More extreme weather events are expected as a result of climate change.

POST-SCRIPT

It is prescient of the Centre for Liveable Cities to publish this study amid the COVID-19 pandemic, which usefully reminds readers of the long-term challenge of climate change. COVID-19 is a crisis of a generation, but climate change, if not tackled decisively, could well become the crisis of many generations.

The responsibility is on all of us to look beyond the immediate COVID-19 crisis and prepare for the long-term challenges ahead, including climate change. This has been Singapore's approach to development—to look long term and plan ahead. As a small city-state that is vulnerable to the impact of climate change, notably sea level rise, we take the issue of climate change very seriously. The Chinese word for “crisis” contains both “danger” and “opportunity”. I believe COVID-19 provides useful lessons for our fight against climate change.

First, we need strong collective action. COVID-19 has brought many activities to a standstill, resulting in a reduction in carbon emissions. A pandemic is not the best answer to the climate crisis, but the global reduction in emissions has shown the power of collective action. If we want to effectively deal with a global problem like climate change, we need a strong global response. This is why Singapore has actively and consistently advocated a multilateral rules-based approach to addressing climate change. Alone, Singapore will not be able to solve the climate problem. But by collectively working with others, we stand a better chance of addressing climate change. We have therefore decided, despite the uncertainties presented by the COVID-19 situation, to submit our enhanced climate pledge and long-term low emissions development strategy to the United Nations Framework Convention on Climate Change in March 2020. We did this as we wanted to send a strong signal that Singapore remains fully committed to tackling climate change. These strategies demonstrate our commitment to support global climate action and move towards a low-carbon and climate resilient future.

Second, COVID-19 has underscored the importance of planning ahead. Singapore was better prepared for COVID-19 than we were for SARS in 2003 as we had learnt from our SARS experience and planned for potential virus outbreaks. Likewise, Singapore has taken early action to address climate change. We formed an Inter-Ministerial Committee on Climate Change to provide a coordinated and integrated whole-of-government response to climate change. Singapore is the first country in Southeast Asia to implement a carbon tax. Given the potential risks of climate change, we are taking early action to build up our climate science capabilities and

strengthen our climate resilience defences. This forward-looking approach is not only preparing us to deal with the risks of climate change, it has also equipped us to deal with unexpected challenges. For example, when international food supply chains were disrupted during the COVID-19 outbreak, we were already putting in place measures to strengthen our food security as part of our goal to produce 30% of our nutritional needs locally by 2030.

Third, technology and innovative solutions are vital. Just as the international community is working hard to find a vaccine for COVID-19, so too must we continue to find low-emissions solutions. Unlike other larger countries, Singapore, as a small and highly urbanised city state, does not have the same opportunities to deploy renewable energy at scale. However, we have never let our constraints inhibit our will to act. The Singapore story is about turning our limitations into strategic opportunities. This is why we are investing in low-carbon solutions to drive the decarbonisation of our electricity grid and industrial processes, and are encouraging research and development in promising new industries, such as agri-tech. The Singapore government recently announced that it will set aside over S\$20 billion to support basic and applied research in high impact areas, notably climate change, to pioneer solutions for some of the world's major challenges. In addition, to transform Singapore in a resource and carbon constrained world, we are adopting a circular economy approach so that we remain sustainable and competitive. We have transformed incinerated bottom ash into construction material called NEWSand. We need to prepare for such shifts and be ready to seize opportunities for growth as we transition to a low-carbon climate resilient future.

Finally, everyone must play their part. To contain COVID-19, everyone must exercise social responsibility. Similarly, to tackle climate change, we also need everyone to work together. No action is too small. Every small action counts.

Like the COVID-19 pandemic, climate change will bring about unprecedented changes to the world. With bold long-term plans and decisive action, we can avert a crisis and make this world a better place for future generations.

Albert Chua

Permanent Secretary
Ministry of Sustainability and the Environment

TIMELINE

ENVIRONMENTAL, SUSTAINABILITY AND CLIMATE CHANGE MILESTONES

1951

National Reserves Ordinance enacted to protect primary forests and conserve and protect biodiversity.

1967

Garden City campaign launched with intensive tree-planting programme.

1970

Garden City Action Committee established to oversee national greening.

Anti-Pollution Unit formed to control industrial pollution.

1971

Annual Tree Planting Day launched to involve Singaporeans to maintain the Garden City movement.

Clean Air Act passed to manage enforcement issues and stipulate allowable emission standards.

1972

Ministry of the Environment formed to address air and water pollution, environmental health and waste.

First Water Master Plan completed to develop water supply infrastructure and policies. Drainage Master Plan implemented to alleviate flood risk.

1975

Parks and Trees Act enacted to set aside spaces for trees and greenery.

1977

Singapore River clean-up started to clean the central business district and waterway.

1979

First waste-to-energy incineration facility—the Ulu Pandan Incineration Plant—commissioned.

Energy Conservation Standards in Building Code Regulations incorporated to improve energy efficiency in buildings.

1989

Singapore became a party to the Montreal Protocol.

1990

First Assessment Report of the Intergovernmental Panel on Climate Change launched.

1991

Vehicular exhaust emissions standards introduced for diesel vehicles and motorcycles.

1992

First Singapore Green Plan launched to guide Singapore's sustainability efforts through sound environmental management.

Singapore co-chaired the Preparatory Committee (start 1990) and actively participated at the UN Conference on Environment and Development (Earth Summit) in Rio de Janeiro.

Senoko Power Station, the largest power station switched to natural gas.

1994

Vehicular exhaust emissions standards introduced for petrol vehicles.

1995

Liberalisation of the energy sector.

1996

Accelerated Depreciation Allowance for Energy Efficient Equipment Technology scheme introduced.

Voluntary Green Label certification encouraged for manufacturers.

National Parks Board formed.

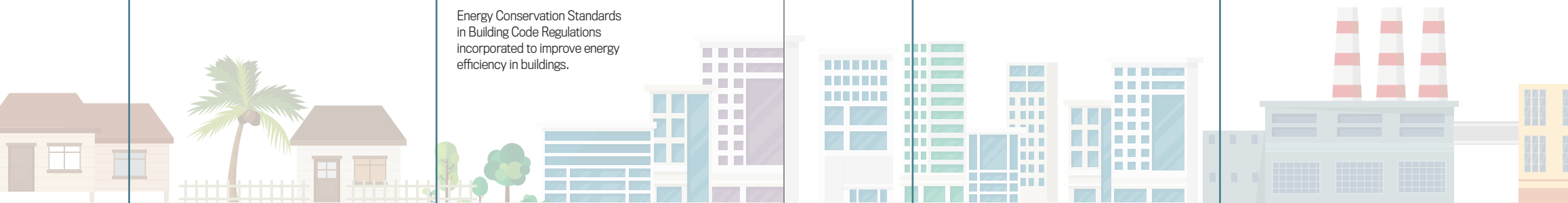
1997

Adoption of combined cycle gas turbine plant, which is more efficient than conventional gas turbines.

1998

Transition towards the City in a Garden vision to bring people closer to greenery and integrate it closer with the urban environment.

Leaded petrol phased out.



1999

Pulau Semakau offshore landfill commissioned.

2000

Initial National Communication submitted to the United Nations Framework Convention on Climate Change.

2001

National Recycling Programme launched.

Energy Market Authority formed; Energy Market Company appointed as a regulator.

Green Vehicle Rebate Scheme launched.

2002

Singapore Green Plan 2012 released.

2003

NEWater (reclaimed water programme) launched.

2005

First water desalination plant operational, "4th tap" completed.

Green Mark Incentive Scheme launched for green buildings.

Ultra-low sulphur diesel (<0.005%) introduced.

2006

Singapore acceded to the Kyoto Protocol.

First Green Building Masterplan launched.

ABC Waters Programme launched.

2007

Inter-Ministerial Committee for Climate Change formed to coordinate whole-of-government climate change efforts.

First nationwide study on the long-term impact of climate change commissioned.

Energy Efficiency Master Plan launched and Energy Efficiency Programme Office established.

2008

Inter-Ministerial Committee for Sustainable Development formed to coordinate national strategy for sustainable development.

First National Climate Change Strategy launched.

Mandatory Energy Labelling Scheme for air-conditioners and refrigerators introduced and subsequently expanded to include clothes dryers (2009), televisions (2014) and lamps (2016).

2009

Second Green Building Masterplan released.

Sustainable Singapore Blueprint released.

Singapore pledged to reduce carbon emissions by 16% from business-as-usual levels by 2020.

Landscaping Urban Spaces and High-Rises (LUSH) programme launched; further updates were made in LUSH 2.0 (2014) and LUSH 3.0 (2017) to include more types of feature enhancement such as rooftop urban farming and solar panels.

2010

National Climate Change Secretariat formed under the Prime Minister's Office.

Inter-Ministerial Committee for Food Security formed.

2011

Drainage code updated, requiring additional 1 m of clearance.

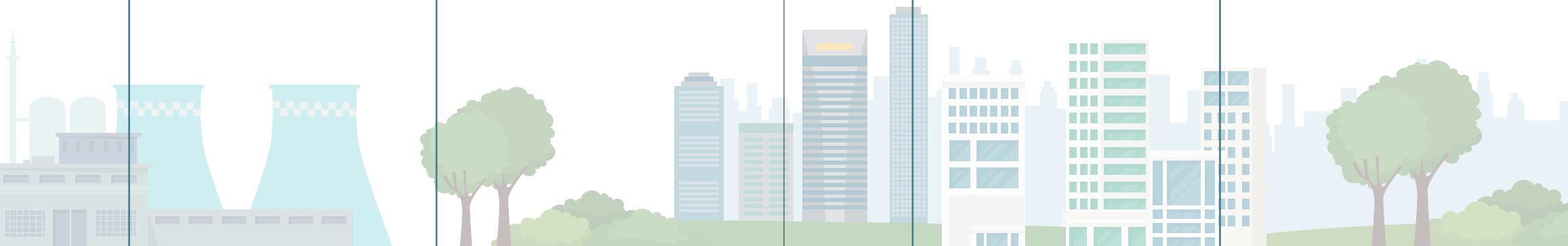
2012

Energy Conservation Act introduced to mandate energy efficiency.

National Climate Change Strategy 2012 launched.

Food Security Roadmap launched.

Singapore joined the C40 Cities Climate Leadership Group as an observer city.



2013

Centre for Climate Research Singapore set up.

Housing and Development Board (HDB) Biophilic Town Framework released.

Land Transport Master Plan 2013 released.

Carbon Emissions-based Vehicle Scheme (CEVS) and Fuel Economy Labelling Scheme announced.

2014

Third Green Building Masterplan released, with revised Green Mark scheme.

Launch of the SolarNova programme to adopt solar energy as a viable alternative source of energy.

Transboundary Haze Pollution Act enacted.

Introduction of domestic measurement, reporting and verification of mitigation actions as part of a whole-of-government effort.

2015

Singapore pledged to reduce emissions intensity by 36% from 2005 levels by 2030.

2016

Singapore ratified the Paris Agreement.

Water Master Plan 2016 released.

Climate Action Plan 2016 launched.

2017

Launch of the Public Sector Sustainability Plan 2017-2020.

2018

Flood-prone areas reduced to 30 ha (0.3 km²) from more than 3,200 ha (32 km²) in the 1970s.

Designated as Year of Climate Action to rally a whole-of-society effort for a sustainable future.

Vehicular Emissions Scheme launched to replace the CEVS.

2019

Prime Minister Lee Hsien Loong highlighted climate change as an existential threat for Singapore at the National Day Rally.

The joint warmest year on record for Singapore, with a mean annual temperature of 28.4°C.

Carbon tax introduced at S\$5 per tonne of carbon dioxide-equivalent for industrial facilities.

Declaration of the Year Towards Zero Waste, with the aim to reduce landfill waste by 30% by 2030.

Launch of the "Four Switches" policy for diversification of energy sources to meet long-term energy demands.

Singapore Food Agency took over roles relating to food. Launched policy to increase local food production to 30% by 2030.

2020

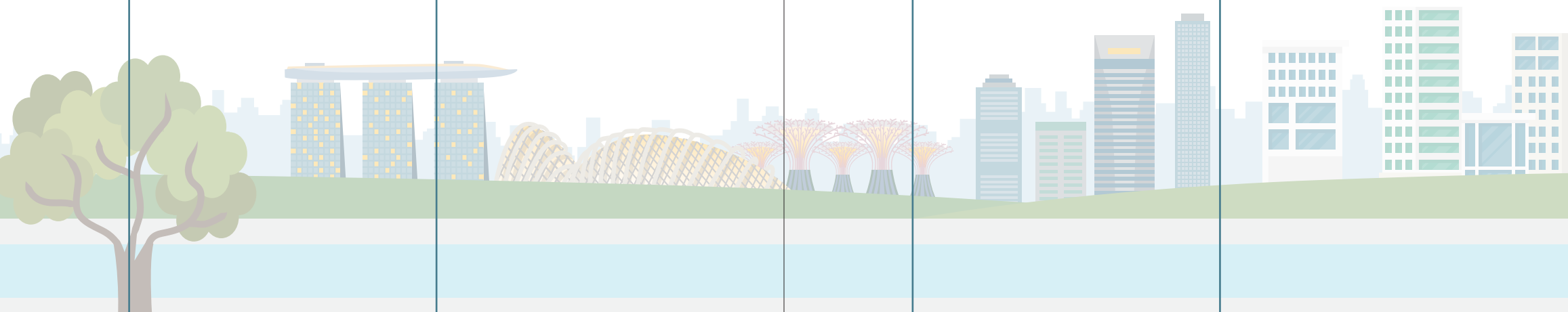
Singapore committed to an absolute peak in the Long-Term Low-Emissions Development Strategy of 65 million tonnes of CO₂ by 2030 and halving the amount by 2050.

A re-branded Ministry of Sustainability and the Environment to reflect sustainability as an important national agenda.

HDB Green Towns Programme launched to reduce energy consumption in public housing by 15% by 2030.

Transition towards a City in Nature, to better integrate natural and built environments. Enhanced greening effort was also announced with the One Million Trees movement to plant 1 million trees by 2030.

A S\$5 billion Coastal and Flood Protection Fund was set up to address the threat of rising sea levels.



APPENDIX

Complete List of Documents Relevant to Climate Change

Major documents

Document	Details	Year of Publication
Charting Singapore's Low Carbon and Resilient Future https://www.nccs.gov.sg/docs/default-source/publications/nccsleeds.pdf	Singapore submitted its Long-Term Low-Emissions Development Strategy to the UNFCCC, aiming to achieve a target of reducing total emissions to 33 MtCO ₂ e by 2050.	2020
Singapore's update of its first Nationally Determined Contribution (NDC) https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Singapore%20First/Singapore's%20Update%20of%201st%20NDC.pdf	Singapore's enhanced NDC document updates Singapore's climate pledge submitted in July 2015 under the Paris Agreement.	2020
Zero Waste Masterplan https://www.towardszerowaste.gov.sg/images/zero-waste-masterplan.pdf	The Zero Waste Masterplan sets a new waste reduction target for Singapore—to reduce the waste sent to Semakau Landfill by 30% by 2030. This will help to extend Semakau Landfill's lifespan beyond 2035, when it is estimated to reach capacity.	2019
Singapore's Fourth National Communication and Third Biennial Update Report https://www.nccs.gov.sg/docs/default-source/default-document-library/singapore-s-fourth-national-communication-and-third-biennial-update-repo.pdf	Singapore's communication to the UNFCCC on Singapore's plans to reduce emissions intensity by 36% from 2005 levels by 2030.	2018
Public Sector Sustainability Plan 2017–2020 https://www.mse.gov.sg/docs/default-source/default-document-library/grab-our-research/Public_Sector_Sustainability_Plan_2017-2020.pdf	The Public Sector Sustainability Plan 2017–2020 charts the Singapore government's path towards achieving environmental sustainability, as part of the nationwide Sustainable Singapore Movement.	2017

Document	Details	Year of Publication
Our Water, Our Future https://www.pub.gov.sg/Documents/PUBOurWaterOurFuture.pdf	This publication sets out Singapore's water strategies and plans that will be undertaken in the next 50 years and illustrates how Singapore plans to expand its capacities on water supply, used water management and drainage against the challenges of urbanisation, climate change and the rising cost of energy.	2016 (updated 2017)
Singapore's Climate Action Plan: Take Action Today, For a Carbon-Efficient Singapore https://sustainabledevelopment.un.org/content/documents/1545Climate_Action_Plan_Publication_Part_1.pdf	The Climate Action Plan contains Singapore's strategies for energy and carbon efficiency, deploying low-carbon technology and encouraging collective climate action to meet Singapore's 2030 pledge.	2016
Sustainable Singapore Blueprint https://www.nccs.gov.sg/docs/default-source/default-document-library/sustainable-singapore-blueprint-2015.pdf	The Sustainable Singapore Blueprint outlines Singapore's vision and plans for a more liveable and sustainable Singapore to support the diverse needs and growing aspirations of Singaporeans through various initiatives.	2015
National Climate Change Strategy 2012 https://www.nccs.gov.sg/docs/default-source/publications/national-climate-change-strategy.pdf	The National Climate Change Strategy 2012 outlines Singapore's plans to address climate change through a whole-of-nation approach. The key elements of Singapore's climate strategy include reducing emissions across sectors, building capabilities to adapt to the impact of climate change, harnessing green growth opportunities as well as forging partnerships on climate change action.	2012

Other documents

- Air Con System Efficiency Primer (2011) <https://www.nccs.gov.sg/docs/default-source/default-document-library/air-con-system-efficiency-primer-a-summary.pdf>
- Biorenewables Technology Primer (2011) <https://www.nccs.gov.sg/docs/default-source/default-document-library/biorenewables-technology-primer-a-summary.pdf>
- Carbon Capture and Storage/Utilisation Technology Primer (2011) <https://www.nccs.gov.sg/docs/default-source/default-document-library/carbon-capture-and-storage-utilisation-technology-primer-a-summary.pdf>
- Energy Storage Technology Primer (2011) <https://www.nccs.gov.sg/docs/default-source/default-document-library/energy-storage-technology-primer-a-summary.pdf>
- Smart Grid Technology Primer (2011) <https://www.nccs.gov.sg/docs/default-source/default-document-library/smart-grid-technology-primer-a-summary.pdf>
- Solar Energy Technology Primer (2011) <https://www.nccs.gov.sg/docs/default-source/default-document-library/solar-energy-technology-primer-a-summary.pdf>
- Green Data Centre Technology Prime (2011) <https://www.nccs.gov.sg/docs/default-source/default-document-library/green-data-centre-technology-primer-a-summary.pdf>
- Carbon Capture and Storage/Utilisation Roadmap (2014) <https://www.nccs.gov.sg/docs/default-source/default-document-library/carbon-capture-and-storage-utilisation-singapore-perspectives.pdf>
- Solar Photovoltaic Roadmap (2014) <https://www.nccs.gov.sg/docs/default-source/default-document-library/Solar%20PV%20Roadmap%20for%20Singapore%202020.pdf>
- Green Data Centre Roadmap (2014) <https://www.nccs.gov.sg/docs/default-source/default-document-library/green-data-centre-technology-roadmap.pdf>
- Building Energy Efficiency Roadmap (2014) <https://www.nccs.gov.sg/docs/default-source/default-document-library/building-energy-efficiency-r-and-d-roadmap.pdf>
- Industry Energy Efficiency Roadmap (2014) <https://www.nccs.gov.sg/docs/default-source/default-document-library/industry-energy-efficiency-technology-roadmap.pdf>
- Waste Management Roadmap (2016) <https://www.nccs.gov.sg/docs/default-source/default-document-library/solid-waste-management-technology-roadmap.pdf>
- E-Mobility Roadmap (2016) <https://www.nccs.gov.sg/docs/default-source/default-document-library/e-mobility-technology-roadmap.pdf>

ENDNOTES

- 1 Meteorological Service Singapore, "2019 Climate and Weather: The Year in Review", <http://www.weather.gov.sg/wp-content/uploads/2020/01/The-Year-In-Review-2019.pdf>
- 2 Lee Kuan Yew, "The World: More Globalized, More Troubled", *Forbes*, 28 September 2007, <https://www.forbes.com/forbes/2007/1015/027.html#4fd74b01d340>
- 3 World Meteorological Organization, "WMO Climate Statement: Past 4 Years Warmest On Record", 29 November 2018, <https://public.wmo.int/en/media/press-release/wmo-climate-statement-past-4-years-warmest-record>
- 4 World Economic Forum, "The Global Risk Report 2019", 15 January 2019, <https://www.weforum.org/reports/the-global-risks-report-2019>
- 5 Prime Minister's Office Singapore, "Speech by Senior Minister and Coordinating Minister for National Security, Teo Chee Hean at the 'Shell Powering Progress Together' Forum on 4 July 2019", <https://www.pmo.gov.sg/Newsroom/SM-Teo-Chee-Hean-Shell-Powering-Progress-Together-Forum>
- 6 Prime Minister's Office Singapore, "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean at the PMO Committee of Supply 2020 on 'A Low-Carbon and Climate Resilient Singapore' on 28 February 2020", <https://www.pmo.gov.sg/Newsroom/Speech-by-SM-Teo-Chee-Hean-at-the-PMO-Committee-of-Supply-2020>
- 7 Mark Stoop, "Singapore's Skyline", digital image, Unsplash, 21 July 2020, accessed 14 September 2020, https://unsplash.com/photos/As_WAg_6BPg
- 8 Prime Minister's Office Singapore, "National Day Rally 2019", 18 August 2019, <https://www.pmo.gov.sg/Newsroom/National-Day-Rally-2019>
- 9 Meteorological Service Singapore, Centre for Climate Research Singapore, "Annual Climate Assessment Report 2019", 2019, 20, <http://www.weather.gov.sg/wp-content/uploads/2020/03/Annual-Climate-Assessment-Report-2019.pdf>
- 10 National Climate Change Secretariat, "Impacts Of Climate Change In Singapore", <https://www.nccs.gov.sg/singapores-climate-action/impact-of-climate-change-in-singapore/>
- 11 National Climate Change Secretariat, *National Climate Change Strategy 2012* (Singapore: National Climate Change Secretariat, 2012), 36, <http://www.nccs.gov.sg/docs/default-source/default-document-library/national-climate-change-strategy.pdf>
- 12 Stephen P. Leatherman, Keqi Zhang and Bruce C. Douglas, "Sea Level Rise Shown to Drive Coastal Erosion", *EOS* 81.6 (2000): 55-7, <http://onlinelibrary.wiley.com/doi/10.1029/00E000034/pdf>
- 13 Data is based on Singapore's main climate station. A climate station monitors the climate over a long-term period to provide data that enables detection of climate change signals at the national level and should minimally have 30 years of rainfall and temperature data. Meteorological Service Singapore, "Climate of Singapore", <http://www.weather.gov.sg/climate-climate-of-singapore/>
- 14 A day is considered to have "rained" if total rainfall for that day is 0.2 mm or more.
- 15 Large storms are rainfall events with total rainfall exceeding 70 mm.
- 16 PUB, Singapore's National Water Agency, *Managing Urban Runoff—Drainage Handbook, 1st Ed* (Singapore: PUB, Singapore's National Water Agency, 2013), 9, <https://www.pub.gov.sg/Documents/managingUrbanRunoff.pdf>
- 17 National Climate Change Secretariat, "Impacts Of Climate Change In Singapore".
- 18 PUB, Singapore's National Water Agency, "Frequently Asked Questions: Flash Floods", 2018, https://www.pub.gov.sg/Documents/Flash_Floods_FAQs.pdf
- 19 Winston T.L. Chow, Brendan D. Cheong and Beatrice H. Ho, "A Multimethod Approach towards Assessing Urban Flood Patterns and Its Associated Vulnerabilities in Singapore", *Advances in Meteorology*, 2016, 3, <http://dx.doi.org/10.1155/2016/7159132>
- 20 PUB, Singapore's National Water Agency, *Report on Key Conclusions and Recommendations of the Expert Panel on Drainage Design and Flood Protection Measures* (Singapore: PUB, Singapore's National Water Agency, 2012), 4, <https://www.pub.gov.sg/Documents/fullReport.pdf>
- 21 PUB, Singapore's National Water Agency, *PUB Annual Report 2018/2019* (Singapore: PUB, Singapore's National Water Agency, 2018), 22, <https://www.pub.gov.sg/Documents/annualreport2018.pdf>
- 22 Xin Li, Wang Xuan and Vladan Babovic, "Analysis of Variability and Trends of Precipitation Extremes in Singapore During 1980-2013", *International Journal of Climatology* 38.1 (2018): 125-41, <https://doi.org/10.1002/joc.5165>
- 23 Ministry of Sustainability and the Environment, Let's Game Change Climate Change, "Climate Change is Here. It's Happening", <https://www.climategamechanger.sg/2020/01/08/impacts-of-climate-change-in-singapore/>
- 24 Meteorological Service Singapore, "Climate and Weather: The Year in Review", Meteorological Service Singapore, 16 January 2020, 3, <http://www.weather.gov.sg/wp-content/uploads/2020/01/The-Year-In-Review-2019.pdf>
- 25 Meteorological Service Singapore, "Annual Climate Assessment Report 2019".
- 26 Ibid.
- 27 Centre for Climate Research Singapore, *Singapore's Second National Climate Change Study—Phase 1* (Singapore: Centre for Climate Research Singapore, 2015), Chapter 5, 44, https://ccrs.weather.gov.sg/wp-content/uploads/2015/07/V2_Ch5_Climate_Change_Projections.pdf
- 28 The urban heat island effect refers to the phenomenon where an urban area is warmer than its surrounding rural areas and is defined as the temperature difference between an urban-setting locality and a rural reference point.
- 29 National Climate Change Secretariat, "Impacts Of Climate Change In Singapore".
- 30 Lee Kuan Yew, *From Third World to First: The Singapore Story: 1965-2000, Memoirs of Lee Kuan Yew Vol. 2* (Singapore: Marshall Cavendish, 2012), 200.
- 31 John Keung, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 25 November 2019, transcript, accession number CLC/056/2019/002.
- 32 Loh Ah Tuan, Email correspondence, 16 April 2020.
- 33 *The Straits Times*, "Spore to Become Beautiful, Clean City Within Three Years", *The Straits Times*, 12 May 1967, <https://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19670512-1.2.20>
- 34 National Parks Board, "Mission and History", <https://www.nparks.gov.sg/about-us/mission-and-history>
- 35 Ibid.
- 36 Kenneth Er, "Growing a Biophilic City in a Garden", Civil Service College Singapore, 5 July 2018, <https://www.csc.gov.sg/articles/growing-a-biophilic-city-in-a-garden>
- 37 Since 2000, the JTC has become the JTC Corporation.
- 38 Stephen Yeh, "The Idea of The Garden City", in *The Management of Success: The Moulding of Modern Singapore*, edited by Kernal Singh Sandhu and Paul Wheatly (Singapore: Institute of Southeast Asian Studies, 1989), 813-32.
- 39 *The Straits Times*, "Tree-Planting Day to Keep the City Clean, Green", *The Straits Times*, 16 October 1971, <http://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19711016-1.2.123>
- 40 David Ayres, "Fullerton Road", digital image, Flickr, 1967, accessed 4 September 2020, <https://www.flickr.com/photos/argentem/34003572952/>
- 41 Compared to pre-colonial times. Richard T. Corlett, "The Ecological Transformation of Singapore, 1819-1990", *Journal of Biogeography* 19.4 (1992): 411-20, <https://www.jstor.org/stable/2845569>
- 42 Biblioasia, "When Tigers Used to Roam: Nature & Environment in Singapore", *Biblioasia*, 2019.
- 43 Loh Ah Tuan, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 11 November 2019, transcript, accession number CLC/056/2019/001.
- 44 Mr Loh was involved in environmental planning, pollution control, solid waste and wastewater management and environmental public health since 1982.

- ⁴⁵ Joseph Hui, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 28 November 2019, transcript, accession number CLC/056/2019/003.
- ⁴⁶ In 1983, the APU was transferred from the PMO to ENV. The Water Department and Meteorological Services Department, which were under the Public Utilities Board and the Ministry of Transport respectively, were also subsumed under the ENV in 2004. In 2004, the ENV was renamed the Ministry of the Environment and Water Resources (MEWR) to reflect the larger scope of environment, water and environmental public health. Subsequently, in 2020, the MEWR was renamed the Ministry of Sustainability and the Environment to emphasise the importance of sustainability and climate adaptation.
- ⁴⁷ The Straits Times, "Minister Opens Keep Water Clean Campaign", *The Straits Times*, 28 June 1973, <https://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19730628-1.2.88>
- ⁴⁸ Loh Ah Tuan, Email correspondence, 16 April 2020.
- ⁴⁹ Incineration would also have the added benefit of reducing methane emissions that are often emitted from traditional landfill sites.
- ⁵⁰ Ministry of Information, Communications and the Arts, "Speech by the Prime Minister Inaugurating the 'Keep Singapore Clean' Campaign on Tuesday, 1st October 1968", <https://www.nas.gov.sg/archivesonline/data/pdfdoc/lky19681001.pdf>
- ⁵¹ Fong Tiew Weng, "The Planning and Development of Jurong New Town, Through the Years", *Singapore Institute of Planners (SIP) Journal* 1 (1971-8): 23-8.
- ⁵² The Straits Times, "Garden Town to Have 100,000 People: Woon", *The Straits Times*, 14 December 1968, <https://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19681214-1.2.62>
- ⁵³ Cecilia Tortajada, Yugal Joshi and Asit K. Biswas, *The Singapore Water Story: Sustainable Development in an Urban City-State* (London and New York: Routledge, 2013), 37.
- ⁵⁴ Jessica Cheam, *Forging a Greener Tomorrow: Singapore's Environmental Journey from Slum to Eco-City* (Singapore: Straits Times Press, 2012), 32-5, <https://www.mse.gov.sg/docs/default-source/default-document-library/grab-our-research/forging-a-greener-tomorrow.pdf>
- ⁵⁵ P.P. Wong, "Singapore", in *Artificial Structures and Shorelines*, edited by H. Jesse Walker (Dordrecht, NL: Springer, 1988), 383-92.
- ⁵⁶ Ibid.
- ⁵⁷ S.Y. Chew, P.P. Wong and Y.Y. Leong, "Beach Development Between Headland Breakwaters in a Low Wave Energy Environment, Pasir Ris, Singapore", *Coastal Engineering*, 1986, 1016-31, <https://doi.org/10.1061/9780872626003.076>
- ⁵⁸ Centre for Liveable Cities, *USS Port and the City: Balancing Growth and Liveability* (Singapore: Centre for Liveable Cities, 2016), 21, <https://www.clc.gov.sg/docs/default-source/urban-systems-studies/rb162799-mnd-uss-bk4-seaports-final.pdf>
- ⁵⁹ budak, "_Z2A8443 Singapore from Kusu Island", digital image, Flickr, 15 October 2016, accessed 2 September 2020, <https://flickr.com/photos/budak/29731201594>
- ⁶⁰ Centre for Liveable Cities, *USS Energising Singapore: Balancing Liveability and Growth* (Singapore: Centre for Liveable Cities, 2018), 20, <https://www.clc.gov.sg/docs/default-source/urban-systems-studies/uss-energising-singapore.pdf>
- ⁶¹ Cheam, *Forging a Greener Tomorrow*.
- ⁶² Parliament of Singapore, "Addenda, Prime Minister's Office", Singapore Parliamentary Reports Vol. 31, Col. 11, 21 July 1971, https://sprs.parl.gov.sg/search/topic?reportid=004_19710721_S0003_T0014
- ⁶³ Teo Chee Hean, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 16 December 2019, Internal Notes.
- ⁶⁴ Yeh, "The Idea of The Garden City", 813-32.
- ⁶⁵ Loh, CLC Interview.
- ⁶⁶ Tan Yong Soon, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 17 December 2019, transcript, accession number CLC/056/2019/005.
- ⁶⁷ Svante Arrhenius, "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground", *Philosophical Magazine and Journal of Science* 5.41 (1896): 237-76, https://www.rsc.org/images/Arrhenius1896_tcm18-173546.pdf
- ⁶⁸ Union of Concerned Scientists, "The IPCC: Who Are They and Why Do Their Climate Reports Matter?", 11 October 2018, <https://www.ucsusa.org/resources/ipcc-who-are-they>
- ⁶⁹ Subsequent reports were leased in 2001 (Third Assessment Report), 2007 (Fourth Assessment Report) and 2013/2014 (Fifth Assessment Report) as well as special reports on global warming of 1.5°C and sea level change.
- ⁷⁰ Tommy Koh, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 26 February 2020, transcript, accession number CLC/056/2020/014.
- ⁷¹ United Nations, *United Nations Framework Convention on Climate Change* (United States: United Nations, 1992), 4, <https://unfccc.int/resource/docs/convkp/conveng.pdf>
- ⁷² Vivian Balakrishnan, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 23 December 2019, transcript, accession number CLC/056/2020/009.
- ⁷³ Kwok Fook Seng, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 23 December 2019, transcript, accession number CLC/056/2019/007.
- ⁷⁴ Ministry of the Environment and Water Resources, "Singapore Accedes to the Kyoto Protocol", 13 April 2006, <https://www.nas.gov.sg/archivesonline/data/pdfdoc/20060413999.htm>
- ⁷⁵ Lim Swee Say, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 6 February 2020, transcript, accession number CLC/056/2020/012.
- ⁷⁶ Ibid.
- ⁷⁷ Lena Chan, Geoffrey Davison and Cheryl Chia, "Biodiversity Conservation in Singapore", *City Green Issue #1*, May 2010, 60, https://www.nparks.gov.sg/-/media/cuge/ebook/citygreen/cg1/cg1_11.pdf
- ⁷⁸ Loh, CLC Interview.
- ⁷⁹ National Environment Agency, "Solid Waste Management Infrastructure", <https://www.nea.gov.sg/our-services/waste-management/3r-programmes-and-resources/waste-management-infrastructure/solid-waste-management-infrastructure>
- ⁸⁰ Hui, CLC Interview.
- ⁸¹ Eric Bland, "Island of Trash or the 'Garbage of Eden'?", *NewScientist*, 11 April 2007, <https://www.newscientist.com/article/mg19425991-600-island-of-trash-or-the-garbage-of-eden/>
- ⁸² Hui, CLC Interview.
- ⁸³ National Environment Agency, "Waste Statistics and Overall Recycling", 15 April 2020, <https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling>
- ⁸⁴ Lim, CLC Interview.
- ⁸⁵ Ibid.
- ⁸⁶ Ibid.
- ⁸⁷ Tan Yong Soon, Lee Tung Jean and Karen Tan, *Clean, Green and Blue: Singapore's Journey Towards Environmental and Water Sustainability* (Singapore: ISEAS Publishing, 2008), 177-200.
- ⁸⁸ Ng How Yong, "Making Sure Singapore's Taps Don't Run Dry", *TODAY*, 1 September 2015, <https://www.todayonline.com/commentary/making-sure-singapores-taps-dont-run-dry>
- ⁸⁹ Balakrishnan, CLC Interview.
- ⁹⁰ Ministry of the Environment and Water Resources, "Speech by Minister Vivian Balakrishnan, Minister for the Environment and Water Resources and Minister-in-Charge of the Smart Nation Initiative at the Inaugural Smarter Cities Roundtable on 14 July 2015", <https://www.mse.gov.sg/news/speech-by-minister-vivian-balakrishnan-minister-for-the-environment-and-water-resources-and-minister-in-charge-of-the-smart-nation-initiative-at-the-inaugural-smarter-cities-roundtable-on-14-july-2015>
- ⁹¹ Ministry of the Environment, *Singapore's Initial National Communication* (Singapore: Ministry of the Environment, 2000), 36, https://www.nea.gov.sg/docs/default-source/our-services/climate-change/initial-nc_21-aug-2000.pdf
- ⁹² Grace Chua, "Singapore's First Coal-Burning Utility Plant Now Operational", *The Straits Times*, 22 February 2013, <https://www.straitstimes.com/singapore/singapores-first-coal-burning-utility-plant-now-operational>
- ⁹³ Ministry of Trade and Industry, "Second Minister S Iswaran's Reply on the Use of Coal at Tembusu Multi-Utilities Complex on Jurong Island", 13 March 2013, <https://www.mti.gov.sg/Newsroom/Parliamentary-Replies/2013/03/Second-Minister-S-Iswarans-reply-on-the-use-of-coal-at-Tembusu-Multi-Utilities-Complex-on-Jurong-Island>

- ⁹⁴ Energy Market Authority, "Statistics: Fuel Mix for Electricity Generation", 31 December 2019, https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Statistics/Yearly%20Data/Fuel-Mix-for-Electricity-Generation-Yearly.pdf
- ⁹⁵ Gavin Chua H.Y., "Energy Conservation Policy Development in Singapore", in *Energy Conservation in East Asia: Towards Greater Energy Security*, edited by Elspeth Thomson, Chang Youngho and Lee Jae-Seung (Singapore: World Scientific Publishing, 2010).
- ⁹⁶ Ibid.
- ⁹⁷ Building and Construction Authority, "About Green Mark", https://www.bca.gov.sg/greenmark/green_mark_buildings.html
- ⁹⁸ ZDL, "Singapore High Density Residential Building HDB Facade", digital image, Shutterstock, 12 June 2018, accessed 13 October 2020, <https://shutterstock.com/image-photo/singapore12-jun-2018singapore-high-density-residential-1113250364>
- ⁹⁹ National Environment Agency, *Singapore's Second National Communication* (Singapore: National Environment Agency, 2010), 24, https://www.nea.gov.sg/docs/default-source/our-services/climate-change/second-nc_12-nov-2010.pdf
- ¹⁰⁰ Land Transport Authority, *White Paper: A World Class Land Transport System* (Singapore: Land Transport Authority, 1996), 8, https://www.lta.gov.sg/content/dam/ltagov/who_we_are/statistics_and_publications/master-plans/pdf/White-Paper.pdf
- ¹⁰¹ Land Transport Authority, *Singapore Land Transport Statistics in Brief 2005* (Singapore: Land Transport Authority, 2005).
- ¹⁰² Chua, "Energy Conservation Policy Development in Singapore".
- ¹⁰³ Loh, CLC Interview.
- ¹⁰⁴ Ibid.
- ¹⁰⁵ Ibid.
- ¹⁰⁶ Lim, CLC Interview.
- ¹⁰⁷ Ministry of National Development, "Deferment of Reclamation Works at Pulau Ubin", Press Statement, 14 January 2002, <https://www.nas.gov.sg/archivesonline/data/pdfdoc/2002011403.htm>
- ¹⁰⁸ Ibid.
- ¹⁰⁹ travel oriented, "Singapore | Chek Jawa Wetlands", digital image, Flickr, 21 December 2014, accessed 14 September 2020, <https://www.flickr.com/photos/traveloriented/16222383865/>
- ¹¹⁰ Chan, Davison and Chia, "Biodiversity Conservation in Singapore", 60.
- ¹¹¹ Teo, CLC Interview.
- ¹¹² Ibid.
- ¹¹³ Jenny Chan, "Case Study: Singapore's Role at the Climate Change Negotiations from Bali to Paris 2007 to 2015", Civil Service College Singapore, 22 August 2017.
- ¹¹⁴ Hui, CLC Interview.
- ¹¹⁵ Tan, CLC Interview.
- ¹¹⁶ Masagos Zulkifli, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 2 March 2020, Written Reply.
- ¹¹⁷ National Climate Change Secretariat, "Inter-Ministerial Committee on Climate Change", <https://www.nccs.gov.sg/who-we-are/inter-ministerial-committee-on-climate-change/>
- ¹¹⁸ Tan, CLC Interview.
- ¹¹⁹ Refueling ships.
- ¹²⁰ Kwok, CLC Interview.
- ¹²¹ Shunmugam Jayakumar, *Be at the Table or Be on the Menu: A Singapore Memoir* (Singapore: Straits Times Press, 2015).
- ¹²² Burhan Gafoor, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 6 February 2020, transcript, accession number CLC/056/2020/011.
- ¹²³ Ibid.
- ¹²⁴ Ibid.
- ¹²⁵ Ibid.
- ¹²⁶ Ministry of Foreign Affairs of Japan, "9th Informal Meeting on Further Actions against Climate Change", 3-4 March 2011, <https://www.mofa.go.jp/policy/environment/warm/cop/imfa/pdfs/list1103.pdf>
- ¹²⁷ Fredvik Bo-Alex, "International Partnership on Mitigation and MRV Reports on Workshops in Chile, Thailand and Costa Rica", International Institute for Sustainable Development, 7 December 2012, <http://sdg.iisd.org/news/international-partnership-on-mitigation-and-mrv-reports-on-workshops-in-chile-thailand-and-costa-rica/>
- ¹²⁸ Originally known as the Major Emitters Forum.
- ¹²⁹ National Climate Change Secretariat, "Remarks by Senior Minister S Jayakumar, Minister for National Development Mah Bow Tan and Minister for the Environment and Water Resources Yaacob Ibrahim at Media Conference, 29 November 2010", <https://www.nccs.gov.sg/media/speeches/remarks-by-senior-minister-s-jayakumar-minister-for-national-development-mah-bow-tan-and-minister-for-the-environment-and-water-resources-yaacob-ibrahim-at-media-conference-29-november-2010>
- ¹³⁰ Gafoor, CLC Interview.
- ¹³¹ Kwok, CLC Interview.
- ¹³² Winston Chow, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 15 January 2020, transcript, accession number CLC/056/2020/008.
- ¹³³ Gafoor, CLC Interview.
- ¹³⁴ Balakrishnan, CLC Interview.
- ¹³⁵ Kwok, CLC Interview.
- ¹³⁶ Balakrishnan, CLC Interview.
- ¹³⁷ Kwok, CLC Interview.
- ¹³⁸ Centre for Climate Research Singapore, *Singapore's Second National Climate Change Study—Phase 1*, Chapter 3, 16.
- ¹³⁹ Liong Shie-Yui, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 28 February 2020, transcript, accession number CLC/056/2020/015.
- ¹⁴⁰ Ibid.
- ¹⁴¹ Ministry of Sustainability and the Environment, Let's Game Change Climate Change, "Meeting the Challenge of Climate Change Through Climate Science", <https://www.climategamechanger.sg/2019/12/09/meeting-the-challenge-of-climate-change-with-actions-based-on-robust-science/>
- ¹⁴² National Environment Agency, "Launch of Climate Science Research Programme Office (CSRPO) To Spearhead National Capability Building In Climate Science", 5 November 2020, [https://www.nea.gov.sg/media/news/news/index/launch-of-climate-science-research-programme-office-\(csrpo\)-to-spearhead-national-capability-building-in-climate-science](https://www.nea.gov.sg/media/news/news/index/launch-of-climate-science-research-programme-office-(csrpo)-to-spearhead-national-capability-building-in-climate-science)
- ¹⁴³ Prime Minister's Office Singapore, "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean".
- ¹⁴⁴ Emissions intensity refers to carbon emissions (from fuel combustion) per US\$GDP. International Energy Agency, "CO₂ Emissions From Fuel Combustion 2018", *OECDILibrary*, 30 October 2018, II.4-II.6, https://doi.org/10.1787/co2_fuel-2018-en
- ¹⁴⁵ National Climate Change Secretariat, *Charting Singapore's Low-Carbon and Climate Resilient Future* (Singapore: National Climate Change Secretariat, 2020), 28, <https://www.nccs.gov.sg/docs/default-source/publications/nccsleads.pdf>
- ¹⁴⁶ Ministry of the Environment and Water Resources, "Singapore Unveils Climate Change Strategy", Media Release, 29 February 2008, <https://www.nas.gov.sg/archivesonline/data/pdfdoc/20080229995.pdf>
- ¹⁴⁷ Tan, CLC Interview.
- ¹⁴⁸ Energy Efficient Singapore, 10 November 2020, <https://www.e2singapore.gov.sg>
- ¹⁴⁹ Elga Reyes, "Singapore: \$12 Million In Grants Awarded To Solar Energy Research", *Eco-Business*, 27 June 2013, <https://www.eco-business.com/news/singapore-12-million-grants-awarded-solar-energy-research/>
- ¹⁵⁰ Pamela Almeda, "Clean Energy R&D Gets \$170m Boost", *CNA*, 6 November 2007, <http://www.wildsingapore.com/news/20071112/071106-5.htm>

- ¹⁵¹ National Research Foundation, "The Energy Challenge", <https://www.nrf.gov.sg/programmes/national-innovation-challenges/the-energy-challenge>
- ¹⁵² Balakrishnan, CLC Interview.
- ¹⁵³ Tan, CLC Interview.
- ¹⁵⁴ Keung, CLC Interview.
- ¹⁵⁵ Ibid.
- ¹⁵⁶ Ibid.
- ¹⁵⁷ The BCA considers buildings to be "green" if they meet the minimum environmental sustainability standards (which only took effect in April 2018) or achieve the BCA's Green Mark certification.
- ¹⁵⁸ The minimum environmental sustainability standards was launched in 2014 for large commercial buildings and subsequently extended in 2017 to cover medium-sized commercial buildings and other building types.
- ¹⁵⁹ Under the Periodic Energy Audit, the BCA would serve notice on a 3-yearly basis to ensure that the building cooling systems installed continue to operate as efficiently as per its initial design throughout its life cycle and meet the energy efficiency standard prescribed in the regulations.
- ¹⁶⁰ Building and Construction Authority, "What is Zero Energy Building?", <https://www.bca.gov.sg/zeb/whatiszeb.html>
- ¹⁶¹ Mina Zhan, Clarice Chow and Kuang Jin Yi, "District Cooling Systems: A More Efficient Way to Cool Our Residential Neighbourhoods", *CLC Insights*, Issue No. 26, Centre for Liveable Cities, April 2017.
- ¹⁶² National Climate Change Secretariat, *Charting Singapore's Low-Carbon and Climate Resilient Future*.
- ¹⁶³ From 2018, the methodology behind the taxi ridership data has been updated with more granular data available to the LTA.
- ¹⁶⁴ Singapore Department of Statistics, *M651351—Public Transport Operation And Ridership, Annual*, Singapore Department of Statistics, <https://www.tablebuilder.singstat.gov.sg/publicfacing/createDataTable.action?refId=14582>
- ¹⁶⁵ National Environment Agency, "Air Pollution Regulations", <https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-pollution-regulations>
- ¹⁶⁶ Christopher Tan, "Owners of Electric Vehicles Can Pay to Use BlueSG Chargers from Today", *The Straits Times*, 23 April 2019, <https://www.straitstimes.com/singapore/transport/electric-vehicle-owners-can-pay-to-use-bluesg-chargers-from-today>
- ¹⁶⁷ BlueSG, "BlueSG's Electric Vehicle Car-sharing Celebrates its Second Anniversary in Singapore with More Than 300 Charging Stations, Launching More Flexible New Subscription Plans and Expanding its Charging Offer Network", 12 December 2019, https://www.bluesg.com.sg/sites/bluesg/files/medias/images/PDF/bluesg_celebrates_its_2nd_anniversary_with_more_than_300_stations.pdf
- ¹⁶⁸ Land Transport Authority, "Joint News Release by the Land Transport Authority (LTA) & NEA—Promoting the Adoption of Cleaner Commercial Vehicles", News Releases, 4 March 2020, https://www.lta.gov.sg/content/ltagov/en/newsroom/2020/march/news-releases/Promoting_the_adoption_of_cleaner_commercial_vehicles.html
- ¹⁶⁹ Christopher Tan, "COE Supply Dips as Zero-Growth Cap Kicks in", *The Straits Times*, 19 January 2018, <https://www.straitstimes.com/singapore/transport/coe-supply-dips-as-zero-growth-cap-kicks-in>
- ¹⁷⁰ Ministry of Trade and Industry, "Speech by Minister Chan Chun Sing at the 12th Singapore International Energy Week 2019", 29 October 2019, <https://www.mti.gov.sg/Newsroom/Speeches/2019/10/Speech-by-Minister-Chan-Chun-Sing-at-the-12th-Singapore-International-Energy-Week-2019>
- ¹⁷¹ Solar Energy Research Institute of Singapore (SERIS), NUS, National University of Singapore (NUS) and Energy Reserch Institute @ NTU (EIR@N), including the Experimental Power Grid Centre (EPGC), "Update of the Solar Photovoltaic (PV) Roadmap for Singapore", Technical Report, March 2020, [http://www.seris.nus.edu.sg/doc/publications/Update-of-the-Solar-Roadmap-for-Singapore-\(March-2020\).pdf](http://www.seris.nus.edu.sg/doc/publications/Update-of-the-Solar-Roadmap-for-Singapore-(March-2020).pdf)
- ¹⁷² Keung, CLC Interview.
- ¹⁷³ Choi Shing Kwok, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 19 December 2019, transcript, accession number CLC/056/2019/006.
- ¹⁷⁴ David Roberts, "The Hottest New Thing In Sustainable Building Is, Uh, Wood", *Vox*, 15 January 2020, <https://www.vox.com/energy-and-environment/2020/1/15/21058051/climate-change-building-materials-mass-timber-cross-laminated-clt>
- ¹⁷⁵ Keung, CLC Interview.
- ¹⁷⁶ Tan, CLC Interview.
- ¹⁷⁷ Hui, CLC Interview.
- ¹⁷⁸ Teo, CLC Interview.
- ¹⁷⁹ Loh Ah Tuan, Email correspondence, 16 April 2020.
- ¹⁸⁰ World Bank, "State and Trends of Carbon Pricing 2020", May 2020, <https://openknowledge.worldbank.org/bitstream/handle/10986/33809/9781464815867.pdf>
- ¹⁸¹ Ibid.
- ¹⁸² Choi, CLC Interview.
- ¹⁸³ Tan, CLC Interview.
- ¹⁸⁴ Zulkifli, CLC Interview.
- ¹⁸⁵ Tan, CLC Interview.
- ¹⁸⁶ National Climate Change Secretariat, *National Climate Change Strategy 2012*, 71.
- ¹⁸⁷ Prime Minister's Office Singapore, "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean".
- ¹⁸⁸ Khoo Teng Chye, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 29 November 2019, transcript, accession number CLC/056/2019/004.
- ¹⁸⁹ Centre for Liveable Cities, Singapore and Rotterdam Office of Climate Adaptation, Netherlands, *Living with Water: Lessons from Singapore and Rotterdam* (Singapore: Centre for Liveable Cities, 2019), 30, <https://www.clc.gov.sg/docs/default-source/books/living-with-water.pdf>
- ¹⁹⁰ Keung, CLC Interview.
- ¹⁹¹ Prime Minister's Office Singapore, "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean".
- ¹⁹² Khoo, CLC Interview.
- ¹⁹³ Ibid.
- ¹⁹⁴ Ibid.
- ¹⁹⁵ M.O. Mughal, X.X. Li, T. Yin, A. Martilli, O. Brousse, M.A. Dissegna and L.K. Norford, "High-Resolution, Multilayer Modeling of Singapore's Urban Climate Incorporating Local Climate Zones", *Journal of Geophysical Research: Atmospheres* 124.14 (2019): 7764–85.
- ¹⁹⁶ National Climate Change Secretariat, *Singapore's Climate Action Plan: Take Action Today, for a Carbon-Efficient Singapore* (Singapore: National Climate Change Secretariat, 2016), 4, https://sustainabledevelopment.un.org/content/documents/1545Climate_Action_Plan_Publication_Part_1.pdf
- ¹⁹⁷ Housing and Development Board, "Homes At One With Nature", 18 July 2018, <https://www.hdb.gov.sg/cs/infoweb/about-us/news-and-publications/press-releases/homes-at-one-with-nature1>
- ¹⁹⁸ Nicholas Khong, "Nature Parks and Reserves to Receive Boost Against Climate Change", *TODAY*, 26 January 2019, <https://www.todayonline.com/singapore/250000-trees-be-planted-nature-parks-reserves-over-10-years-boost-resilience-singapore>
- ¹⁹⁹ Food and Agriculture Organisation of the United Nations, *Climate Change and Food Systems: Global Assessment and Implications for Food Security and Trade*, edited by Aziz Elbehri (Italy: Food and Agriculture Organisation of the United Nations, 2015), 1, <http://www.fao.org/3/a-i4332e.pdf>
- ²⁰⁰ Ministry of National Development, "COS 2016: Speech by MOS Dr Koh Poh Koon 'Working Together for an Inclusive and Innovative City'", 11 April 2016, <https://www.mnd.gov.sg/newsroom/parliament-matters/speeches/view/cos-2016-speech-by-mos-dr-koh-poh-koon-working-together-for-an-inclusive-and-innovative-city>
- ²⁰¹ The AVA was disbanded on 1 April 2019, with animal welfare and management functions transferred to NParks and food-related functions transferred to the newly formed statutory board, the Singapore Food Agency.

- 202 National Environment Agency, "New NEA Facility to Boost Production of Male Wolbachia-Aedes Aegypti Mosquitoes to Benefit More Residents", 2 December 2019, <https://www.nea.gov.sg/media/news/news/index/new-nea-facility-to-boost-production-of-male-wolbachia-aedes-aegypti-mosquitoes-to-benefit-more-residents>
- 203 Keung, CLC Interview.
- 204 Teo, CLC Interview.
- 205 Vivian Balakrishnan, Remarks at the CIFOR Forests Asia Summit 2014.
- 206 Keung, CLC Interview.
- 207 Ibid.
- 208 Building and Construction Authority, *3rd Green Building Masterplan* (Singapore: Building and Construction Authority, 2015), https://www.bca.gov.sg/GreenMark/others/3rd_Green_Building_Masterplan.pdf
- 209 Lee Chuan Seng, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 28 January 2020, transcript, accession number CLC/056/2020/010.
- 210 Ministry of the Environment and Water Resources, "Speech by Mr Masagos Zulkifli, Minister for the Environment and Water Resources at MEWR COS 2016", 12 April 2016, <https://www.mse.gov.sg/news/speech-by-mr-masagos-zulkifli--minister-for-the-environment-and-water-resources-at-mewr-cos-2016>
- 211 Chuang Peck Ming, "Temasek Sets 2030 Target for its Portfolio to Halve Greenhouse Emissions", *The Business Times*, 13 November 2019, <https://www.businesstimes.com.sg/companies-markets/temasek-sets-2030-target-for-its-portfolio-to-halve-greenhouse-emissions>
- 212 Cross Laminated Timber is one type of mass engineered timber.
- 213 Sustainability Office, CDL, Email correspondence, 2 April 2020.
- 214 Esther An, "Interview by CLC", Centre for Liveable Cities, Ministry of National Development, 21 February 2020, transcript, accession number CLC/056/2020/013.
- 215 Ibid.
- 216 Ministry of the Environment and Water Resources, "Written Reply by Masagos Zulkifli, Minister for the Environment and Water Resources, to Parliamentary Question on Climate Action Engagement on 7 October 2019", <https://www.mse.gov.sg/news/written-reply-by-masagos-zulkifli--minister-for-the-environment-and-water-resources--to-parliamentary-question-on-climate-action-engagement-on-7-october-2019>
- 217 Zulkifli, CLC Interview.
- 218 Ibid.
- 219 National Climate Change Secretariat, *Climate Change Public Perception Survey 2019* (Singapore: National Climate Change Secretariat, 2019), <https://www.nccs.gov.sg/docs/default-source/publications/pps-infographic-final.pdf>
- 220 Zulkifli, CLC Interview.
- 221 Balakrishnan, CLC Interview.
- 222 Amit Prakash, "Boiling Point", International Monetary Fund, *Finance & Development*, No. 3, September 2018, 55, <https://www.imf.org/external/pubs/ft/fandd/2018/09/southeast-asia-climate-change-and-greenhouse-gas-emissions-prakash.htm>
- 223 Ibid.
- 224 David A. Raitzer, Francesco Bosello, Massimo Tavoni, Carlo Orecchia, Giacomo Marangoni and Jindra Nuella G. Samson, *Southeast Asia and the Economics of Global Climate Stabilization* (Mandaluyong City, Philippines: Asian Development Bank, 2015), 43, <https://www.adb.org/sites/default/files/publication/178615/sea-economics-global-climate-stabilization.pdf>
- 225 This refers to the 10 ASEAN countries plus Australia, China, India, Japan, Korea and New Zealand.
- 226 Association of Southeast Asian Nations, "ASEAN Cooperation on Climate Change", <https://environment.asean.org/avgcc/>
- 227 World Bank, "Southeast Asia Disaster Risk Insurance Facility (SEADRIF) Technical Briefing for Japanese Insurance Industry", 17 January 2019, <https://www.worldbank.org/en/news/feature/2019/01/17/southeast-asia-disaster-risk-insurance-facility-seadrif-technical-briefing-for-japanese-insurance-industry-drmhbtokyo>
- 228 Audrey Tan, "Singapore Will Work With Asean Neighbours on Climate Change Issues: Masagos", *The Straits Times*, 16 November 2017, <https://www.straitstimes.com/singapore/environment/singapore-will-work-with-asean-neighbours-on-climate-change-issues-masagos>
- 229 Ibid.
- 230 Khoo, CLC Interview.
- 231 Balakrishnan, CLC Interview.
- 232 Ibid.
- 233 Ibid.
- 234 Michal Kurtyka, "Expectations for Poland's Global Climate Change Summit", *The Straits Times*, 28 November 2018, <https://www.straitstimes.com/opinion/expectations-for-polands-global-climate-change-summit>
- 235 Prime Minister's Office Singapore, "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean".
- 236 Prime Minister's Office Singapore, "National Day Rally 2019", 18 August 2019, <https://www.pmo.gov.sg/Newsroom/National-Day-Rally-2019>
- 237 Ibid.
- 238 Liong, CLC Interview.
- 239 Zulkifli, CLC Interview.
- 240 Choi, CLC Interview.
- 241 Ministry of the Environment and Water Resources, "Singapore to Strengthen Capabilities In Climate Science", 17 July 2019, Press Release, <https://www.mse.gov.sg/news/singapore-to-strengthen-capabilities-in-climate-science>
- 242 Kwok, CLC Interview.
- 243 Prime Minister's Office Singapore, "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean".
- 244 Land Transport Authority, "Land Transport Master Plan 2040: Bringing Singapore Together", News Releases, 25 May 2019, <https://www.lta.gov.sg/content/ltagov/en/newsroom/2019/5/2/land-transport-master-plan-2040-bringing-singapore-together.html>
- 245 Hui, CLC Interview.
- 246 *The Business Times*, "Tesla's EVs are About 'Lifestyle', Not Climate: Masagos Zulkifli", *The Business Times*, 23 August 2019, <https://www.businesstimes.com.sg/transport/teslas-evs-are-about-lifestyle-not-climate-masagos-zulkifli>
- 247 Rachael Graham, "Hydrogen Fuel Cell vs Electric Cars: What You Need To Know But Couldn't Ask", *EuroNews*, 14 February 2020, <https://www.euronews.com/living/2020/02/13/hydrogen-fuel-cell-vs-electric-cars-what-you-need-to-know-but-couldn-t-ask>
- 248 Lee, CLC Interview.
- 249 Ministry of the Environment and Water Resources, *Zero Waste Masterplan* (Singapore: Ministry of the Environment and Water Resources, 2019), 40, https://www.towardszerowaste.gov.sg/images/zero_waste_masterplan.pdf
- 250 Zulkifli, CLC Interview.
- 251 Balakrishnan, CLC Interview.
- 252 Ibid.
- 253 Jonathan Pearlman, "Aussie Solar Farm Project Aims to Power Up Singapore Too", *The Straits Times*, 21 July 2019, <https://www.straitstimes.com/asia/australianz/aussie-solar-farm-project-aims-to-power-up-spore-too>
- 254 Ibid.
- 255 Adwo, "Solar Power Station—Australia", digital image, Shutterstock, accessed 14 October 2020, <https://shutterstock.com/image-photo/solar-power-station-australia-1041363820>
- 256 Joseph Teo, "The Change Maker", *Experience Singapore*, Issue 69, Ministry of Foreign Affairs, 2020, <https://www.mfa.gov.sg/Newsroom/Resources/Experience-Singapore/Issue-69>
- 257 David Fogarty, "World is On Track to Finalise Climate Deal: UN", *The Straits Times*, 11 July 2018, <https://www.straitstimes.com/world/world-is-on-track-to-finalise-climate-deal-un>

- ²⁵⁸ Audrey Tan, "Singapore has Vested Interest in Strong Result at Climate Talks, Says Masagos", *The Straits Times*, 10 December 2018, <https://www.straitstimes.com/world/europe/spore-has-vested-interest-in-strong-result-at-climate-talks>
- ²⁵⁹ United Nations, "Net Zero Greenhouse Gas Emissions Vital Amid Catastrophic Climate Change Scenario, Secretary-General Tells International Renewable Energy Agency Meeting", 10 January 2019, <https://www.un.org/press/en/2019/sgsm19429.doc.htm>
- ²⁶⁰ Catherine Benson Wahlén, "73 Countries Commit to Net Zero CO₂ Emissions by 2050", *SDG Knowledge Hub*, 17 December 2019, <https://sdg.iisd.org/news/73-countries-commit-to-net-zero-co2-emissions-by-2050/>
- ²⁶¹ Faris Mokhtar, "Singapore Has a S\$100 Billion Plan to Survive in a Far Hotter World Than Experts Predicted", *Bloomberg News*, 26 February 2020, <https://www.bloomberg.com/news/features/2020-02-25/singapore-has-a-100-billion-plan-for-adapting-to-climate-change>
- ²⁶² Balakrishnan, CLC Interview.
- ²⁶³ Prime Minister's Office Singapore, "National Day Rally 2019".
- ²⁶⁴ Ministry of the Environment and Water Resources, "Speech by Mr Masagos Zulkifli, Minister for the Environment and Water Resources, at the Committee of Supply Debate, 4 March 2020", <https://www.mse.gov.sg/resource-room/category/2020-03-04-speech-at-the-committee-of-supply-debate/>
- ²⁶⁵ Ibid.
- ²⁶⁶ 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>
- ²⁶⁷ Ibid.
- ²⁶⁸ Cindy Co, "Singapore to Plant 1 Million Trees, Develop More Gardens and Parks by 2030", *CNA*, 4 March 2020, <https://www.channelnewsasia.com/news/singapore/singapore-to-plant-1-million-trees-develop-more-gardens-and-12500858>
- ²⁶⁹ Ibid.
- ²⁷⁰ Parliament of Singapore, "Committee of Supply—Head L (Ministry of Environment and Water Resources)", Singapore Parliamentary Reports Vol. 94, 6 March 2018, <https://sprs.parl.gov.sg/search/sprs3topic?reportid=budget-834>
- ²⁷¹ Zulkifli, CLC Interview.
- ²⁷² Agri-Food and Veterinary Authority of Singapore, *AVA Vision: A Legacy of Excellence: A Commemorative Issue* (Singapore: Agri-Food and Veterinary Authority of Singapore, 2019), 11, <https://www.sfa.gov.sg/docs/default-source/publication/ava-vision/ava-vision-issue-1-2019.pdf>
- ²⁷³ Singapore Food Agency, "Our Singapore Food Story", <https://www.sfa.gov.sg/food-farming/sgfoodstory/grow-local>
- ²⁷⁴ Singapore Food Agency, "SFA Launches Grant Call For 30x30 Express To Ramp Up Local Food Production", Media Release, 8 April 2020, <https://www.sfa.gov.sg/docs/default-source/default-document-library/sfa-media-release---launch-of-30x30-express-grant-call.pdf>
- ²⁷⁵ Singapore Food Agency, "Keynote Address by Mr Lim Kok Thai, Chief Executive Officer of Singapore Food Agency, at the Asia-Pacific Agri-Food Innovation Week (Day 2—Urban Agriculture, Sustainable Aquaculture and Protein Innovation) on 21 November 2019 at Grand Hyatt Singapore", [https://www.sfa.gov.sg/docs/default-source/default-document-library/keynote-address-by-mr-lim-kok-thai-ceo-of-sfa-at-asia-pacific-agri-food-innovation-week-\(21-nov-2019\).pdf](https://www.sfa.gov.sg/docs/default-source/default-document-library/keynote-address-by-mr-lim-kok-thai-ceo-of-sfa-at-asia-pacific-agri-food-innovation-week-(21-nov-2019).pdf)
- ²⁷⁶ Singapore Food Agency, "Tender Closing For 9 HDB MSCP Rooftop Sites For Urban Farming", Media Release, 17 June 2020, <https://www.sfa.gov.sg/docs/default-source/default-document-library/joint-hdb-sfa-media-release---tender-closing-for-9-hdb-mscp-rooftop-sites-for-urban-farmingefa9900662d8448ea2878d5913775938.pdf>
- ²⁷⁷ Singapore Food Agency, "Our Singapore Food Story", <https://www.sfa.gov.sg/food-farming/sgfoodstory/grow-local>
- ²⁷⁸ Lee, CLC Interview.
- ²⁷⁹ Ibid.
- ²⁸⁰ Ibid.
- ²⁸¹ Rexlee Hah, Personal correspondence, 16 March 2020.
- ²⁸² Sim Lye Huat, Personal correspondence, 12 October 2019.
- ²⁸³ K6ka, "You'll Die of Old Age I'll Die of Climate Change—*Climate Strike Toronto, 27 September 2019*", digital image, Wikimedia Commons, 29 September 2019, accessed 25 August 2020, <https://commons.wikimedia.org/w/index.php?curid=82680839>
- ²⁸⁴ C40 Cities, Email correspondence, 7 July 2020.
- ²⁸⁵ Gafoor, CLC Interview.
- ²⁸⁶ Ministry of the Environment and Water Resources, "Speech by Mr Masagos Zulkifli, Minister for the Environment and Water Resources, at the Partners for the Environment Forum, 17 July 2019", <https://www.mse.gov.sg/news/speech-by-mr-masagos-zulkifli--minister-for-the-environment-and-water-resources--at-the-partners-for-the-environment-forum--17-july-2019>
- ²⁸⁷ Zulkifli, CLC Interview.
- ²⁸⁸ UN Environment Programme, "The Renewables in Cities 2019 Global Status Report", 26 November 2019, <https://www.unenvironment.org/resources/report/renewables-cities-2019-global-status-report>
- ²⁸⁹ Balakrishnan, CLC Interview.
- ²⁹⁰ David Fogarty, "World is on Track to Finalise Climate Deal: UN".
- ²⁹¹ Balakrishnan, CLC Interview.
- ²⁹² Gafoor, CLC Interview.
- ²⁹³ Ministry of the Environment and Water Resources, "Keynote Address by Mr Masagos Zulkifli, Minister for the Environment and Water Resources, at the IPCC Scoping Meeting for the Synthesis Report of the Sixth Assessment Report Opening Ceremony, 21 October 2019", <https://www.mse.gov.sg/news/keynote-address-by-mr-masagos-zulkifli--minister-for-the-environment-and-water-resources--at-the-ipcc-scoping-meeting-for-the-synthesis-report-of-the-sixth-assessment-report-opening-ceremony--21-october-2019>

Back cover quote:

Prime Minister's Office Singapore, "SM Teo Chee Hean at the Launch of Clean & Green Singapore 2019", <https://www.pmo.gov.sg/Newsroom/SM-Teo-Chee-Hean-at-the-Launch-of-Clean-Green-Singapore-2019>

BIBLIOGRAPHY

Books, Journals and Conference Proceedings

- Arrhenius, Svante. "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground". *Philosophical Magazine and Journal of Science* 5.41 (1896): 237–76. https://www.rsc.org/images/Arrhenius1896_tcm18-173546.pdf
- Cheam, Jessica. *Forging a Greener Tomorrow: Singapore's Environmental Journey from Slum to Eco-City*. Singapore: Straits Times Press, 2012. <https://www.mse.gov.sg/docs/default-source/default-document-library/grab-our-research/forging-a-greener-tomorrow.pdf>
- Chew, S.Y., P.P. Wong and Y.Y. Leong. "Beach Development Between Headland Breakwaters in a Low Wave Energy Environment, Pasir Ris, Singapore". *Coastal Engineering* (1986): 1016–31. <https://doi.org/10.1061/9780872626003.076>
- Chow, Winston T. L., Brendan D. Cheong and Beatrice H. Ho. "A Multimethod Approach towards Assessing Urban Flood Patterns and Its Associated Vulnerabilities in Singapore". *Advances in Meteorology* (2016): 3. <http://dx.doi.org/10.1155/2016/7159132>
- Chua, G.H.Y. "Energy Conservation Policy Development in Singapore". In *Energy Conservation in East Asia: Towards Greater Energy Security*, edited by Elspeth Thomson, Youngho Chang and Jae-Seung Lee. Singapore: World Scientific Publishing, 2010.
- Corlett, Richard T. "The Ecological Transformation of Singapore, 1819–1990". *Journal of Biogeography* 19.4 (1992): 411–20. <https://www.jstor.org/stable/2845569>
- Fong, Tiew Weng. "The Planning and Development of Jurong New Town, Through the Years". *Singapore Institute of Planners (SIP) Journal* 1 (1971–78): 23–8.
- Food and Agriculture Organisation of the United Nations. *Climate Change and Food Systems: Global Assessment and Implications for Food Security and Trade*, edited by Aziz Elbehri. Italy: Food and Agriculture Organisation of the United Nations, 2015: 1. <http://www.fao.org/3/a-i4332e.pdf>
- Fredvik, Bo-Alex. "International Partnership on Mitigation and MRV Reports on Workshops in Chile, Thailand and Costa Rica". International Institute for Sustainable Development, 7 December 2012. <http://sdg.iisd.org/news/international-partnership-on-mitigation-and-mrv-reports-on-workshops-in-chile-thailand-and-costa-rica/>
- International Energy Agency. "CO₂ Emissions From Fuel Combustion 2018". *OECD Library*, 30 October 2018, II.4-II.6. https://doi.org/10.1787/co2_fuel-2018-en
- Jayakumar, Shunmugam. *Be at the Table or Be on the Menu: A Singapore Memoir*. Singapore: Straits Times Press, 2015.
- Leatherman, Stephen P., Keqi Zhang and Bruce C. Douglas. "Sea Level Rise Shown to Drive Coastal Erosion". *EOS* 81.6 (8 February 2000): 55–7. <http://onlinelibrary.wiley.com/doi/10.1029/00E000034/pdf>
- Lee, Kuan Yew. *From Third World to First: The Singapore Story: 1965–2000, Memoirs of Lee Kuan Yew Vol. 2*. Singapore: Marshall Cavendish, 2012.
- Li, Xin, Wang Xuan and Vlado Babovic. "Analysis of Variability and Trends of Precipitation Extremes in Singapore During 1980–2013". *International Journal of Climatology* 38.1 (2018): 125–41. <https://doi.org/10.1002/joc.5165>
- Mughal, M.O., X.X. Li, T. Yin, A. Martilli, O. Brousse, M.A. Dissegna and L.K. Norford. "High-Resolution, Multilayer Modeling of Singapore's Urban Climate Incorporating Local Climate Zones". *Journal of Geophysical Research: Atmospheres* 124.14 (2019): 7764–85.
- Prakash, Amit. "Boiling Point". International Monetary Fund. *Finance & Development* No. 3, September 2018, 55. <https://www.imf.org/external/pubs/ft/fandd/2018/09/southeast-asia-climate-change-and-greenhouse-gas-emissions-prakash.htm>
- Raitzer, David A., Francesco Bosello, Massimo Tavoni, Carlo Orecchia, Giacomo Marangoni and Jindra Nuella G. Samson. *Southeast Asia and the Economics of Global Climate Stabilization*. Mandaluyong City, Philippines: Asian Development Bank, 2015. <https://www.adb.org/sites/default/files/publication/178615/sea-economics-global-climate-stabilization.pdf>
- Tan, Yong Soon, Lee Tung Jean and Karen Tan. *Clean, Green and Blue: Singapore's Journey Towards Environmental and Water Sustainability*. Singapore: ISEAS Publishing, 2008.
- Tortajada, Cecilia, Yugal Joshi and Asit K. Biswas. *The Singapore Water Story: Sustainable Development in an Urban City-State*. London and New York: Routledge, 2013.
- UN Environment Programme. "The Renewables in Cities 2019 Global Status Report". 26 November 2019. <https://www.unenvironment.org/resources/report/renewables-cities-2019-global-status-report>
- United Nations. "Net Zero Greenhouse Gas Emissions Vital Amid Catastrophic Climate Change Scenario, Secretary-General Tells International Renewable Energy Agency Meeting". 10 January 2019. <https://www.un.org/press/en/2019/sgsm19429.doc.htm>
- _____. *United Nations Framework Convention on Climate Change*. United States: United Nations, 1992. <https://unfccc.int/resource/docs/convkp/conveng.pdf>
- Wong, P.P. "Singapore". *Artificial Structures and Shorelines*, edited by H. Jesse Walker, 383–92. NL: Springer, Dordrecht, 1988.
- World Bank. "Southeast Asia Disaster Risk Insurance Facility (SEADRIF) Technical Briefing for Japanese Insurance Industry". 17 January 2019. <https://www.worldbank.org/en/news/feature/2019/01/17/southeast-asia-disaster-risk-insurance-facility-seadrif-technical-briefing-for-japanese-insurance-industry-drmhubtokyo>
- _____. "State and Trends of Carbon Pricing 2020". May 2020. <https://openknowledge.worldbank.org/bitstream/handle/10986/33809/9781464815867.pdf>
- World Economic Forum. "The Global Risk Report 2019". 15 January 2019. <https://www.weforum.org/reports/the-global-risks-report-2019>
- World Meteorological Organization. "WMO Climate Statement: Past 4 Years Warmest On Record". 29 November 2018. <https://public.wmo.int/en/media/press-release/wmo-climate-statement-past-4-years-warmest-record>
- Yeh, Stephen. "The Idea of The Garden City". *The Management of Success: The Moulding of Modern Singapore*, edited by Kernial Singh Sandhu and Paul Wheatly, 813–32. Singapore: Institute of Southeast Asian Studies, 1989.

Government Publications, Press Releases and Singapore Parliamentary Reports

- Agri-Food and Veterinary Authority of Singapore. *AVA Vision: A Legacy of Excellence: A Commemorative Issue*. Singapore: Agri-Food and Veterinary Authority of Singapore, 2019. <https://www.sfa.gov.sg/docs/default-source/publication/ava-vision/ava-vision-issue-1-2019.pdf>
- Building and Construction Authority. *3rd Green Building Masterplan*. Singapore: Building and Construction Authority, 2015. https://www.bca.gov.sg/GreenMark/others/3rd_Green_Building_Masterplan.pdf
- Chan, Lena, Geoffrey Davison and Cheryl Chia. "Biodiversity Conservation in Singapore". *City Green Issue #1*, 2010. https://www.nparks.gov.sg/-/media/cuge/ebook/citygreen/cg1/cg1_11.pdf
- Centre for Climate Research Singapore. *Singapore's Second National Climate Change Study—Phase 1*. Singapore: Centre for Climate Research Singapore, 2015. https://ccrs.weather.gov.sg/wp-content/uploads/2015/07/V2_Ch5_Climate_Change_Projections.pdf
- Centre for Liveable Cities, Singapore and Rotterdam Office of Climate Adaptation, Netherlands. *Living with Water: Lessons from Singapore and Rotterdam*. Singapore: Centre for Liveable Cities, 2019. <https://www.clc.gov.sg/docs/default-source/books/living-with-water.pdf>
- _____. *USS Energising Singapore: Balancing Liveability and Growth*. Singapore: Centre for Liveable Cities, 2018. <https://www.clc.gov.sg/docs/default-source/urban-systems-studies/uss-energising-singapore.pdf>

- _____. *USS Port and the City: Balancing Growth and Liveability*. Singapore: Centre for Liveable Cities, 2016. <https://www.clc.gov.sg/docs/default-source/urban-systems-studies/rb162799-mnd-uss-bk4-seaports-final.pdf>
- Chan, Jenny. "Case Study: Singapore's Role at the Climate Change Negotiations from Bali to Paris 2007 to 2015". Singapore: Civil Service College, 22 August 2017.
- Energy Market Authority. "Statistics: Fuel Mix for Electricity Generation". 31 December 2019. https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Statistics/Yearly%20Data/Fuel-Mix-for-Electricity-Generation-Yearly.pdf
- Er, Kenneth. "Growing a Biophilic City in a Garden". Civil Service College Singapore, 5 July 2018. <https://www.csc.gov.sg/articles/growing-a-biophilic-city-in-a-garden>
- Land Transport Authority. "Joint News Release by the Land Transport Authority (LTA) & NEA—Promoting the Adoption of Cleaner Commercial Vehicles". News Release. 4 March 2020. https://www.lta.gov.sg/content/ltagov/en/newsroom/2020/march/news-releases/Promoting_the_adoption_of_cleaner_commercial_vehicles.html
- _____. "Land Transport Master Plan 2040: Bringing Singapore Together". News Release. 25 May 2019. <https://www.lta.gov.sg/content/ltagov/en/newsroom/2019/5/2/land-transport-master-plan-2040-bringing-singapore-together.html>
- _____. *Singapore Land Transport Statistics in Brief 2005*. Singapore: Land Transport Authority, 2005.
- _____. *White Paper: A World Class Land Transport System*. Singapore: Land Transport Authority, 2 January 1996. https://www.lta.gov.sg/content/dam/ltagov/who_we_are/statistics_and_publications/master-plans/pdf/White-Paper.pdf
- Meteorological Service Singapore. "2019 Climate and Weather: The Year in Review". Singapore: Meteorological Service Singapore, 16 January 2020. <https://www.weather.gov.sg/wp-content/uploads/2020/01/The-Year-In-Review-2019.pdf>
- _____. "Annual Climate Assessment Report 2019". Singapore: Centre for Climate Research Singapore, 2019. <http://www.weather.gov.sg/wp-content/uploads/2020/03/Annual-Climate-Assessment-Report-2019.pdf>
- Ministry of Foreign Affairs of Japan. "9th Informal Meeting on Further Actions against Climate Change". 3-4 March 2011. <https://www.mofa.go.jp/policy/environment/warm/cop/imfa/pdfs/list1103.pdf>
- Ministry of National Development. "Deferment of Reclamation Works at Pulau Ubin". Press Statement. 14 January 2002. <https://www.nas.gov.sg/archivesonline/data/pdfdoc/2002011403.htm>
- Ministry of the Environment. *Singapore's Initial National Communication*. Singapore: Ministry of the Environment, 2000. https://www.nea.gov.sg/docs/default-source/our-services/climate-change/initial-nc_21-aug-2000.pdf
- Ministry of the Environment and Water Resources. "Singapore Accedes to the Kyoto Protocol". 13 April 2006. <https://www.nas.gov.sg/archivesonline/data/pdfdoc/20060413999.htm>
- _____. "Singapore to Strengthen Capabilities In Climate Science". 17 July 2019. Press Release. <https://www.mse.gov.sg/news/singapore-to-strengthen-capabilities-in-climate-science>
- _____. "Singapore Unveils Climate Change Strategy". Media Release. 29 February 2008. <https://www.nas.gov.sg/archivesonline/data/pdfdoc/20080229995.pdf>
- _____. *Zero Waste Masterplan*. Singapore: Ministry of the Environment and Water Resources, 2019. https://www.towardszerowaste.gov.sg/images/zero_waste_masterplan.pdf
- National Climate Change Secretariat. *Charting Singapore's Low-Carbon and Climate Resilient Future*. Singapore: National Climate Change Secretariat, 2020. <https://www.nccs.gov.sg/docs/default-source/publications/nccsleeds.pdf>
- _____. *Climate Change Public Perception Survey 2019*. Singapore: National Climate Change Secretariat, 2019. <https://www.nccs.gov.sg/docs/default-source/publications/pps-infographic-final.pdf>
- _____. *National Climate Change Strategy 2012*. Singapore: National Climate Change Secretariat, 2012. <https://www.nccs.gov.sg/docs/default-source/default-document-library/national-climate-change-strategy.pdf>
- _____. *Singapore's Climate Action Plan: Take Action Today, for a Carbon-Efficient Singapore*. Singapore: National Climate Change Secretariat, 2016. https://sustainabledevelopment.un.org/content/documents/1545Climate_Action_Plan_Publication_Part_1.pdf
- National Environment Agency. "Launch of Climate Science Research Programme Office (CSRPO) To Spearhead National Capability Building In Climate Science". 5 November 2020. <https://www.nea.gov.sg/media/news/news/index/launch-of-climate-science-research-programme-office-csrpo-to-spearhead-national-capability-building-in-climate-science>
- _____. "New NEA Facility to Boost Production of Male Wolbachia-Aedes Aegypti Mosquitoes to Benefit More Residents". 2 December 2019. <https://www.nea.gov.sg/media/news/news/index/new-nea-facility-to-boost-production-of-male-wolbachia-aedes-aegypti-mosquitoes-to-benefit-more-residents>
- _____. *Singapore's Second National Communication*. Singapore: National Environment Agency, 2010. https://www.nea.gov.sg/docs/default-source/our-services/climate-change/second-nc_12-nov-2010.pdf
- _____. "Waste Statistics and Overall Recycling". 15 April 2020. <https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling>
- 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>
- Ng Lang. "A City in a Garden". Singapore: Civil Service College. 1 June 2008. <https://www.csc.gov.sg/articles/a-city-in-a-garden>
- Parliament of Singapore. "Addenda, Prime Minister's Office". Singapore Parliamentary Reports Vol. 31, Col. 11, 21 July 1971. https://sprs.parl.gov.sg/search/topic?reportid=004_19710721_S0003_T0014
- _____. "Committee of Supply—Head L (Ministry of Environment and Water Resources)". Singapore Parliamentary Reports Vol. 94, 6 March 2018. <https://sprs.parl.gov.sg/search/sprs3topic?reportid=budget-834>
- _____. "Current and Projected 2030 Energy Consumption for Electricity Generation and Plans to Phase Out Fossil Fuels". Singapore Parliamentary Reports Vol. 94, 4 June 2020. <https://sprs.parl.gov.sg/search/sprs3topic?reportid=written-answer-6012>
- _____. "Efforts to Reduce Greenhouse Emissions by Industries in Singapore". Singapore Parliamentary Reports Vol. 94, 7 October 2019. <https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-2071>
- _____. "Singapore's Flood Resilience Plans". Singapore Parliamentary Reports Vol. 93, 20 January 2015. <https://sprs.parl.gov.sg/search/sprs3topic?reportid=oral-answer-799>
- PUB, Singapore's National Water Agency. "Frequently Asked Questions: Flash Floods". 2018. https://www.pub.gov.sg/Documents/Flash_Floods_FAQs.pdf
- _____. *Managing Urban Runoff—Drainage Handbook, 1st Ed*. Singapore: PUB, Singapore's National Water Agency, 2013. <https://www.pub.gov.sg/Documents/managingUrbanRunoff.pdf>
- _____. *Our Water, Our Future*. Singapore: PUB, Singapore's National Water Agency, 2016. <https://www.pub.gov.sg/Documents/PUBOurWaterOurFuture.pdf>
- _____. *PUB Annual Report 2018/2019*. Singapore: PUB, Singapore's National Water Agency, 2018. <https://www.pub.gov.sg/Documents/annualreport2018.pdf>
- _____. *Report on Key Conclusions and Recommendations of the Expert Panel on Drainage Design and Flood Protection Measures*. Singapore: PUB, Singapore's National Water Agency, 2012. <https://www.pub.gov.sg/Documents/fullReport.pdf>
- Singapore Department of Statistics. *M651351—Public Transport Operation and Ridership, Annual*. Singapore Department of Statistics. <https://www.tablebuilder.singstat.gov.sg/publicfacing/createDataTable.action?refId=14582>

- Singapore Food Agency. "SFA Launches Grant Call For 30x30 Express To Ramp Up Local Food Production". 8 April 2020. Media Release. <https://www.sfa.gov.sg/docs/default-source/default-document-library/sfa-media-release---launch-of-30x30-express-grant-call.pdf>
- _____. "Tender Closing For 9 HDB MSCP Rooftop Sites for Urban Farming". 17 June 2020. Media Release. <https://www.sfa.gov.sg/docs/default-source/default-document-library/joint-hdb-sfa-media-release---tender-closing-for-9-hdb-mscp-rooftop-sites-for-urban-farmingefa9900662d8448ea2878d5913775938.pdf>
- Solar Energy Research Institute of Singapore (SERIS), NUS, National University of Singapore (NUS) and Energy Research Institute @ NTU (EIR@N), including the Experimental Power Grid Centre (EPGC). "Update of the Solar Photovoltaic (PV) Roadmap for Singapore". Technical Report. March 2020. [http://www.seris.nus.edu.sg/doc/publications/Update-of-the-Solar-Roadmap-for-Singapore-\(March-2020\).pdf](http://www.seris.nus.edu.sg/doc/publications/Update-of-the-Solar-Roadmap-for-Singapore-(March-2020).pdf)
- Teo, Joseph. "The Change Maker". *Experience Singapore*. Ministry of Foreign Affairs, Issue 69, 2020. <https://www.mfa.gov.sg/Newsroom/Resources/Experience-Singapore/Issue-69>
- Zhan, Mina, Clarice Chow and Kuang Jin Yi. "District Cooling Systems: A More Efficient Way to Cool Our Residential Neighbourhoods". *CLC Insights*, Centre for Liveable Cities, Issue No.26, April 2017.
- Interviews, Speeches, Lectures and Oral Histories**
- An, Esther. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 21 February 2020. Transcript, accession number CLC/056/2020/013.
- Balakrishnan, Vivian. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 20 January 2020. Transcript, accession number CLC/056/2020/009.
- Choi, Shing Kwok. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 19 December 2019. Transcript, accession number CLC/056/2019/006.
- Chow, Winston. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 15 January 2020. Transcript, accession number CLC/056/2020/008.
- Gafoor, Burhan. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 6 February 2020. Transcript, accession number CLC/056/2020/011.
- Hui, Joseph. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 28 November 2019. Transcript, accession number CLC/056/2019/003.
- Keung, John. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 25 November 2019. Transcript, accession number CLC/056/2019/002.
- Khoo, Teng Chye. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 29 November 2019. Transcript, accession number CLC/056/2019/004.
- Koh, Tommy. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 26 February 2020. Transcript, accession number CLC/056/2020/014.
- Kwok, Fook Seng. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 23 December 2019. Transcript, accession number CLC/056/2019/007.
- Lee, Chuan Seng. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 28 January 2020. Transcript, accession number CLC/056/2020/010.
- Lim, Swee Say. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 6 February 2020. Transcript, accession number CLC/056/2020/012.
- Liong, Shie-Yui. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 28 February 2020. Transcript, accession number CLC/056/2020/015.
- Loh, Ah Tuan. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 27 October 2011. Transcript, accession number CLC/005/2011/002.
- _____. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 11 November 2019. Transcript, accession number CLC/056/2019/001.
- Ministry of Information, Communications and the Arts. "Speech by the Prime Minister Inaugurating the 'Keep Singapore Clean' Campaign on Tuesday, 1st October, 1968". <https://www.nas.gov.sg/archivesonline/data/pdfdoc/lky19681001.pdf>

- Ministry of National Development. "COS 2016: Speech by MOS Dr Koh Poh Koon 'Working Together for an Inclusive and Innovative City'". 11 April 2016. <https://www.mnd.gov.sg/newsroom/parliament-matters/speeches/view/cos-2016-speech-by-mos-dr-koh-poh-koon-working-together-for-an-inclusive-and-innovative-city>
- Ministry of the Environment and Water Resources. "Keynote Address by Mr Masagos Zulkifli, Minister for the Environment and Water Resources, at the IPCC Scoping Meeting for the Synthesis Report of the Sixth Assessment Report Opening Ceremony, 21 October 2019". 21 October 2019. <https://www.mse.gov.sg/news/keynote-address-by-mr-masagos-zulkifli-minister-for-the-environment-and-water-resources-at-the-ipcc-scoping-meeting-for-the-synthesis-report-of-the-sixth-assessment-report-opening-ceremony---21-october-2019>
- _____. "Speech by Mr Masagos Zulkifli, Minister for the Environment and Water Resources at MEWR COS 2016". 12 April 2016. <https://www.mse.gov.sg/news/speech-by-mr-masagos-zulkifli-minister-for-the-environment-and-water-resources-at-mewr-cos-2016>
- _____. "Speech by Mr Masagos Zulkifli, Minister for the Environment and Water Resources, at the Committee of Supply Debate, 4 March 2020". 4 March 2020. <https://www.mse.gov.sg/resource-room/category/2020-03-04-speech-at-the-committee-of-supply-debate/>
- _____. "Speech by Mr Masagos Zulkifli, Minister for the Environment and Water Resources, at the Partners for the Environment Forum, 17 July 2019". 17 July 2019. <https://www.mse.gov.sg/news/speech-by-mr-masagos-zulkifli-minister-for-the-environment-and-water-resources-at-the-partners-for-the-environment-forum---17-july-2019>
- _____. "Written Reply by Masagos Zulkifli, Minister for the Environment and Water Resources, to Parliamentary Question on Climate Action Engagement on 7 October 2019". 7 October 2019. <https://www.mse.gov.sg/news/written-reply-by-masagos-zulkifli-minister-for-the-environment-and-water-resources-to-parliamentary-question-on-climate-action-engagement-on-7-october-2019>
- _____. "Speech by Minister Vivian Balakrishnan, Minister for the Environment and Water Resources and Minister-in-Charge of the Smart Nation Initiative at the Inaugural Smarter Cities Roundtable on 14 July 2015". 14 July 2015. <https://www.mse.gov.sg/news/speech-by-minister-vivian-balakrishnan-minister-for-the-environment-and-water-resources-and-minister-in-charge-of-the-smart-nation-initiative-at-the-inaugural-smarter-cities-roundtable-on-14-july-2015>
- Ministry of Trade and Industry. "Second Minister S Iswaran's Reply on the Use of Coal at Tembusu Multi-Utilities Complex on Jurong Island". 13 March 2013. <https://www.mti.gov.sg/Newsroom/Parliamentary-Replies/2013/03/Second-Minister-S-Iswarans-reply-on-the-use-of-coal-at-Tembusu-Multi-Utilities-Complex-on-Jurong-Island>
- _____. "Speech by Minister Chan Chun Sing at the 12th Singapore International Energy Week 2019". 29 October 2019. <https://www.mti.gov.sg/Newsroom/Speeches/2019/10/Speech-by-Minister-Chan-Chun-Sing-at-the-12th-Singapore-International-Energy-Week-2019>
- National Climate Change Secretariat. "Remarks by Senior Minister S Jayakumar, Minister for National Development Mah Bow Tan and Minister for the Environment and Water Resources Yaacob Ibrahim at Media Conference, 29 November 2010". 29 November 2010. <https://www.nccs.gov.sg/media/speeches/remarks-by-senior-minister-s-jayakumar-minister-for-national-development-mah-bow-tan-and-minister-for-the-environment-and-water-resources-yaacob-ibrahim-at-media-conference-29-november-2010>
- Prime Minister's Office Singapore. "National Day Rally 2019". 18 August 2019. <https://www.pmo.gov.sg/Newsroom/National-Day-Rally-2019>
- _____. "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean at the Launch of Clean & Green Singapore 2019 on 2 November 2019". 2 November 2019. <https://www.pmo.gov.sg/Newsroom/SM-Teo-Chee-Hean-at-the-Launch-of-Clean-Green-Singapore-2019>
- _____. "Speech by Senior Minister and Coordinating Minister for National Security Teo Chee Hean at the PMO Committee of Supply 2020 on 'A Low-Carbon and Climate Resilient Singapore' on 28 February 2020". 28 February 2020. <https://www.pmo.gov.sg/Newsroom/Speech-by-SM-Teo-Chee-Hean-at-the>
- _____. "Speech by Senior Minister and Coordinating Minister for National Security, Teo Chee Hean at the 'Shell Powering Progress Together' Forum on 4 July 2019". 4 July 2019. <https://www.pmo.gov.sg/Newsroom/SM-Teo-Chee-Hean-Shell-Powering-Progress-Together-Forum>

- Singapore Food Agency. "Keynote Address by Mr Lim Kok Thai, Chief Executive Officer of Singapore Food Agency, at the Asia-Pacific Agri-Food Innovation Week (Day 2—Urban Agriculture, Sustainable Aquaculture and Protein Innovation) on 21 November 2019 at Grand Hyatt Singapore". 21 November 2019. [https://www.sfa.gov.sg/docs/default-source/default-document-library/keynote-address-by-mr-lim-kok-thai-ceo-of-sfa-at-asia-pacific-agri-food-innovation-week-\(21-nov-2019\).pdf](https://www.sfa.gov.sg/docs/default-source/default-document-library/keynote-address-by-mr-lim-kok-thai-ceo-of-sfa-at-asia-pacific-agri-food-innovation-week-(21-nov-2019).pdf)
- Tan, Yong Soon. "Interview by CLC". Centre for Liveable Cities, Ministry of National Development, 17 December 2019. Transcript, accession number CLC/056/2019/005.

Newspapers and Magazines

- Almeda, Pamela. "Clean Energy R&D Gets \$170m Boost". *CNA*, 6 November 2007. <http://www.wildsingapore.com/news/20071112/071106-5.htm>
- Chua, Grace. "Singapore's First Coal-Burning Utility Plant Now Operational". *The Straits Times*, 22 February 2013. <https://www.straitstimes.com/singapore/singapores-first-coal-burning-utility-plant-now-operational>
- Chuang, Peck Ming. "Temasek Sets 2030 Target for its Portfolio to Halve Greenhouse Emissions". *The Business Times*, 13 November 2019. <https://www.businesstimes.com.sg/companies-markets/temasek-sets-2030-target-for-its-portfolio-to-halve-greenhouse-emissions>
- Co, Cindy. "Singapore to Plant 1 Million Trees, Develop More Gardens and Parks by 2030". *CNA*, 4 March 2020. <https://www.channelnewsasia.com/news/singapore/singapore-to-plant-1-million-trees-develop-more-gardens-and-12500858>
- Fogarty, David. "World is on Track to Finalise Climate Deal: UN". *The Straits Times*, 11 July 2018. <https://www.straitstimes.com/world/world-is-on-track-to-finalise-climate-deal-un>
- Khong, Nicholas. "Nature Parks and Reserves to Receive Boost Against Climate Change". *TODAY*, 26 January 2019. <https://www.todayonline.com/singapore/250000-trees-be-planted-nature-parks-reserves-over-10-years-boost-resilience-singapores>
- Kurtyka, Michal. "Expectations for Poland's Global Climate Change Summit". *The Straits Times*, 28 November 2018. <https://www.straitstimes.com/opinion/expectations-for-polands-global-climate-change-summit>
- Lee, Kuan Yew. "The World: More Globalized, More Troubled". *Forbes*, 28 September 2007. <https://www.forbes.com/forbes/2007/1015/027.html#4fd74b01d340>
- Ng, How Yong. "Making Sure Singapore's Taps Don't Run Dry". *TODAY*, 1 September 2015. <https://www.todayonline.com/commentary/making-sure-singapores-taps-dont-run-dry>
- Pearlman, Jonathan. "Aussie Solar Farm Project Aims to Power Up Singapore Too". *The Straits Times*, 21 July 2019. <https://www.straitstimes.com/asia/australian/aussie-solar-farm-project-aims-to-power-up-spore-too>
- Tan, Audrey. "Singapore has Vested Interest in Strong Result at Climate Talks, Says Masagos". *The Straits Times*, 10 December 2018. <https://www.straitstimes.com/world/europe/spore-has-vested-interest-in-strong-result-at-climate-talks>
- _____. "Singapore Will Work With Asean Neighbours on Climate Change Issues: Masagos". *The Straits Times*, 16 November 2017. <https://www.straitstimes.com/singapore/environment/singapore-will-work-with-asean-neighbours-on-climate-change-issues-masagos>
- Tan, Christopher. "COE Supply Dips as Zero-Growth Cap Kicks in". *The Straits Times*, 19 January 2018. <https://www.straitstimes.com/singapore/transport/coe-supply-dips-as-zero-growth-cap-kicks-in>
- _____. "Owners of Electric Vehicles Can Pay to Use BlueSG Chargers from Today". *The Straits Times*, 23 April 2019. <https://www.straitstimes.com/singapore/transport/electric-vehicle-owners-can-pay-to-use-bluesg-chargers-from-today>
- The Business Times. "Tesla's EVs are About 'Lifestyle', Not Climate: Masagos Zulkifli". *The Business Times*, 23 August 2019. <https://www.businesstimes.com.sg/transport/teslas-evs-are-about-lifestyle-not-climate-masagos-zulkifli>

- The Straits Times. "Garden Town to have 100,000 People: Woon". *The Straits Times*, 14 December 1968. <http://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19681214-1.2.62>
- _____. "Minister Opens Keep Water Clean Campaign". *The Straits Times*, 28 June 1973. <https://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19730628-1.2.88>
- _____. "Spore to Become Beautiful, Clean City Within Three Years". *The Straits Times*, 12 May 1967. <https://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19670512-1.2.20>
- _____. "Tree-Planting Day to Keep the City Clean, Green". *The Straits Times*, 16 October 1971. <http://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19711016-1.2.123>

Websites

- Association of Southeast Asian Nations. "ASEAN Cooperation on Climate Change". <https://environment.asean.org/awgcc/>
- Biblioasia. "When Tigers Used to Roam: Nature & Environment in Singapore". *Biblioasia*, 2019.
- Bland, Eric. "Island of Trash or the 'Garbage of Eden'?" *NewScientist*, 11 April 2007. <https://www.newscientist.com/article/mg19425991-600-island-of-trash-or-the-garbage-of-eden/>
- BlueSG. "BlueSG's Electric Vehicle Car-sharing Celebrates its Second Anniversary in Singapore with More Than 300 Charging Stations, Launching More Flexible New Subscription Plans and Expanding its Charging Offer Network". 12 December 2019. https://www.bluesg.com.sg/sites/bluesg/files/medias/images/PDF/bluesg_celebrates_its_2nd_anniversary_with_more_than_300_stations.pdf
- Building and Construction Authority. "About Green Mark". https://www.bca.gov.sg/greenmark/green_mark_buildings.html
- _____. "What is Zero Energy Building?" <https://www.bca.gov.sg/zeb/whatsizeb.html>
- Energy Efficient Singapore. <https://www.e2singapore.gov.sg>
- Graham, Rachel. "Hydrogen Fuel Cell vs Electric Cars: What You Need To Know But Couldn't Ask". *EuroNews*, 14 February 2020. <https://www.euronews.com/living/2020/02/13/hydrogen-fuel-cell-vs-electric-cars-what-you-need-to-know-but-couldn-t-ask>
- Housing and Development Board. "Homes at One with Nature". 18 July 2018. <https://www.hdb.gov.sg/cs/infoweb/about-us/news-and-publications/press-releases/homes-at-one-with-nature1>
- Meteorological Service Singapore. Centre for Climate Research Singapore. "Climate Projections". <http://ccrs.weather.gov.sg/climate-projections/>
- _____. "Climate of Singapore". <http://www.weather.gov.sg/climate-climate-of-singapore/>
- Ministry of Sustainability and the Environment. Let's Game Change Climate Change. "Climate Change is Here. It's Happening". <https://www.climategamechanger.sg/2020/01/08/impacts-of-climate-change-in-singapore/>
- _____. "Meeting the Challenge of Climate Change Through Climate Science". <https://www.climategamechanger.sg/2019/12/09/meeting-the-challenge-of-climate-change-with-actions-based-on-robust-science/>
- Mokhtar, Faris. "Singapore Has a S\$100 Billion Plan to Survive in a Far Hotter World Than Experts Predicted". *Bloomberg News*, 26 February 2020. <https://www.bloomberg.com/news/features/2020-02-25/singapore-has-a-100-billion-plan-for-adapting-to-climate-change>
- National Climate Change Secretariat. "Impacts Of Climate Change In Singapore". <https://www.nccs.gov.sg/singapores-climate-action/impact-of-climate-change-in-singapore/>
- _____. "Inter-Ministerial Committee on Climate Change". <https://www.nccs.gov.sg/who-we-are/inter-ministerial-committee-on-climate-change/>
- _____. "Singapore's Emissions Profile". <https://www.nccs.gov.sg/singapores-emissions-profile/>
- National Environment Agency. "Air Pollution Regulations". <https://www.nea.gov.sg/our-services/pollution-control/air-pollution/air-pollution-regulations>

- _____. "Solid Waste Management Infrastructure". <https://www.nea.gov.sg/our-services/waste-management/3r-programmes-and-resources/waste-management-infrastructure/solid-waste-management-infrastructure>
- National Parks Board. "Mission and History". <https://www.nparks.gov.sg/about-us/mission-and-history>
- National Research Foundation. "The Energy Challenge". <https://www.nrf.gov.sg/programmes/national-innovation-challenges/the-energy-challenge>
- Reyes, Elga. "Singapore: \$12 Million In Grants Awarded To Solar Energy Research". *Eco-Business*, 27 June 2013. <https://www.eco-business.com/news/singapore-12-million-grants-awarded-solar-energy-research/>
- Roberts, David. "The Hottest New Thing In Sustainable Building Is, Uh, Wood". *Vox*, 15 January 2020. <https://www.vox.com/energy-and-environment/2020/1/15/21058051/climate-change-building-materials-mass-timber-cross-laminated-clt>
- Singapore Food Agency. "Our Singapore Food Story". <https://www.sfa.gov.sg/food-farming/sgfoodstory/grow-local>
- Union of Concerned Scientists. "The IPCC: Who Are They and Why Do Their Climate Reports Matter?" 11 October 2018. <https://www.ucsusa.org/resources/ipcc-who-are-they>
- Wahlén, Catherine Benson. "73 Countries Commit to Net Zero CO2 Emissions by 2050". *SDG Knowledge Hub*, 17 December 2019. <https://sdg.iisd.org/news/73-countries-commit-to-net-zero-co2-emissions-by-2050/>

IMAGE CREDITS

(Page numbers indicated below)

- | | |
|---|---|
| A J Hawker Collection, National Archives of Singapore | Finbarr Fallon |
| 19 | 151 |
| Adwo, Shutterstock.com | Fong Tiew Weng, The Planning and Development of Jurong New Town, Through the Years |
| 133 | 20 |
| budak, Flickr, CC BY-NC-ND 2.0 | Housing and Development Board |
| 26 | 30, 104, 137, 138 |
| Building and Construction Authority | K6ka, Wikimedia Commons, CC BY-SA 3.0 |
| 78, 79 | 148 |
| Centre for Climate Research Singapore | Kevin Fan Hsu |
| 72 | Cover |
| Centre for Liveable Cities | Land Transport Authority |
| 17 (right), 98, 100, 147 | 82, 127 |
| Citiponics | Mark Stoop, Unsplash |
| 107 | 7 |
| City Developments Limited | Ministry of Communications and Information |
| 115 | 119, 124 |
| Clement Chai, Unsplash | Ministry of Foreign Affairs |
| 58 | 134, 135 |
| David Ayres, Flickr | Ministry of Information and the Arts Collection, National Archives of Singapore |
| 17 (left) | 29 |
| Filbert Koung, Singapore Research Nexus, SG Photobank, CC BY-SA 4.0, cropped from original | |
| 4 | |

Ministry of Sustainability and the Environment

109 (all except 2nd row [left] and 3rd row)

Ministry of Trade and Industry

85

Muhammad Omer Mughal et al., High-Resolution, Multilayer Modeling of Singapore's Urban Climate Incorporating Local Climate Zones

103

Nanyang Technological University

91

National Climate Change Secretariat

35, 93, 109 (2nd row [left] and 3rd row)

National Environment Agency

43, 83

National Parks Board

40, 105 (bottom), 139, 145

People's Association

31

Prime Minister's Office Singapore

97, 99

PUB, Singapore's National Water Agency

45, 47, 88, 131

Singapore Food Agency

143

Singapore Green Building Council

55, 113

Singapore Tourist Promotion Board Collection, National Archives of Singapore

21

Sino-Singapore Tianjin Eco-City Investment and Development Co., Ltd.

121

The Straits Times, Photonico.asia

16, 23, 24

tobiasjo, iStock.com

122

travel oriented, Flickr, CC BY-NC-ND 2.0

57

Urban Redevelopment Authority

28, 105 (top)

ZDL, Shutterstock.com

52

