

Chapter 6

Singapore

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Chapter 6

Singapore

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1. Introduction

Like other countries in South-East Asia, Singapore is located along the equator. Its temperature ranges from 24°C to 35°C throughout the year. It has achieved tremendous economic growth since its independence in 1965. The gross domestic product (GDP) in 2015 constant prices was S\$8,170.2 million in 1965 and S\$475,279.5 million in 2019, increasing about 58 times. Indeed, Singapore has become one of the highest per-capita income countries in the world. Its per capita GDP was S\$1,581 in 1965 and S\$88,991 in 2019.¹

Singapore's carbon dioxide emissions were 218.9 million tonnes in 2019 (BP, 2020). It ranks 126th of 142 countries in terms of carbon dioxide emissions per US dollar of GDP and 27th out of 142 countries in terms of emissions per capita (NCCS, 2020).

Unlike other member countries of the Association of Southeast Asian Nations (ASEAN), Singapore has not been affected by any major natural disasters such as earthquakes, tsunamis, or tropical storms. However, Singapore has suffered from flooding due to torrential and heavy rains. It also had four incidences of viral disease outbreaks since its independence in 1965 – encephalitis in 1998; hand, foot, and mouth disease in 2000; severe acute respiratory syndrome (SARS) in 2002; and dengue in 2016.²

The National Climate Change Secretariat (NCCS) published a report in 2020 that presents the structure of the Inter-Ministerial Committee on Climate Change (IMCCC), a list of relevant legislation on climate change, and relevant climate-change publications (NCCS, 2020). The list of the relevant publications includes United Nations Framework Convention on Climate Change (UNFCCC) submissions, master plans, and road maps.

The IMCCC, which is tasked to enhance whole-of-government coordination on climate change policies, is chaired by Teo Chee Hean, senior minister and coordinating minister for national security. Consisting of seven ministers, it has three working groups: the Long-Term Emissions and Mitigation Working Group, International Negotiations Working Group, and Resilience Working Group.

Examples of key legislation are the Carbon Pricing Act 2018, Energy Conservation Act 2012, Environmental Protection and Management Act 2019, and Resource Sustainability Act 2019.

Examples of UNFCCC publications are *Singapore's Initial National Communication* in 2000, *Singapore's Second National Communication* in 2010, *Singapore's Third National Communication and First Biannual Update Report* in 2014, *Singapore's Second Biannual Update*

¹ Department of Statistics Singapore, <https://www.singstat.gov.sg/> (accessed 15 September 2020).

² EM-DAT Public, <https://public.emdat.be/> (accessed 6 October 2021).

Report in 2016, Singapore's Fourth National Communication and Third Biannual Update Report in 2018 and Enhanced Nationally Determined Contribution in 2020. Examples of master plans and road maps are Singapore Green Plan 2030 in 1992, Sustainable Singapore Blueprint in 2009, National Climate Change Strategy in 2012, Singapore's 2nd National Climate Change Study – Climate Projections to 2100 Science Report in 2014, Climate Action Plan: Take Action Today, for a Sustainable Future in 2016, and Zero Waste Masterplan in 2019.

The *Singapore Green Plan 2030* is a national sustainability movement that seeks to rally bold and collective action to tackle climate change. It comprises five key pillars: City in Nature, Energy Reset, Sustainable Living, Green Economy, and Resilient Future. It also sets out concrete sectoral plans and targets for the next 10 years. It is a 'living' plan, which will evolve and be refined over time.³

2. Financing Infrastructure for Climate-Change Adaptation

This section describes adaptation efforts in Singapore and presents three cases of implementing climate adaptation in Singapore: coastal protection, water resources management, and drainage and flood protection.

2.1. Adaptation Efforts

Singapore has always adopted whole-of-government efforts; at the centre is the NCCS. To address the projected effects of climate change over the next 50 to 100 years, the government has introduced a resilience framework for safeguarding Singapore. Singapore's adaptation approaches comprise two pillars – risk assessment and adaptation planning. The former identifies and categorises climate-change risks along with advances in climate science. The latter formulates options to tackle the risks identified in a dynamic and flexible manner.

Early adaptation efforts are reflected in the *Singapore Green Plan 2030* and *Sustainable Singapore Blueprint 2015* (CLC, 2015). Singapore strives to maintain a balance between development and conserving the environment in adaptation plans. Along with early preparation to adapt to the impacts of climate change, Singapore established its resilience framework along three key themes – an open economy, overcoming limitations to create a sustainable environment, and maintaining a multi-cultural and diverse city.

2.2. Climate-Change Study

Singapore's 2nd National Climate Change Study examines anticipated climate change impacts on the country (MSS, 2014; 2015). The study has two phases. Phase 1 projected the changes in the main climate variables of interest to Singapore (e.g. temperature, rainfall, and sea-level rise). A key consideration was to understand the intended uses of the climate projections to tailor them as far as possible into the future to address the needs of key stakeholders. The centre of this report thus became downscaled climate and sea-level projections for the 21st century in the region centred around Singapore, derived from the latest available climate models. A brief

³ Singapore Green Plan 2030, <https://www.greenplan.gov.sg/>

overview of plausible longer-term changes for sea-level rise, temperature, and precipitation to 2300 was also provided (MSS, 2014).

Phase 2 of the study, which began in 2014, made use of these projections to examine the climate-change impacts on water resources and drainage, biodiversity and greenery, network infrastructure, and infrastructure. This, in turn, will guide government agencies in their planning and serve as inputs to help shape Singapore's resilience plans. The Phase 2 study also aims to provide the best available scientific information on the spatial and temporal scales most relevant to Singapore. This will inform the discussion and decision-making around the actions required to safeguard its population, environment, and infrastructure. Measures that address physical vulnerabilities in Singapore are included in Phase 2 as well as the Building and Construction Authority's risk map study.

2.3. Implementation of Climate-Change Adaptation

Singapore is within 15 metres above sea level, and 30% of the land is less than 5 metres above sea level. A rise in sea level due to climate change will thus cause an immediate threat. Protecting the coastline and improving drainage are amongst Singapore's priorities in dealing with the effects of climate change. The construction of walls and stone embankments cover 70%–80% of Singapore's coastline. Plants, like mangroves and seagrasses, can be used as natural barriers to inundation. The minimum level of land reclamation in Singapore was raised in 2011 from 3 metres to 4 metres above sea level. To protect Singapore's coasts in the long term, Singapore continues to assess the possible impacts of coastal inundation under various scenarios of climate change and to develop long-term strategies and adaptation measures applicable to its coasts.

Singapore has very limited water sources. There are five sources – local catchment, imported water, NEWater (i.e. the brand name of highly treated reclaimed wastewater), reclaimed water, and desalinated water. Ensuring the sustainability of these water resources through appropriate measures is a top priority. NEWater and desalinated water are not dependent on rainfall and will meet 70% of Singapore's water demand by 2030. The capacity for these two sources of water will be further increased to meet up to 80% of water demand by 2060.

Securing the water supply and enhancing flood resilience come in tandem. Singapore is taking a holistic approach in managing its drainage system, considering its need for water and flood risks. Flexibility and adaptability are the two key pillars in its approach to stormwater management, known as 'Source-Pathway-Receptor'. Measures are developed and applied to ensure that pathways, such as drains and canals, function through widening and deepening; sources perform the key role of retaining water while running off stormwater; and receptors work as buffers to floods.

3. Challenges and Opportunities for Better Implementation of Climate-Change Adaptation Measures

Singapore has aligned its climate-change adaptation efforts with green growth. This presents challenges as well as potential opportunities for better implementation of climate-change adaptation measures. Green growth is pursued through five thematic areas – clean technology, test bedding, clean information and communication technology (ICT), carbon services and climate finance, and climate risk management.

2.1. Clean Technology and Test Bedding

The clean-energy industry is a strategic growth area for Singapore. Singapore has implemented a comprehensive blueprint to develop the industry and to ensure key investments in several areas, such as high-value manufacturing, engineering, biofuels, research and development, and regional headquarters. However, a long lead period for such investments – and the ensuing uncertainties – are challenges.

Singapore has created a suite of supporting services and opportunities for firms and researchers to develop, test, and validate clean-energy technologies in real-world settings. Test bedding facilitates the commercialisation process for new technologies and positions Singapore as a ‘living laboratory’ to evaluate, pilot, and commercialise innovative solutions for Asian and global markets. There are several examples of test beds in Singapore:

- (i) **CleanTech Park.** CleanTech Park is the first eco-business park in the region. It clusters clean-technology companies together and serves as a platform for test bedding and prototyping of clean technologies and sustainable urban solutions. The 50-hectare Park at Nanyang Avenue is planned to be fully developed in three phases over the next 20 years. Upon completion, it will house a population of 20,000 ‘green-collar’ workers.
- (ii) **Floating solar.** A photovoltaic (PV) pilot is a joint project between the Singapore Economic Development Board and Singapore water agency, PUB. It aims to assess the feasibility and cost-effectiveness of installing floating solar PV systems on freshwater reservoirs.
- (iii) **Renewable Energy Integration Demonstration in Singapore.** The Renewable Energy Integration Demonstration in Singapore (REIDS) is a large-scale offshore test and demonstration microgrid located in Semakau Landfill that integrates renewable energy production from solar, wind, tidal, biofuel, and fuel cells with smart-grid technologies.
- (iv) **Punggol Eco-Town.** This eco-town demonstrates sustainable urban planning and design, green technology adoption, and active community partnership. Social, economic, and environmental considerations have been formulated by the Housing Development Board (HDB) to steer its development. LED lighting and elevator energy-regenerative systems, renewable solar energy, water conservation and rainwater harvesting systems, and recycling solutions are some of the technologies being test-bedded. HDB is also working with government agencies such as the Energy Market Authority to pilot an intelligent energy system smart-grid project, and with industry partners such as Panasonic to test-bed home energy management systems to monitor energy consumption to reduce overall energy consumption within the town.

- (v) **Housing Development Board Greenprint.** This is a framework of goals and strategies to guide town development, aligned with *Sustainable Singapore Blueprint 2015* targets, to reduce the consumption of resources from current business-as-usual levels. Greenprint aims to create sustainable homes with the community in both existing and new HDB towns. HDB will pilot the Greenprint in 38 blocks of flats in Yuhua Estate in Jurong, refining the framework to suit the needs of different towns.
- (vi) **Electric vehicle test bed.** The electric vehicle test bed is driven by a multi-agency taskforce co-led by the Energy Market Authority and Land Transport Authority. It aims to assess different electric vehicle prototypes and charging technologies in Singapore's urbanised environment and road conditions. Phase 1 was launched in June 2011 and completed in December 2013. Phase 2 will be a car-sharing programme, which will introduce up to 1,000 electric vehicles and charging infrastructure to trial the viability of implementing electric vehicle fleets and to catalyse their widespread adoption. It was launched in 2016.
- (vii) **Zero-energy building.** This is a 4,500-square metre Building and Construction Authority flagship project under the *Green Building Masterplan*. The building generates its own electricity from solar panels and reduces its energy needs using green-building technology and design. It now serves as a test-bedding facility for the integration of green-building technology into existing buildings. Since its launch in October 2009, the building has achieved net-zero energy consumption for 3 consecutive years.
- (viii) **Jurong Lake District.** Jurong Lake District is a new area identified in the Urban Redevelopment Authority's master plan to support Singapore's economic growth for the next 10 to 15 years and to decentralise commercial activities out of the city centre by bringing jobs closer to where people live. The district is envisioned to be a model for a mixed-used urban precinct that is sustainable, smart, and connected. The government will collaborate with industry to conduct pilots and trials of smart technologies within the district.
- (ix) **Nanyang Technological University EcoCampus.** In partnership with the Economic Development Board and JTC Corporation, the EcoCampus initiative will transform Nanyang Technological University's 200-hectare campus into a super test bed for research projects in cutting-edge green technologies. These range from smart building systems and renewable energy to electric transport and water conservation technologies, complementing the vibrant sustainability research and development community in the adjoining 50-hectare CleanTech Park developed by JTC Corporation.
- (x) **Smart Campus Platform.** Temasek Polytechnic, in January 2015, announced its collaboration with private sector firms, such as Cisco, EMC, Johnson Controls, and NCS, focussing on ICT solutions for education. The platform will utilise innovative technologies to collect and to analyse data to improve decision-making on campus, enhancing the work and education experience.

3.2. Clean Information and Communication Technology

With a vibrant and thriving green ICT industry comprising more than 80 of the top 100 software and services companies in the world, Singapore is at the forefront of green ICT development. The Infocomm Media Development Authority routinely works with industry partners and companies to advance Singapore's position within the ICT industry. This makes Singapore the perfect location for companies looking to develop and to test new solutions.

The Green Data Centre Innovation Programme has three sub-programmes – the Research Programme, Innovation Programme, and Hub Programme. The Research Programme provides funding to research entities to improve green data centre technologies and to translate them into actual products or solutions that can be adopted to produce positive economic impacts. The Innovation Programme focusses on driving the prototyping, integration, and demonstration of technologies. This is done by inviting companies to form a consortium to develop and to pilot innovative solutions that will significantly improve the energy efficiency of local data centres. The Hub Programme complements the two programmes by establishing Singapore's first Green Data Centre Hub. It will be a test bed that mirrors a data centre environment to develop, prototype, demonstrate, and benchmark energy-efficient data centre technologies.

In addition, a tax incentive was introduced in 2012 to encourage data centre operators to become more energy efficient. Under the Investment Allowance Scheme for Energy Efficiency Projects (Data Centres), eligible companies will be granted an investment allowance to offset 30% to 50% of the fixed capital expenditure incurred when implementing energy-efficiency retrofits for their data centres.

3.3. Carbon Services and Climate Finance

This has two specific areas:

- (i) **Commodities trading hub.** Singapore aims to be the region's top commodities trading hub. Indeed, it is home to many energy traders, who make up most of the clientele for carbon services companies. This makes Singapore an ideal location for companies working on carbon projects in the region – especially since it is close to the biggest sources of carbon credits, India and China. The Economic Development Board and Enterprise Singapore have engaged carbon companies to establish a presence. These companies offer low-carbon project development, consulting and verification services for the Clean Development Mechanism (CDM), carbon footprinting, project financing, and legal services.
- (ii) **Carbon credits trading.** To curb carbon emissions caused by industry and businesses, many developed countries enable companies to purchase carbon credits. These carbon credits can then be used to meet part of their emissions reduction requirements. As the main source of carbon credits, the CDM allows emissions reduction projects in developing countries to earn certified emission reduction (CER) credits, which represent 1 tonne of carbon dioxide each. CER credits can be traded, sold, and used by developed nations to help them meet their obligations for emissions reduction under the Kyoto Protocol. As of 31 December 2012, more than 5,511 CDM projects have been registered worldwide since 2006, leading to over 2.191 million CERs issued by the UNFCCC. Asia is a key supplier of

carbon credits, with more than 82% of registered CDM projects originating in the region. Its strategic location and ideal business environment make Singapore a prime location for trading and services companies wanting to develop carbon projects in the region.

3.4. Climate Risk Management

The impact of climate change has been increasingly felt in recent years, adding to the growing importance of climate risk assessment. Climate risk assessment helps nations prepare for the effects of climate change by evaluating the distribution of resources, diversification, risk pooling, insurance, and infrastructure and capability development.

As a major financial centre, Singapore is an ideal launch pad for leading insurance, reinsurance, and insurance brokerage companies to meet the region's insurance needs for climate-related risks. Currently, there are more than 200 insurance players in Singapore tapping into Asia's market potential. Moreover, the following Singaporean institutions conduct research on the risks of climate change: Nanyang Technological University's Institute for Catastrophe Risk Management, which studies the vulnerabilities and potential damages of catastrophic events; Earth Observatory of Singapore, which forecasts the regional consequences of global climate change by assessing global climate drivers that are active in the region; and National University of Singapore's Centre for Hazard Research, which studies the long- and short-term effects of natural disasters.

3.5. Singapore's Adaptation Strategy for Infrastructure

Singapore has developed a low-emissions development strategy for adaptation focusing on six areas: coastal protection, water resources, and drainage; buildings and infrastructure; network infrastructure; biodiversity and greenery; public health and food security; and the urban heat island effect.

Singapore is also preparing a road map to develop the capabilities needed to regulate its urban climate. The project, New Cooling Singapore 2.0, is funded by the National Research Foundation Campus for Research Excellence and Technological Enterprise (CREATE). It is led by the Singapore-ETH Centre, a collaboration between ETH Zurich and the National Research Foundation. It brings together researchers from the Singapore-Massachusetts Institute of Technology Alliance for Research and Technology, TUMCREATE (established by the Technical University of Munich) and the National University of Singapore.

4. Key Long-Term Climate Actions

Singapore prepared and implemented climate actions over the long term under eight thematic areas: the future electricity grid, Energy Efficiency Fund, transport, buildings, Green Towns Programme, waste and water, Energy Grid 2.0, and sustainable finance.

4.1. Future Electricity Grid

Singapore will work to ensure a sustainable, reliable, and affordable energy supply. Its vision for a sustainable energy future not only builds on past and existing efforts but also considers future possibilities that could enable its electricity grid to be significantly decarbonised. Singapore will

harness the four supply switches of natural gas, solar, regional power grids, and emerging low-carbon alternatives, together with greater energy-efficiency, to accelerate its energy transformation.

4.2. Energy-Efficiency Fund

The government expects revenue of about S\$1 billion from carbon tax revenues over the first 5 years, and it is prepared to spend more than that amount during this period to support companies, including small and medium-sized enterprises (SMEs) and generation companies, in improving their energy- and carbon-efficiency by adopting greener and cleaner technologies and practices.

The Energy Efficiency Fund and the Resource Efficiency Grant for Energy cover costs for equipment, materials and consumables, technical software, and professional services towards this goal. To further support industrial facilities in being more energy-efficient, the funding support for both initiatives was increased in 2019 from a cap of 30% to a cap of 50%. In October 2019, the government launched a new grant to encourage companies to implement energy management information systems. These systems can help companies more accurately monitor and analyse their energy usage using real-time data to identify performance gaps and opportunities for improvement.

4.3. Transport

Singapore aims to reduce carbon emissions in the transport sector via the walk-cycle-ride mode. It also intends to expand the active mobility network by expanding and improving mass public transport and shared transport, introducing cleaner and greener vehicles, and establishing greener transport infrastructure.

4.4. Buildings

Singapore aims to reduce energy use and to increase sustainability in the building sector through the adoption of super low-energy (SLE) buildings (i.e. net-zero energy buildings). SLE building initiatives include the Green Mark Scheme for SLE Buildings, SLE Challenges, and *SLE Building Technology Roadmap*. Singapore aims to sustain optimal performance throughout the life cycle of buildings.

4.5. Green Towns Programme

Singapore is targeting reducing carbon emissions in the household sector by putting more energy-efficient appliances into homes and promoting energy-conservation habits. The Mandatory Energy Labelling Scheme (MELS) and Minimum Energy Performance Standards (MEPS) are key policies to reduce energy consumption and emissions in households using energy-efficient appliances. The government provided incentives to purchase climate-friendly appliances by introducing the S\$24.8-million Climate Friendly Household Programme in 2020. This programme is a joint initiative by the National Environment Agency and PUB to encourage households to reduce energy and water consumption while saving costs in the long run.

Since 2005, HDB has been driving sustainability efforts in public housing estates, which provide affordable housing to 80% of Singaporeans. Over the years, Singapore has managed to achieve

a 10% reduction in annual energy consumption in these public housing estates. Through the Green Towns Programme, HDB aims to reduce annual energy consumption by a further 15% by 2030. The programme will focus on addressing three areas on sustainability and liveability: reducing energy consumption, recycling rainwater, and cooling HDB towns.

4.6. Waste and Water

Singapore's inaugural *Zero Waste Masterplan* launched in 2019 outlines a changing approach to managing waste to achieve the vision of a zero-waste nation. Under the plan, the government announced a new target to reduce the amount of waste sent to Semakau Landfill per capita per day by 30% by 2030 (MEWR, 2019). This is in addition to existing recycling targets under the *Sustainable Singapore Blueprint 2015*. Collectively, these targets would extend Semakau Landfill's lifespan beyond 2035.

Singapore promotes sustainable waste management through its Resource Sustainability Act. It also is upgrading its waste management infrastructure to increase the efficiency of recycling and waste incineration. To reduce water consumption and energy use in water treatment, Singapore is promoting water conservation in households. It is also working to reduce energy use in producing desalinated water along with promoting water efficiency in businesses and industries.

4.7. Energy Grid 2.0

Over the next 5 years, Singapore will be investing S\$55 million in Energy Grid 2.0, a next-generation grid system that will transform how energy supply and demand are managed by consolidating gas, solar, thermal, and other sources of energy into a single intelligent network that is more efficient, sustainable, and resilient. The research for Energy Grid 2.0 will focus on power distribution; district cooling; and the design, intelligence, management, and optimisation of energy systems.

To push the boundaries of innovation in the energy sector, National Research Foundation and Energy Market Authority launched two consortia in 2019 under Energy Grid 2.0, and both have set aside up to S\$9 million over 3 years for this. The Smart Grid and Power Electronics Consortium Singapore (SPECS) and Cooling Energy Science and Technology Singapore (CoolestSG) Consortium will bring together research institutes, companies, and the government to develop solutions in smart grids and green cooling.

4.8. Sustainable Finance

Singapore aims to support the financial sector in mobilising global capital for the green economy and channelling it to new investments in green businesses, technology, and infrastructure, which reduces emissions while creating jobs and growth opportunities. Its goal is to be a leading centre for green finance in Asia and globally.

Singapore is trying to build a financial system that is resilient to environmental risks. The Monetary Authority of Singapore has included banks' sustainability practices in its supervisory assessment. This aims to strengthen banks' efforts to integrate sustainability into their business models and risk management functions. Environmental risk management guidelines are also being developed for the banking, insurance, and asset management sectors to reinforce industry standards on governance, risk management, and disclosure of environmental risks.

Singapore's financial institutions are also taking action to make financing practices more environmentally responsible. Local banks have implemented policies aligned with guidelines on responsible financing issued by the Association of Banks in Singapore in 2015 to evaluate their borrowers' environmental, social, and governance (ESG) risks and to help borrowers improve their sustainability profiles. Several asset managers in Singapore have signed the United Nations Principles for Responsible Investment and developed the *Singapore Stewardship Principles for Responsible Investors* (Stewardship Asia Centre, 2022). Singapore is continuing to work with the asset management industry to foster good stewardship amongst investors and to drive sustainable investments based on ESG considerations.

In 2016, in line with the practice of other leading stock exchanges, the Singapore Exchange (SGX) introduced a requirement for its listed issuers to produce annual sustainability reports. In these reports, listed issuers must disclose ESG parameters on a comply-or-explain basis. The number of SGX-listed issuers communicating their sustainability disclosures has increased significantly, with almost all listed issuers publishing their sustainability reports for 2018. Moving forwards, SGX plans to provide more guidance on ESG data disclosure to make such data more meaningful for investors.

Singapore is developing solutions and markets for green finance by introducing and promoting green finance instruments such as green bonds. To catalyse more green bond issuances, Singapore launched the Green Bond Grant Scheme in 2017 to level the cost associated with issuing green bonds compared to that of a conventional bond and to promote the adoption of internationally accepted standards on sustainability. The scheme was renamed to the Sustainable Bond Grant Scheme after its expansion to include social and sustainability bonds in 2019. To date, more than S\$6.5 billion of green bonds have been issued in Singapore.

To encourage green and sustainable bond issuance in ASEAN, Singapore supported the development of *ASEAN Green Bond Standards*, which reference the *International Capital Market Association Green Bond Principals*. Building on the *ASEAN Green Bond Standards*, the Second ASEAN Capital Market Forum launched *ASEAN Social Bond Standards* and *ASEAN Sustainability Bond Standards* in October 2018 to provide issuers and investors with a wide-ranging set of green, social, and sustainability bond standards that are aligned with international standards. These standards provide guidance to ASEAN companies seeking to raise financing through green, social, and sustainability bonds, and to raise the profile of ASEAN as a region that is committed to sustainable finance.

To further promote environmentally sustainable projects in Singapore and the region, Singapore launched the US\$2 billion Green Investments Programme in November 2019, which places funds with asset managers committed to drive regional green efforts beyond Singapore and to contribute to other national green finance initiatives. As part of the programme, Singapore will allocate US\$100 million to the Bank for International Settlements Green Bond Fund in support of its global green finance initiatives.

Singapore also supports a greener global financial system. The Monetary Authority of Singapore is one of the founding members of the Network for Greening the Financial System, which aims to enhance the ability of the financial system to manage the risks of climate change and to mobilise capital for green and low-carbon investments. The Monetary Authority of Singapore

also actively participates in the Sustainable Insurance Forum, which is a network for leading insurance supervisors and regulators seeking to strengthen their understanding of and responses to sustainability issues pertaining to the insurance sector. SGX is a member of the Financial Stability Board's Task Force on Climate-Related Financial Disclosures, which develops recommendations for voluntary climate-related financial disclosures for organisations. The task force is actively promoting and monitoring the adoption of its recommendations, which were released in June 2017.

5. Key Long-Term Adaptation Actions

There are three key adaptation actions in the long-term: developing Singapore's resilience framework, building Singapore's climate science capabilities, and establishing Singapore's adaptation measures.

5.1. Resilience Framework

To address the effects of climate change on Singapore's physical environment effectively, Singapore has already begun working on long-term infrastructure adaptation plans. The multi-agency Resilience Working Group, set up under the IMCCC, oversees the study and implementation of measures to address the physical vulnerabilities to climate change and serves as the coordinating body on climate-change adaptation efforts across government agencies.

The government established the *National Resilience Framework* (Centre for Liveable Cities, 2018) to guide the Resilience Working Group in identifying and assessing climate-change risks and impacts and formulating adaptation plans to address Singapore's physical vulnerabilities to impacts.

5.2. Building Singapore's Climate Science Capabilities

Singapore has been systematically building up its climate science capabilities. The Centre for Climate Research Singapore (CCRS) was established in 2013 to develop research expertise on the climate of Singapore and South-East Asia and has since grown to be one of the region's most advanced tropical climate research centres. Some of the key research works by CCRS are *Singapore's 2nd National Climate Change Study* and Convective Scale Numerical Weather Prediction model (SINGV).

In 2015, CCRS published results from the *2nd National Climate Change Study*, which analysed future climate change scenarios for Singapore and South-East Asia at high spatial resolution. The findings from this study provide the scientific basis to inform Singapore's current climate adaptation plans. CCRS is currently working on the third study, and the results are expected to be released in 2022.

Many weather models are developed for temperate regions and hence, are not customised to Singapore's local conditions. CCRS is undertaking cutting-edge research to develop weather models tailored to Singapore. One such model is the convective-scale numerical weather prediction model known as SINGV. The SINGV model will provide prediction of heavy rainfall at longer lead times and over higher spatial resolutions. Today, Singapore can provide advance

warnings of heavy rains about 15–30 minutes before a downpour. With this model, the Meteorological Service Singapore will be able to provide an earlier assessment of the risk of heavy rain, giving people more time to prepare for flash floods.

5.3. Singapore's Adaptation Measures

The government has implemented a variety of adaptation measures to enhance its climate resilience and to minimise the adverse impacts of climate change on the community, economy, and people's daily lives. *Singapore's Climate Action Plan: Take Action Today, for a Sustainable Future* details how Singapore may be affected by climate change as well as strategy to prepare for its effects (NCCS, 2016).

Adaptation measures have been developed, and seven ways forwards were identified: protect coasts; protect Singapore's water supply and alleviate floods; enhance climate and ecological resilience through greenery and biodiversity conservation management; strengthen resilience in public health, especially reducing risk of dengue; strengthen food security; keep cool in a warming world; and keep buildings and infrastructure in Singapore safe.

6. Conclusions

Singapore has always adopted whole-of-government efforts for adaptation to climate change. At the centre is NCCS. Early adaptation efforts are well reflected in the *Singapore Green Plan 2030* and *Sustainable Singapore Blueprint 2015*.

Climate-change adaptation in Singapore is occurring through coastal protection, water resources management and drainage, and flood protection. To protect Singapore's coasts in the long term, Singapore continues to assess the possible impacts of coastal inundation under various scenarios of climate change and to develop long-term strategies and adaptation measures that can be best applicable to Singapore's coasts. Singapore takes a holistic approach in managing its drainage system considering its need for water and managing flood risks. Flexibility and adaptability to the drainage system are the two key pillars in its approach to stormwater management.

The *2nd National Climate Change Study* provides information on anticipated climate change. Singapore has aligned adaptation efforts to climate change with green growth. Green growth is being pursued under five thematic areas – clean technology, test bedding, clean ICT, carbon services and climate finance, and climate risk management. Along with the five thematic areas, Singapore has developed a low-emissions development strategy for adaptation focussing on six areas – coastal protection, water resources, and drainage; buildings and infrastructure; network infrastructure; biodiversity and greenery; public health and food security; and the urban heat island effect.

There are three key adaptation actions in the long term – developing Singapore's resilience framework, building Singapore's climate science capabilities, and establishing Singapore's adaptation measures. For the climate actions in the long term, Singapore prepares and implements those actions under eight thematic areas – the future electricity grid, Energy

Efficiency Fund, transport, buildings, Green Towns Programme, waste and water, Energy Grid 2.0, and sustainable finance.

The COVID-19 pandemic has slowed the economic growth of Singapore, especially in 2020. However, there are signs of economic growth in Singapore. In 2019, Singapore pledged S\$100 billion to protect itself from rising sea levels. How to finance the required amount has been debated in Parliament, and the government is considering various borrowing options (Lai, 2019).

The *Singapore Green Plan 2030* is a national sustainability movement that seeks to tackle climate change. Under five key pillars – City in Nature, Energy Reset, Sustainable Living, Green Economy, and Resilient Future – it sets out concrete sectoral plans and targets for the next 10 years. As a ‘living’ plan, the plan will evolve and be refined over time.

With the government’s determined pledge and long-term commitments to protecting Singapore from negative impacts of climate change, Singapore has put tremendous efforts towards mitigation and adaptation. The pandemic may have slowed the pace, but the pledge to a long-term commitment is expected to continue through public–private partnerships.

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