

CHARTING SINGAPORE'S LOW-CARBON AND CLIMATE RESILIENT FUTURE



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This document was prepared taking on board inputs and feedback from relevant government agencies, academia, industry and civil society whose opinions and views were gathered through technology roadmaps, surveys, the public consultation on Singapore’s long-term low-emissions development strategy and various stakeholder engagements.

More details of the public consultation process can be found on <http://www.nccs.gov.sg/public-consultation/feedback-from-public-on-singapores-long-term-low-emissions-development-strategy/>.

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Preface

Climate change is a complex global challenge that calls for concerted international action. All nations must work together to address the challenges of climate change.

Singapore recognises the urgent need for multilateral action and is committed to doing our part as a responsible member of the international community. Our National Climate Change Strategy document, *Climate Change and Singapore: Challenges. Opportunities. Partnerships.* published in 2012 outlined Singapore's plans to address climate change, followed by *Climate Action Plan: Take Action Today, for a Carbon Efficient Singapore* in 2016, which outlined our strategies to achieve our first Nationally Determined Contribution (NDC). These documents set out the whole-of-nation approach we are adopting to address climate change, and detail the comprehensive suite of actions that we are taking to reduce our carbon emissions.

We have progressively and systematically implemented the strategies outlined in these documents, but there is a need to do more in the face of the rising risks of climate impacts from a warming world. This document hence outlines our long-term low-emissions development strategy (LEDS), which aims to guide our transition to a low-carbon and climate resilient future.

Singapore's LEDS builds upon our past strategies and early actions. It outlines our long-term development priorities and climate action policies and will serve as a reference point to inform our subsequent NDCs under the Paris Agreement. It aims to facilitate long-term action to address the effects of climate change and to enable a well-managed transition to a low-carbon economy, while growing new sectors of our economy and creating jobs and opportunities.

Our LEDS has been prepared by government agencies under the Inter-Ministerial Committee on Climate Change (IMCCC), in consultation with academia, industry and civil society whose opinions and expert views were gathered through technology roadmaps, surveys, and various stakeholder engagements. The involvement of multiple parties in this planning process reflects our intent to take a whole-of-nation, and whole-of-society approach to address climate change.

To take into account new developments from emerging climate-friendly technological solutions and other prevailing conditions and developments at the international, regional or domestic level, this document may be updated from time to time.

Foreword



Climate change is an existential challenge for Singapore

Across the globe, the effects of climate change are clear and present. Extreme climate and weather patterns have become more frequent, ice sheets are melting and glaciers are receding. Singapore too has experienced more episodes of unusually heavy rainfall accompanied by flooding. As a low-lying island, we remain fundamentally vulnerable. The ongoing effects of climate change, particularly the threat of rising sea levels, mean that we will continue to face further threats to our living environment and disruptions to the supply of food and resources.

All countries must cooperate to achieve a low-carbon future

The adoption of the Paris Agreement in 2015 was a clear response to the urgent call for global climate action. Given the diversity in the national circumstances of individual countries, as recognised in Article 4.19 of the Paris Agreement, it is clear that there is no “one-size-fits-all” approach for countries in the formulation of their long-term low-emissions development strategies (LEDS). For example, small island states like Singapore, have different circumstances from countries with a large land mass. Nonetheless, it is clear is that all countries need to do their utmost to reduce emissions and plan for the transition to a low-carbon future as soon as possible.

¹ Source: International Energy Agency, CO₂ Emissions from Fuel Combustion (2019).

Planning for a low-carbon future

This document represents an important next step in Singapore’s planning towards a low-carbon future. By setting out our vision well in advance, we aim to provide a clear sense of direction, to give ourselves and our stakeholders the time to effect a well-managed transition to a low-carbon economy. This will also allow us to grow new sectors in our economy, and create new jobs and economic opportunities.

The development of our LEDS aspiration for 2050 and beyond is guided by a principled approach - it is **Considered, Committed and Collective**.

Our climate policies and strategies are carefully and thoroughly considered, taking into account the best available science and technology, and fully integrated with the larger context of challenges we face in our national policy framework. We believe that the pursuit of economic growth can be compatible and mutually reinforcing with environmental objectives. This approach has allowed Singapore today to have one of the lowest carbon emissions per GDP dollar, or emissions intensity. We ranked among the 20 best out of 141 countries in 2017.¹

Singapore is committed to play our part in supporting global climate action. We are well on track to achieve our 2009 Copenhagen pledge to reduce our emissions by 16% below our business-as-usual (BAU) level in 2020. To build on these efforts, we have submitted an enhanced Nationally Determined Contribution (NDC) to peak our emissions at no higher than 65 million tonnes of carbon dioxide equivalent (MtCO₂e) around 2030. We have also expanded the coverage of our pledge to include nitrogen trifluoride (NF₃) within this same ceiling.

Beyond 2030, our LEDS aspires to halve emissions from its peak to 33 MtCO₂e by 2050, with a view to achieving net-zero emissions as soon as viable in the second half of the century. Our enhanced 2030 NDC and LEDS build on policies and initiatives we have progressively implemented over the years. They demonstrate our seriousness and commitment to support global climate action and to work towards a low-carbon future.

There are three thrusts in our strategy.

First, we need to transform 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, carbon storage, and regional electricity grids.

Each thrust will contribute to our aspiration of halving our emissions. We will pursue all three vigorously to achieve this 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 collaboration become formalised. If the actual reductions that can be realised 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 LEDS aspiration to the best of our ability even though the task would have become more difficult.

We will do our utmost to press ahead on our LEDS aspiration and strategies, and implement our commitments under the Paris Agreement in good faith on the basis that other countries do likewise.

Planning for a climate resilient future

For small island nations like Singapore, climate change poses an asymmetrical challenge. On the one hand, our impact on global emissions is small, but on the other hand, the effect of climate change on us is disproportionately large and existential.

We are working to identify and assess climate change risks and impacts, and to formulate and implement adaptation plans to enhance our climate resilience and to minimise the adverse impacts of climate change on the community, economy and our daily lives. Protecting Singapore from sea level rise is a large-scale and long-term effort requiring considerable resources, and is estimated to cost S\$100 billion over the next 100 years. We have set up a new Coastal and Flood Protection Fund, with an initial injection of S\$5 billion, to start setting aside the resources for this. We will implement our plans in phases, and be prepared to adjust and adapt them as necessary to take into account the latest sea level rise projections and engineering solutions.

All must play a part

A collective effort is required to realise our LEDS.

The Government, individuals, households and businesses must work together in a whole-of-nation effort. We will also continue to work actively in international forums to strengthen consensus among countries to tackle climate change, and collaborate actively with international partners to build capabilities and share experiences.

While Singapore’s efforts alone may be modest, our collective efforts with all nations can be substantial, and will help achieve the long-term temperature goal of the Paris Agreement.

Teo Chee Hean

Senior Minister

Chairman of the Inter-Ministerial Committee on Climate Change (IMCCC)

Overview

The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Global Warming of 1.5°C highlights that human-induced warming has already reached approximately 1°C above pre-industrial levels in 2017. Multiple changes in the climate system have been observed, including increased intensity and frequency of climate and weather extremes.

A global solution is needed to address a global problem. Along with the rest of the global community, Singapore will play our part to reduce emissions in support of the long-term temperature goal of the Paris Agreement.

We have put forth a long-term low-emissions development strategy (LEDS) that aspires to **halve emissions from its peak to 33 MtCO₂e by 2050, with a view to achieving net-zero emissions as soon as viable in the second half of the century.**

This will require serious and concerted efforts across our industry, economy and society. We also need to rely on global advances in low-carbon technology and on

increased international collaboration, to realise such an aspiration.

At the same time, we will pursue active and systematic adaptation efforts. As a small low-lying, island city-state, Singapore is particularly vulnerable to the effects of climate change. We face an existential threat from sea level rise and will increasingly experience other climate impacts such as increased temperature, prolonged dry spells, more intense rainfall, and exposure to vector-borne diseases. Globally, there will be greater pressures on resources, particularly for water, energy, food and raw materials, most of which Singapore imports. We will need to continue to pursue innovative solutions to optimise our resources in a carbon- and resource-constrained world.

Overcoming our geographical constraints

Singapore's approach to climate action and sustainability is constrained by our geography, which limits our ability to access renewable or alternative clean energy at scale. We are a small and highly urbanised city-state with low wind speeds, relatively flat land and lack of geothermal resources. As such, we have limited access to alternative clean energy options such as geothermal, wind and tidal power. Nuclear energy production is not yet suitable for deployment in Singapore. We are vigorously pursuing solar energy production but due to our small size, high urban density and heavy cloud cover, we expect that this can meet about 4% of our current annual electricity needs and 10% of current peak daily electricity demand.

These geographical constraints have driven us to look into innovative and progressive ways to pursue climate action. Long before climate change became a global concern, Singapore had sought to balance economic growth with environmental protection in a mutually reinforcing manner, and not one at the expense of the other.

For example, Singapore is a pioneer in establishing stringent vehicle control and use measures in cities. Since the early 2000s, we have made a nation-wide switch to the use of natural gas for electricity generation instead of more pollutive fuel oil. We also rigorously pursued efforts in energy efficiency and conservation across our industry, economy and society.

Singapore's commitment to global climate action

Singapore is well on track to achieve our 2009 Copenhagen pledge to reduce our emissions by 16% below our business-as-usual (BAU) level in 2020.

In support of the Paris Agreement, we committed in our Nationally Determined Contribution (NDC) to reduce our emissions intensity by 36% from 2005 levels by 2030, and to stabilise emissions with the aim of peaking around 2030. We are also on track to achieve this commitment. We remain among the 20 best-performing countries in terms of emissions intensity.^{2,3} Our greenhouse gas (GHG) emissions grew at a compounded annual growth rate (CAGR) of 1.8% from 2000 to 2017, compared to the growth of our GDP at a CAGR of 5.2% in the same period.

Our NDC was enhanced in 2020 to reflect an absolute emissions limitation target, use of the latest IPCC methodologies, and expanded coverage of gases to include nitrogen trifluoride (NF₃). Under our enhanced NDC, Singapore has committed to peak its absolute emissions at 65 million tonnes of carbon dioxide equivalent (MtCO₂e) around 2030. Constraining our total emissions within this absolute cap up to 2030 means that every sector in Singapore will need to put in significant effort to limit our emissions. We will need to do so in order to move towards a low-carbon nation in the coming decade, with new commercial and industrial enterprises, and new growth areas such as the digital economy.

² Source: International Energy Agency, CO₂ Emissions from Fuel Combustion (2019).

³ Emissions intensity refers to GHG emissions per dollar of GDP, measured in CO₂-equivalent per \$S\$.

OVERVIEW OF SINGAPORE'S LEDS

Beyond 2030, Singapore aims to significantly reduce our emissions. **Our LEDS aspires to halve emissions from its peak to 33 MtCO₂e by 2050, with a view to achieving net-zero emissions as soon as viable in the second half of the century.**



Singapore hosted the 2nd Association of Southeast Asian Nations (ASEAN) Climate Change Partnership Conference in August 2019. This conference provided a useful platform for ASEAN Member States and its dialogue partners to explore opportunities for climate action collaboration.

SINGAPORE'S LEDS IS BUILT ON THREE THRUSTS.

To transform our industry, economy, and society.

Our industry will need to make the necessary adjustments, capture new business opportunities and build up their competitive advantage to be best-in-class in global energy and carbon efficiency. We will also promote energy efficiency and conservation in every sector, identify new growth opportunities, spur innovation and drive behavioural change to achieve these transformations;

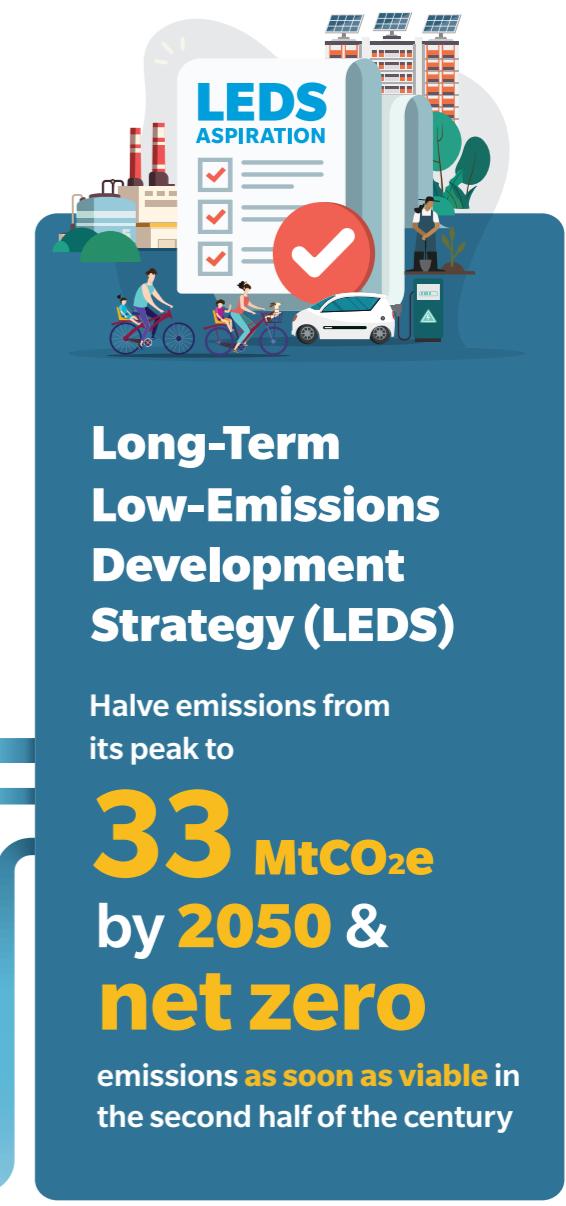
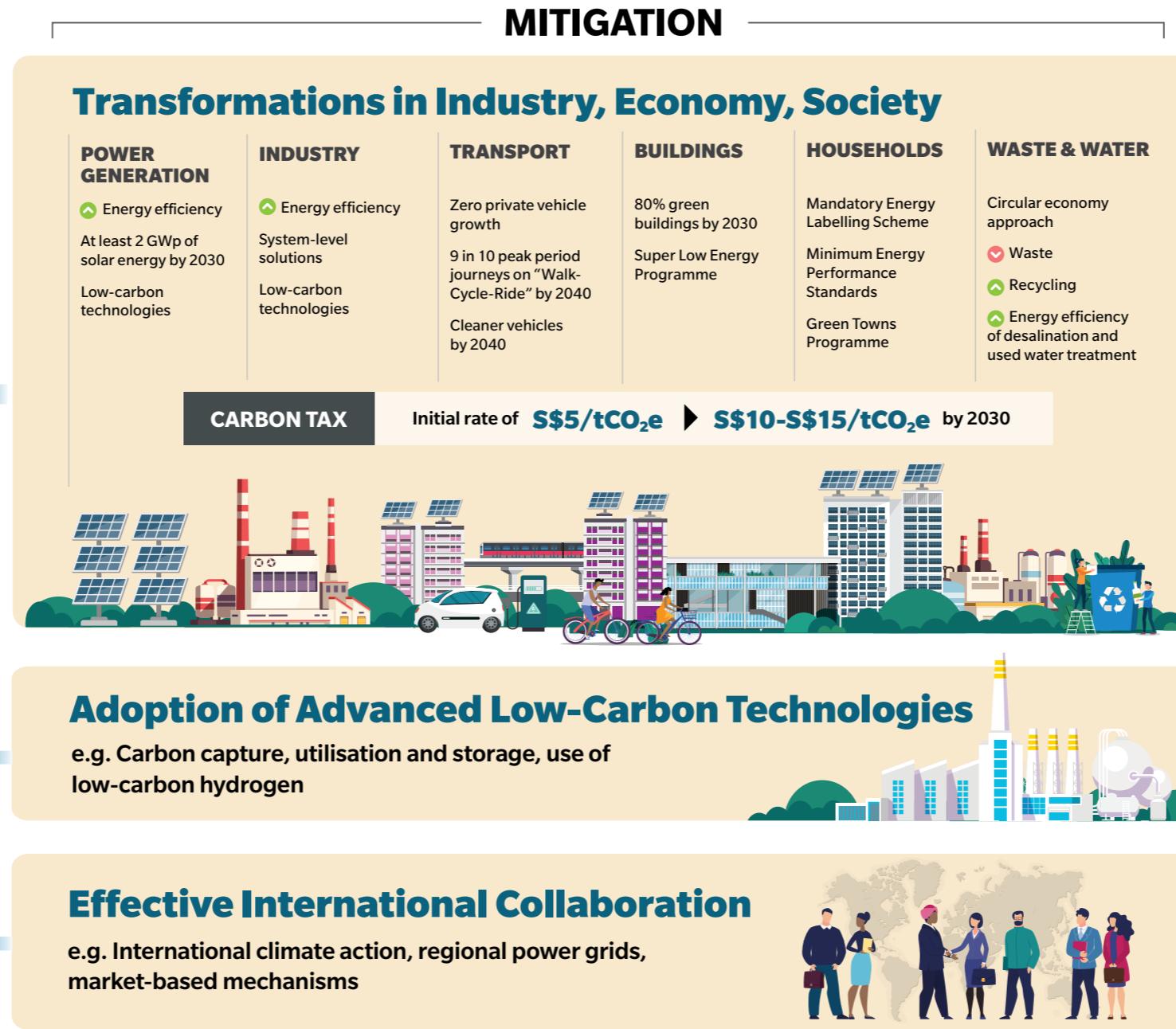
Harness emerging technologies as they mature.

We are investing in research and development (R&D) to increase energy efficiency, harness renewable energy and decarbonise our grid, industries, and buildings. This includes emerging technologies currently still in the developmental phase, e.g. carbon capture, utilisation and storage (CCUS) and low-carbon hydrogen. Our ability to realise a low-carbon future will depend on the maturing of such emerging technologies; and

Pursue and leverage international collaborations

We will forge effective collaborations and partnerships with like-minded countries in areas such as carbon storage, energy imports via regional power grids and other innovative platforms, and leverage market-based mechanisms that support environmental integrity.

Charting Singapore's Low-Carbon Future



Transformations of key sectors

Power Sector

Our key strategy for the power sector is to harness the four supply “Switches”, namely: 1) Natural Gas; 2) Solar; 3) Regional Power Grids; and 4) Emerging Zero-Carbon Alternatives.

We are scaling up the deployment of solar energy, including through innovative modes of deployment such as floating, offshore, and building-integrated photovoltaics (BIPV). Our solar deployment target has been raised from 350 megawatt-peak (MWp) by 2020, to at least 2 gigawatt-peak (GWp) by 2030. This will however meet only around 4% of our current annual electricity needs and 10% of our current peak daily electricity needs.

To go significantly beyond this, we need technical breakthroughs, for example, to safely deploy highly efficient solar panels on vertical building surfaces that receive solar radiation for only part of the day. Efforts such as energy storage solutions and solar forecasting are also being pursued to identify solutions to manage the intermittency challenge of solar photovoltaics (PV).

We are also exploring tapping on regional power grids, and studying emerging low or zero-carbon alternatives such as solar-derived hydrogen.

Industry Sector

For industries which draw on the electricity grid to power their activities, the progressive decarbonisation of our electricity grid will significantly reduce emissions.

Our industries produce not just for Singapore but also for the global market. We will work with our industries so that they are among the best-in-class in global energy and carbon efficiency. We enhanced our grant schemes in 2019 to support companies to improve their energy efficiency. We will also bring companies within a sector together to achieve systems-level efficiency gains across the sector.

We are studying emerging technologies that can help drive decarbonisation in industrial processes. We will work with industry and our research community to undertake R&D and pilots to evaluate and improve their feasibility. For example, we have commissioned studies to evaluate the harnessing of CCUS and low-carbon hydrogen.

We will work closely with industry to make the necessary adjustments, capture new business opportunities, and build up their competitive advantage in this transition. We aspire to be at the forefront of the global move towards environmentally sustainable production, and seize the new opportunities this creates.

Transport Sector

Our transport policies address the urban transport issue at its root, to reap the most gains in energy and carbon efficiency.

Since 2018, we have capped private car and motorcycle growth at zero. We have made major investments in public transport and active mobility infrastructure, and now target for nine in ten of all peak period journeys to be made using Walk-Cycle-Ride (WCR) transport modes by 2040.

We aim to phase out internal combustion engine vehicles by 2040, and have all vehicles running on cleaner energy. All new public bus purchases will be cleaner energy buses, including fully electric or hybrid models. To encourage take-up of cleaner vehicles, new electric vehicle (EV) purchases will receive rebates for a three-year period from January 2021. We will also expand the public EV charging infrastructure significantly.

We will also green our major international transport facilities. Tuas Port, when completed by the 2040s, will consolidate Singapore’s container operations in a single automated terminal. This, and the reduction in inter-haulage operations by road and sea, will provide greater efficiency and lower emissions. Changi Airport will continue to invest in environmental sustainability initiatives, such as energy efficiency improvements and electrification. The new Terminal 5 will be designed and built according to stringent energy efficiency standards, and is anticipated to achieve Green Mark Platinum standards.

Building Sector

We are on schedule to green 80% of our buildings by gross floor area (GFA) by 2030. As of March 2020, we have greened more than 40% of our buildings.

We have developed the Super Low Energy (SLE) Building Programme, to encourage the industry to achieve best-in-class building energy performance in a cost-effective manner. To support the push towards more energy efficient buildings, we plan to raise the minimum energy performance standards for all new and existing buildings undergoing major retrofitting works. In addition, we will identify all buildings in the annual publication of building energy performance data, to facilitate benchmarking and spur building owners to undertake retrofitting measures to improve the energy efficiency of their buildings.

Transformations of key sectors

Household Sector

To reduce energy consumption in the household sector, we have introduced Minimum Energy Performance Standards (MEPS) and a Mandatory Energy Labelling Scheme (MELS) for common household appliances. These standards are reviewed regularly and will be raised over time to increase the adoption of more energy-efficient appliances. In addition, we have implemented incentives for households to switch to energy-efficient appliances and launched campaigns to increase public awareness on energy efficiency and conservation.

Waste Sector

We launched our inaugural Zero Waste Masterplan and enacted a Resource Sustainability Act (RSA) in 2019 to design waste out of our economy. The aim is to develop a circular economy, where materials are retained and reused in the value chain as long as possible. This will reduce our carbon footprint and complement our efforts to address climate change. We aim to reduce the amount of waste sent to landfill each day by 30% by 2030.

Public sector to lead by example

The Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative aims to leverage the collective capabilities across the whole-of-government to improve resource efficiency and pursue environmental sustainability within the public service.

The public sector is on track to achieve 15% energy and 5% water savings by 2020 from 2013 levels and pursues green procurement practices (e.g. energy efficient electrical appliances, eco-labelled printing papers). Public sector buildings have to achieve stringent Green Mark standards (e.g. new buildings are required to attain Green Mark platinum). Public sector agencies will also segregate their food waste for recycling and switch to equipment using low Global Warming Potential (GWP)⁴ refrigerant ahead of 2024 and 2022 national mandates respectively.

To promote solar adoption in Singapore, demand for solar deployment across public sector buildings and spaces is aggregated under the government's SolarNova Programme. The Housing & Development Board (HDB) targets to deploy 540 MWp of solar on the rooftops of public housing blocks by 2030, which accounts for a significant proportion of our national solar deployment target to achieve at least 2 GWp by 2030.

We are reviewing PSTLES to develop programmes and measures for the next phase of the PSTLES initiative from 2021 to 2030, with more ambitious post-2020 targets.

Cross-sectoral measures

Singapore is the first country in Southeast Asia to put a price on carbon. The carbon tax came into force in 2019 and applies uniformly to all sectors, without exemption. The initial carbon tax rate (currently pegged at S\$5/tCO₂e to provide companies with a transitional period to improve their energy- and carbon-efficiency) will be reviewed by 2023, with the intention to increase it to between S\$10/tCO₂e and S\$15/tCO₂e by 2030. The carbon tax covers around 80% of our total emissions, which is one of the highest carbon tax coverage globally, and sends a fair, uniform and transparent price signal to incentivise emissions reduction.

To reduce emissions from hydrofluorocarbons (HFCs), which are GHGs with high GWP, we will mandate the recovery, reclamation and destruction of spent refrigerants and roll out a package of HFC mitigation measures. A training and certification scheme for technicians will be introduced to raise the competencies of the refrigeration and air-conditioning (RAC) industry on the proper handling of refrigerants during installation, maintenance and decommissioning of RAC equipment. We will also progressively phase out the supply of RAC equipment that use HFCs with high GWP, starting with commercial water-cooled chillers, household refrigerators and air-conditioners from 2022.

⁴ GWP is a measure of the warming effect of a gas relative to the warming effect of an equivalent mass of CO₂, usually over a 100-year time horizon.

Promoting green growth

Singapore aims to be a hub for green finance and facilitate more financial flows towards low-carbon sectors. Singapore's Green Finance Action Plan, launched in November 2019, details our strategies to build financial system resilience to environmental risks, develop green finance solutions and markets, and leverage innovation and technology.

We also launched a US\$2 billion Green Investments Programme (GIP) in 2019 to anchor green activities of asset managers in Singapore, and support the mainstreaming of green finance. As part of the GIP, the Government will allocate US\$100 million to the Bank for International Settlements' Green Bond Fund, in support of its global green initiatives.

The Government is collaborating with industries to develop Environmental Risk Management guidelines, which will be issued for public consultation in March 2020. These guidelines will set standards on governance, risk management and disclosure and encourage the right-pricing of loans and investments, to promote new green investments.

We also worked with fellow ASEAN countries to develop the ASEAN Green Bond Standards to promote the development of a regional green bond market in line with international green bond principles.

We are also investing close to S\$1 billion in research and development in areas such as new urban mobility solutions and a next generation energy grid. As a "living laboratory", we will continue to be available as a test-bed for innovative sustainability solutions that can be deployed globally.

Planning for a climate resilient future

Singapore's Climate Action Plan: A Climate-Resilient Singapore, For a Sustainable Future, outlines how climate change will affect us, and our strategy to prepare for its effects. Our adaptation measures include: protecting our coasts and water supply; alleviating floods; enhancing climate and ecological resilience; ensuring a healthy ecosystem of flora and fauna; caring for our coral reefs; strengthening resilience in public health; strengthening food security; keeping cool in a warming world; and keeping our buildings and infrastructure safe.

In particular, we are carefully studying the options for protecting different parts of our coastline. These coastal protection plans may include a combination of sea walls, tide gates, polders, as well as nature-based solutions. Protecting Singapore from sea level rise is a large-scale and long-term effort requiring considerable resources, and is estimated to cost S\$100 billion over the next 100 years. The Government has created a Coastal and Flood Protection Fund, with an initial injection of S\$5 billion, to start setting aside the resources for this. We will implement our plans in phases, and be prepared to adjust and adapt them according to the latest sea level rise projections.

Supporting international efforts

We support the international climate action effort on multiple fronts. Principally, we work actively to support global climate action under the United Nations Framework Convention on Climate Change (UNFCCC).

Singapore is also working with the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) to reduce international carbon emissions from the aviation and maritime transport sectors respectively. We are ready to participate in the voluntary phase of the ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), which will commence in 2021. We will also develop a decarbonisation blueprint detailing how Singapore, as a global maritime hub, can contribute to the maritime sector's commitment to reduce emissions.

Under the Singapore Cooperation Programme (SCP), we are sharing experiences, knowledge and best practices in sustainable development with other developing countries. More than 130,000 government officials from over 170 countries have benefitted from such training programmes. In 2018, we launched a Climate Action Package (CAP) under the SCP aimed at supporting the efforts of fellow developing countries, in particular, ASEAN Member States, Small Island Developing States (SIDS) and Least Developed Countries (LDCs), towards achieving their climate pledges and building resilience.

The Centre for Climate Research Singapore (CCRS) is a key node for climate and weather research in the Southeast Asia region. The ASEAN Specialised Meteorological Centre launched a five-year Regional Capability Building Programme in 2018, to improve regional capabilities to interpret climate change scenarios to inform national climate change adaptation plans.

Everyone and every nation must play their part

Singapore will take climate action as one nation, through the collective action of government agencies, individuals, businesses, and the community. Our collective efforts, in both mitigation and adaptation, aim to ensure Singapore remains a vibrant and liveable city for current and future generations.

However, no country can solve this formidable challenge alone. Every country has to be part of a larger global vision to bring the world back on track towards achieving the long-term temperature goal of the Paris Agreement. This can only be possible through collective international action and effective international partnerships.

Chapter 1

Global Context

Climate science underscores the urgency for global emissions to be on track towards achieving the global temperature goal of the Paris Agreement.

The current climate pledges on the table are not on track to achieve the long-term temperature goal and are likely to lead to a 3.2°C global warming scenario.⁵ As such, all countries must re-double their efforts to make their long-term transition to a low-carbon economy.

⁵ Source: United Nations Environment Programme, UNEP Emissions Gap Report 2019.



Singapore hosted the Scoping Meeting of the Synthesis Report of the IPCC Sixth Assessment Report (AR6) in October 2019. The meeting laid the foundation for the drafting of AR6, which will provide policy makers with the most up-to-date scientific information related to climate change in 2022.

WHAT THE SCIENCE IS SAYING

More than 90% of climate scientists who publish studies on climate change agree that humans are causing recent global warming.⁶ According to the World Meteorological Organization (WMO), 2019 was the second warmest year on record after 2016, with annual global mean temperature rising 1.1°C above the pre-industrial average (1850-1900). The average temperatures for the last five-year (2015-2019) and ten-year (2010-2019) periods were also the highest on record.⁷ This increase in temperatures has corresponded with global averaged concentrations of CO₂ climbing to 407.8 parts per million in 2018 and reaching a new record of 410.9 parts per million in November 2019.⁸

Under its sixth assessment cycle, the IPCC released a series of special reports on global warming and its impacts in 2018 and 2019.⁹ According to these reports, human activities have been responsible for approximately 1.0°C of global warming since pre-industrial times, and temperature rise is likely to breach 1.5°C between 2030 and 2052 at current rates of warming. More intense and frequent climate and weather extremes have been observed. Warming from historical anthropogenic emissions since the pre-industrial period will continue to drive long-term shifts in the climate system such as sea level rise. According to the *Special Report on the Ocean and Cryosphere in a Changing Climate*, under a “business-as-usual” (RCP8.5) scenario, global mean sea level rise could increase to 1.1m by 2100, which is 10cm above the most likely estimate from the Fifth Assessment Report released in 2014. This is due to a larger projected ice mass loss from the Antarctica ice sheet.

The reports also point out that many impacts will still occur even with declining emissions, and that there would be limits to the effectiveness of adaptation measures. Worryingly, small island nations are particularly vulnerable, and some are likely to become uninhabitable.

According to the IPCC’s *Special Report on the Global Warming of 1.5°C*, global pathways consistent with 1.5°C warming will require urgent collective action, with rapid and far-reaching transitions in land, energy, industry, buildings, transport, and cities. According to the IPCC’s model pathways with no or limited overshoot of 1.5°C, global net anthropogenic CO₂ emissions have to be reduced by 45% from 2010 levels by 2030 (40% to 60% interquartile range), and reach ‘net-zero’ around 2050 (2045-2055 interquartile range). To limit warming to 2°C, CO₂ emissions have to decline by about 20% by 2030 in most pathways (10% to 30% interquartile range) and reach net-zero around 2075 (2065-2080 interquartile range).

These reports provide a strong scientific foundation that underscore the importance of the temperature goal of the Paris Agreement and the need to ensure that global emissions are on track to achieve it.

It is clear that the global community must take urgent, concerted and sustained climate action to collectively bring the world back to the path of climate safety.

⁶ Source: J. Cook, et al, "Consensus on consensus: a synthesis of consensus estimates on human-caused global warming," Environmental Research Letters Vol. 11 No. 4, (13 April 2016); DOI:10.1088/1748-9326/11/4/048002

⁷ Source: WMO, Press Release: Greenhouse gas levels in atmosphere reach new record (20 November 2018).

⁸ Source: WMO, Press Release: 2019 concludes a decade of exceptional global heat and high-impact weather (3 December 2019).

⁹ IPCC’s Special Report on the Global Warming of 1.5°C (released in October 2018), Special Report on Climate Change and Land (released August 2019), and Special Report on the Ocean and Cryosphere in a Changing Climate (released September 2019).

A GLOBAL RESPONSE TO CLIMATE CHANGE IS NEEDED

The findings from climate science underscore the need to continue driving the urgency and pace of international negotiations on climate change.

In December 2015, at the twenty-first session of the Conference of the Parties (COP) to the UNFCCC in Paris, all 196 Parties to the UNFCCC adopted a landmark agreement to take the world in an ambitious new direction in terms of global climate action.

The Paris Agreement sets out a long-term temperature goal and underscores the urgency for Parties to play their part to enable global emissions to peak and decline as soon as possible.

Article 2.1(a) of the Paris Agreement sets out its long-term temperature goal to hold the increase in the global average temperature to well below 2°C and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

Article 4.1 of the Paris Agreement recognises that in order to achieve the long-term temperature goal set out in Article 2, Parties should aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

The Paris Agreement puts in place a hybrid top-down/bottom-up mechanism whereby Parties' NDCs are nationally determined and communicated or updated every five years, with a robust transparency and reporting framework to track the progress of NDC implementation and achievement, as well as an ambition cycle to enhance NDCs over time. Successive NDCs must represent a progression beyond previous ones. A five-yearly Global Stocktake process, starting in 2023, is aimed at reviewing collective progress on mitigation, adaptation, and means of implementation. This review process would then inform Parties' preparation of their next round of NDCs.

The Paris Agreement also invites Parties to formulate and communicate long-term low GHG emission development strategies, mindful of Article 2, taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

Given the need for sustained climate action over the long-term, the onus is on all Parties to plan for their long-term transition to a low-carbon future in support of the long-term temperature goal of the Paris Agreement. This will help provide a clear sense of direction to the populace, industry and investors, and minimise any negative disruptions to the economy and workforce. For the global community, it will provide confidence that all Parties are moving forward in good faith by playing their part towards achieving the long-term temperature goal of the Paris Agreement.



At the request of the Chilean COP Presidency, Singapore and Spain co-facilitated the key overarching conference decisions at COP-25, in December 2019, in Madrid. These were eventually adopted by the Parties.

Chapter 2

Singapore's National Circumstances

Singapore's national circumstances shape our approach to climate action.

Being a low-lying island-state, we are particularly vulnerable to the impact of climate change. Our access to renewable energy at scale is greatly limited, which constrains our options in carbon abatement.

We will continue to build on a long-standing, comprehensive national approach that seeks to achieve sustainable growth alongside environmental protection. This has allowed us to limit our growth in emissions and stay on track to achieve our international commitments, notwithstanding our geographical constraints.

NATIONAL CIRCUMSTANCES

Country profile

Singapore is a small island-state in Southeast Asia with a total land area of about 725.7km², consisting of one main island and more than 60 small ones. Singapore is located 1 Degree 30 Minutes latitude north of the equator, situated at the south of Peninsular Malaysia, and east of Sumatra just across the Strait of Malacca. Much of the island is less than 15m above the Singapore Height Datum (SHD)¹⁰ and is generally flat.

Climate

Singapore is situated near the equator and has a tropical climate, with relatively uniform temperature, abundant rainfall, and high humidity. The climate of Singapore is characterised by two monsoon seasons separated by inter-monsoonal periods. The Northeast Monsoon occurs from December to early March, and the Southwest Monsoon from June to September. The early part of the Northeast Monsoon, in December and January, is the wetter period of the year when monsoon surges occur, occasionally bringing prolonged heavy rain to Singapore. In comparison, the Southwest Monsoon is drier. Afternoon thunderstorms are common throughout the year, especially during the inter-monsoonal periods from late March to May and October to November.

Population

Singapore's total population, including those on work passes in Singapore, stood at around 5.7 million as of 2019. Singapore's small land area also means that our population density of 7,866 people per km² is among the highest worldwide.

Water supply

Singapore has limited land to collect and store water, and is water-scarce despite being located in the equatorial rain belt and receiving abundant rainfall. Demand for water is expected to nearly double by 2060 in tandem with economic growth, while local catchment remains limited by available land area. To ensure water sustainability, Singapore has developed a diversified and robust supply of water through the "Four National Taps", namely: local catchment water, imported water, NEWater, which is high-grade reclaimed water produced from treating used water, and desalinated water.

Economy

Singapore as an open and globalised economy produces goods and services that are consumed globally. While Singapore's share of global GDP is small at 0.4%, as an advanced manufacturing hub it plays a key role to meet the demands of the region and the world, accounting for 2.1% of the world's total merchandise exports.¹¹ Our small domestic market has necessitated such an export-oriented economy. In 2019, Singapore's external merchandise trade amounted to around S\$1,022 billion, which is about two times the GDP of Singapore. Singapore is also a major air and sea transport hub given its geographical location at the crossroads of key international trade routes.

¹⁰ The SHD is defined as the mean sea level determined at Victoria Dock, Singapore, between 1935-1937.

¹¹ Source: World Trade Organization, Trade Profiles – Singapore (2019)



Singapore's economic structure by nominal value added share (2019)

Climate vulnerabilities

Fundamentally, climate change poses an asymmetrical and existential challenge to small island nations like Singapore. Although our impact on global emissions is small, the effect of climate change is disproportionately large on us as a low-lying island nation.

Singapore's vulnerabilities to the impacts of climate change will require the Government to pursue a comprehensive adaptation programme to protect our coasts, low-lying areas and communities (see Chapter 6 for details of Singapore's adaptation vulnerabilities and strategies). These adaptation actions will impose significant fiscal costs for the Government.

Alternative energy constraints

Singapore has limited land area, high urban density, relatively flat land, low wind speeds and lack of geothermal resources. Therefore, harnessing alternative energy sources such as hydroelectric, wind, geothermal or nuclear power is a major challenge.

With a small land area and dense urban landscape, Singapore has to accommodate not only housing and commercial hubs, but also power plants, reservoirs, air and seaports and industries all within our city boundaries. Hence, competing uses for land greatly limit our access to renewable energy at scale. These difficulties in transitioning to alternative energy sources are recognised in Article 4.10 of the UNFCCC.¹²

Biomass

Biomass, which is used by many countries with available land mass as a fossil fuel alternative, is not viable as a significant energy resource. Singapore already converts much of our waste to energy, providing about 2.3% of our current electricity needs. Nonetheless, we will continue to monitor developments in this area to keep abreast of progress in biomass.

Geothermal

Geothermal energy is not commercially viable in Singapore given the lack of conventional geothermal resources and our small land area. Unconventional geothermal resources are unable to be utilised in a cost-effective manner with current technologies.

Hydroelectric power

Hydroelectricity harnesses the energy of flowing water for the generation of electricity. Much of Singapore is generally flat and less than 15m above the mean sea level.

Marine (tidal and wave power)

Our tidal range (difference between high and low tide) is about 1.7m, well below the 4m tidal range that is typically required for commercial tidal power generation. The availability of wave power is determined by the height and frequency of the waves, but the waters around Singapore are relatively calm as we are sheltered by land masses around us.

Nuclear

Singapore conducted a pre-feasibility study (Pre-FS) on nuclear energy as an option to meet Singapore's long-term energy needs. The study concluded in 2012 that nuclear energy technologies presently available are not yet suitable for deployment in Singapore.

Since the conclusion of the Pre-FS, we have been monitoring the development of safer nuclear energy technologies. Newer nuclear power plant designs that are being developed and tested have the potential to be much safer than many of the plants that are in operation today. However, the risks to Singapore, given that we are a small and densely populated city, still outweigh the benefits at this point. Most of these newer technologies are still at the testing phase and have not been operationally proven. As we are planning for the long term and not for our immediate energy needs, we will continue to monitor the progress of these nuclear energy technologies.

¹² Article 4.10 of the UNFCCC states that Parties shall, in accordance with Article 10, take into consideration in the implementation of the commitments of the Convention the situation of Parties, particularly developing country Parties, with economies that are vulnerable to the adverse effects of the implementation of measures to respond to climate change. This applies notably to Parties with economies that are highly dependent on income generated from the production, processing and export, and/or consumption of fossil fuels and associated energy-intensive products and/or the use of fossil fuels for which such Parties have serious difficulties in switching to alternatives.



Located along the Straits of Johor, Sunseap's 5 MWp solar farm is one of the largest offshore floating system in the world. The amount of solar energy generated will reduce greenhouse gas emissions by about 2,600 tonnes a year.

to keep our energy options open for the future. We will also continue to strengthen our capabilities to understand nuclear science and technology.

Wind

Harnessing wind energy is also not viable, given our low average wind speeds between 2m/s and 3m/s and lack of land for large-scale application of wind turbines. Most commercial wind farms leverage average wind speeds of at least 4.5m/s, while prime wind sites require annual average wind speeds in excess of 7.5m/s. In addition, there are challenges to harnessing offshore winds due to busy maritime traffic in our waters.

Solar

Despite Singapore's space constraints, the Government is pressing ahead to promote solar photovoltaic (PV) deployment, with solar energy being our most viable renewable energy source. Efforts include enhancement of the regulatory

framework and streamlining of compliance requirements. The SolarNova Programme also aggregates demand for solar deployment across public sector buildings and spaces, and hence generates demand to catalyse the growth of solar energy in Singapore and to support the solar industry in developing its capabilities. In addition, the Government is actively investing in R&D and test-bedding to improve the efficiencies and lower the costs of solar PV and related technologies.

Efforts are also being pursued to identify solutions to manage the intermittency challenge of solar PV, which if left unaddressed would limit solar deployment. For example, we are studying how energy storage solutions and solar forecasting can be used in Singapore's context to manage intermittency. By 2030, we aim to deploy at least 2 GWp of solar energy.

Dependency on imports

As one of the most globalised economies and a trading nation with no indigenous resources, Singapore is heavily dependent on the global supply chain for our food and energy. Singapore's economic activity and emissions are also highly sensitive to the volatility of regional and global developments. These challenges mean that Singapore's climate strategies have to take into account international developments that may negatively affect our economy, and our food and energy security.

Pursuit of sustainable development

Singapore has always placed a high priority on environmental issues and has pursued the concurrent goals of growing the economy and protecting the environment. We regard these goals as mutually reinforcing. Our pursuit of sustainability and environmental protection is reflected in our approach to urban development and resource management, including how we manage transportation, housing, waste, greenery, energy and water. Details on our sustainability journey are provided in Chapter 3.



By pursuing sustainable development, we can ensure a liveable environment for future generations.

EMISSIONS PROFILE

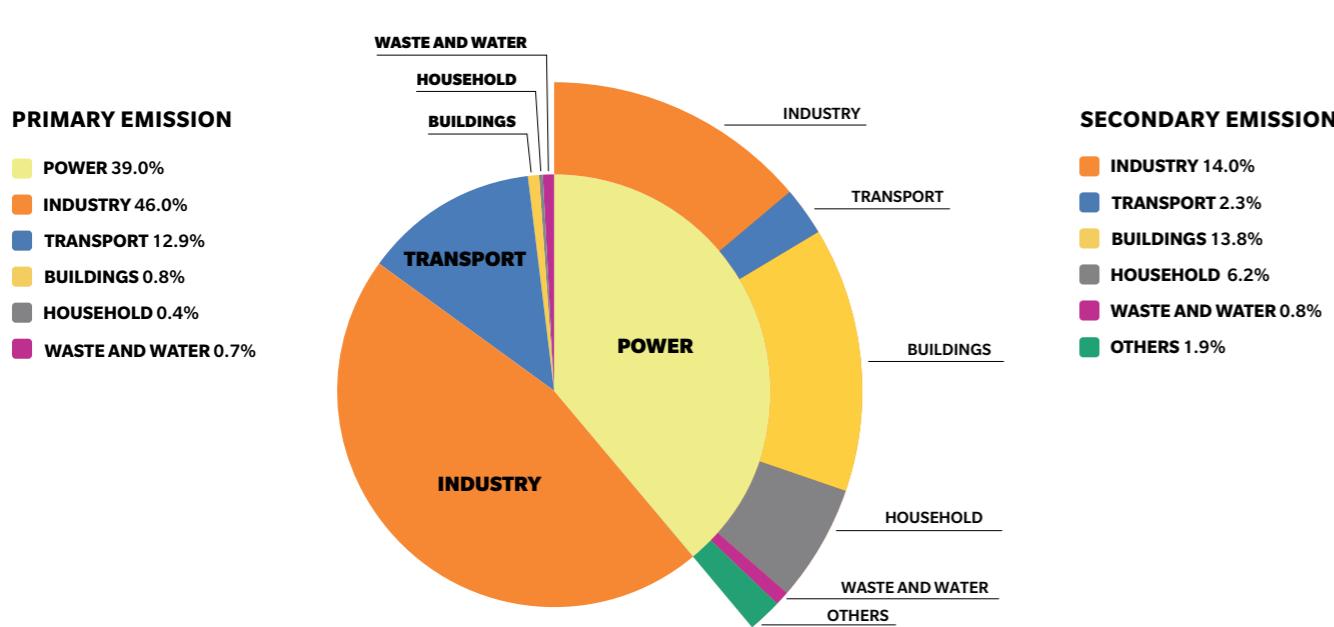
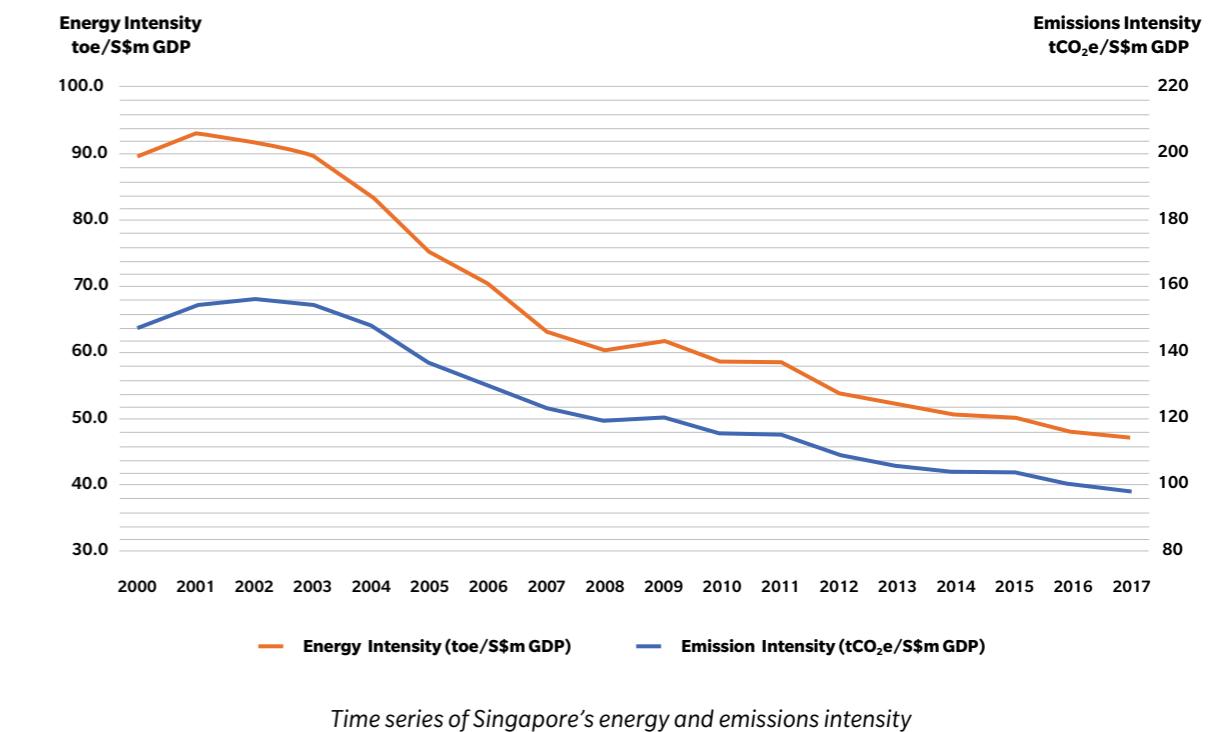
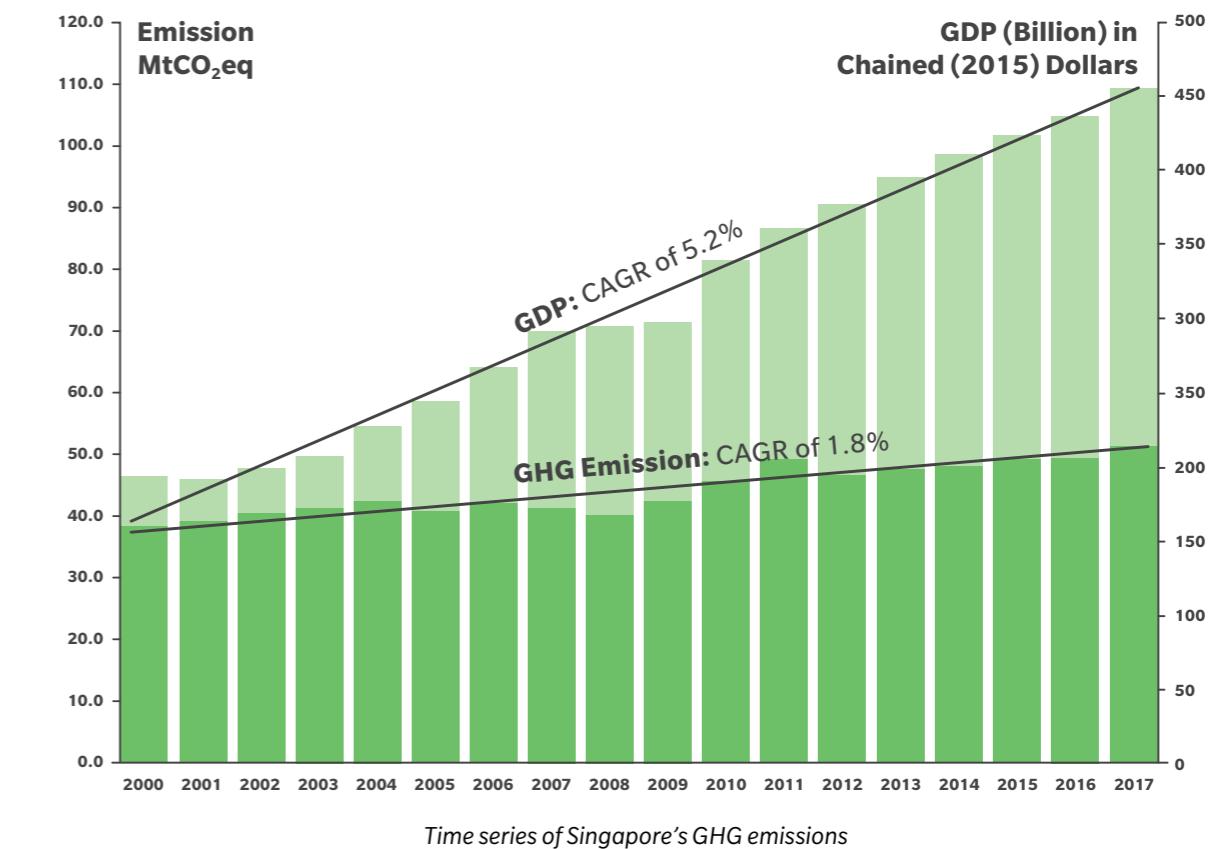
Overview of historical emissions

Singapore's GHG emissions in 2017 totalled 52.0 MtCO₂e. The figure below shows the share of direct emissions per sector, as well as the breakdown of indirect emissions from each sector's electricity usage.

Historical time series

From 2000 to 2017, Singapore's economy grew at a compounded annual growth rate (CAGR) of 5.2%, while real GDP levels (in chained (2015) dollars) increased by 136% from S\$193.13 billion in 2000 to S\$456.14 billion in 2017. In the same period, Singapore's GHG emissions grew at a slower rate with a CAGR of 1.8%, and an increase of 34.8% (13.4 MtCO₂e) from 2000 to 2017.

Overall, emissions intensity improved by 43% while energy intensity improved by 39% from 2000 to 2017. Some of the key policy initiatives implemented during this period include a switch in fuel mix from fuel oil to natural gas, which is a cleaner fuel source, as well as various schemes promoting energy efficiency. These included the Green Mark Scheme as a benchmarking standard to encourage the development of environmentally friendly buildings and energy efficiency grants to encourage industries to integrate resource and energy efficiencies into their facility operations.



Chapter 3

Singapore's Long-Term Low-Emissions Aspiration

Singapore has always sought to develop sustainably. Long-term integrated planning is at the heart of Singapore's economic and environmental management.

Singapore's LEDS aims to provide a clear sense of direction and keep us competitive in a carbon-constrained world.

Since our independence in 1965, long before climate change became a global issue, Singapore has taken progressive steps to pursue the twin goals of growing the economy and protecting the environment. Our goal is sustainable growth – to pursue economic and environmental objectives together, not one at the expense of the other, or either at all costs.

Timeline of Singapore's sustainable development journey

1970

Established Anti-Pollution Unit under the Prime Minister's Office to tackle air pollution.

1972

Established Ministry of the Environment following the UN Conference on the Human Environment in Stockholm.

1992

Adoption of the UNFCCC at the 1992 United Nations Conference on Environment and Development, where Singapore's Ambassador-at-Large Tommy Koh played a key role in drafting the Framework Convention. We also issued the first Singapore Green Plan for environmental sustainability.

2009

Publication of first Sustainable Singapore Blueprint on Singapore's sustainable development targets up to 2030.

2010

Communicated 2020 climate pledge in support of the Copenhagen Accord to the UNFCCC.

2012

Publication of Climate Change & Singapore: Challenges. Opportunities. Partnerships on Singapore's strategy and plans to address climate change.

2015

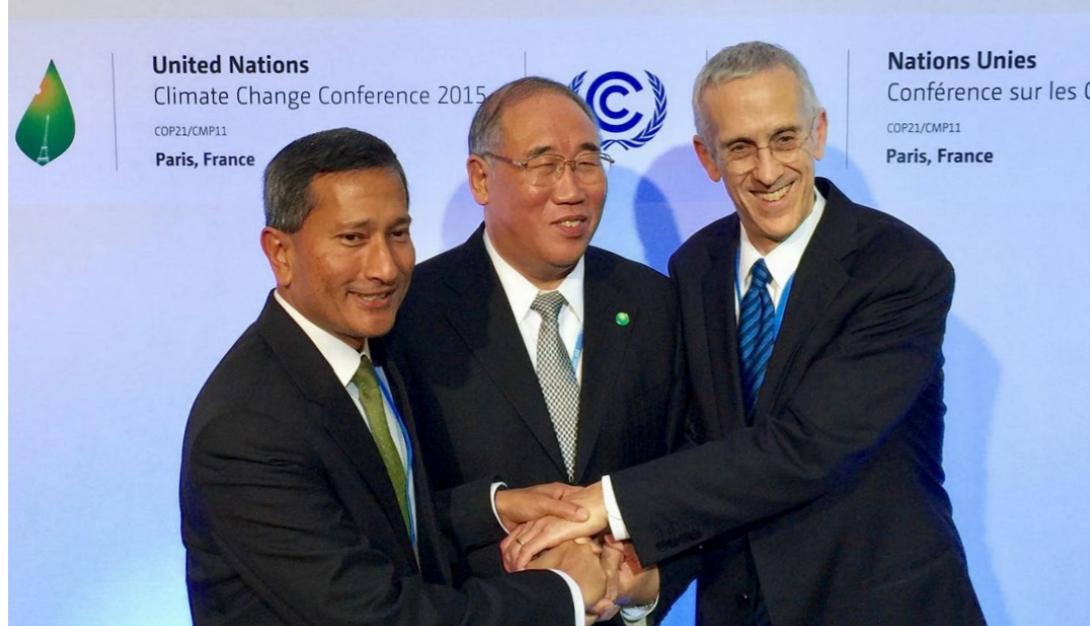
Adoption of the Paris Agreement at the 21st Session of the Conference of the Parties to the UNFCCC. We also submitted Singapore's NDC to the UNFCCC.

2016

Publication of Climate Action Plan: Take Action Today, For a Carbon-Efficient Singapore on Singapore's mitigation strategies to achieve our NDC.

2020

Communicated LEDS and enhanced NDC to the UNFCCC.



Singapore's Minister for Foreign Affairs Dr Vivian Balakrishnan with then-People's Republic of China Special Envoy for Climate Change Xie Zhenhua and then-United States Special Envoy for Climate Change Todd Stern celebrating the successful adoption of the Paris Agreement at COP-21 in Paris in December 2015.

Singapore is a clean and green garden city today due to decades of sustained effort and conscious decisions to implement environmentally friendly measures as part of our development efforts.

For instance, since the early 2000s, we have been replacing fuel oil with natural gas – the cleanest form of fossil fuel – as the primary fuel for electricity generation. In 2019, natural gas accounted for around 95% of our electricity generation. We also price energy at market cost, without any subsidy, to reflect resource scarcity and promote judicious usage. We also maintain stringent measures to discourage

vehicle ownership and usage, and to encourage energy efficiency and conservation across all the sectors.

We strive for our industries to be as carbon-efficient as possible. This approach has allowed Singapore's emissions intensity today to be one of the lowest in the world. We ranked among the 20 best-performing out of 141 countries in terms of emissions intensity in 2017. We are recognised as Asia's most sustainable city and fourth most sustainable city globally according to the 2018 Sustainability Cities Index.

Charting the way forward towards a low-carbon future

There is a need to do even more in the face of the rising risks of climate impacts from a warming world.

We therefore undertook a considered approach to develop our LEDS to guide our transition to a low-carbon, sustainable and climate resilient future. This document aims to facilitate action over successive generations to address the effects of climate change, and to help us to effect a well-managed transition to a low-carbon economy, while growing new sectors of our economy, and creating jobs and opportunities in a sustainable way. It will also serve as a reference point for informing our subsequent NDCs under the Paris Agreement.

Methodology

The development of Singapore's LEDS was overseen by the Inter-Ministerial Committee on Climate Change (IMCCC),¹⁴ which is chaired by Senior Minister Teo Chee Hean and supported by the National Climate Change Secretariat (NCCS), the national coordinating agency for climate change issues under the Strategy Group, Prime Minister's Office.

Under the IMCCC, the Long-Term Emissions and Mitigation Working Group (LWG) is responsible for envisioning Singapore's post-2020 future in a carbon-constrained world. The LWG provides the planning framework for government agencies to work together to discuss and

identify the mitigation actions through a combination of top-down and bottom-up analysis.

A whole-of-government/nation approach driven by the IMCCC was taken to develop possible climate measures for our LEDS.

The approach taken for our LEDS was to ensure that it was fully integrated within the larger context of our national policy framework, and to take into account our national circumstances, the best available science and technology, and consultations with key stakeholders, towards developing a suite of effective and practical strategies.

¹³ Source: International Energy Agency, CO₂ Emissions from Fuel Combustion (2019).

¹⁴ Details on the organisation of the IMCCC can be found in the Annex.

Some of the key questions that were considered include:

What is the long-term mitigation potential for a small island city-state with limited access to alternative energy sources?

How can Singapore achieve energy security and environmental sustainability?

What are the key technological solutions necessary to lower Singapore's long-term emissions to align with the global temperature goals of the Paris Agreement?

A rigorous modelling exercise was conducted under the supervision of the LWG to develop the key mitigation strategies and low-emissions pathways for Singapore. Relevant government agencies worked together to iteratively evaluate possible mitigation measures in terms of cost effectiveness and practicability, taking into account the objectives of the Paris Agreement temperature goal.

Various research institutes in Singapore were also engaged to study the technologies and mitigation measures possible for Singapore, as well as the long-term abatement potential and costs of these options.

A recursive-dynamic numerical model, MARKAL,¹⁵ was used to simulate possible mitigation pathways, based on the possible technology options available to Singapore in light of our national circumstances. Technology roadmaps, prepared by the Government in collaboration with industry stakeholders, academic experts, and technical consultants, served as inputs for estimating the long-term mitigation potential of future technologies in Singapore.¹⁶

The Government also undertook an extensive public consultation between July and September 2019 on potential long-term low-emissions strategies for Singapore.¹⁷ The public consultation was aimed at seeking views on measures and actions that could be taken by the government, businesses, households and individuals towards becoming a low-carbon global city-state. About 2,000 responses¹⁸ from the public, various non-governmental organisations (NGOs), green groups, green councils, academics, non-profit organisations, companies and business organisations were received. Several engagement sessions were organised from August 2019 to January 2020 to facilitate in-depth discussions with experts and stakeholders across a wide variety of sectors, which include the transport, industry, buildings, infocomm and logistics sectors.

LEDS aspiration

Having taken into account Singapore's national circumstances, the urgency of global climate action, inputs from the above processes, and building on our NDC (which aims to peak our emissions at 65 MtCO₂e around 2030), we set out our long-term low-emissions aspiration to guide our future efforts.

We have put forth a long-term low-emissions development strategy (LEDS) that aspires to **halve emissions from its peak to 33 MtCO₂e by 2050, with a view to achieving net-zero emissions as soon as viable in the second half of the century.** This will require serious and concerted efforts across our industry, economy and society. We also need to rely on global advances in low-carbon technology and on increased international collaboration, to realise such an aspiration.

There are three thrusts in our strategy. First, we need to transform 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, carbon storage, and regional electricity grids.

Each thrust will contribute to our aspiration of halving our emissions. We will pursue all three vigorously to achieve this 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 collaboration become formalised. If the actual reductions that can be realised 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 LEDS aspiration to the best of our ability even though the task would have become more difficult.

¹⁵ MARKAL (MARKet Allocation) is a widely used recursive-dynamic numerical model for economic analysis of various energy-related systems over a period of several decades.

¹⁶ The technology roadmaps can be downloaded at <http://www.nccs.gov.sg/media/technology-roadmaps>.

¹⁷ The public consultation document can be downloaded at [https://www.nccs.gov.sg/docs/default-source/default-document-library/2050-public-consultation-document-\(for-publication\)_revised-151019.pdf](https://www.nccs.gov.sg/docs/default-source/default-document-library/2050-public-consultation-document-(for-publication)_revised-151019.pdf)

¹⁸ A summary of the responses to the public consultation process can be downloaded at www.nccs.gov.sg/public-consultation/response-to-feedback-on-singapore-s-long-term-low-emissions-development-strategy/

Chapter 4

Key Long-Term Climate Actions

To realise our LEDS aspiration, we need transformations in industry, economy, and society. We will need to draw on emerging technologies that are not yet mature, such as carbon capture, utilisation and storage (CCUS) and low-carbon fuels. We will also need to leverage international collaboration in areas such as well-functioning carbon markets and regional energy grids. Singapore will pursue these thrusts through implementing policies and frameworks to maximise the potential emission reductions from all sectors.

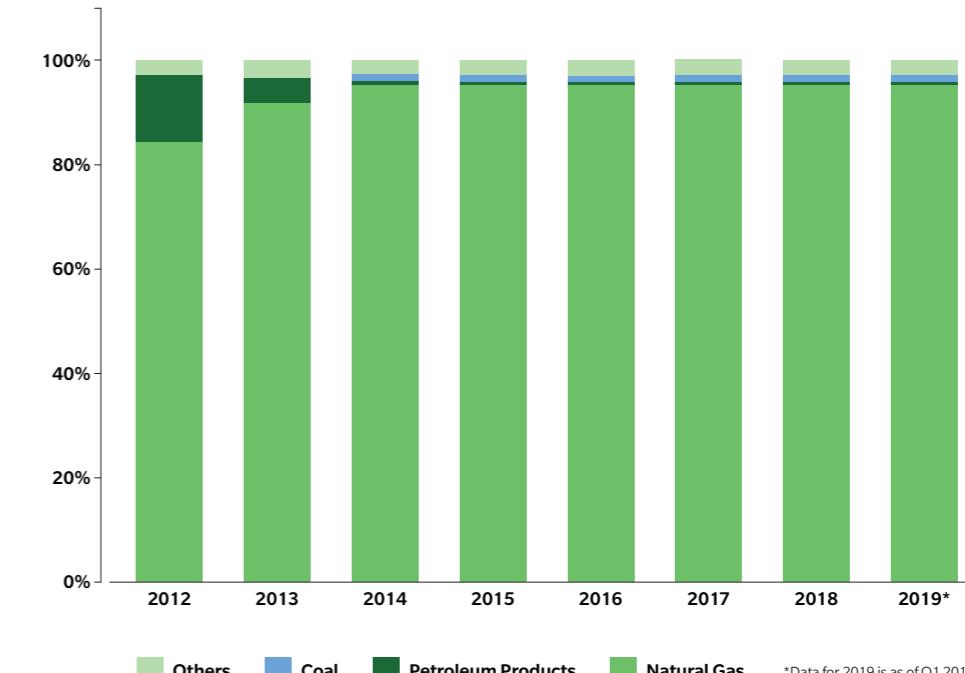
POWER

Current landscape

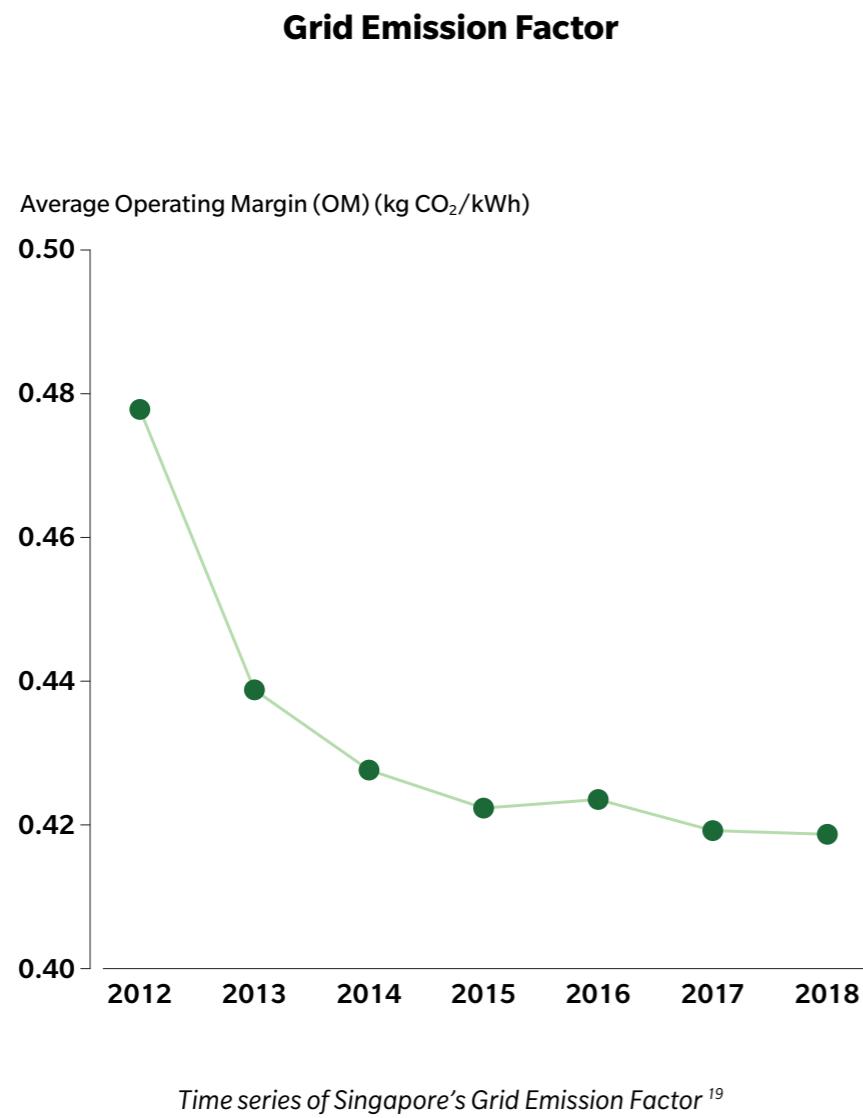
As of 2017, emissions from power generation represented around 39% of Singapore's national emissions. While Singapore's electricity consumption grew by almost 40% from 2005 to 2017, our Grid Emission Factor (GEF) has improved from 0.5255 tCO₂/MWh in 2005 to 0.4188 tCO₂/MWh in 2019. This is largely due to our switch to natural gas, which accounts for more than 95% of Singapore's fuel mix in 2019. Beyond natural gas, Singapore's solar capacity has also increased significantly over the years. We are well on track to achieve 350 MWp in 2020, and aim to achieve at least 2 GWp by 2030.

Decarbonising the power grid is an essential component of Singapore's long-term emissions reduction aspiration. A cleaner power grid would mean cleaner electricity for all sectors, and would support the push for greater electrification in sectors such as transport. Singapore is committed to transforming our power sector and significantly reducing its emissions. We will pursue these goals through the use of cleaner energy sources and technology efficiency improvements.

Electricity Generation Fuel Mix

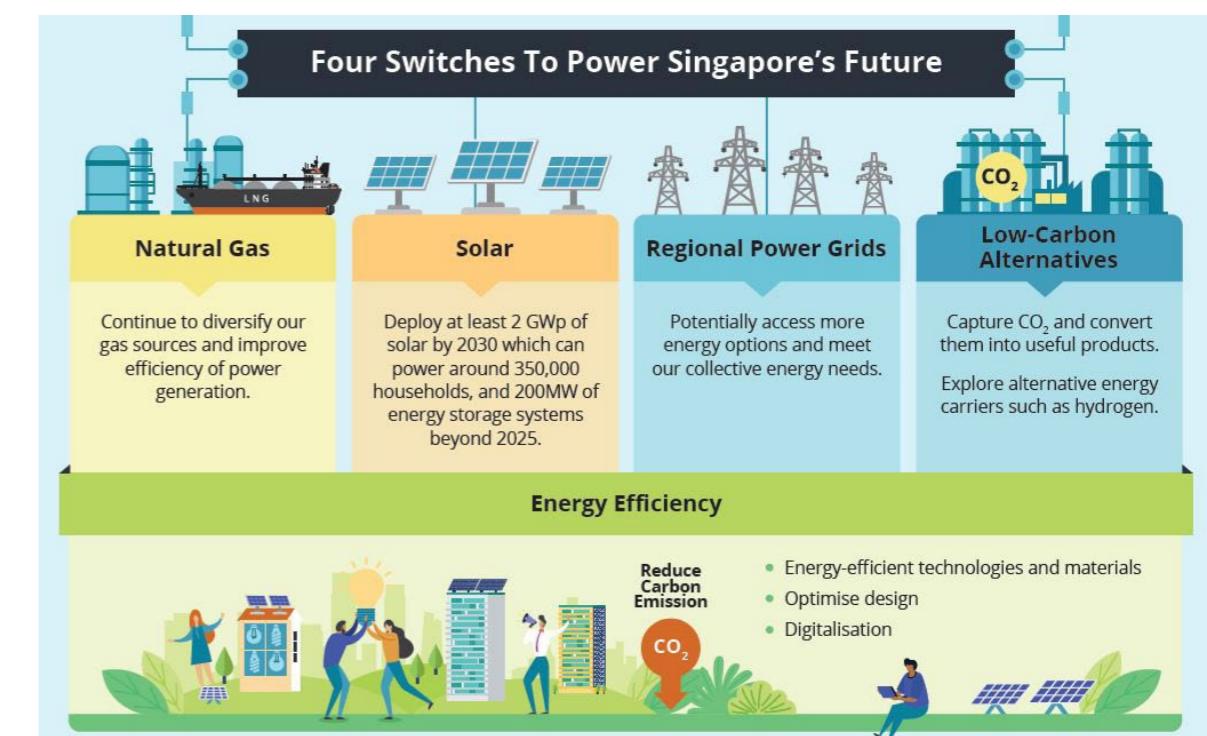


Singapore's electricity generation fuel mix



Singapore's future electricity grid

We will press on in our efforts to ensure a sustainable, reliable and affordable energy supply. Our vision for a sustainable energy future not only builds on past and existing efforts, but also considers future possibilities that could enable our electricity grid to be significantly decarbonised. We 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 our energy transformation.



¹⁹ The Grid Emission Factor (GEF) measures average CO₂ emissions per Megawatt-hour (MWh) of electricity generated. The Operating Margin (OM) GEF measures all generating power plants' generation-weighted average CO₂ emissions per unit net electricity generation in the system. The Build Margin (BM) emission factor refers to the most recently-built power units' generation-weighted average CO₂ emissions per unit net electricity generation. With the introduction of new and more efficient combined cycle gas turbines, Singapore's BM emission factor trends lower than the OM emission factor.

Developing the Four Switches will be key to overcoming Singapore's energy challenges.

1st Switch – Natural gas

As it takes time to shift away from conventional fossil fuel power generation, and to develop and scale up alternative energy options, natural gas will continue to be the dominant fuel for Singapore in the near future. We will continue to explore ways to reduce emissions from the combustion of natural gas for power generation, and ensure that our energy supply remains resilient for the future.

Generate power from natural gas more efficiently to reduce emissions

As technology improves, power generation systems are expected to become more efficient over time. This will enable further carbon emissions reductions, improve cost competitiveness and ensure more efficient use of natural gas.

Singapore will continue to encourage the power generation companies to upgrade their systems and technologies to improve the efficiency of power generation. We launched the Energy Efficiency Grant Call to encourage power generation companies to invest in energy-efficient equipment or technologies to reduce their carbon emissions. We will also encourage the deployment of more advanced and efficient gas turbines, as existing gas turbines are retired.

Diversify our natural gas sources to improve energy security

To ensure a more resilient supply of natural gas, Singapore built a liquefied natural gas (LNG) terminal, which began operations in 2013. Our LNG terminal allows us to source for natural gas globally, in addition to our piped natural gas (PNG) supply. We will continue to diversify Singapore's gas supplies.

Singapore intends to appoint up to two new LNG importers. The Government has also issued an Expression-of-Interest to identify potential technologies, business models, and sites for deployment of an offshore LNG terminal when needed.

2nd Switch – Solar

Solar energy remains the most viable renewable energy option for Singapore. In recent years, solar installed capacity has exponentially increased. The Government is taking the following active steps to support greater solar adoption:

- **Streamlining regulations to make it easier for solar players to sell excess solar electricity to the grid;**
- **Aggregating public sector demand for solar photovoltaics (PV) through the SolarNova programme;**
- **Enhancing capabilities in forecasting solar power output to mitigate the effects of solar intermittency. For example, we awarded a research grant to develop an accurate multi-timescale solar forecasting solution customised to Singapore's tropical weather conditions; and**
- **Deploying solar panels on spaces such as reservoirs besides building rooftops, to overcome our land constraints.**

SolarNova Programme

The SolarNova Programme, which aggregates demand for solar deployment across public sector buildings and spaces, catalyses the growth of solar energy in Singapore. Four leasing tenders totalling 236 MWp have been awarded since 2015, with a fifth tender to be awarded in 2020 for 60 MWp of solar energy. The SolarNova programme remains the largest driver of solar adoption across the whole-of-government and Singapore.



Solar panels deployed on Housing & Development Board (HDB) roofs as part of the SolarNova Programme

Facilitating greater solar deployment

Singapore aims to deploy at least 2 GWp of solar by 2030, which will meet around 4% of our current annual electricity needs and 10% of current peak daily electricity demand. This is equivalent to meeting the annual electricity needs of around 350,000 households in Singapore. To meet this ambitious target, we will drive solar deployment beyond the rooftops of public sector buildings, to include private sector buildings in partnership with private developers and industry players. We will also explore innovative deployment possibilities on vertical and horizontal surfaces. To overcome Singapore's land constraints, we will also explore the deployment of floating solar modules on our reservoirs and offshore sea space.

Improvements in solar cell efficiency will also allow us to increase the amount of solar-powered electricity. Currently, conventional solar panel efficiency is between 15% and 20%. As cell efficiencies improve, the amount of energy generated will correspondingly increase.

Mitigating the variability of solar power

Local solar energy output is intermittent due to our tropical weather conditions, such as monsoon winds and cloud cover, which impact the variability of solar generated power. Possible measures to address the variability of solar power include: i) enhancing solar forecasting systems; ii) reducing the dispatch interval for electricity generation and regulation reserves; and iii) enabling energy storage systems (ESS), flexible conventional generation, demand response management, regional grid integration and vehicle-to-grid (V2G) systems.

In 2018, the Government awarded a research grant to a consortium led by the National University of Singapore (NUS) to develop a solar irradiance forecasting model customised to Singapore's tropical weather conditions. Further studies could help determine how to address the impact of solar intermittency in the most cost-effective manner through accurate solar forecasting and matching with the dispatch interval, whilst minimising the need for other costlier measures such as energy storage.

Presently, the relatively higher cost of ESS makes commercial viability challenging. However, the costs of ESS are falling. The Government is working with industry players to implement test-beds, build local capabilities and develop technical standards to safely deploy ESS in Singapore's hot and humid environment. We will establish a set of deployment guidelines to maximise space, co-locate ESS with other infrastructure safely and bootstrap the deployment of ESS solutions. As Singapore pushes for greater solar deployment, we have set an ESS deployment target to be able to deliver 200 MW beyond 2025.

Separately, with Singapore's push to introduce more electric vehicles (EVs), V2G technology will potentially allow us to treat each EV as an off-grid energy storage device. As such, EVs can help to stabilise grids by providing ancillary services such as frequency regulation and peakload shaving.

Underground ESS deployment at Marina Bay District Cooling

Under the Smart Grid 2.0 Grant Call in 2015, the Government awarded a project to design and implement a novel hybrid ESS, combining a 400 kilowatt (kW) lithium-ion battery with thermal storage. The development of this innovative project allows the district cooling network to participate in the Energy Market Authority's (EMA) ancillary services initiatives (e.g. demand response programme). This project was awarded the Merit Award under the Minister for National Development's R&D Awards in 2019.



Underground ESS deployment for district cooling at Marina Bay area

3rd Switch – Regional power grids

Singapore is exploring ways to tap on regional power grids to access energy that is cost competitive and meets our climate change obligations, while ensuring continued energy security. These include new bilateral power trading arrangements with neighbouring systems, as well as regional arrangements such as the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project. Through these initiatives, we can tap into new energy options that may be unavailable in Singapore such as hydropower and large scale solar.

The longer-term vision of an ASEAN Power Grid – in which electricity is traded freely between ASEAN member states – will enhance regional energy connectivity, trade and cooperation. Greater grid interconnections within ASEAN will also help the region reach its aspiration of increasing the share of renewable energy in its energy mix to 23% by 2025, and allow Singapore to access green electricity from the region.

4th Switch – Emerging low-carbon alternatives

Singapore is carrying out research into adopting several promising low-carbon technologies, including CCUS and low-carbon hydrogen. These technologies could allow us to significantly decarbonise the power sector, as well as other sectors. We will address our strategy for pursuing these emerging technologies later in this chapter.

INDUSTRY

Current landscape

The industry sector is a key engine of Singapore’s economic growth. Our industries produce not only for Singapore but also to meet the needs of the global market. Today, the industry sector contributes to 20.9% of our GDP, provides employment for 12.9% of our workforce and has strong linkages with the service sector. Emissions from our industry sector accounted for about 60% of our total emissions in 2017. The most significant part of our industry emissions come from the combustion of fossil fuels in the refining and petrochemical sector.

Energy efficiency improvement will remain a key strategy to reduce the industry sector’s emissions. Improving energy efficiency and prioritising energy reduction will give companies a competitive edge in an increasingly carbon-constrained world. We will push for our industries to be among the best-in-class in global energy and carbon efficiency. We will also study how advances in technology can help drive decarbonisation in industrial processes in the longer-term.

Energy costs are not subsidised in Singapore, and there is an economy-wide carbon tax. Companies are therefore incentivised to use energy judiciously and embrace energy-efficient technologies. The Government facilitates the adoption of energy-efficient technologies through grants and other policy tools to help companies overcome high upfront capital investments and other non-market barriers, in order to reap longer-term energy and lower carbon emissions.

Improving industrial energy efficiency

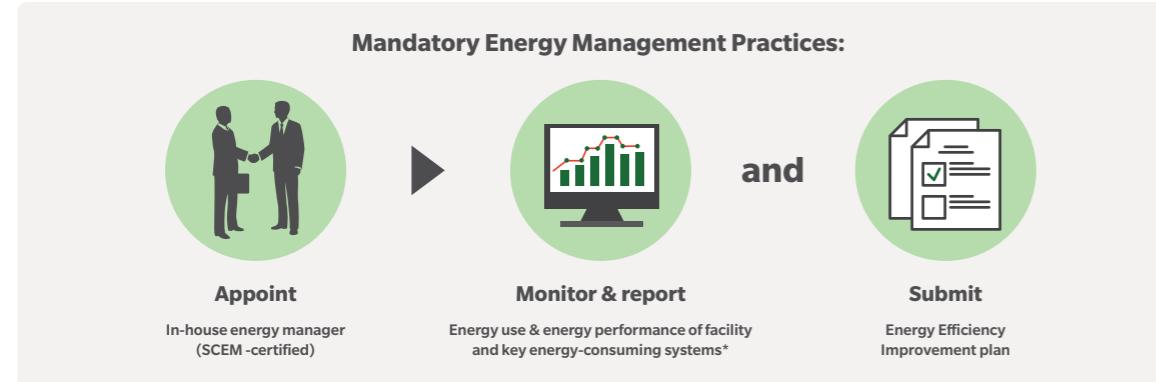
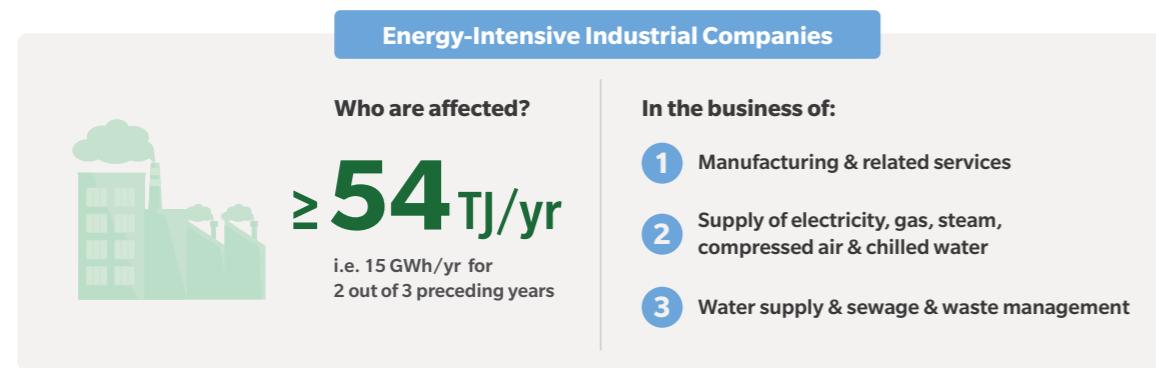
The implementation of energy efficiency projects and good energy management practices can help companies save energy, reduce operational costs and increase business competitiveness. Over the years, Singapore has implemented regulations, incentives and capacity-building programmes to encourage industries to implement energy efficiency projects and improve their energy management practices. We will push ahead in our efforts and aspire to achieve annual improvement rates of 1% to 2% for industrial energy efficiency.

Regulation to improve energy efficiency

The Energy Conservation Act (ECA), introduced in 2013, was Singapore's first legislative framework for industrial energy efficiency. It mandated energy management practices to steer companies to improve their energy efficiency practices. Since the enactment of the ECA, the annual energy efficiency improvement rate²⁰ of the industry sector has steadily increased from 0.4% in 2014 to 0.95% in 2018.

The Government enhanced the ECA in 2017 to include a new suite of measures that is being progressively implemented. Since 2018, companies investing in new and major expansions of energy-intensive industrial facilities are required to review

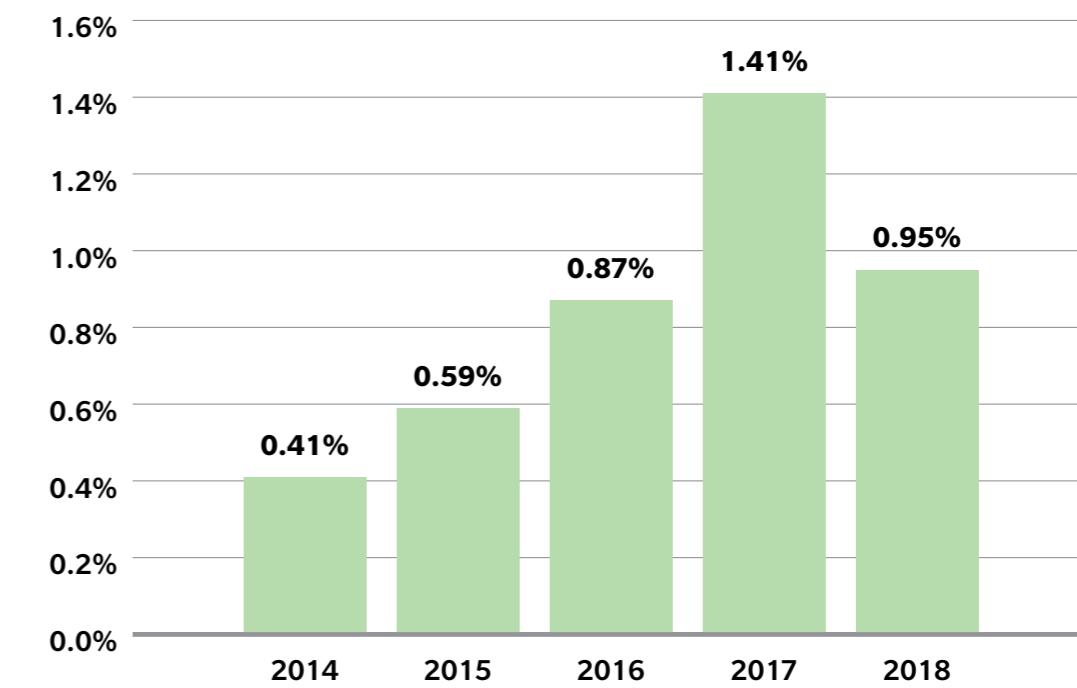
the facility design to identify technically and economically feasible energy efficiency improvement opportunities for incorporation in the new facilities. These companies must also report the energy performance of key systems that account for at least 80% of the new facilities' total energy consumption. From 2021, companies regulated under the ECA will be required to have a structured energy management system. They will also be required to conduct regular assessments to identify energy efficiency opportunities at their industrial facilities. Minimum Energy Efficiency Standards (MEES) have also been introduced to phase out the least efficient industrial electric motors in 2018 and chilled water systems in 2020.



* Account for 80% of the facility's annual energy consumption

Key requirements under the Energy Conservation Act

Annual EE Improvement



Annual energy efficiency improvement of the industry sector in Singapore

²⁰ Energy efficiency improvement rate is calculated as the energy savings realised in a year over energy consumption in the immediate preceding year, based on energy efficiency measures reported by companies.

Incentives to improve energy efficiency

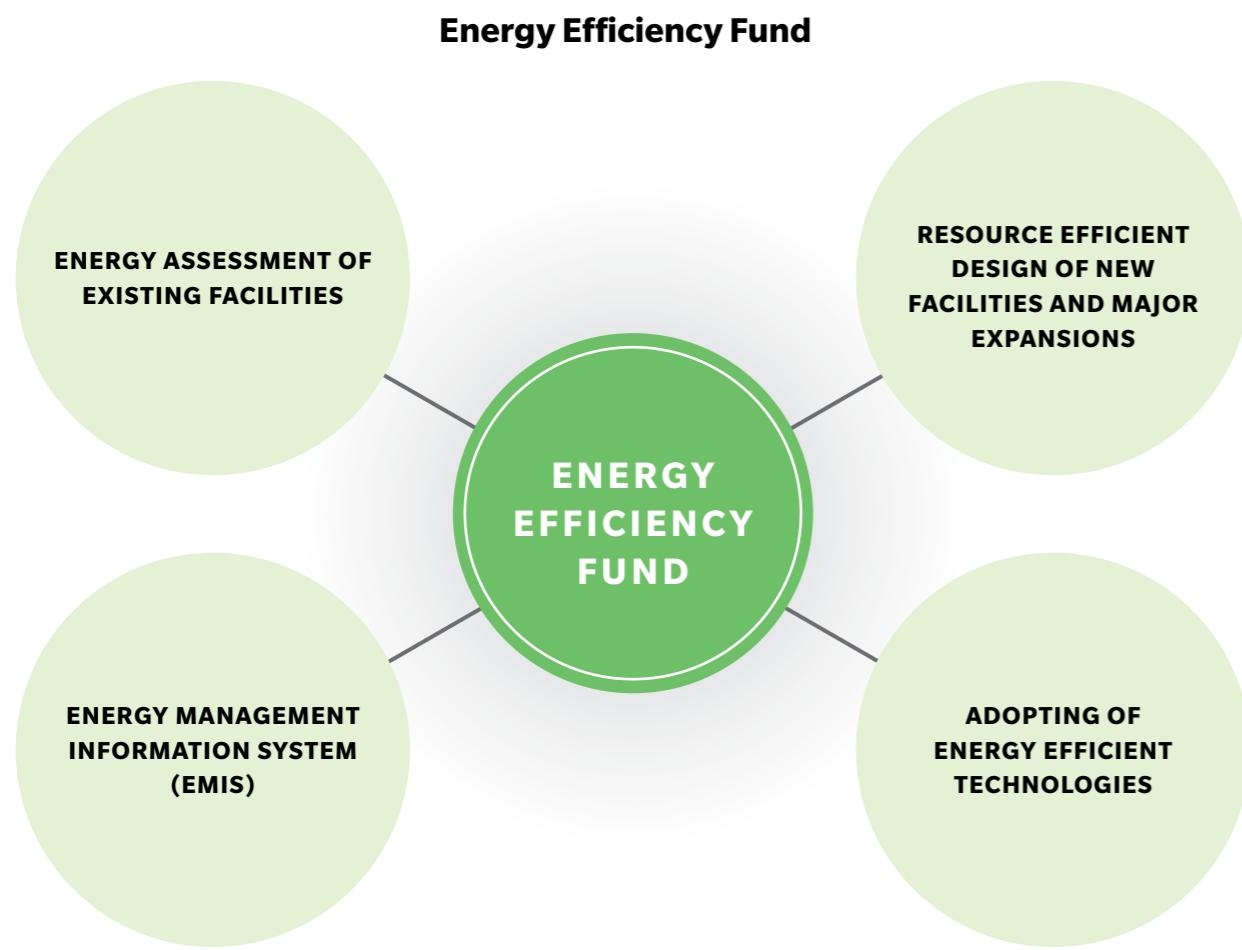
Companies may face significant challenges in implementing energy efficiency projects. Key challenges include the high upfront capital cost of more energy-efficient technologies or processes, and difficulties in implementing these energy efficiency projects at their existing industrial facilities due to infrastructural constraints. The Government provides assistance to help companies overcome these barriers.

Since 2005, the Government has provided grants to help industrial facilities review their facility design to incorporate energy and resource efficiency

measures, carry out energy assessments to identify and implement energy efficiency opportunities. The Government expects revenue of about S\$1 billion from the carbon tax revenue over the first five years. We are prepared to spend more than the amount collected during this period to support companies, including small and medium enterprises (SMEs) and Generation Companies (Gencos), to improve their energy and carbon efficiency by adopting greener and cleaner technologies and practices.

- **The Energy Efficiency Fund (E2F) and the Resource Efficiency Grant for Energy cover costs for equipment, materials and consumables, technical software and professional services. 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%.**

- **Accurate monitoring of energy consumption helps companies identify opportunities for energy efficiency improvement. In October 2019, the Government launched a new grant under the E2F 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.**



End-to-end approach for incentives in the industry sector

Capacity building

The effectiveness of our energy efficiency efforts will also depend on building up the capability, knowledge and expertise of professionals and companies in the energy sector. These initiatives include:

- **The Energy Efficiency Opportunities (EEO) Assessor Certification Scheme was jointly developed by the Government and the Institution of Engineers, Singapore (IES) in 2018. To support the enhanced ECA requirements, companies can identify engineers to be certified as EEO Assessors to conduct energy assessments for energy-intensive industrial facilities.**
- **The Energy Efficiency Technology Centre (EETC) is a collaboration between the Government and the Singapore Institute of Technology (SIT) to help companies, in particular SMEs, discover and implement energy efficiency improvement measures and build up local industrial energy efficiency capabilities. Participating SMEs will receive a diagnosis of their energy performance and recommendations on areas of improvement, and have their staff trained in energy assessment skills to enable continuous improvement in energy efficiency.**

Fostering a culture of sustained energy efficiency improvement

To support private sector efforts in energy efficiency, the Government launched the Energy Efficiency National Partnership (EENP) programme in 2010. The EENP provides networking opportunities and resources, and facilitates the sharing of best practices on energy management. The annual EENP Awards recognises companies' commitment to improve energy efficiency and management. Examples of the best practices and initiatives of the EENP "Excellence in Energy Management" award recipients are provided below.



Winners of the EENP 2019 were recognised for their best practices and innovations in energy efficiency and management.

- **HP Singapore (Private) Limited (2019 recipient):** Implemented ISO 50001 Energy Management System certification across its three manufacturing plants in Singapore, the first global HP site to do so, and established an energy policy to reduce its emissions. Its key initiatives included using online energy monitoring systems to proactively reduce energy wastage, installing solar PV systems across its manufacturing sites, improving the efficiency of its chillers, replacing tube lighting with energy-efficient light-emitting diodes (LEDs), replacing its air compressors with more energy-efficient sets, and improving its heating system.
- **Roche Singapore Technical Operations Pte Ltd (2019 recipient):** Established sustainability targets for reducing water consumption, energy consumption and waste generation, initiated sustainability projects and internal awareness campaigns and participated in external training programmes to build capacity on sustainable practices. Its key projects for reducing energy consumption included adding an insulation coating on boilers, using heat recovery for its air handling unit and replacing chillers.
- **BASF South East Asia Pte Ltd (2018 recipient):** Introduced measures to improve energy efficiency of their processes, maintenance, and modification projects, such as bypassing a heating a cooling step in a crystallisation process with no impact on product quality. Other key projects include replacing chilled water and glycol chillers with more energy-efficient models, and arranging training sessions for energy managers to promote energy stewardship among employees.

Emerging low-carbon alternatives

Amongst the promising low-carbon technologies being explored, CCUS and low-carbon hydrogen (as alternative fuel and industrial feedstock) can be significant needle-movers to support the decarbonisation of the industry sector. We will address our strategy for pursuing these technologies later in this chapter.

TRANSPORT

Current landscape

As of 2017, emissions from domestic transport accounted for about 15.2% of Singapore's national emissions, with private cars contributing the largest share of land transport emissions. We have comprehensive measures to discourage vehicle ownership and usage, through a vehicle quota system and road pricing. Since 2018, we have capped private car and motorcycle growth at zero. In 2013, we introduced a system of rebates and surcharges to encourage car buyers to purchase low-emission cars.

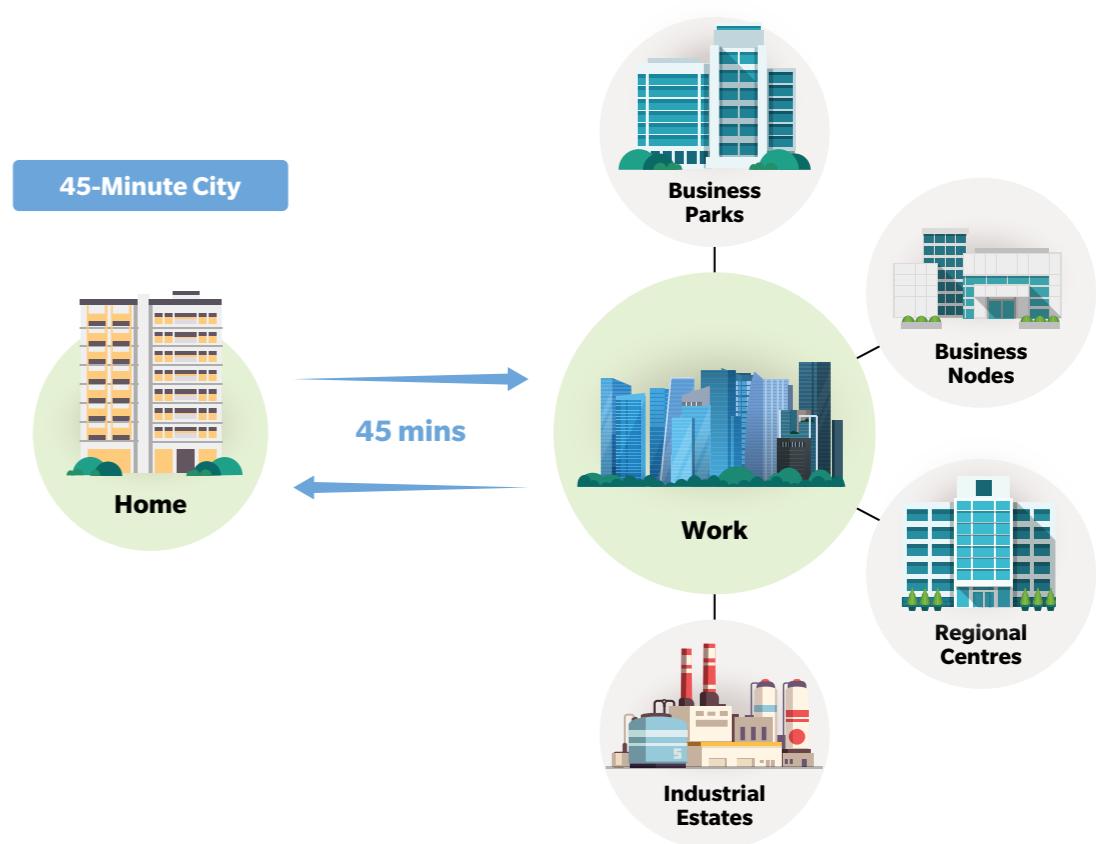
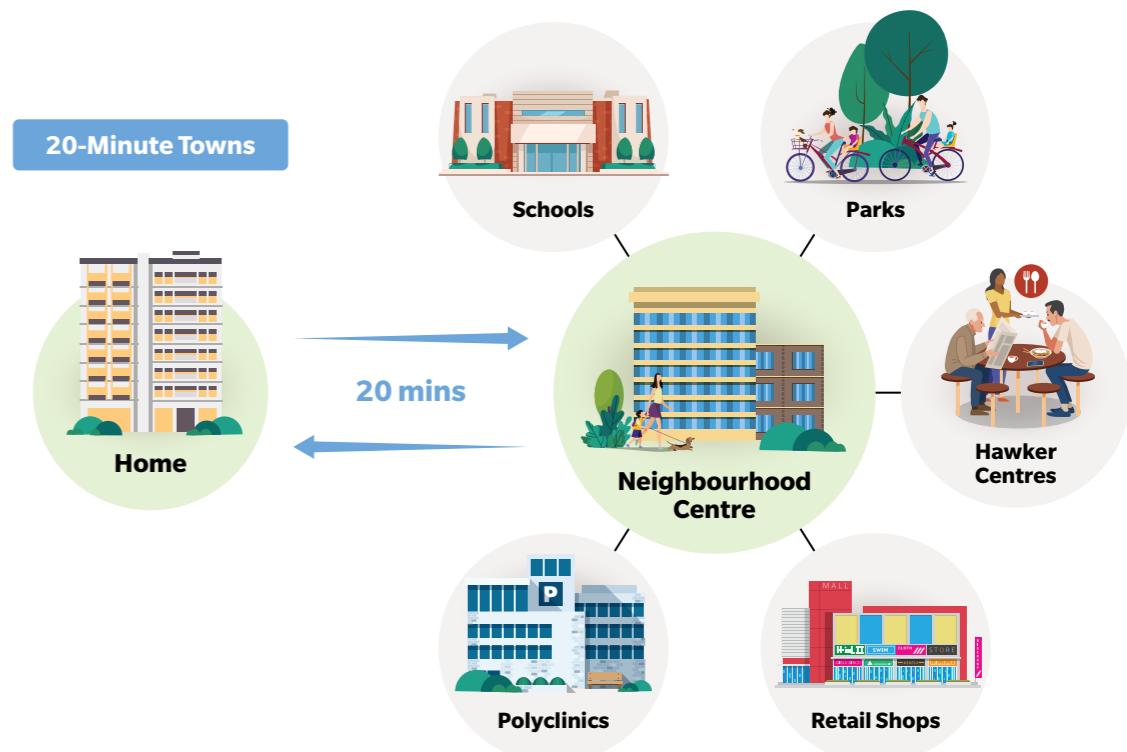
Building on this, we have drawn up a vision of a clean and green transport system for generations of Singaporeans, with a well-connected, inclusive and green transport network that supports a growing community and economy.

We are making Walk-Cycle-Ride (WCR) the preferred modes of transport, introducing cleaner and greener vehicles on our roads, and enhancing the environmental friendliness of our transport infrastructure.

Reducing emissions through Walk-Cycle-Ride

Increasing the public transport modal share has been a key strategy to reducing emissions in Singapore. We are a global pioneer in controlling vehicle population and reducing traffic congestion.

By 2040, Singapore aims to establish WCR, comprising active mobility²¹ as well as public and shared transport modes, as the preferred way to travel. All journeys to the nearest neighbourhood centre using WCR modes of transport will take no more than 20 minutes, while nine in ten of peak period WCR journeys, such as between the home and workplace, will be completed in less than 45 minutes. By expanding and improving our transport infrastructure to reduce travel times and encourage more people to take WCR transport modes, we can reduce our vehicular emissions footprint further.



All journeys within a town, using public, shared and active modes of transport will take no more than 20 minutes, while nine in ten peak period journeys, such as between the home and workplace, using public, shared and active modes of transport, will be completed in less than 45 minutes.

²⁰ Active mobility modes include walking, cycling or using Personal Mobility Devices such as electric scooters.

Expanding the Active Mobility Network

Singapore will accelerate the building of cycling paths and active mobility infrastructure to make cycling and walking more convenient and attractive. By 2040, our cycling path network will be extended to more than 1,000km from 440km in 2019. Under the Walk2Ride programme, which was introduced in the 2013 Land Transport Master Plan, the Government built 200km of sheltered walkways from transport nodes to homes and public amenities. A further 150km of these covered linkways will be added by 2040. In addition, private developers will have to submit walking and cycling plans as part of development applications. These measures will help facilitate safe and convenient first-and-last mile connections between homes, public amenities and key public transport nodes, therefore encouraging more commuters to walk or cycle as opposed to taking private transport.

Expanding and improving mass public transport and shared transport

Singapore will continue to push for public transport, which has the lowest emissions per passenger journey, to be the preferred transport mode. Increasing the public transport modal split will remain essential for supporting our mobility needs while reducing transport emissions. We will continue to encourage people to switch from private to public transport by expanding and improving the public transport system by:

- **Expanding the rail network from 230km in 2017 to 360km by 2030, with eight in ten households to be within a ten-minute walk from a train station;**
- **Progressively implementing Transit Priority Corridors that serve as dedicated and continuous bus lanes and deploying smarter traffic control solutions to reduce passengers' commute times; and**
- **Maintaining an open and contestable point-to-point market to allow people to have access to taxis and private hire cars, and encouraging car-sharing to give commuters more choices for their journeys without having to own a car.**



To encourage more people to take public transport, our public housing towns are designed such that their transport hubs integrate train stations with bus interchanges and are equipped with sheltered walkways that connect to housing blocks and amenities.

Cleaner and greener vehicles on our roads

Singapore is working to enhance the overall carbon efficiency of our land transport system through the large-scale adoption of green vehicles. By 2040, we aim to phase out internal combustion engine vehicles and have all vehicles running on cleaner energy. We will introduce policies and initiatives to encourage the adoption of EVs. The public sector itself will take the lead and progressively procure and use cleaner vehicles.

To promote the adoption of cleaner and more environmentally friendly vehicles, the Government will implement an EV Early Adoption Incentive scheme from 2021 to 2023 to encourage the early adoption of cleaner vehicles. Under this incentive, drivers and businesses who purchase fully electric cars and taxis will receive a rebate of up to 45% off the vehicle's Additional Registration Fee,²² capped at S\$20,000.



The Nanyang Technological University, Singapore (NTU Singapore) and Volvo Buses are trialling a full size, autonomous electric bus equipped with a comprehensive artificial intelligence system developed by NTU Singapore engineers.

In addition, based on the promising results of the Vehicular Emissions Scheme that provides rebates to car owners and taxi operators who use cleaner car models, the Government will introduce a similar scheme, the Commercial Vehicle Emissions Scheme, for light goods vehicles.

To make EVs more accessible and promote their adoption, Singapore will expand the public charging infrastructure for EVs. The Government will work with the private sector to improve charging provisions in public and private carparks. By 2030, we aim to have up to 28,000 chargers in public carparks island-wide, from around 1,600 today.

These efforts are expected to make a significant difference. Technological advancements on EV charging and the availability of attractive, cost-effective EV models in the market will also be important factors that will influence how quickly we can achieve these goals.



Charging infrastructure will be improved as part of efforts to support the adoption of EVs.

Greener transport infrastructure

We are also enhancing our existing transport infrastructure and building new transport facilities that are more energy-efficient and sustainable.



A greener commute

Canberra Station, which is the newest Mass Rapid Transit (MRT) station in Singapore, opened for service in November 2019. In addition to covered linkways and bicycle parking lots to facilitate convenient first-and-last mile journeys to and from the station, Canberra Station has many green features such as energy-efficient air-conditioning, LED lighting systems and green roofs. With its extensive use of environmentally friendly building materials, products and services, Canberra Station became the first MRT station to receive the Green Mark Platinum certification under the Green Mark scheme for transit stations.

Canberra Station's clear roof panels and glass panels installed along its facade are able to take advantage of natural lighting to be more energy efficient.

²² The Additional Registration Fee is a tax imposed upon registration of a vehicle and is calculated based on a percentage of the Open Market Value of the vehicle.

Energy efficiency improvements at Changi Airport

Singapore has proactively taken measures to develop Changi Airport as a world-class air hub that champions sustainability. To improve its energy efficiency, a series of equipment replacement and service improvement projects have taken place throughout the airport, such as modernising existing lifts, upgrading to energy-efficient chillers and replacing conventional lighting in terminal buildings with LED lights.

The new Terminal 5 will also be designed and built according to stringent energy efficiency standards and is anticipated to achieve Green Mark Platinum standards. As Terminal 5's development will extend well into the 2020s, the adoption of new emerging technologies may result in further improvements in the terminal's energy efficiency.



Electric baggage handling tractors are deployed at Changi Airport Terminal 4.

Greening airport operations

With the support of ground handling partners, Changi Airport Group (CAG) has introduced clean-energy tractors within the baggage handling areas, starting with Terminal 4 in November 2017. CAG has also installed 114 charging points for its 80 electric baggage tractors at the airside of its passenger terminals. The fleet of electric baggage tractors will grow to over 300 tractors by end-2020. This will support the Changi Airport community's goal of reducing airside emissions and creating a better work environment.

Green innovation and emission reductions in Singapore's maritime sector

The Government has been working with stakeholders to improve the sustainability of our port infrastructure. Singapore's main commercial port terminal operators, PSA Corporation Limited and Jurong Port Pte Ltd, have deployed solar PV systems at their terminals and embarked on other electrification projects at existing terminals.

Tuas Port – Port of the Future

Expected to be fully completed in 2040, the new Tuas Port will be the world's largest fully automated terminal in a single location. It will have a fleet of over 1,000 fully electric automated guided vehicles that have a carbon footprint of 25% less than that of conventional diesel-powered prime movers. The port will also feature electric automated rail-mounted gantry cranes to be more energy-efficient.



In addition to an automated wharf and yard that will raise efficiency, the waters around Tuas Port will be managed with a next-generation vessel traffic management system for safe and efficient navigation.

BUILDINGS

Current landscape

As Singapore is a highly urbanised city-state, the building sector contributed 14.6% of our total emissions in 2017. As such, greening our buildings is an integral part of reducing Singapore's overall long-term emissions. The Government has worked closely with stakeholders to roll out a comprehensive suite of initiatives and policies under three successive editions of Green Building Masterplans. These Masterplans have steered Singapore's green building efforts, comprising a mix of regulatory policies and financial incentives, workforce capability-building programmes, engagement and awareness activities, and R&D capability-building programmes.

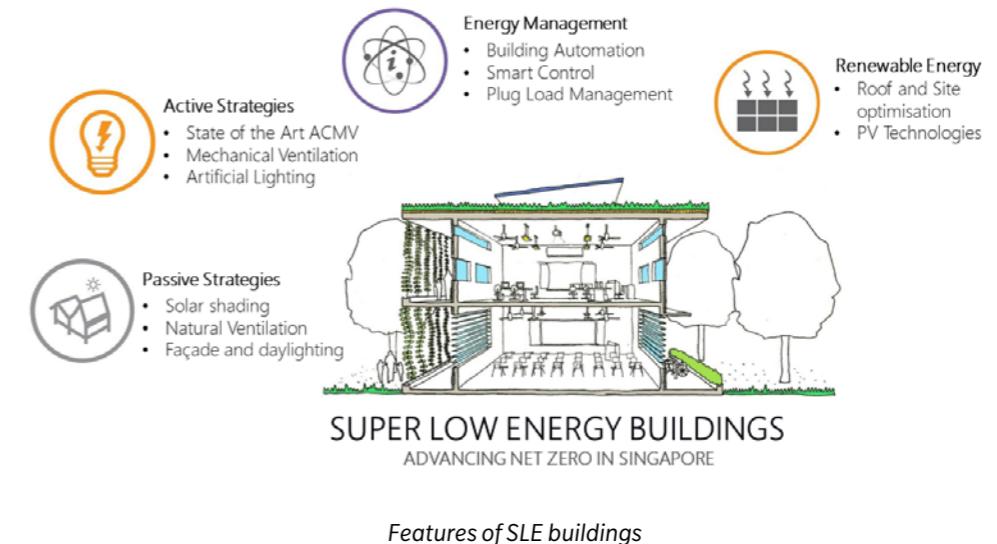
Singapore has set a target to green 80% of our total building gross floor area (GFA) by 2030. As of March 2020, we have greened more than 40% of our total building GFA. We will continue to pursue efforts towards this target through promoting sustainable and energy-efficient design and performance at the individual building level as well as at the district level.

Reducing energy use and increasing sustainability

The Building and Construction Authority (BCA) Green Mark Scheme was launched in January 2005 as an initiative to drive Singapore's construction industry towards more environmentally friendly buildings. It is a benchmarking scheme to promote sustainability in the built environment and raise environmental awareness among developers, designers, and builders. The coverage of the benchmarking scheme extends from the start of the project's conceptualisation and design, to its construction and even operation.

Spurring the adoption of Super Low Energy buildings

Widespread adoption of Super Low Energy (SLE) buildings in Singapore will help reduce energy use and emissions in the buildings sector. The Government has worked closely with our industries and academia to co-develop the SLE Buildings Programme, launched in September 2018. The SLE Buildings Programme encourages the deployment of cost-effective, energy-efficient and renewable energy solutions in the built environment sector. This will also encourage the development of more Zero Energy buildings that produce as much electricity as they consume, or Positive Energy buildings that produce surplus electricity that can be fed into the electricity grid.



The SLE Buildings Programme comprises:

- Green Mark Scheme for SLE buildings,
- SLE Challenge, and
- SLE Buildings Technology Roadmap.

- The Green Mark Scheme for SLE buildings was developed to encourage industry to push boundaries on energy efficiency to achieve best-in-class building energy performance in a cost-effective manner. SLE buildings achieve at least 60% energy savings (compared to our 2005 building code baseline) by adopting energy-efficient measures and deploying on-site renewable energy solutions.
- The SLE Challenge was launched in September 2018. To date, 20 progressive public and private developers have stepped forward to take the lead by committing to achieve at least one Green Mark SLE project within five years.
- The SLE Buildings Technology Roadmap examines a wide spectrum of emerging energy technologies, analyses their interaction and integration, and explores their feasibility in our tropical and urban context. The Roadmap comprises 60 innovative solutions to help the industry design and develop cost-effective SLE buildings.

The Government established the Green Buildings Innovation Cluster (GBIC) programme in 2014 to fund collaborative research on environmentally sustainable buildings between the Built Environment sector and the research community. The GBIC programme develops innovative and viable solutions to achieving SLE buildings. By tapping on GBIC, developers can work with research partners to develop new energy efficiency solutions and test-bed them in their own buildings.

BCA has also set up the SLE Buildings Smart Hub, a one-stop knowledge centre to support the industry's efforts with implementing SLE building standards. The Smart Hub is a central database that collects information from existing buildings and reports of completed R&D projects. Researchers may access the data from the Smart Hub to analyse the performance of the demonstrated technologies, while building owners can refer to the expanding list of green technologies and select options best suited to their needs. Industry players may also access the Smart Hub for best practices and success stories.



NUS, School of Design & Environment, SDE 4

As the first purpose-built net-zero energy building in Singapore commissioned by a tertiary institution, SDE 4 makes the case – through design and operations – that stringent energy targets for Singapore buildings are possible without sacrificing functional efficiency or architectural aesthetics.



Surbana Jurong Campus

The Surbana Jurong campus is the new global headquarters of Surbana Jurong, which has grown to become one of the largest Asia-based urban and infrastructure consultancy firms in the world. It is located at the new Jurong Innovation District, the next-generation district in Singapore to promote the future of innovation for enterprise, learning and living. When completed by 2021, the 68,915m² development will serve to demonstrate what a smart, sustainable and future-ready workplace looks like.

BCA Green Mark Award Rating (2019)	Platinum (Zero Energy)
Estimated Percentage Annual Energy Savings²³	40.8%
Notable Green Features	<ul style="list-style-type: none"> First institution in Singapore to extensively deploy a hybrid-cooling system. With daylight utilisation maximised through architectural design, energy savings are further enhanced through a network of photocell and vacancy sensors. Extensive roof coverage with solar PV arrays allows SDE 4 to generate all its energy requirements within the building footprint. Water saving features such as rainwater harvesting, condensate water recycling, and greywater recycling boost the water sustainability of the building.

BCA Green Mark Award Rating (2019)	Platinum (Super Low Energy)
Estimated Percentage Annual Energy Savings	40.8%
Notable Green Features	<ul style="list-style-type: none"> Optimised design of the shape and size of buildings for greater environmental performance (e.g. usage of daylight, optimal use of renewable energy sources). Smart lighting controls. Live energy and water monitoring dashboard. Integrated Building Management System (iBMS) to ensure building systems perform optimally in relation to current demand. Rain gardens and bio-swale built into design to enhance water sustainability. Smart cooling system with under-floor air distribution system. Full adoption of precast walls, columns, beams and planks.

²³ Estimated Percentage Annual Energy Savings refers to the estimated improvement in energy efficiency compared to 2005 levels achieved by implementing passive and active energy efficiency measures. When these savings are combined with power generated by renewable sources, buildings' overall energy status can be net-zero or positive.



NTU Singapore, Wee Kim Wee School of Communication and Information

The Wee Kim Wee School of Communication and Information (SCI) is a mixed development (Institutional and Offices) built in 1996 with a gross floor area of 9,024.55m². The SCI building consists of five levels with a central open atrium. It has advanced laboratory facilities for audio, video, radio, television and print media, among others. The project is an existing building that has been refurbished to achieve Green Mark Platinum (Zero Energy) rating.

BCA Green Mark Award Rating (2019)	Platinum (Zero Energy)
Notable Green Features	<ul style="list-style-type: none"> • Efficient water-cooled air-conditioning system. • Variable speed drives for pumps and cooling towers. • Energy-efficient Task LED lighting for all areas. • Attained PUB Water Efficient Building certification. • Provision of solar PV panels. • Use of motion sensors for toilets and staircases. • Automatic fresh air control. • Low friction loss electro-static air filter for air-handling units. • Future upgrade to passive displacement cooling with high efficiency pre-treated fresh air unit.

Improving building energy efficiency

The Government will continue to put in place measures to improve building energy efficiency, and encourage building owners and developers to implement energy efficiency projects. In the next step of our Green Building journey, we will work with all stakeholders, including developers, building owners, Built Environment professionals and the public to co-create the Singapore Green Building Masterplan 2020 (SGBMP 2020). Apart from traditional industry stakeholders, such as the trade associations and chambers, BCA will also be engaging other groups, including tenants, home-buyers, youths and activists for the development of SGBMP 2020.

One of the key initiatives under SGBMP 2020 will be to review the minimum energy performance standards for buildings. The Government plans to make the minimum energy performance standards more stringent for new and existing buildings in the coming years. Raising the energy performance of buildings will lower emissions and also allow building owners to reap cost savings over the building lifecycle.

We will also provide the identity of all buildings in the annual publication of buildings' energy performance data, to facilitate benchmarking and spur building owners to undertake retrofitting measures to improve the energy efficiency of their buildings.

Sustaining optimal performance throughout the building lifecycle

The operations phase of a building is the longest stage in its lifecycle. Thus, it is important that buildings are designed for optimal performance and maintenance during this phase.

Sound facility management (FM) practices will help our buildings achieve sustained optimal performance. Incorporating elements of Design for Maintainability²⁴ upfront during the building design stage will ensure ease of maintenance and also help our buildings operate optimally throughout their lifespan. Additionally, the use of Smart FM solutions can help to optimise energy performance.

Challenges and potential opportunities

As Singapore greens the majority of its buildings and pushes the boundaries in building energy efficiency, the challenge remains to nudge the owners of less energy-efficient buildings into taking action to improve the energy performance of their buildings. We will explore ways to encourage and help these building owners advance their greening efforts, which can reap energy and cost savings throughout the building lifecycle.

²⁴ Design for Maintainability is the practice of integrating operations & maintenance considerations into project planning and design to achieve effectiveness, safety, and economy of maintenance tasks during the lifespan of a facility.

District-level energy savings

District-level measures to green the building sector will enable even greater energy efficiency improvements, and more energy savings to be reaped. Beyond the individual building level, we intend to scale up efforts to the district level to achieve wider adoption of sustainability measures. District-level concepts will be test-bedded in identified districts, and if successful, considered for future districts. Some concepts under consideration include enhancing BCA's Green Mark Scheme for Districts, sharing of renewable energy sources and district-level cooling.



With two district cooling plants at Marina Bay Sands and One Raffles Quay, chilled water is centrally produced to support air-conditioning systems in buildings in the Marina Bay area, helping them save energy and cost.

Staying cool with less energy

Advancements in technology and engineering have made it possible to cool Singapore while using less energy and using our underground spaces more effectively. For example, instead of conventional chillers and cooling towers in separate buildings, Singapore introduced district cooling systems at the Marina Bay area in 2006. The Marina Bay district cooling system centralises the production of chilled water that is piped into buildings within the district to support their air-conditioning systems, and has helped customers achieve significant energy savings. Apart from reducing energy costs, the district cooling system is built 20m to 25m underground, removing the need for chilling equipment in each building, and freeing up more premium commercial space. More district cooling systems will be rolled out over time.

HOUSEHOLDS

Current landscape

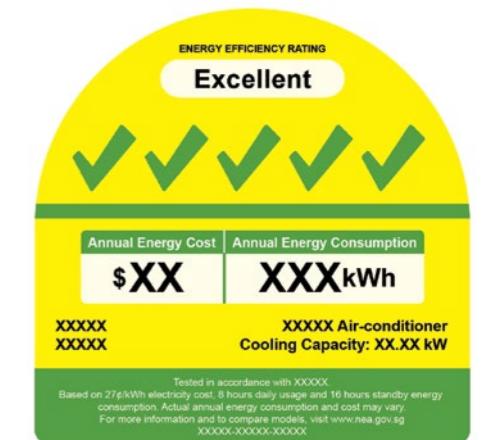
Emissions from the household sector accounted for about 6.6% of emissions in Singapore in 2017. We aim to achieve more energy savings by adjusting behaviour and consumption patterns. By having an energy-efficient home, buying energy-efficient appliances and adopting good energy consumption habits, households will enjoy lower utility bills whilst contributing towards climate action. The Government will continue implementing initiatives to empower homeowners to make better choices and influence usage behaviour.

Reducing the household sector's emissions for the long term

To reduce emissions in the household sector, the Government promotes the use of energy-efficient appliances in homes and encourages energy conservation habits amongst households. The Mandatory Energy Labelling Scheme (MELS) and the Minimum Energy Performance Standards (MEPS) are key policies undertaken to reduce energy consumption and emissions in the household sector through the use of energy-efficient appliances.

Mandatory Energy Labelling Scheme

To help consumers make more informed purchasing decisions, the Government introduced MELS in 2008, which requires suppliers of major energy-consuming household appliances to affix their products with energy labels. To date, MELS covers air-conditioners, refrigerators, televisions, clothes dryers and lamps. We will continue to assess the feasibility of extending MELS to other appliances, such as water heaters.



Energy label for air-conditioners

Raising Minimum Energy Performance Standards

MEPS raises the average energy efficiency of household appliances by removing energy inefficient appliances from the market. This protects consumers from being locked into the high energy costs that result from operating energy inefficient appliances. Currently, MEPS covers air-conditioners, refrigerators, clothes dryers and lamps.

Singapore will regularly review the MEPS to ensure that it provides adequate differentiation of appliance models and reflects improvements in energy efficient technologies in the market. We aim to have all light bulbs to be as energy-efficient as LED bulbs from 2023 onwards. This will save households about S\$3.5 million in energy costs annually. We will also continue to assess the feasibility of extending the coverage of MEPS to other appliances and progressively raise the standards for these appliances to best-in-class levels.

Since the introduction of MELS and MEPS, the average energy efficiency of air-conditioners, refrigerators and clothes dryers have improved by 42%, 46% and 14% respectively.²⁵ In 2018, the total energy savings for all households from the use of more efficient household appliances was estimated to be about S\$270 million. Singapore will continue to look at ways to make the Energy Label more prominent and useful to the consumers. For example, we are exploring the use of augmented reality to allow consumers to compare the lifecycle cost across similar models, facilitating their purchase of more energy-efficient appliances.

Incentives to purchase climate-friendly appliances

The Government introduced a S\$24.8 million Climate-friendly Household Package in 2020 to foster a climate-friendly mindset among households and encourage individuals to take action to reduce energy and water consumption. All households living in one-, two- and three-room public housing apartments in Singapore will receive a S\$150 voucher to purchase energy-efficient and climate-friendly refrigerators and a S\$50 voucher to purchase water-efficient shower fittings. In addition, the “Switch and Save – Use LED” (SSUL) programme, first launched in 2018 to all one-room to two-room HDB households, has been expanded to all three-room public housing households. Under this SSUL programme, each eligible household will receive a S\$25 voucher to purchase LED lights. The package can save up to 90 gigawatt hours (GWh), equivalent to 40 ktCO₂e per year.

Increasing awareness of energy-efficient appliances

Increasing awareness of the importance and ways of conserving energy is also key to reducing energy use in households. The Government will continue different outreach initiatives to promote energy efficiency and conservation, across several platforms to target different audiences. One example is “The Energy-Saving Challenge”, where households are encouraged to reduce their energy consumption by practising energy-saving habits.

Building an Eco Town

In Tampines town, we have created a community-based circular ecosystem for food production. Food waste will be segregated to be fed to black soldier fly larvae. The larvae frass will be used to fertilise a new vertical vegetable farm and the larvae will be fed to tilapias cultivated in a pond in Tampines Park. The project will reduce food waste and strengthen the community’s food resilience.

In addition, Eco Boards, which are low-energy digital boards providing information on water and energy use, will be built across Tampines to enhance the community’s mindfulness of their resource use and illustrate the impact of green infrastructure such as solar PV systems.

Smart Home Technologies

Currently, the analogue electricity meters installed at households are read manually once every two months, and households are billed based on estimated and actual consumption on alternate months. Advanced electricity meters will be deployed in all Singapore households within the next five years. With advanced electricity meters, households can access and track their half-hourly electricity consumption via the (Singapore Power) SP Utilities mobile application. This will allow them to better understand their consumption patterns and reduce their usage to be more energy-efficient.



Advanced electricity meters enable households to track their half-hourly electricity consumption via the SP Utilities mobile app.

²⁵ MELS and MEPS covered air-conditioners and refrigerators from 2008, whilst clothes dryers was included from 2009.

Green Towns Programme

Since 2005, HDB has been driving sustainability efforts in our public housing estates, which provide affordable housing to 80% of Singaporeans. Over the years, we have managed to achieve a 10% reduction in annual energy consumption in our 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: (i) reducing energy consumption, (ii) recycling rainwater and (iii) cooling HDB towns.

To reduce energy consumption, the Government will install smart LED lighting in all public housing estates and scale up

the deployment of solar panels to cover 70% of housing blocks. This will provide clean energy to power common services in our housing estates. To recycle rainwater, we will pilot a new underground water detention system to capture and recycle the rainwater for non-potable uses. We will also undertake a large-scale pilot on the application of “cool paint”, which reduces heat absorbed by HDB blocks. With the learning points and data collected from the pilot, the application of cool coatings can be extended island-wide. Finally, we will increase the green cover on top decks of more multi-storey carparks by repurposing them for urban farming, skyscraper greenery or community gardens, where feasible.



Features of Green Towns Programme

WASTE AND WATER

Current landscape

The waste and water sectors represented around 1.5% of our total emissions in 2017 and there are significant opportunities for mitigating these emissions. Singapore strives to create resource-efficient waste and water management systems to reduce emissions in these sectors.

Singapore has successfully developed an efficient waste management system over the years. In Singapore, waste that is not recycled is incinerated in waste-to-energy (WTE) plants. This reduces the waste volume significantly by about 90%, while generating energy from the process. The excess energy is sold to the grid, which helps to meet 2% to 3% of Singapore’s electricity needs. Incinerating waste also generates less GHG emissions, including methane, compared to direct landfilling.

To reduce the amount of energy use and emissions in the water sector, we have taken key measures such as deploying energy-efficient technologies to process and treat water, and policies to encourage sustainable water consumption.

Achieving a sustainable level of water consumption and waste production, and managing the amount of energy used will be important moving forward, as waste quantities and water demand will likely continue to increase as our economy and population grow. We will continue to push towards sustainable waste and water management, and explore avenues to reduce emissions in both sectors.



Aerial view of Singapore's only landfill, Semakau Landfill

Semakau Landfill

The development of Semakau Landfill, the first offshore landfill in the region, showcases Singapore's innovative spirit and strong engineering capability, in response to the twin challenges of Singapore's growing waste generation and severe land constraints. The thriving coral colonies, mangrove and wild birds in their natural habitat on Semakau Landfill show that the landfill operations and preservation of the local natural environment can be both achieved at the same time.

The National Environment Agency (NEA) was awarded the 2019 Hassib J. Sabbagh Award for Engineering Construction Excellence by the World Federation of Engineering Organisations for the development of

Semakau Landfill. This international award affirms our efforts to leverage technology to manage Singapore's waste effectively and sustainably.

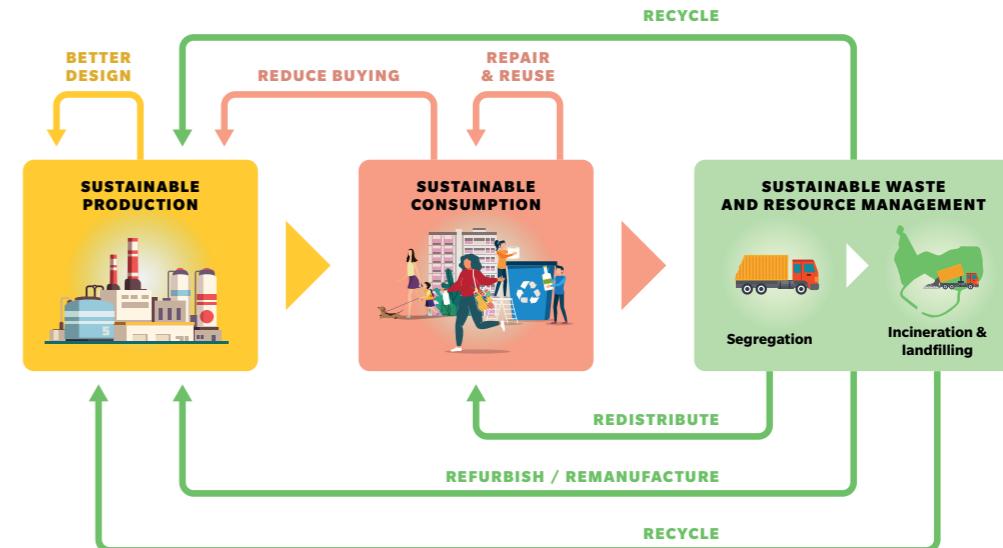
However, Semakau Landfill is not the silver bullet for waste management. It is projected to run out of space by 2035 based on current rates of waste disposal. We need a paradigm shift to manage our waste in new, more sustainable ways to deal with our growing resource constraints and extend the lifespan of Semakau Landfill.

Waste reduction and recycling to reduce waste incineration

Singapore's inaugural Zero Waste Masterplan launched in 2019 outlines our changing approach to managing waste to achieve our vision of a Zero Waste Nation. Under the Zero Waste Masterplan, we announced a new target to reduce the amount of waste sent to Semakau Landfill per capita per day by 30% by 2030. This is in addition to existing recycling targets under the Sustainable Singapore Blueprint 2015. Collectively, these targets would extend Semakau Landfill's lifespan beyond 2035.²⁶

To achieve this new target, we are adopting a circular economy approach where waste is designed out of the value chain and the resources are maximised by keeping them in use for as long as possible.

A circular economy approach will require measures to be taken across the entire value chain



The circular economy approach outlined in the Zero Waste Masterplan Singapore

²⁶ Under the Sustainable Blueprint Singapore 2015, we aim to achieve a 70% overall recycling rate, 30% domestic recycling rate and 81% non-domestic recycling rate by 2030.

Promoting sustainable waste management: Resource Sustainability Act

The landmark Resource Sustainability Act (RSA) introduced in 2019 encourages sustainable production and sustainable waste management by giving legislative effect to new upstream measures to address our key priority waste streams – e-waste, packaging waste including plastics, and food waste. The new measures include an Extended Producer Responsibility (EPR) framework for e-waste, where producers of regulated products bear the physical and/or financial responsibility for the sustainable management of end-of-life products, and mandatory food waste segregation and treatment for large commercial and industrial food waste generators, above certain thresholds from 2024.

Producers of packaged products and supermarkets will also be required to report packaging data and submit plans to reduce, reuse or recycle packaging from 2021, with data collection to commence on 1 July 2020. The mandatory packaging reporting framework will also lay the foundation for an EPR framework for managing packaging waste, including plastics. This will ensure producers are responsible for the collection and recycling of the materials they use to package their products. The Government will be implementing the EPR for packaging waste in phases, starting with a Deposit Refund Scheme for beverage containers by 2022.²⁷ The RSA marks a paradigm shift in our approach to waste management – while efficient waste disposal is necessary, our primary goal is to reduce, reuse and recycle to divert waste away from incineration.

Upgrading our waste management infrastructure to increase the efficiency of recycling and waste incineration

Even as we implement new policies to achieve our vision of a Zero Waste Nation, we continue to improve our existing waste management infrastructure to enhance waste treatment and resource recovery.

TuasOne WTE Plant, Singapore's sixth WTE plant, developed on 4.8 hectares of land and with a treatment capacity of 750 tonnes of waste per day per hectare, will be the most compact plant in the world. When completed, it will also be the most efficient in energy generation among Singapore's existing WTE plants. The plant will help meet our waste incineration needs for the next 25 years, and will have the capacity to incinerate 3,600 tonnes of waste per day from incineration.

Co-creating solutions with the community

Ground-up movements engaging communities to promote sustainable waste management and waste reduction, and drive awareness, action and advocacy will continue to be important. These main areas of work include raising awareness among Singaporeans on the need for sustainable consumption through campaigns such as the "Say YES to Waste Less" Campaign, and inculcating values of environmental stewardship in our young as part of the school curriculum for Character and Citizen Education. More details are provided in Chapter 7.

Reducing water consumption and energy use in water treatment

Promoting water conservation in households

The results of Singapore's water conservation efforts have been encouraging, with household water consumption decreasing from 148 litres per person per day in 2016 to 141 litres in 2019. To reduce water consumption further to 130 litres per person per day by 2030, PUB, Singapore's National Water Agency, will continue to phase out inefficient water fittings and deploy 300,000 smart meters by 2021. The smart meters provide near real-time consumption information and early leak detection in households to encourage water conservation and reduce water loss through leaks.

Reducing energy use in producing desalinated water

PUB invests in research and technology to find more efficient ways to desalinate seawater, which currently uses about 3.5 kWh/m³. We aim to minimally halve the energy used in the future through a combination of technologies such as electro-deionisation, ultra-permeable membranes, Pressure Retarded Osmosis and other process improvements.

Promoting water efficiency in businesses and industries

In addition to phasing out inefficient water fittings and appliances via the Mandatory Water Efficiency Labelling Scheme, businesses/industries that consume 60,000 m³ or more in the preceding year are required to submit water efficiency management plans to PUB annually. This requirement promotes the establishment of water management systems so that businesses/industries can better understand and manage their water usage. PUB is drawing on the data collected to develop water efficiency benchmarks and best practice guidelines to help businesses identify more opportunities to improve water efficiency.

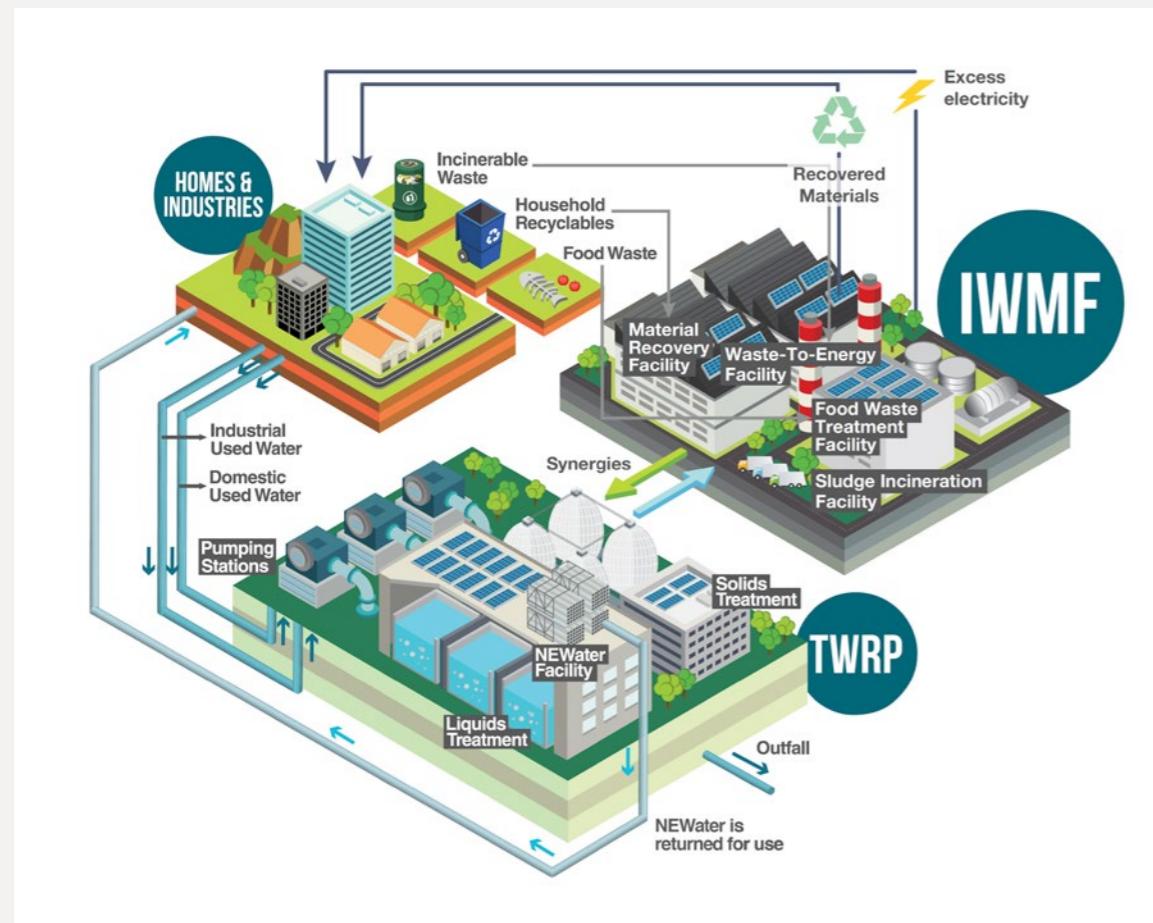
Knowledge sharing is facilitated through the Water Efficiency Manager Course, where participants are assessed and certified as Water Efficiency Managers. Water-efficient businesses are recognised via the Water Efficient Building (Basic) certification and the Water Efficiency Awards. Businesses can also tap on PUB's Water Efficiency Fund and Industrial Water Solutions Demonstration Fund to implement water-saving projects.

²⁷ Generally, with a Deposit Refund Scheme for beverage containers, producers would finance the take-back of the used beverage containers with refunds offered to consumers when they return their empty beverage containers to designated return points.

FORESTRY

Maximising Resource and Energy Recovery – the Tuas Nexus

To leverage the water-energy-waste nexus, the Government is building an integrated development comprising the Tuas Water Reclamation Plant and the Integrated Waste Management Facility, collectively known as the “Tuas Nexus”. The co-location of these facilities allows food waste and used water sludge to be co-digested to generate up to three times more biogas than conventional sludge treatment processes. The biogas generated will boost electricity production and contribute to making Tuas Nexus an energy self-sufficient facility. Incinerated bottom ash, which would otherwise be landfilled, will also be extracted from the waste at Tuas Nexus, further extending the lifespan of Semakau Landfill. The facility is expected to be completed by 2027.



Drawing on the water-energy-waste synergy allows the Tuas Nexus facility to be fully energy self-sufficient.

Current landscape

Singapore is one of the most densely populated countries in the world, without a hinterland or forestry industry. Nonetheless, we safeguard more than 7,800 hectares of green spaces, consisting of four nature reserves, nature areas, over 350 parks and an extensive network of streetscape greenery. These green spaces serve as carbon sinks and are used for recreational and educational purposes. We will continue to protect and enhance these carbon sinks through sustainable management and nature conservation.

Singapore remains committed to the long-term sustainability of our forests and vegetated areas. Singapore’s green policies began with the vision of transforming Singapore into a Garden City in the 1960s. We have since evolved into a biophilic City in a Garden, where greenery pervades our urban landscape.

Transformation of Singapore into a City in Nature

As the next bound of our urban planning, we will transform Singapore into a City in Nature to create a sustainable and distinctive Singapore that provides a high-quality living environment for residents. Moving forward, we will continue to increase our green spaces by extending our nature park network, intensifying nature in our new and redeveloped gardens and parks, restoring nature in our urban areas, and strengthening the connectivity between Singapore’s green spaces. City in Nature has been infused into our city’s planning and development systems to ensure that the greening of the city increases even as we develop. This also allows us to effectively protect our natural heritage and enhance the resilience of our natural ecosystem.

Safeguarding Singapore's carbon sinks

We strengthen our climate resilience by safeguarding and enhancing our natural ecosystems that provide carbon storage and sequestration. These ecosystems are protected within our four legally gazetted nature reserves in Singapore, where they receive protection for biodiversity conservation purposes. Some 350 hectares of forested areas around nature reserves have been converted to nature parks to serve as complementary habitats and buffers to safeguard our nature reserves against the impact of urbanisation and human activities. The nature parks also provide complementary habitats for Singapore's native flora and fauna to thrive beyond the nature reserves. We will continue to grow our nature park network, and aim to have at least an additional 200 hectares of nature parks by 2030.



The Mandai Mangrove and Mudflat is home to threatened species of plants and will be conserved as a nature park.

Coastal and marine environments are also effective ecosystems in carbon storage and sequestration. Carbon stocks in mangrove ecosystems can be three times or more than that of terrestrial forests. In this regard, mangrove restoration projects are being implemented at key conservation sites such as Sungei Buloh Wetland Reserve. Mandai Mangrove and Mudflat will be conserved as a nature park. To complement the habitats at Sungei Buloh Wetland Reserve and Mandai Mangrove and Mudflat, we will also be establishing a 40-hectare nature park at Khatib Bongsu, a rich mangrove and mudflat habitat on the northeastern coast of Singapore.

Restoring nature in our urban areas

As part of our efforts to restore nature in Singapore's urban areas, we will intensify the greening of our streetscapes through creating Nature Ways, which are roads that feature forest-like structures built with multi-tiered planting. Over the long term, we aspire to make every road a Nature Way to provide a stronger network of ecological connectivity across the island, by providing green corridors to link green nodes.

We will also increase the skyscraper greenery footprint in our buildings and infrastructure, by encouraging the adoption of vertical green walls, green roofs and rooftop gardens that mimic epiphytic plants in a tropical rainforest. This will create a naturalistic landscape that adds more greenery across Singapore and helps to mitigate the urban heat island effect. We aim to have 200 hectares of skyscraper greenery by 2030, up from 120 hectares currently. We are working on greening Singapore's industrial estates, which are among the hottest areas in Singapore. More than 100,000 trees will be planted in industrial estates by 2030. We have begun working with development partners and other stakeholders to plant more than 30,000 trees on Jurong Island alone.

As part of our efforts under City in Nature, we have launched a "One Million Trees" movement to plant a million trees across Singapore by 2030. These trees will be planted along streets and park connectors, and in gardens, parks, nature reserves and nature parks. The movement will involve the community through initiatives such as the Community in Nature (CIN). CIN connects and engages different groups in the community to help conserve Singapore's natural heritage, encouraging Singaporeans to bond over, and with, nature.



The Kheam Hock Nature Way provides a green corridor for birds and butterflies to travel between the Central Catchment Nature Reserve and the Singapore Botanic Gardens. As part of the City in Nature vision, there will be 300km of Nature Ways in Singapore by 2030, with future plans to make every road a Nature Way.



Students and teachers from St Margaret's School participating in a BioBlitz survey. In 2019, about 4,900 citizen scientists were engaged in activities, boosting nature conservation efforts.

CROSS-SECTORAL MEASURES

Apart from sectoral measures, Singapore also adopts cross-sectoral measures to drive comprehensive climate action across multiple sectors.

Carbon pricing

Singapore implemented a carbon tax, the first carbon pricing scheme in Southeast Asia, on 1 January 2019. The carbon tax provides the price signal to encourage companies to reduce their emissions, yet gives them the flexibility to take action where it makes the most economic sense. The carbon tax is not standalone. It forms part of our comprehensive suite of mitigation measures to reduce emissions, create green growth opportunities, and transit to an energy-efficient low-carbon economy. To maintain a transparent, fair, and consistent price signal across the economy, the carbon tax is applied uniformly to all sectors including energy-intensive and trade-exposed sectors, without exemption.

Coverage

The tax applies to direct emissions from facilities emitting 25 ktCO₂e or more in a year, covering carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons. This covers around 80% of Singapore's total emissions. The carbon tax does not apply to transport fuels, for which there already are excise duties to encourage the reduction of their use.

Tax rate

The carbon tax rate is set at S\$5/tCO₂e in the first instance from 2019 to 2023. This serves as a transition period for facilities to implement energy efficiency and emissions reduction projects. The carbon tax will be reviewed by 2023, with the intention to increase it to a rate of between S\$10/tCO₂e and S\$15/tCO₂e by 2030. In doing so, the Government will take into account international climate change developments, the progress of Singapore's emissions mitigation efforts and economic competitiveness.

Revenue use

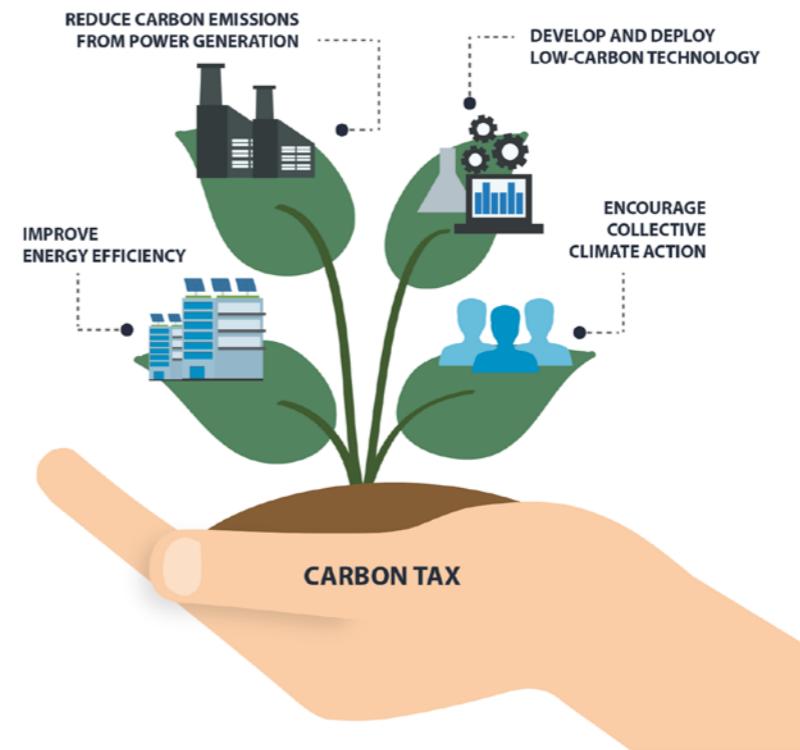
The Government is prepared to spend more than the estimated S\$1 billion in carbon tax revenues collected in the first five years, to help companies invest in energy- and carbon-efficient technologies.

Leveraging international market-based mechanisms

The Paris Agreement also provides for jurisdictions to cooperate in achieving their climate pledges, such as through the use of international carbon credits or through the linking of carbon pricing systems. Singapore has implemented a Fixed-Price Credit Based (FPCB) tax mechanism where companies pay their carbon tax by surrendering non-tradeable, fixed-price carbon credits purchased from the Government. The FPCB mechanism puts in place key building blocks that help regulatory bodies and companies build up necessary capabilities to operate in a linked market, should we decide to do so in the longer term.

As there may be benefits in linking our carbon tax framework to other jurisdictions, Singapore will continue to monitor international developments, and study how we can leverage robust international market mechanisms to complement our domestic mitigation efforts and position Singapore as an international hub for carbon trading.

SINGAPORE'S CLIMATE ACTION PLAN



The carbon tax plays a key role in supporting Singapore's climate actions.

HOW A CARBON TAX WORKS

1 INTRODUCE A TAX ON EMISSIONS

- Carbon tax will generally be applied upstream, for example, on power stations and large industrial facilities.
- 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.

Mitigating hydrofluorocarbon emissions from refrigeration and air-conditioning

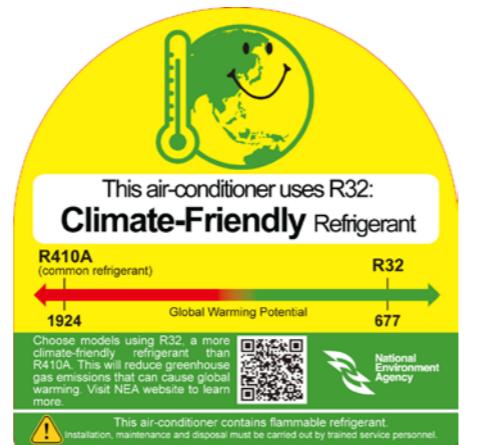
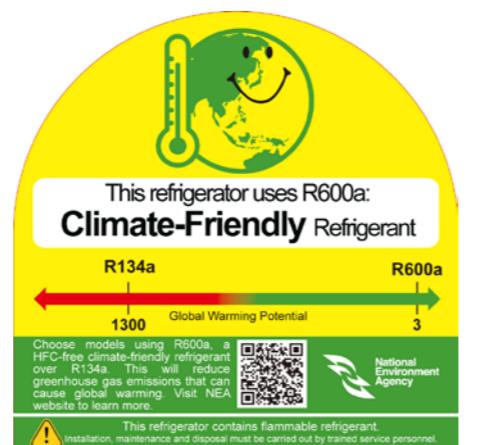
Cooling solutions will be increasingly vital to keep Singapore liveable given rising temperatures. HFCs have high Global Warming Potentials (GWPs), and are commonly used as refrigerants in refrigeration and air-conditioning (RAC) equipment and systems. Singapore has developed a comprehensive package of HFC mitigation measures to reduce HFC emissions from RAC equipment. This includes introducing a voluntary label for climate-friendly refrigerants that will help consumers to identify and select RAC models that use climate-friendly refrigerants.

Restrict the supply of refrigeration and air-conditioning equipment that use hydrofluorocarbons with high Global Warming Potential

From 2022, a restriction will be imposed on the supply of commercial water-cooled chillers²⁸ and household refrigerators that use refrigerants with GWP above 15, and household air-conditioners that use refrigerants with GWP above 750.

Training and certification of technicians

A training and certification programme will be introduced to improve the proficiency of RAC technicians on proper installation, maintenance and decommissioning of RAC equipment to reduce the likelihood of refrigerant leakages.



The voluntary labels for refrigerators (top) and air-conditioners (bottom) using climate-friendly refrigerants.

Mandatory recovery and reclamation or destruction of spent refrigerants

The recovery, reclamation or destruction of spent refrigerants will be mandatory from 2021. This will apply to household air-conditioners and refrigerators at the first instance, and will be extended to commercial water-cooled chillers from 2022. The recovered refrigerants can be reclaimed and reintroduced into the market or destroyed to prevent emissions.

EMERGING TECHNOLOGICAL SOLUTIONS

To realise our LEDS aspiration, we will need to harness emerging technological solutions that can achieve mitigation outcomes beyond our existing range of mitigation options, such as CCUS and low-carbon hydrogen. Whilst such solutions have been conceptually proven, their large-scale deployment in Singapore is currently limited by economic, institutional, and technical constraints. We will continue to evaluate such technologies and invest in R&D initiatives to facilitate the cost-effective application of such technologies.

Carbon capture, utilisation and storage

CCUS has the potential to reduce emissions from Singapore's industrial and power sectors. CO₂ emissions from power plants and industrial facilities can be captured, and either stored in suitable sub-surface geological formations (i.e. CCS) or converted into usable products (i.e. CCU). CO₂ can be used to produce carbonate-based building materials, through a reaction called mineralisation. Mineralisation processes can make

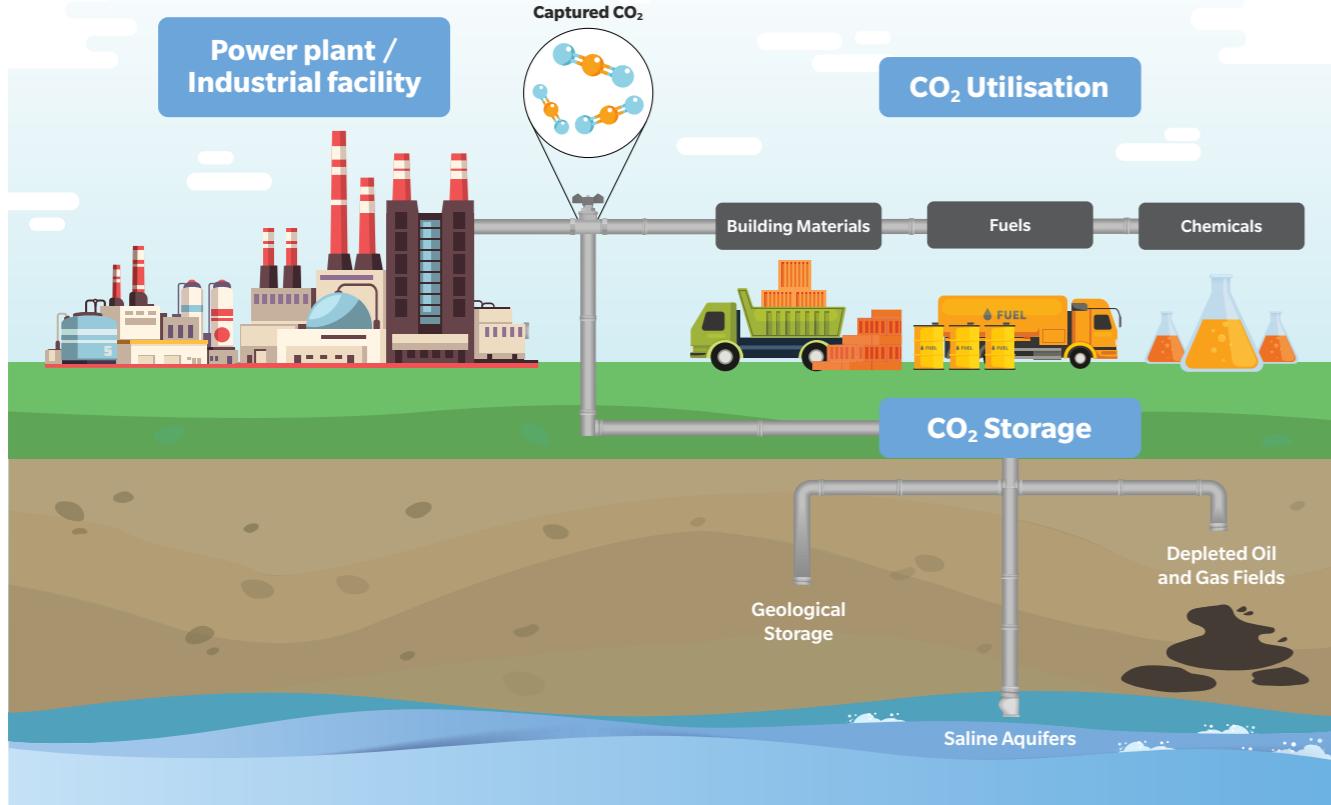
use of waste-based feedstock, such as incineration ash, thus contributing to Singapore's waste reduction efforts. Captured CO₂ can also be used as feedstock for chemicals and synthetic fuels, such as kerosene and methanol, which have the potential to be used as fuel for aircraft and marine vessels.

Preliminary findings show that the potential for CCUS to reduce Singapore's emissions in the long-term is significant, but there are near-term challenges to deploy CCUS solutions at a large scale:

- i) Singapore does not have any known suitable geological formations for the permanent storage of CO₂ underground. We will need to explore partnerships with companies and other countries with such geological formations in order to leverage CO₂ storage opportunities; and
- ii) Costs are still high currently, in part due to the substantial amount of energy needed to separate and concentrate CO₂ from emissions of industrial facilities and power plants. In addition, manufacturing fuel and chemicals from CO₂ is more energy-intensive than conventional processes, although this will improve over time as the technology matures.

Researchers and companies around the world are actively working to reduce the costs by developing new catalysts and novel chemical pathways to capture and utilise CO₂. We will build on our strengths in material science, chemical engineering and computer science to develop research, development and demonstration initiatives and facilitate the cost-effective application of CCUS for Singapore.

²⁸ With a capacity of at least 1,055 kW for air-conditioning.



Hydrogen

Hydrogen is a versatile energy carrier and industrial feedstock. It is currently mainly produced by reacting fossil fuels with steam or controlled amounts of oxygen (e.g. reforming or gasification), or by splitting water (i.e. electrolysis), and is used primarily as a feedstock for a range of industrial processes.

We are studying the technical and economic feasibility of importing low-carbon hydrogen and its use in potential downstream applications. Low-carbon hydrogen produced from increasingly cost-competitive renewable electricity or fossil fuels with CCUS can facilitate our industry sector's decarbonisation. The use of low-carbon hydrogen can also add diversity to our fuel mix across a number of energy applications such as electricity generation and transport.

However, key challenges remain. While the cost of producing low-carbon hydrogen is decreasing, it is still higher than the cost of conventional hydrogen. In addition, a global and diverse supply chain for hydrogen has yet to be established. The development of infrastructure to support hydrogen production, transportation, storage and use will also entail significant costs.

Nonetheless, we are optimistic that solutions can be found to overcome these challenges. Technological advancements in low-carbon hydrogen production and use, as well as the commitment of many governments and companies to pursue the wider use of hydrogen point to an increasingly positive outlook for hydrogen to contribute to Singapore's long-term decarbonisation efforts.



Potential downstream applications of hydrogen in Singapore

Chapter 5

Seizing Green Growth Opportunities

Addressing climate change will be challenging but can also present opportunities. We aim to develop an ecosystem, supported by green finance and active R&D that nurtures the development and adoption of low-carbon innovations. With such an ecosystem, we can seize green growth opportunities, grow our economy and create new jobs as we transit to a low-carbon economy. At the same time, we will help create green solutions that have application beyond our shores.

DEVELOPING AND DEPLOYING LOW-CARBON TECHNOLOGY

Following Singapore's early identification of clean technology as a strategic growth sector in 2007, we have strengthened our capabilities to grow as a global hub for the development of clean and low-carbon technologies. We have established multiple research institutes, built up a pool of skilled local expertise, cultivated a conducive business environment and established a comprehensive suite of supporting services and opportunities for firms and researchers. These efforts contribute to a vibrant ecosystem that will spur the development of innovative low-carbon solutions suitable for urban environments.

Investment in R&D

Research, innovation, and enterprise (RIE) are the cornerstones of Singapore's national strategy to develop a knowledge-based, innovation-driven economy and society. Since 1995, the Government has set out five-year plans to develop Singapore into a global R&D hub. Public investment in R&D has grown from S\$2 billion through 1995-2000 (National Technology Plan), to S\$19 billion through 2016-2020 (RIE2020).

Under the National Research Foundation's (NRF) RIE2020 Plan, the Government is investing close to S\$1 billion in R&D in the Urban Solutions and Sustainability domain to tackle Singapore's energy, water, land and liveability challenges. Investments under RIE2020 build on earlier investments in R&D to enhance the living environment and address the country's resource constraints. Following a mid-term review of RIE2020, an additional S\$144 million was allocated to the Singapore Food Story R&D Programme. The programme seeks to support R&D in sustainable urban food production, production of future foods such as alternative proteins, as well as food safety science and innovation. NRF is working with partner agencies and stakeholders on the next five-year plan (RIE2025).



The NTU WTERF is equipped to undertake waste-to-energy and waste-to-resource processes and able to produce syngas to power the plant and slag that can be used for construction.

WTE Research Facility

As Singapore moves to become a Zero Waste Nation, a vibrant R&D ecosystem will be necessary to close the resource loops at the individual, industry, and district level.

Recognising that testing prototypes at existing waste-to-energy facilities will not be feasible, the National Environment Agency (NEA) is co-funding the construction of a WTE Research Facility (WTERF) with the Nanyang Technological University, Singapore (NTU Singapore) Nanyang Environment and Water Research Institute (NEWRI). The S\$40 million facility houses a slagging gasification plant that converts waste collected from NTU Singapore into electricity and other by-products. The WTERF provides researchers and interested companies a platform that supports experimentation and test-bedding at scale, bridging the gap between research and commercial deployment.

Energy Grid 2.0

Over the next five years, Singapore will be investing S\$55 million in Energy Grid 2.0. Energy Grid 2.0 is the 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, NRF and the Energy Market Authority (EMA) launched two consortia in 2019 under the Energy Grid 2.0 Programme and have set aside up to S\$9 million over three years for both consortia. The Smart Grid and Power Electronics Consortium Singapore (SPECS) and the Cooling Energy Science and Technology Singapore (CoolestSG) Consortium will bring together research institutes, companies, and the Singapore Government to develop solutions in smart grid and green cooling.

Developing research capabilities

We aim to build up the research capabilities and innovation capacity of our universities and companies to drive economic growth and address national challenges. Developing cutting-edge technologies requires collective effort, bringing together the expertise and resources of academia, industry, and the Government.

Institutes working on green technologies in Singapore

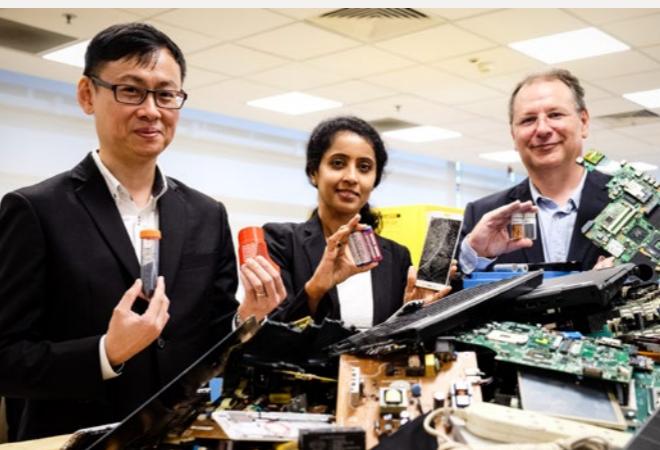
Academia and research institutes

- Energy Research Institute @ NTU Singapore (ERI@N), which includes the Experimental Power Grid Centre:** ERI@N develops industry-oriented innovations and trains specialists in clean energy. Its focus areas include wind and marine renewables, green buildings, e-mobility, energy storage and fuel cells.
- Nanyang Environment and Water Research Institute:** Based in NTU Singapore, NEWRI promotes interdisciplinary interaction and a contiguous value chain from research to translation, development and application. Its research areas include urban heat island effect, WTE, energy efficiency in waste and wastewater treatment, and energy from bioprocesses.
- Energy Studies Institute (ESI):** Based in the National University of Singapore (NUS), ESI conducts research and promotes discussion on energy policy development. It focuses on energy economics, energy efficiency, climate change mitigation and adaptation, environmental sustainability, and energy security.
- Singapore Energy Centre (SgEC):** SgEC is a consortium founded by NTU, NUS and other founding members such as ExxonMobil. The centre focuses on both technological and socioeconomic issues in sustainable energy development.

- Solar Energy Research Institute of Singapore (SERIS):** Based in NUS, SERIS conducts industry-oriented research in solar energy conversion, collaborates with industry players and trains specialists for the solar energy sector. Main areas of R&D include novel high-efficiency solar technologies such as tandem solar cells, as well as solar energy systems such as floating photovoltaics and building integrated photovoltaics.
- NTU-Singapore CEA Alliance for Research in Circular Economy (NTU-SCARCE):** NTU-SCARCE is a joint research centre by NTU Singapore and the French Alternative Energies and Atomic Energy Commission (CEA). The NTU-SCARCE research centre focuses on formulating advanced e-waste separation and extraction techniques that are more eco-friendly and energy-efficient than current methods. It also looks into developing eco-friendly methods to recycle lithium ion batteries, and extract up to 75% of rare earth metals such as cobalt, nickel, lithium and manganese.

Government research arm

- Agency for Science, Technology and Research (A*STAR):** A*STAR is a statutory board under the Ministry of Trade and Industry. It houses research institutes that conduct a wide range of basic, applied and translational research and development activities to create economic growth and jobs for Singapore. It integrates the relevant capabilities of its research institutes with those of local Institutes of Higher Learning (IHLs), to build strategic partnerships with multi-national corporations and globally competitive companies that drive research and innovation. A*STAR also partners with local companies to promote productivity and nurtures R&D-driven start-ups. In addition, A*STAR's research contributes to societal benefits such as improving outcomes in healthcare, urban living, and sustainability. Examples of such capabilities include power distribution, sustainable manufacturing, and clean energy



The NTU-SCARCE research centre will draw on the research capabilities from NTU Singapore and CEA.

International research and innovation hubs

- Singapore-MIT Alliance for Research and Technology (SMART):** SMART is a major research enterprise established by the Massachusetts Institute of Technology (MIT) in partnership with NRF. SMART's research areas include urban mobility, low energy electronics, environmental sensing and modelling.
- Cambridge Centre for Advanced Research and Education (CARES):** CARES is the University of Cambridge's only research centre outside the United Kingdom that focuses on addressing carbon reduction and energy efficiency in the industry sector. CARES' research programmes include the Cambridge Centre for Carbon Reduction in Chemical Technology that focuses on reducing carbon emissions from the chemical industry, and the eCO₂EP programme for studying how industrial CO₂ may be reused in the chemical industry supply chain.
- Evonik (SEA) Pte Ltd Asia Research Hub:** This is the first regional hub operated by German speciality chemicals manufacturer Evonik. The institute conducts research on resource efficiency topics, functional surfaces, additive manufacturing and tissue engineering.



Over the last decade, SERIS has trained more than 110 PhD students. Many of them are now contributing to Singapore's solar energy sector, and some have founded their own start-ups.

Test-bedding new technologies

Singapore offers an enabling environment, for example by offering regulatory sandboxes, to encourage companies and research institutes to develop, test and assess green technologies under real-world conditions without compromising the environment, public health and safety. The test-beds facilitate the commercialisation process for new technologies. These technologies can then be scaled up and exported to other cities requiring similar solutions. Located around the island, these test-beds position Singapore as a “living laboratory” to evaluate, pilot and commercialise innovative solutions for Asian and global markets.

Singapore as a living laboratory



- **Jurong Innovation District:**

An advanced manufacturing hub and a leading model for a sustainable, smart, connected mixed-use district in Singapore.



- **JTC CleanTech One:**

Completed in 2012, JTC CleanTech One is the first development located in Singapore’s first eco-business park, CleanTech Park @ Jurong Innovation District. The park and its buildings serve as a living lab for companies and industries to test-bed innovations and sustainable solutions.



- **NTU offshore hybrid microgrid:**

The first in the region, NTU Singapore’s offshore hybrid microgrid on Pulau Semakau has over 4,500 m² of solar panels alongside a 14-storey high long-span wind turbine, generating enough electricity to power 45 four-room apartment units a year. Under its Renewable Energy Integration Demonstrator – Singapore (REIDS) initiative, several hybrid microgrids will be developed in the coming years, with each producing stable and consistent power in the half-megawatt range, which is suitable for small islands, isolated residential areas, and emergency power supplies. The microgrids will eventually occupy over 64,000 m² of land or roughly about nine soccer fields.



- **Zero Energy Building @ Building and Construction Authority (BCA):**

The Zero Energy Building is a test-bedding facility with net-zero energy consumption that was conceived to test the integration of green building technologies in existing buildings, and to serve as a hub for practitioners and students in the study of energy efficiency and green buildings.

- **NTU Smart Campus:**

Home to vast arrays of solar panels producing over 5,000 kWp, it is also a living test-bed. NTU Singapore targets to achieve a 35% reduction in energy, water and waste intensity by 2020, making it one of the world’s most eco-friendly university campuses in the world. A model of sustainable living, NTU Singapore has 57 Green Mark-certified building projects of which 95% are certified as Green Mark Platinum.



- Energy and Environmental Sustainability Solutions for Megacities:**

This is a collaborative programme between Shanghai Jia Tong University and NUS to test eco-solutions for environmental sustainability in urbanised spaces. Its projects include synthesising fuel from alternative energy sources and examining contaminants in the urban environment.



- Floating Solar PV Pilot:**

A joint project between the Singapore Economic Development Board (EDB) and PUB, the pilot test-bed aims to assess the feasibility and cost effectiveness of installing floating solar PV systems on freshwater reservoirs. Given positive results from the test-bed, PUB will be deploying two 1.5 MWp systems at Bedok and Lower Seletar Reservoirs by the end of 2020. A 60 MWp solar PV system will be deployed on Tengeh Reservoir by 2021. The power generated from this system alone is sufficient to meet the energy needs of all our water treatment plants at local reservoirs. With this, Singapore's waterworks will be one of the few in the world to be 100% green. When completed, it will be one of the largest of its kind in the world, spanning 45 football fields



- Zero-Waste Management System:**

This is a pilot project for on-site WTE treatment at Gardens by the Bay. The system, which reduces carbon emissions by up to 20%, harvests energy from the gasification process to heat water that is used by food and beverage tenants at this attraction. The facility also produces solid carbon material for possible horticultural R&D, thus closing the waste loop and removing the need to transport waste to incineration plants.



- Airabitat Cool Bus Stop:**

This project aims to make use of data analytics and sustainable deep cooling technology, with Internet of Things (IoT) control for bus stops. Developed by Innosparks, an Open Innovation Lab of ST Engineering, the cool bus stop is equipped with an air-cooling and filtration system that is embedded in seating columns. Delivering air that is cooled to 24°C through evaporation, this technology results in energy savings of up to 70% compared to the average air conditioner of an equivalent capacity. A similar air-cooling system was previously deployed in Resorts World Sentosa and the Singapore Zoo.



- CETRAN Autonomous Vehicle (AV) test centre:**

Spanning two hectares, the CETRAN AV test centre was launched in 2017 to spearhead the development of testing requirements for AVs. Operated by NTU scientists, it comes equipped with elements of Singapore's roads, with common traffic schemes, road infrastructure, traffic rules, and even a rain simulator and flood zone to test AVs' navigation abilities under different weather conditions.



- Punggol Digital District (PDD):**

Powered by an Open Digital Platform, PDD will be Singapore's first business park to offer businesses and students a 'plug-and-play' digital infrastructure with district-level data to conduct rapid prototyping and technological solutions in a real-world setting. Besides being a car-lite district, smart innovations will be used in PDD to reduce carbon emissions and make buildings 30% more energy-efficient. The estate will also boast a smart energy grid, fitted with solar panels and smart meters, which will manage power consumption of the whole estate in real time.

Sharing our solutions globally

The environmental challenges that we face are not unique to Singapore. Partnerships beyond borders are crucial so that we can learn from the experience and expertise of other countries, while sharing ours as well. For example, the BCA Green Mark Scheme is an internationally recognised green building rating system, notably in Asia, as it was developed specially for the tropical climate. Since receiving applications for overseas developments in 2006, BCA has certified over 100 overseas projects under the BCA Green Mark Scheme. We also welcome innovative partnerships with countries and institutions that share the same vision of a global circular economy and a low-carbon future. Although the ability to harness alternative energy sources at scale is limited in Singapore, leaders in this field have chosen to base their operations here, tapping on the local R&D capability talent pool to develop low-carbon solutions that can be deployed.

Sustainable power generation beyond Singapore

Sunseap Group, a leading supplier of solar PV systems based in Singapore, has established regional operations in the Asia Pacific. Given the high potential for solar PV deployment in the region, Sunseap Group has worked with infrastructure development and investment companies to develop solar projects abroad, such as solar farms in Cambodia (output of 10 MWp), India (output of 140 MWp) and Vietnam (output of 168 MWp). Beyond solar farms, Sunseap has plans to supply floating solar plants to countries in the region, as land is becoming a premium in Southeast Asia.

To support a low-carbon future, Sembcorp Industries (Sembcorp), an integrated energy and urban player headquartered in Singapore, has grown its global wind and solar renewables capacity to 2,600 MW by the end of 2019, with 2,450 MW in markets overseas.

While harnessing wind energy is not a viable option for Singapore, Sembcorp has 1,692 MW of wind assets in operation and under development across seven states in India. It currently has the highest renewable energy capacity under self-operation for an independent power producer in the market. In China, it has 725 MW of wind power projects.

Beyond operational capabilities, Sembcorp has also harnessed technology as a key enabler and differentiator in its renewable energy offerings. The proprietary Virtual Brain platform developed for the wind farms in India is an example of how Sembcorp uses data analytics and artificial intelligence to monitor and manage wind turbine assets remotely from a central location.



Sunseap's 168 MWp solar farm in Ninh Thuan, Vietnam is one of the largest in the country. Sunseap and InfraCo Asia contributed three billion Vietnamese dong (\$173,749) to fund the construction of concrete roads surrounding the site. At peak construction period, the project created over 2,000 jobs, mostly for locals in the area.



Sembcorp's 250 MW wind energy project in Tamil Nadu is the first reverse auction wind power project in India.

PROMOTING SUSTAINABLE FINANCE

Finance is key to unlocking a global sustainable future, and serves as a force for good to facilitate the transition to a green, low-carbon economy. Singapore aims to support the financial sector in mobilising global capital for the green economy and channelling them to new investments in green businesses, technology, and infrastructure, which reduces emissions while creating jobs and growth opportunities. Our goal is to be a leading centre for Green Finance in Asia and globally.

Building a financial system resilient to environmental risks

The Monetary Authority of Singapore (MAS) has included banks' sustainability practices in its supervisory assessment. It aims to strengthen banks' efforts to integrate sustainability into their business models and risk management functions. Environmental risk management guidelines are being developed for the banking, insurance and asset management sectors to reinforce industry standards on governance, risk management and the disclosure of environmental risk.

Our financial institutions are also taking action to make financing practices more environmentally responsible. Our local banks have implemented policies aligned with the 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 help borrowers improve their sustainability profiles. Several asset managers in Singapore have signed the UN Principles for Responsible Investment and developed the Singapore Stewardship Principles for Responsible Investors. We will continue to work with the asset management industry to foster good stewardship among investors and drive sustainable investment 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 an annual sustainability report. 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 forward, SGX plans to provide more guidance on ESG data disclosure to make such data more meaningful for investors.

Developing green finance solutions and markets

Investing and raising capital through green financial instruments, such as green bonds, have grown significantly over recent years. These investments into green sectors have promoted new economic opportunities, such as in CleanTech and other growth areas.

To catalyse more green bond issuances, Singapore launched a Green Bond Grant Scheme in 2017 to level the costs 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 issuances in ASEAN, Singapore supported the development of the ASEAN Green Bond Standards, which reference the International Capital Market Association Green, Social and Sustainability Bond Standards.

Building on the ASEAN Green Bond Standards, the 2nd ASEAN Capital Market Conference launched the ASEAN Social Bond Standards and ASEAN Sustainability Bond Standards in October 2018 to provide issuers and investors a wide-ranging set of green, social and sustainability bonds 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 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 (GIP) in November 2019, which places funds with asset managers committed to drive regional green efforts out of Singapore and contribute to other national green finance initiatives. As part of the GIP, Singapore will allocate US\$100 million to the Bank for International Settlements' Green Bond Fund, in support of its global green finance initiatives.



ASEAN capital market regulators launch social and sustainability bond standards.

Supporting a greener global financial system

In addition to greening the financial landscape in Singapore and across the region, collective leadership and globally coordinated action will be necessary to advance the global agenda for sustainable finance. Singapore actively contributes to these global efforts by participating in international and multilateral organisations.

MAS 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 mobilise capital for green and low-carbon investments. MAS 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 (TCFD), which develops recommendations for voluntary climate-related financial disclosures for organisations. TCFD is actively promoting and monitoring the adoption of its recommendations, which were released in June 2017.

ECONOMIC TRANSITION TO A CARBON-CONSTRAINED FUTURE

Working towards a low-carbon future will be challenging given Singapore's high dependence on international trade and export-oriented economy. Nonetheless, we believe that the efficient use of resources is essential in maintaining our economic competitiveness and enabling sustainable economic growth in an increasingly carbon constrained world. Singapore will continue to drive sustainability in our industries and pursue best-in-class resource efficiency standards.

As part of our ongoing industry transformation efforts, the Government launched 23 sector-specific Industry Transformation Maps (ITMs) covering about 80% of the Singapore economy to identify new growth opportunities, increase productivity and drive innovation, while recognising the challenges that each industry faces, including the need to be more energy and carbon efficient. In the Built Environment Cluster, one example where energy efficient technologies and solutions have been test-bedded is BCA's Green Buildings Innovation Cluster (GBIC). Through the use of building-integrated

photovoltaics to replace ordinary façade cladding, GBIC has successfully partnered PSA Corporation to develop a Net Zero Energy Building as part of the Tuas Port. This building is projected to achieve energy savings of 58% compared to if it had been designed to meet existing regulations.

We continue to promote energy efficiency in all our sectors, as it lowers business costs, increases business competitiveness, and enhances our energy security. In particular, the Government is working with the industry sector to accelerate the adoption of energy-efficient technologies, and has launched various schemes to support businesses across different sectors. Success stories where businesses reaped significant energy and cost savings demonstrate the positive results of investing in energy-efficient technology.

To bridge the gulf between the laboratory and the real world, Singapore's Living Lab proposition brings businesses, government agencies and research institutes together to drive R&D and test-bed green technologies under real-world conditions.

One promising area is in the development of clean energy technologies. As addressed earlier in this chapter, Singapore is well-positioned to be a leading CleanTech Hub. Businesses can use Singapore as a springboard to serve the fast-growing markets in the region. Businesses can also leverage our skilled labour force, conducive business environment, dedicated eco-business park and strong financial services, to develop and demonstrate new low-carbon solutions for use domestically and globally. In the solar industry alone, Singapore has grown the number of companies from just a handful in 2008 to about 50 local and international companies today. As testament to our efforts in developing Singapore as

a sustainability hub, leading international companies such as REC Solar and Neste, which produce solar PVs and biofuels respectively, have chosen to set up operations in Singapore.

Singapore is also pursuing other green growth opportunities. For example, we are working to develop research, development and demonstration initiatives and facilitate the cost-effective application of carbon capture, utilisation and storage (CCUS) and low-carbon hydrogen for Singapore. As Singapore moves to become a Zero Waste Nation, we are investing in R&D and collaborating with industry experts to develop new, more efficient and eco-friendly ways to support a circular economy.

The Government will complement and catalyse these efforts through key enablers such as standards, accreditation and a pro-enterprise regulatory environment, as we continue to create green solutions for Singapore and the world. We will also continue efforts to seek to attract and anchor world-class investments in related fields, to capitalise on green growth opportunities.

NEWSand – turning trash into treasure

NEWSand was born out of our determination to overcome resource constraints and create new products from what would otherwise have been disposed in landfills. NEWSand refers to residues from waste treatment, such as slag and incineration bottom ash, which have been treated to meet a comprehensive set of environmental standards. NEWSand is environmentally safe for use as construction material. Singapore has developed provisional environmental standards for the use of NEWSand, and field trials will begin in 2020.

NEWSand will bring Singapore a step closer to closing our waste loop and further extend the lifespan of Singapore's only landfill.



The 105m long footpath opposite Our Tampines Hub, which links to the Darul Ghufran Mosque, is made from concrete which incorporates slag from processing municipal solid waste.

Building the workforce of the future

As we shift towards a low-carbon future, there will be new job roles created from the emerging green economy, while some job roles today may need to be transformed. To ensure that our workforce is well-equipped with the necessary knowledge and skills to take on these job roles, various initiatives have been put in place to upskill and reskill our workers.

The national SkillsFuture movement provides support for Singaporeans to embrace lifelong learning and pursue skills mastery at different stages of their careers. Under the movement, there are various opportunities for individuals to take up relevant training programmes to prepare themselves for the low-carbon future. Subsidies are also available to help individuals offset the costs of such training.

For instance, the Singapore Institute of Manufacturing Technology currently offers a Singapore Workforce Skills Qualification programme in “Integrated Carbon Footprint Assessment Methodology”, which is supported by SkillsFuture Singapore to help reskill employees in the area of carbon efficiency. The Government has also partnered the Singapore Institute of Technology to offer carbon emission assessment and training programmes under the new Energy Efficiency Technology Centre (EETC), which aims to upskill working professionals with skillsets in energy assessment and drive awareness of energy best practices and new technologies amongst companies.



One of the courses in the Workforce Skills Qualification programme on carbon efficiency

To help jobseekers to transit into new jobs, Workforce Singapore offers reskilling programmes such as Professional Conversion Programmes (PCPs) and Place-and-Train Programmes for rank-and-file workers. These programmes provide employers with training and salary support to hire jobseekers who are looking to be reskilled for new jobs in different sectors or job roles. For PCPs alone, we have around 100 reskilling programmes across around 30 sectors. We continue to offer new reskilling programmes as industries transform and shift towards a low-carbon future.

While training our current workforce, Singapore also works with the industry sector and institutes of higher learning to nurture our future generation and equip them with the necessary skills and qualifications to tap on the opportunities of a green economy. The A*STAR Graduate Academy provides scholarships and fellowships to enable young aspiring scientific talent to pursue their passion in science, and prepare them for a rewarding career in R&D. Such initiatives will help to support a burgeoning green growth industry and cultivate a talent pool keen to develop innovative green solutions for Singapore and the world.

Chapter 6

Key Long-Term Adaptation Actions

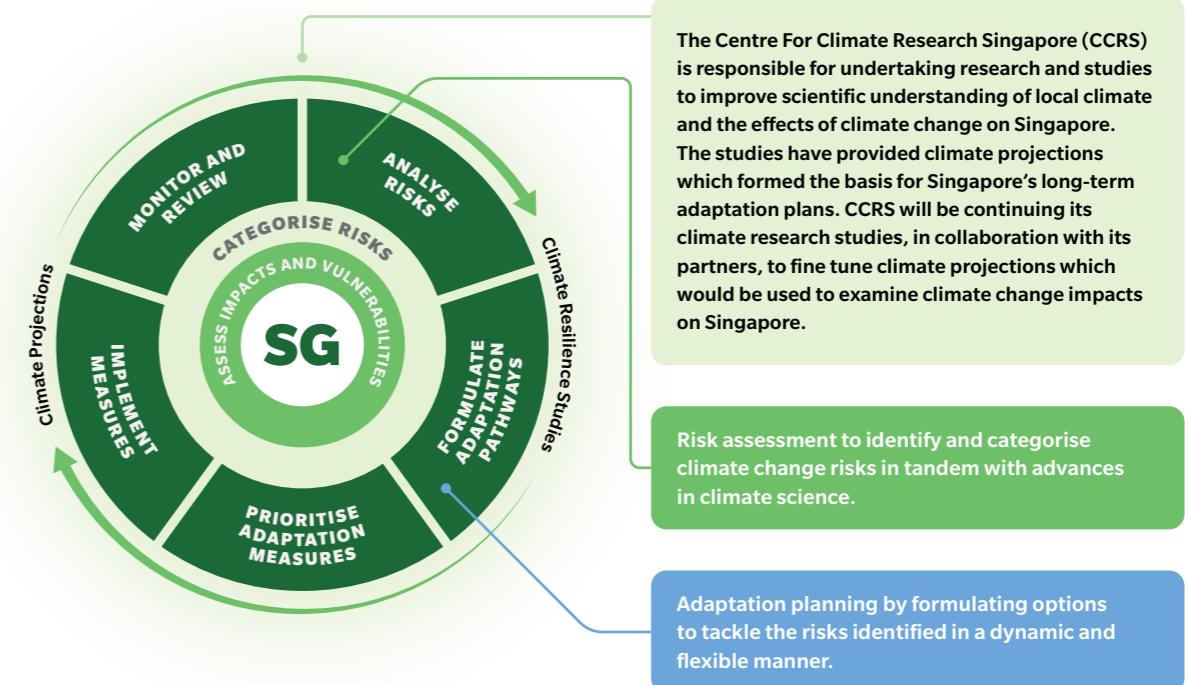
Extreme climate conditions are likely to become more intense and frequent in Singapore in future. Singapore is hence systematically building up climate science capabilities and preparing long-term infrastructure adaptation plans to address our physical vulnerabilities in climate change.

Beyond physical adaptation efforts – an effective response to climate change can only be achieved through the collective action of the government, individuals, businesses and the community.

Singapore's resilience framework

To address the effects of climate change on Singapore's physical environment effectively, we have already begun working on our long-term infrastructure adaptation plans. A multi-agency Resilience Working Group (RWG), set up under the auspices of the Inter-Ministerial Committee on Climate Change (IMCCC), oversees the study and implementation of measures to address our physical vulnerabilities to climate change, and serves as the coordinating body on climate change adaptation efforts across government agencies.

The Government established a National Resilience Framework to guide RWG in identifying and assessing climate change risks and impacts, and formulating adaptation plans to address Singapore's physical vulnerabilities.



Building Singapore's climate science capabilities

Having robust climate science capabilities will strengthen our understanding of the effects of climate change on Singapore and the region, and enable us to identify the most appropriate adaptation measures to build up our climate resilience.

We have been systematically building up our climate science capabilities. The Centre for Climate Research Singapore (CCRS) was established in 2013 to develop research expertise in the climate of Singapore and Southeast 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:

Second National Climate Change Study (V2)

In 2015, CCRS published results from the *Second National Climate Change Study V2* which analysed future climate change scenarios for Singapore and the Southeast Asian region 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 National Climate Change Study V3*, and the results are expected to be released in 2022.

Convective-scale Numerical Weather Prediction model (SINGV)

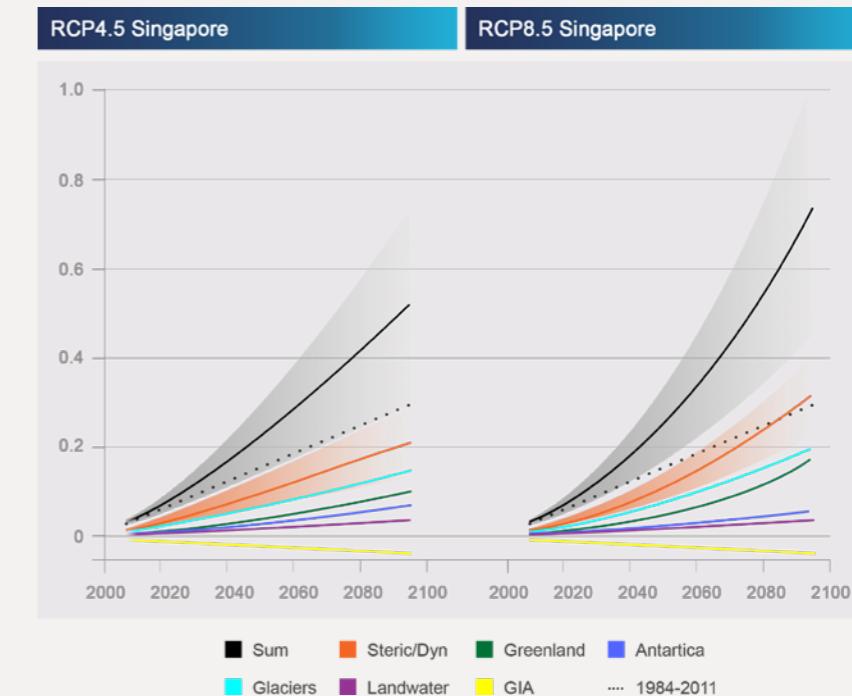
Many weather models are developed for the temperate regions and hence, not customised to our local conditions. CCRS is undertaking cutting-edge research to develop weather models tailored to Singapore. One such model is a convective-scale Numerical Weather Prediction model known as "SINGV". The SINGV will allow us to provide prediction of heavy rainfall at longer lead times and over higher spatial resolutions. Today, we can provide advance warnings of heavy rains about 15-30 minutes before the downpour. With this model, the Meteorological Service Singapore (MSS) will be able to provide an earlier assessment of the risk of heavy rain, giving us more time to prepare for flash floods.

Other institutes have also been established to support climate research, such as the Tropical Marine Science Institute in 1996 for research, development and consultancy on tropical marine science and environmental science, and the Earth Observatory of Singapore in 2009 for research on earthquakes, volcanic eruptions, tsunamis and climate change in Singapore and Southeast Asia.

Driving research in climate science

A new Climate Science Research Programme Office will be set up in CCRS to lead and drive efforts to formulate and implement our National Climate Science Research Masterplan, and strengthen local capabilities for climate science in the tropics. The Programme Office will focus on five key research areas with significant impact on Singapore:

- (i) sea level rise;
- (ii) the impact of climate change on our water resources and flood management;
- (iii) the impact of warming trends on human health and the energy sector;
- (iv) the impact of climate change on our biodiversity and food security; and
- (v) cross-cutting areas.



One of the key research focus areas of the Climate Science Research Programme Office is sea level rise. This is one of the most critical effects of climate change for Singapore, due to the size of the threat, the associated costs and long-term consequences.

Singapore's adaptation measures

The Government has implemented a variety of adaptation measures to enhance our climate resilience and to minimise the adverse impacts of climate change on the community, economy and our daily lives. *Singapore's Climate Action Plan: A Climate-Resilient Singapore, For a Sustainable Future* published in 2016 details how Singapore may be affected by climate change and our strategy to prepare for its effects.

Risk #1: Protecting our coasts

As a low-lying island city-state, Singapore is particularly vulnerable to rising sea levels. Coastal areas are vital for Singapore to carry out shipping activities as a major shipping port.

CCRS has considered that in the rare scenario of high mean sea levels, high tide and high surge all occurring at the same time, sea levels could rise almost 4m above the current mean and cause flooding in low-lying coastal areas in Singapore. Given these risks, we are now undertaking a comprehensive effort to protect our coasts, low-lying areas and our communities, and carefully studying the options and strategies for protection along different parts of our coastline.

These coastal protection plans may include a combination of conventional engineering technologies such as sea walls, tidal gates, pumping stations as well as nature-based solutions. These are necessary long-term investments and will possibly cost Singapore S\$100 billion or more over the next 50 to 100 years. The Government will create a Coastal and Flood Protection Fund, with an initial injection of S\$5 billion to provide for the substantial capital outlay in implementing coastal and flood protection measures.

CCRS has set aside S\$10 million for a National Sea Level Research Programme to develop more robust projections of sea level rise and improve our knowledge on how rising sea levels will affect Singapore. For many of these measures, we will need to start implementing them now and stage them appropriately over the next 100 years. By planning early, we can phase in the necessary measures in a timely manner whilst spreading out the costs over many years.

Engineering solutions

Today, 70% to 80% of Singapore's coastline is protected against erosion by hard structures such as stone revetments or vertical seawalls. We will continue to explore alternative coastal protection solutions that are applicable to Singapore's context and adapt them to our needs. For example, we are building a small polder at Pulau Tekong to gain experience operating one. The polder comprises a dike that protects the low-lying tract of reclaimed land from the sea, and a network of drains and pumps to keep the land dry. This land is buffered from the sea by the dyke and a network of drains and pumps will control the water levels in the polder.

We have raised the minimum platform levels for new developments from 3m to 4m above the Singapore Height Datum (SHD) since 2011. Presently, critical infrastructure on existing coastal land, notably Changi Airport Terminal 5 and Tuas Port, will be constructed with platform levels at least 5m above SHD. Low-lying roads near coastal areas such as Changi have also been raised to protect them from rising sea levels.

Recognising the importance of robust, flexible and innovative engineering solutions, we will tap on internationally recognised best practice coastal protection techniques that are applicable to Singapore's context and adapt solutions to our needs.



Geo-bags at East Coast Park. The geo-bags, which blend in with the beach environment, are used to prevent beach erosion while still allowing for public access.



Sloping revetment at Labrador Nature Reserve. A revetment is a sloping structure built to absorb the energy of incoming waves and prevent coastal erosion.

Nature-based solutions

To boost natural coastal defences such as mangroves, Singapore adopts hard and soft engineering approaches to mitigate coastal erosion and actively restore mangrove areas. The benefits are multi-fold – nature-based solutions help to conserve our biodiversity, and more importantly, contribute to climate mitigation and our ecological resilience.

Mangrove habitats in different areas of Singapore will be enhanced and restored under various initiatives. These include building a living collection of native mangrove species in the Mangrove Arboretum of Sungei Buloh Wetland Reserve, restoring mangroves at abandoned aquaculture ponds in south-eastern part of Pulau Ubin, mangrove restoration and enhancement at the Mandai Mangrove and Mudflat, and the north-eastern coastline of Pulau Tekong



Mangroves are a key element of nature-based solutions for climate change.

and conducting coastal cleanups. Hybrid engineering solutions, integrating both hard and soft innovations, have been employed to arrest scouring and coastal erosion. The implementation of these initiatives will also be carried out in partnership with the community.

As outlined in Chapter 4, wetlands provide key ecosystem services in tackling climate change such as carbon storage, sequestration, and the mitigation of floods and coastal erosion. Collectively, Sungei Buloh Wetland Reserve, Kranji Marshes and the upcoming nature park at Mandai Mangrove and Mudflat form an ecological network of wetlands in north-western Singapore. Another new nature park at Khatib Bongsu in the northeast will complement this network to enhance Singapore's climate and ecological resilience.

Risk #2: Protecting our water supply and alleviating floods

Wet seasons will become wetter and dry seasons will become drier. Droughts may impact the reliability of or affect our water supply while more intense and frequent rainfall increases the risk of flooding.

Protecting our water supply

We have diversified Singapore's water supply through the Four National Taps, namely local catchment water, imported water, NEWater and desalinated water. In particular, NEWater and desalinated water are less dependent on rainfall and are thus more resilient against dry weather.

We have launched Singapore's fifth NEWater plant at Changi in 2017, and opened our third desalination plant, the Tuas Desalination Plant in 2018. Our fourth and fifth desalination plants will be built in Marina East and Jurong Island respectively by 2020.

Managing demand is just as important to ensure Singapore's long-term water sustainability. Singapore has adopted a multi-faceted approach towards water conservation, including mandating water efficiency standards, and engaging businesses and consumers alike on water conservation practices. Singapore also prices water to reflect its scarcity value.

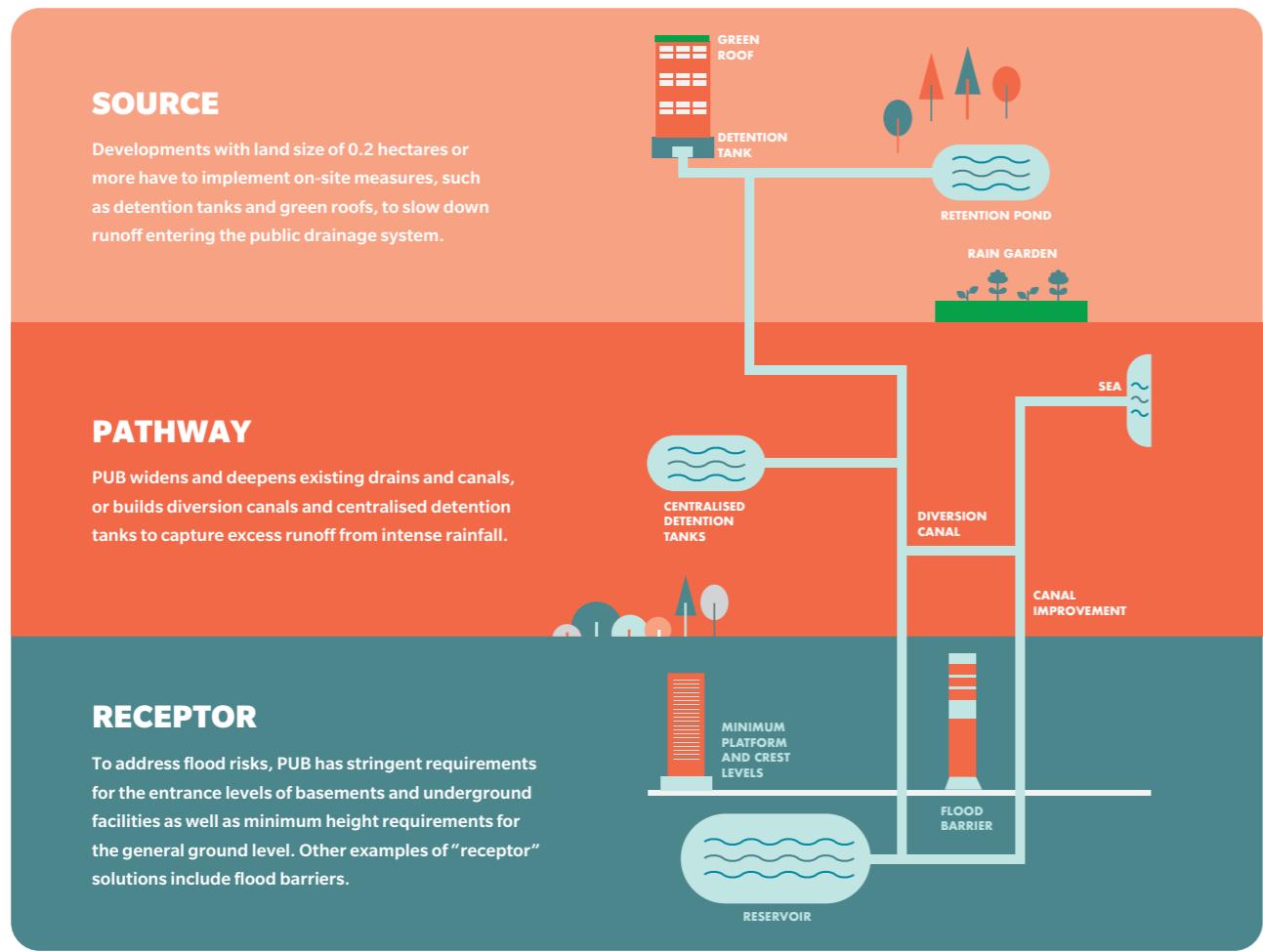


Singapore's first NEWater plant, which is located in Bedok, began operations in 2002.



The Tuas Desalination Plant is the first in Singapore to be fitted with solar panels, with more than half of the total roof area covered by solar panels. The 1.2 MWp solar PV system will meet all of the energy needs of the plant's administrative building.

THE SOURCE-PATHWAY-RECEPTOR APPROACH



Enhancing our flood resilience

To increase our flood resilience, Singapore employs the Source-Pathway-Receptor approach, which looks at catchment-wide solutions to achieve higher drainage and flood protection. This holistic approach covers the entire drainage system, from the pathway over which the stormwater travels (i.e. “Pathway”), to where the rainwater falls onto the ground (i.e. “Source”) and the areas where floods may occur (i.e. “Receptor”). Singapore has spent about almost S\$2 billion since 2011 on drainage improvement works to boost flood resilience, and plans to invest another S\$190 million in 2020 to enhance flood resilience. The Government will also invest in technology, including short-range radars,

to better predict and manage heavier rainfall, giving more lead time to mobilise Quick Response Teams to areas at risk of flash floods.

As part of the City in Nature vision, the National Parks Board (NParks) will also be working with PUB, Singapore’s National Water Agency, to naturalise more waterways and waterbodies in Singapore’s gardens and parks. Coastal and riverine parks will also incorporate designs such as floodplains to protect our coastal and low-lying areas from sea level rise and flooding. The conservation and restoration of our mangrove forests also help to dissipate waves and trap sediment, potentially serving as a flexible form of coastal defence while preventing erosion.

Risk #3: Enhancing Climate and Ecological Resilience Through Greenery and Biodiversity Conservation Management

Ensuring a healthy ecosystem

Singapore’s biodiversity may be at risk with long-term changes in temperature and rainfall, and with more extreme weather. Strengthening our ecological resilience will help ameliorate the effects of climate change. To achieve a sustainable urban ecosystem, we need to maintain our network of nature reserves, nature parks, parks, streetscapes, Nature Ways and green spaces. This network is home to diverse flora and fauna that is beneficial to human well-being and contributes to the resilience of our wider urban ecosystem. We will carry out recovery plans for over 70 additional animals and plant species, and enhance 30 hectares of forest, marine, coastal and ecological habitats in at least half of our gardens, parks and streetscapes by 2030.

In addition, applied research in conservation biology and planning will support and feed into our biodiversity conservation efforts. Such research efforts include comprehensive surveys and long-term monitoring of ecosystems and species, integrating disciplines, research and operations. We will also strengthen our research capabilities by



With climate change, critically endangered species such as the Spotted Wood Owl may be at greater risk.

using technology to collect and analyse data (e.g. through SG BioAtlas, a mobile application that the public can use to share their nature sightings with NParks) and data analytics tools, and applying ecological modelling to facilitate science-based decision-making.

Singapore has increased its green spaces, intensified multi-layered roadside planting, and mandated that new developments in areas with high footfall must incorporate minimum greenery replacement.

As highlighted in Chapter 4, more than a million trees will be planted under the “One Million Trees” movement over the next ten years, with ten trees to be planted for every tree affected by developments across the island. This will increase the number of trees in Singapore from seven million currently, to over eight million by 2030.

Caring for our coral reefs

Rising sea surface temperatures, ocean acidification, more intense rainfall and rising sea levels threaten the rich marine life in Singapore's waters – that includes over 250 species of reef-forming hard corals, 200 species of sponges, 12 seagrass species and numerous crustaceans.

The Sisters' Islands Marine Park was established in 2014 as part of our efforts to protect and conserve our marine biodiversity. The marine park spans 40 hectares around Sisters' Islands, and along the western reefs of St John's Island and Pulau Tekukor. It covers a variety of habitats including coral reefs, sandy shores and seagrass areas. The marine park also serves as a platform for outreach, educational and research activities related to our native marine biodiversity.

Since 2018, the marine park has been home to Singapore's largest artificial reef habitat, which consists of eight purpose-built reef structures that have been lowered onto the seabed. These structures are expected to contribute about 1,000m² of additional reef area by 2030 and will complement our existing reef enhancement efforts. Healthy coral reefs protect our shores against erosion, sustain our fisheries, and serve as an important source of novel compounds from which biomedical projects are developed.



The lagoon at the Big Sister's Island is home to some of Singapore's richest reefs.

Risk #4: Strengthening resilience in public health - Reducing risk of dengue

As Singapore's temperature and humidity increases, the likelihood of certain vector-borne diseases may also increase. Warmer temperatures will result in higher transmission of dengue due to the accelerated development of the Aedes mosquito and the shorter incubation period of the dengue virus. In fact, warmer temperatures was a key factor that contributed to the surge in dengue cases in 2019.

Singapore is undertaking a concerted effort to eradicate mosquito-breeding habitats and suppress their population through regular inspections and enforcement actions, and deploying innovative mosquito control methods such as Gravitraps²⁹ and Project Wolbachia. against erosion, sustain our fisheries, and serve as an important source of novel compounds from which biomedical projects are developed.



The Mosquito Launcher is a lightweight device that allows field operators to carry more mosquitoes in a single trip, thus reducing the release duration.

Project Wolbachia – Singapore

The National Environment Agency (NEA) is conducting phased field studies to evaluate the use of male Wolbachia-carrying Aedes aegypti (*Wolbachia-Aedes*) mosquitoes to suppress the urban *Aedes aegypti* mosquito – the vector of Dengue, Chikungunya and Zika viruses in Singapore.

Male *Wolbachia-Aedes* mosquitoes do not bite or transmit disease. When male *Wolbachia-Aedes* mosquitoes mate with urban female *Aedes aegypti* mosquitoes, the resulting eggs do not hatch. We have achieved more than 90% suppression of urban *Aedes aegypti* mosquito population at the study sites in two districts.

As Project Wolbachia - Singapore expands to cover bigger areas, we will continue to develop automated technologies to improve efficiency and quality in the production and release of *Wolbachia-Aedes* mosquitoes, such as the larvae counter and mosquito launcher.



Male Wolbachia-Aedes mosquitoes being released at Nee Soon East.

Risk #5: Strengthening food security

Presently, Singapore imports over 90% of our food supply. With increasing frequency of widespread extreme weather events and water crises in food producing countries, the global food market is volatile and Singapore is vulnerable to supply shocks.

We will play our part to help alleviate the challenge of global food security by developing and exporting climate resilient urban food solutions to the world. The Singapore Food Agency (SFA), established in 2019 as a statutory board under the Ministry of the Environment and Water Resources (MEWR), leads the effort to strengthen food safety and food security in Singapore by diversifying import sources, growing local and growing overseas.

Singapore aims to develop the capabilities and capacity to produce 30% of Singapore's nutritional needs locally by 2030. To achieve this vision, the agri-food industry will need to transform itself to become highly productive, and employ climate resilient and sustainable technologies. In line with this target, S\$144 million has been allocated for the Singapore Food Story R&D Programme to support R&D in sustainable urban food production, future foods, as well as food safety science and innovation. Farmers can also tap on the S\$63 million Agriculture Productivity Fund (APF) to co-fund the installation of advanced systems for enhanced production capabilities and support R&D of farming technologies.



Companies like Sustenir Agriculture are part of the growing community of urban farmers.



Barramundi Asia's nursery extension is expected to increase the company's fish production to almost 1.8 million fish fry per year.

Farming with technology

Local aquaculture company, Aquaculture Centre of Excellence Pte Ltd (ACE), has developed a purpose-built closed containment floating farm, known as the Eco-Ark. The patented Eco-Ark combines offshore and marine technologies with a recirculating aquaculture system to filter and treat seawater, kill pathogens and reduce the farm's vulnerability to external conditions. The Eco-Ark's capacity is 20 times more than the minimum productivity of Singapore's coastal fish farms today and needs only two workers to operate, thus contributing to Singapore's food security.



ACE leverages technology to produce sea-farmed fish in a climate resilient and sustainable manner.

Risk #6: Keeping cool in a warming world

Higher ambient temperatures and high humidity can lead to outdoor thermal discomfort and increased likelihood of heat-induced health impacts such as heat rashes, heat cramps, heat exhaustion and heat stroke.

Singapore employs microclimatic modelling tools in planning new residential towns and estates, helping planners strengthen key wind corridors, optimise building layouts and orientation for better natural ventilation, and identify hotspots for enhanced greenery placement. Green cooling and skyscraper greenery measures are also deployed to keep the public cool in an energy-efficient manner.

The increase in temperature due to urban heat island effect is a complex topic and Singapore is studying this in greater depth. This includes investing in R&D, such as the Cooling Singapore project, as well as tapping on technology, to develop strategies to address the urban heat island effect.

Risk #7: Keeping our buildings and infrastructure safe

Strong winds and higher temperatures may compromise the safety and reliability of infrastructure. Our buildings have been designed to resist wind forces, based on specifications in the Building Code against extreme wind events. We also regularly review our building design codes and regulations to take into account, among other considerations, the impact of climate change such as higher wind speeds and forces.

As increased rainfall may exacerbate slope stability, Singapore will be conducting studies on the impact of climate change on slope stability and integrity, and exploring appropriate adaptation measures to enhance safety in this area.

Adaptation, mitigation and ecological resilience

Adaptation, mitigation and ecological resilience actions are synergistic. Strong mitigation measures can reduce the need for and the cost of adaptation measures in the long term while initiatives to raise ecological resilience will enable us to rebound from the adverse effects of climate change.

Singapore recognises that mitigation, adaptation, and ecological measures must be jointly undertaken to tackle climate change, and therefore pursues all three aspects as part of our national climate change strategy. This goes beyond physical adaptation – an effective response to climate change can only be achieved through the collective action of the government, individuals, businesses and the community.

Chapter 7

Involving the Whole Nation

Meeting our low-emissions aspiration will require the full participation of and collaboration with individuals, civil society, academia, businesses, and the Government.

We will create opportunities to catalyse more stakeholder partnerships to promote climate-friendly actions across all sectors.

Everyone – individuals, civil society, academia, businesses and the Government – must play their part to contribute to Singapore’s transition to a low-carbon, climate resilient city.

Nation-wide activities to spur climate action

We designated 2018 as the Year of Climate Action to raise the level of national consciousness of the need to take individual and collective action to fight climate change. Under the partnership efforts between the 3P (People, Private, Public) sectors, over 800 climate action related events were organised. To date, more than 340,000 individuals, educational institutions and organisations have pledged to take climate action.

To sustain the momentum for climate action, we designated 2019 as the Year Towards Zero Waste, aimed at promoting more sustainable consumption of resources, and the adoption of circular economy initiatives.

An annual Climate Action Week has been initiated to promote the awareness of climate change and to drive climate action in Singapore, with the inaugural week held from 17 to 23 July 2019.



Over 2,000 people visited the Youth4Climate Fest 2019 and participated in various activities to learn about the importance of preserving our environment.

Some highlights include:

- The Partners for the Environment Forum 2019, organised by the Ministry of Environment and Water Resources (MEWR). The forum featured local and foreign speakers sharing latest research and best practices in climate science, circular economy and 3P partnerships.
- The Youth4Climate Fest 2019, organised by City Developments Limited, in partnership with the National Environment Agency (NEA), National Parks Board (NParks) and ActiveSG. The event provided a platform for youths to express their passion for the environment through the performing arts.
- The Youth Dialogue on Climate Change Education, organised by youths to find innovative solutions to address climate change through education and youth-led action.
- The Ricoh Asia Eco Action Day Tree Planting, organised by Ricoh Asia Pacific, to mark the conclusion of their Eco Action Day campaign.

Citizen-centric approach

In a resource- and carbon-constrained world, we need to adopt a circular economy approach, where scarce resources are valued and kept in use for as long as possible. By conserving resources through reducing, reusing, and recycling, we can also reduce GHG emissions from production and the incineration of waste. These will help mitigate climate change.

In 2019, the Government convened a #RecycleRight Citizens’ Workgroup. More than 40 citizens from diverse backgrounds worked together to co-create solutions to improve the way households recycle in Singapore. Through immersive learning and intense engagement sessions, the Workgroup came up with recommendations spanning several themes such as building awareness, community support, and innovative product design.

This process provided citizen participants with a deeper understanding of the recycling landscape in Singapore, and forged a sense of shared purpose in improving household recycling in Singapore. The Government will continue to convene more engagement platforms to partner the community to come up with effective solutions.



The #RecycleRight Citizens’ Workgroup brought together citizens to co-create solutions to improve household recycling.

Four pilot projects resulted from the workgroup’s recommendations. These were projects to improve education and awareness-building efforts at the community level, piloting a new design for recycling bins, researching the Deposit Refund Scheme, and facilitating the development of an app to encourage consumers to reduce their use of disposables.

As a key outcome from this process, it was announced in March 2020 that NEA would implement a Deposit Refund Scheme for beverage containers by 2022 (following industry consultations in 2020) as the first phase of the Extended Producer Responsibility approach for packaging waste management.

Online platforms to spur climate action

To reach a wider range of stakeholders, various online platforms have been set up to disseminate information on climate change, to collect public feedback, and to encourage all stakeholders to play their part to combat climate change.

Government websites, such as the National Climate Change Secretariat's (NCCS) website (www.nccs.gov.sg), MEWR's website (www.mewr.gov.sg/topic/climate-change) and NEA's Energy Efficient Singapore microsite (www.e2singapore.gov.sg) host a wide range of resources relating to climate change and energy efficiency. The Climate Change SG Facebook page (www.facebook.com/ClimateChangeSG) and MEWR's Facebook page (www.facebook.com/MEWRSingapore) also serve as platforms for the Government to engage the online community.

Since 2011, NCCS has conducted a nation-wide survey every two years to gauge public perception and views on climate change. The latest survey conducted between May and July 2019 showed that public awareness of climate change and its impact was high among Singaporeans, and has risen through the years. The majority of respondents also agreed that collective action – taken together by the Government, businesses and individuals – was needed to address climate change.

Despite the strong conviction expressed by six in ten respondents that individual action would make a difference, less than half of all respondents (48.3%) said they knew what to do to help address climate change. This finding underscores the need for continued efforts to enhance outreach efforts to promote climate-friendly action and behaviour in Singapore.

Ground-up initiatives to spur climate action

Beyond education and awareness, sustained behavioural change is essential for climate change action. Civil society groups and businesses are increasingly coming forward to drive ground-up initiatives to rally businesses, households and individuals to take collective action for a sustainable future.

For example, in November 2019, Sembcorp Industries piloted a mobile application ('ezi') to help boost local recycling rates. Providing users with a recycling collection service at their doorstep, the application also includes interactive educational elements to raise public awareness on how to recycle right. Users are also rewarded for their recyclables with every successful collection.

The Government offers a variety of funds to support ground-up initiatives that seek to address environmental challenges, including the 3P Partnership Fund, Water Efficiency Fund and Call for Ideas Fund.

For instance, "Save That Pen", an initiative by a group of students from the National University of Singapore (NUS) that gives used pens and other stationery a new lease of life, was supported by the Call for Ideas Fund. Discarded pens that are still usable are refilled and donated to underprivileged students in Singapore and within the region, while unusable ones are stripped of plastic and metal parts and sent for recycling. "Save That Pen" not only embraces the 3Rs concept and benefits those in need, informational videos enable other

educational institutions and organisations to implement similar projects, increasing the reach and impact of what began as a small initiative.

With support from the Call for Ideas Fund, not-for-profit organisation Zero Waste SG launched a "Bring Your Own Singapore" campaign in 2017 to encourage consumers to use their own reusable items such as bags, bottles and containers. Since then, more than 400 retail outlets have joined the campaign, saving approximately two million pieces of plastic disposables and packaging. Buoyed by the success of this campaign, the 3P Partnership Fund further supported Zero Waste SG's "Bring Your Own Bag Singapore" campaign in 2019 to focus on reducing plastic bag usage.

To foster more sustainability partnerships between the Government, industries and communities, we will set up the Singapore Eco-Fund later in 2020, which will provide S\$50 million over the next five years to fund impactful sustainability projects. Projects eligible for funding could include, for example, a community farm that offtakes food waste from the nearby community for composting, or an industry project to test-bed new sustainable technologies in an entire town. The Eco-Fund thus aims to enable the co-innovation, co-creation and co-investment in a sustainable Singapore. A new SG Eco Office will also be established to coordinate sustainability efforts across Singapore.

Recognising sustainability champions

The Government, NGOs and business associations are taking steps to recognise individuals and businesses who have championed or led environmental advocacy efforts within their communities and workplaces.

Awards that showcase environmental best practices include the Energy Efficiency National Partnership (EENP), the Building and Construction Authority's (BCA) Green Mark Awards, the Singapore Environment Council's Singapore Environmental Achievement Awards and the BCA-SGBC Green Building Individual Award. There are also awards organised by various government agencies to recognise individuals and businesses who have achieved outstanding performance in the sustainability domain, such as NEA's EcoFriend Awards and 3R Awards, and PUB, Singapore's National Water Agency's Watermark Awards.

MEWR organises the biennial President's Award for the Environment, which is the highest environmental accolade for individuals, educational institutions and organisations that have made outstanding contributions towards environmental and water resource sustainability in Singapore.



Winners of the President's Award for the Environment 2019

Crowdsourcing ideas to spur climate action

We regularly engage the public under a variety of platforms to gather feedback on government policies, to crowdsource ideas and to co-create solutions. For example, as outlined in Chapter 3, an extensive public consultation exercise was conducted between July and September 2019 on Singapore’s LEDS, which saw about 2,000 members of the public, environmental groups and companies contributing comments and suggestions on how Singapore can chart our own sustainable path forward towards a low-carbon future.

The development of the Zero Waste Masterplan also benefited tremendously from ideas from various key stakeholders including companies, NGOs, households and youths. More than 250 companies were consulted through industry engagement sessions, and over 5,000 households were surveyed through door-to-door surveys. An online public consultation was conducted, where more than 1,300 contributions were received. In addition, eight focus group discussions and dialogues were held — two of which were co-facilitated by youth-led groups Zero Waste SG and LepakInSG.

Sustainability networks to spur climate action

To spur ground-up actions, we partnered various stakeholder organisations to amplify climate awareness and encourage the public and businesses to take action. The Climate Action SG Alliance, formed in April 2018, aims to strengthen the narrative on climate change and translate awareness into action. The Alliance brings together representatives from businesses, NGOs and youth-led groups, with the Senior Minister of State for Environment and Water Resources Dr Amy Khor acting as their Advisor.

Key projects by the Alliance include:

- **Project Recycling Right** — a series of videos to raise awareness on the need to reduce consumption of single-use plastics, and to recycle right.
- **Project Business** — an online pledge to get individuals and companies to commit to ridding homes and offices of single-use plastics. Several organisations have committed to make sustainability a part of their daily operations.

Within civil society, non-profit environmental groups such as Green Drinks and Climate Conversations regularly bring together like-minded activists, academics and government representatives to discuss climate change and sustainability issues. In supporting and participating in such engagements, we are able to gather diverse views from a wide range of stakeholders towards shaping Singapore’s climate action strategies.

Empowering youths to spur climate action

Youths are important agents of change, and schools are a key platform to educate and socialise the young on climate change and environmental issues. Our schools, through both formal curriculum and complementary programmes, help build awareness of such issues and how individual actions can count towards combatting climate change. At the primary school level, students learn basic concepts related to global warming and environmental issues such as pollution and deforestation during Science lessons. They also learn about environmental conservation in Social Studies, for example through the 3Rs concepts.

At the secondary school level, students gain more in-depth scientific knowledge on topics such as carbon cycles, GHG emissions and their contribution to global warming, as well as the effects of climate change in Geography. At the Pre-University level, students learn how anthropogenic activity influences climate change, and the need for urgent climate action in local and international contexts.

The “Love Your Food @ Schools” project between 2017 and 2019 brought students, staff, and school canteen stallholders in the entire food management loop, and encouraged proper segregation and weighing of food waste to monitor reduction efforts. A food waste recycling machine was installed in ten schools. Everyone in these schools segregated, weighed and recorded their food waste generated daily. The food waste was then deposited into the food waste recycling machine to be converted into compost for distribution to community partners. In addition, these schools organised events to spread the awareness of composting using the food waste recycling machine.

More sustainability programmes will be introduced in schools and community facilities, such as OBS@Coney. These initiatives will integrate green infrastructure, sustainability programmes, and curriculum design to inculcate positive environmental values in youths, enabling them to be agents of change in our communities.

Teachers play an important role in engaging students in these topics through inquiry-based learning, and the use of real-world examples and case studies. Beyond the classroom, students have opportunities to apply their understanding of climate change to purposeful real-world projects through the Applied Learning Programme³⁰, Values-in-Action Programme³¹, and Co-Curricular Activities.³² Some student-initiated projects include upcycling and repurposing unwanted items to minimise wastage, and recycling food waste into compost for use as fertiliser. Water rationing exercises are also regularly held in schools to instil in youths the importance of conserving water, and to inculcate responsible water usage behaviour, as we enhance our resilience against uncertainties brought about by climate change.

BCA has been working with the Ministry of Education to explore the potential of Positive Energy Schools through tapping on renewable energy and using energy-efficient innovations. Students will have the opportunity to observe the technologies deployed in their schools and learn about climate science and the technologies available to create a greener and more sustainable Singapore.

³⁰ Applied Learning Programme is designed by schools to help students apply their learning in real world contexts

³¹ Values-in-Action Programme provides opportunities for students to learn about community issues and the needs of others, and carry out projects to contribute to improvements in school, at home or in the community.

³² Co-Curricular Activities are a core component of the holistic education in Singapore. These activities inculcate values and develop competencies, and at the same time foster social integration and deepen students’ sense of belonging, commitment and responsibility towards their school, community and nation.



Tampines Secondary School is Singapore's first positive energy school with several innovative energy-saving solutions such as vertical greenery, enhanced sunshades, smart fans and solar panels.

The Youth for the Environment Day (YED) is an annual platform to engage youths to champion environmental ownership through various activities to promote global and local environmental issues. The Environment Fund for Schools and the Environment Fund for Institutes of Higher Learning support efforts by schools and youths to promote a pro-environment mind-set in students and the community.



The YED 2019 saw more than 310 students from 38 schools participating in a series of educational and interactive activities. The YED aims to encourage youths to imagine and create the future environment they want to live in.

Catalysing businesses to spur climate action

The global trend towards corporate social responsibility has prompted many businesses to do their part to reduce emissions and care for the environment.

Businesses have been proactive to adopt more resource-efficient practices, which not only reduce emissions but also help their corporate bottom lines. For example, more than 200 organisations in Singapore have participated in the Singapore Packaging Agreement, a joint initiative by the Government, industry and NGOs to reduce packaging waste. As of 2019, about 54,000 tonnes of packaging waste have been avoided, resulting in estimated cost savings of about S\$130 million for locally consumed products. Firms also contribute through efforts to clean up and safeguard the environment, and support other initiatives through sponsorship or corporate volunteers. Singapore-based firms are part of this growing trend.

Another important focus area for the industry sector is energy efficiency. Beyond the regulations, incentives and capacity-building schemes as outlined in Chapter 4, it is important to increase awareness and promote thought leadership amongst companies. The Government supports companies in improving their energy efficiency by providing knowledge-sharing platforms such as the biennial National Energy Efficiency Conference (NEEC). NEEC offers companies opportunities to share good practices and success stories, and learn from industry experts on energy management strategies. For example, the theme of the sixth NEEC in 2019 was "Enhancing energy management for sustainable growth", and it attracted about 400 participants from various sectors.

Recognition of sustainability efforts by businesses

In September 2019, five Singapore companies – CapitaLand Limited, City Developments Limited, DBS Group Holdings, Sembcorp Industries and ComfortDelGro – saw their initiatives recognised by the Dow Jones Sustainability Index, which is regarded as a key reference for sustainability investment globally. While all five home-grown companies were listed on the Asia Pacific index, real estate developers CapitaLand Limited and City Developments Limited were named on the Dow Jones Sustainability World Index.



Funan Mall, a shopping mall in Singapore developed by CapitaLand, boasts the largest area for urban agriculture in the city with a 1,672 m² garden, and a 464 m² urban farm located within it.

Business perspective for carbon pricing

Beyond compliance requirements, businesses in Singapore have increasingly taken proactive steps to use internal carbon pricing to account for climate risks in their investments and operations.

To facilitate private sector collaboration and support the business case for internal carbon pricing, the World Bank Group's Carbon Pricing Leadership Coalition (CPLC) and the Global Compact Network Singapore (GCNS) jointly launched the first local chapter of the CPLC in Singapore in November 2018. Besides promoting corporate sustainability, the CPLC Singapore has facilitated dialogue, knowledge sharing and collaboration on carbon pricing between the private and public sectors. To date, 33 organisations have joined CPLC Singapore.

CPLC Singapore has developed and launched its Carbon and Emissions Recording Tool to help businesses record, monitor and reduce their emissions footprint and save operational costs. It will also launch a Low-Carbon Mark to recognise businesses for their decarbonising efforts.



At the Global Compact Network Singapore Summit 2018, then-Deputy Prime Minister Teo Chee Hean launched the Singapore chapter of the CPLC.

There is a growing wave of start-ups and SMEs in Singapore that focuses on promoting the sustainability agenda through their businesses. Such enterprises use market-driven strategies in innovative ways that contribute to sustainability efforts in Singapore and beyond. Singapore-based investment funds and business incubators are increasingly playing an active role in catalysing such enterprises.



Circulate Capital invests in businesses such as this plastic recycling facility in Indonesia to reduce pollution from plastic waste.

First investment fund to reduce marine pollution

In 2019, investment management firm Circulate Capital launched its Singapore-based Circulate Capital Ocean Fund, a US\$106 million fund and the world's first investment fund dedicated to preventing plastic from entering Asia's oceans. The fund will provide both debt and equity financing to waste management, recycling and circular economy start-ups and small-and-medium enterprises in South and Southeast Asia.



ECOSOFTT takes an integrated approach to conserving and reusing water at the facility level with its Water WISE™ Buildings and Industries programmes.

Social enterprises with a heart for the environment

The Singapore Centre for Social Enterprise (raiSE) was set up in 2015 to develop the social enterprise sector in Singapore. raiSE supports over 400 social enterprise members in their social enterprise journeys, from set-up to growth and expansion. Some social enterprises under raiSE that are related to the environment include:

Eco Solutions for Tomorrow Today (ECOSOFTT) promotes water sustainability through developing solutions for water treatment and conservation that help estates, buildings and industries reduce their water consumption and waste. As an international social enterprise, ECOSOFTT actively channels technology, expertise and financial resources towards water, sanitation and livelihood projects in rural communities around the world. In 2015, ECOSOFTT installed Singapore's first treatment system to recycle and reuse wastewater in a building. By treating and reusing wastewater,

this system in JTC CleanTech One reduces the building's resource demand on the national infrastructure.

Edible Garden City champions local food production with its urban farms to promote access to fresh and safe produce in an equitable and sustainable manner. Edible Garden City also promotes sustainability education through design-and-build consultancies for businesses and private residences. Its urban farming model, Citizen Farm, is a community of local farmers that grows fresh produce sold to over 40 restaurants and bars in Singapore.

Unpackt is a zero-waste bulk store with a smart selection of food, products and daily necessities that aims to promote waste minimisation, reduction and recycling. The items on sale are selected based on the store's ethos of balancing quality and variety. Consumers are encouraged to bring their own containers to eliminate packaging waste.

We will continue to build climate awareness through regular outreach programmes and campaigns, and provide resources for all stakeholders across the private and people sectors – businesses, academics, households and individuals – to do their part for climate action.

Industry associations and professional bodies such as the Singapore Stock Exchange, Association of Certified Chartered Accountants, the Singapore Business Federation and the Singapore Compact are also taking action to encourage businesses to pursue environmental stewardship as an expression of good corporate citizenship. These bodies encourage their members to adopt a triple bottom line approach in their operations, by focusing not just on the financial aspects of the business, but the environmental and social aspects as well.

Since 2016, SGX has required its listed companies to meet sustainability reporting requirements on a “comply or explain” basis. Several local banks now offer sustainability-linked loans, which are preferential loan interest rates tied to the achievement of certain

environmental, social and governance targets by borrowing companies. Singapore’s largest banks, DBS, the Oversea-Chinese Banking Corporation Limited (OCBC Bank) and the United Overseas Bank (UOB) have also announced moves to stop financing new coal-fired power plants. In addition, these banks and other local firms such as real estate companies City Developments Limited and CapitaLand Limited regularly report their activities and emissions data to the CDP (formerly the Carbon Disclosure Project), which is a United Kingdom-based organisation that administers an international system to measure, disclose, manage and share vital environmental data. More details on Singapore’s green finance initiatives are provided in Chapter 5.

Chapter 8

Building International Partnerships

Climate change is the ultimate challenge facing our global commons. In addition to national efforts, Singapore works at various international fora to strengthen the global response to climate change. We also undertake extensive capacity-building efforts with fellow developing countries and long-term collaboration with key partners to support global and regional climate action.

“South-South cooperation will be vital to ensure mutual support and exchange of best practices, to enhance adaptation and increase the resilience of developing countries and communities facing the devastating impacts of climate change. South-South cooperation can also support the transformation of economies dependent on fossil fuels with strategies that reinforce both sustainable development and environmental protection.”

UN Secretary-General António Guterres, at the Second High-level UN Conference on South-South Cooperation in Buenos Aires, Argentina, March 2019

Supporting South-South and triangular cooperation

Singapore is a firm supporter of South-South and triangular cooperation. Having benefited from the experiences of others during our early years of independence, we want to pay it forward by sharing our own experiences and best practices in climate action with fellow developing countries. We believe in the multiplier effect of investing in human capital and have therefore undertaken extensive capacity-building efforts to help others. We have collaborated actively through various bilateral, regional and multilateral intergovernmental platforms and have worked closely with other countries and international partners to share our experiences and best practices across the globe.

The Singapore Cooperation Programme

The Singapore Cooperation Programme (SCP) is our flagship technical assistance programme and primary platform for South-South and triangular cooperation. Since its inception in 1992, more than 130,000 officials from over 170 countries have participated in SCP programmes on various issues, including climate action, sustainable cities, health, education and good governance. Our SCP courses are closely aligned with the 17 Sustainable Development Goals. The SCP is also the primary vehicle through which we undertake triangular cooperation with both developed and developing countries (e.g. Australia, Chile, Japan, New Zealand, the Republic of Korea, Thailand, and the US), as well as international organisations (e.g. UNFCCC, UN Development Programme (UNDP), the UN Office for Disaster Risk Reduction and the International Energy Agency).

Partnerships under cities networks

Singapore is an active member in the C40 Cities Climate Leadership Group (C40), a network of over 90 cities working together to address climate change. Our partnership with C40 has strengthened over the years. We have worked with C40 to co-organise workshops and mayor-level forums at the World Cities Summit in 2016 and 2018. We have featured our green building efforts globally by organising a technical workshop with C40 in 2017. We have also been tapping on the experiences of cities such as Copenhagen and London to help inform the development of our mitigation measures in the transport sector. These engagements have allowed Singapore to capitalise on C40's network to share our climate efforts and study the best practices of other cities. As a member of C40, we have also reported our emissions and climate actions to the CDP.³³

The C40 agenda aligns with a number of Singapore's key priorities. For instance, C40 is working on how cities can leverage the ongoing global energy transition to decarbonise their economies and develop new engines of growth. This can help inform our work to realise our long-term low-emissions aspirations. Such efforts will also complement our Smart Nation initiatives such as the analytics of urban mobility and transportation in Singapore and smart homes solutions, which will help reduce our emissions. Singapore is also part of the C40 Connecting Delta Cities Network and we will draw on the experience of other cities as we translate the Resilience Working Group Coastal Adaptation Studies into specific measures for implementation.

Promoting sustainable development globally

Recognising the growing importance of addressing climate change, we launched the Climate Action Package (CAP) in 2018 for a three-year period. The CAP focuses on supporting the efforts of fellow developing countries, in particular, fellow Member States of ASEAN, Small Island Developing States (SIDS) and Least Developed Countries (LDCs), towards achieving their climate pledges and building resilience. They cover topics such as climate change adaptation and mitigation strategies, disaster risk reduction and energy efficiency and emissions reduction.



Singapore co-organised with New Zealand (together with the National University of Singapore Centre for International Law) a workshop on "Decoding the Paris Rulebook for Southeast Asia" in October 2019 to discuss the practical implementation of the Paris Agreement and preparations for the Global Stocktake in 2023.

Sharing Singapore's approach on renewable energy

Twenty-three officials from as far as Latin America participated in a week-long CAP programme on Clean Energy and Emissions Reduction that examined Singapore's multi-agency approach to formulating clean and renewable energy solutions. Participants also interacted with experts from Singapore's environment, energy and transport agencies, as well as academics and the private sector.



At the SG Mobility Gallery, the course participants reviewed how Singapore plans, designs and builds its land transport system to achieve energy efficiency, such as through the use of smart LED street lights.

Partnerships under regional and multilateral platforms

Singapore strongly supports a multilateral, rules-based approach to addressing climate change, and participates actively and constructively in ongoing efforts under the UNFCCC and other UN entities, to push for a credible and strong multilateral framework on climate change. Singapore is privileged to have played key facilitator roles in UNFCCC negotiations, which culminated in the adoption of the Paris Agreement at COP-21 in 2015, the agreements on the Katowice Climate Package at COP-24 in 2018 and the 'Chile Madrid Time for Action' decisions at COP-25 in 2019.

Singapore also plays active roles in other platforms such as the World Trade Organization (WTO), World Intellectual Property Organisation (WIPO), the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) to help develop measures in the respective sectors to respond to climate change.

³³ CDP is a not-for-profit charity that organises the global disclosure system for investors, companies, cities, states and regions to manage their environmental impact. Apart from the Government reporting national-level data, our companies have also reported their activities and emissions to CDP. More details are available in Chapter 7.

Partnering ASEAN to advance regional climate efforts

Regionally, we have taken an active role to galvanise climate action. As Chair of ASEAN in 2018, we convened the first-ever Special ASEAN Ministerial Meeting on Climate Action (SAMCA) and Expanded-SAMCA, where the ten ASEAN Member States, China, Japan and the Republic of Korea reaffirmed their commitment to the Paris Agreement and discussed ways to step up regional climate action. A summary of the discussions was submitted to the UNFCCC as input to the Talanoa Dialogue, which was initiated by Fiji as the COP-23 President to take stock of collective progress made in relation to the goals of the Paris Agreement.

ASEAN countries cooperate closely on climate change issues at the technical-level through the ASEAN Working Group on Climate Change (AWGCC). The AWGCC aims to enhance regional cooperation to address the impacts of climate change through the implementation of projects and activities under five thematic areas: (i) Adaptation and Resilience, (ii) Mitigation, (iii) Technology Transfer, (iv) Climate Finance, and (v) Cross-Sectoral Coordination and Global Partnerships.

Through the CAP, we have supported fellow ASEAN Member States' implementation of their Paris Agreement commitments. The CAP courses have helped ASEAN countries enhance their knowledge base and develop capacity in areas related to climate change, such as long-term adaptation and mitigation strategies, green finance, sustainable urban planning and green cities.



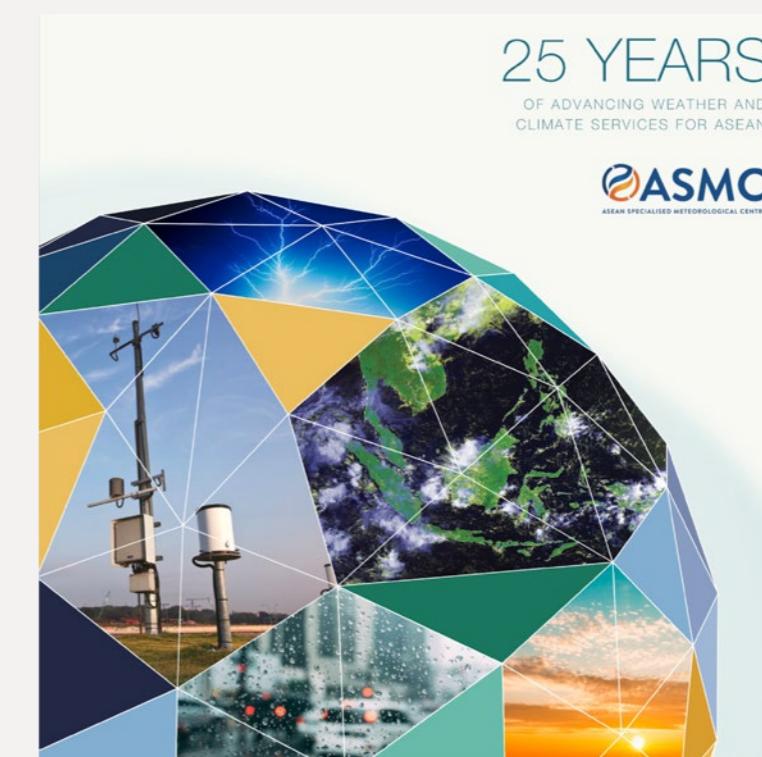
As Chair of ASEAN in 2018, Singapore convened the first ever Special ASEAN Ministerial Meeting on Climate Action (SAMCA) and Expanded SAMCA in 2018, where ASEAN and our Plus Three partners (China, Japan and the Republic of Korea) reaffirmed their commitment to the Paris Agreement and discussed ways to step up regional action to address climate change. Singapore also launched the CAP at this meeting.

To increase ASEAN's financial resilience to climate and disaster risk, we established the Southeast Asia Disaster Risk Insurance Facility (SEADRIF) in tandem with Japan and the World Bank in Singapore in 2019. In tandem with Japan and the World Bank in Singapore in 2019. As ASEAN's first regional catastrophe risk pool, SEADRIF will provide immediate liquidity to cover emergency response costs in the aftermath of catastrophes, with an initial focus of providing a flood risk pool for Laos, Myanmar and potentially Cambodia. SEADRIF will play a significant role in strengthening the region's economic resilience to disaster risks and mitigate the adverse economic impacts of climate change.

Enhancing regional capacity in climate science

Singapore hosts the ASEAN Specialised Meteorological Centre (ASMC), which supports ASEAN Member States in the areas of weather and climate prediction, regional fire and smoke haze monitoring and early warning, and capability development. In 2018, ASMC committed S\$5 million to a five-year regional capability-building programme for Southeast Asia to help enhance ASEAN Member States' capabilities in weather and climate prediction. Under the programme, ASMC conducts a series of training workshops in enhancing climate services, such as the application of climate change projections for local adaptation planning.

Singapore is also host to the World Meteorological Organization (WMO) Regional Office for Asia and the South-West Pacific, which has made enhancing regional capability in climate science one of its priorities. ASMC is working with the WMO to implement regional initiatives by leveraging on its capability building programmes. Collectively, these efforts aim to strengthen regional cooperation in climate projections and adaptation planning.



Singapore hosts the ASMC, which launched its five-year Regional Capability Building Programme for ASEAN at its twenty-fifth anniversary in 2018, strengthening its commitment to advance weather and climate services in the region

Partnering ICAO and IMO to reduce international transport emissions

Given the transboundary nature of international aviation and maritime transport, ICAO and IMO have taken the lead in addressing international transport emissions on a global basis. Singapore plays an active role at ICAO and IMO in the formulation of strategies and measures to reduce international transport emissions.

Addressing international aviation emissions

On the aviation front, we support ICAO's aspirational goals of 2% annual fuel efficiency improvement and carbon neutral growth from 2020. Singapore is ready to participate in the voluntary pilot phase (2021-2023) of the ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The Civil Aviation Authority of Singapore (CAAS) is working closely with Singapore carriers to monitor their emissions, and has accredited two verification bodies to perform CORSIA emissions verification services. Singapore is also working with several States to provide assistance under the ICAO Assistance, Capacity-building and Training on CORSIA (ACT-CORSIA) initiative.

CAAS, Singapore's Air Navigation Service Provider (ANSP), will continue to enhance the efficiency of aircraft movements within the Singapore Flight Information Region. Through continued investment in new technologies and close collaboration with other ANSPs, the improvements

in flight efficiency will reduce aircraft fuel burn and emissions. We are exploring innovative airspace concepts to advance seamless air traffic management across boundaries, such as Free Route Airspace and Trajectory Based Operations. These concepts may further improve flight efficiency by offering greater flexibility in flight planning and better predictability in flight operations.

Singapore carriers are taking various measures to improve fuel efficiency. For example, Singapore Airlines invests in the latest fuel-efficient aircraft models and has an average fleet age that is nearly half of that in the global aviation industry, reaping significant emissions savings. Aircraft and engine modifications to reduce drag during different stages of a flight and operational measures such as data analytics and aircraft weight management, further reduce fuel use and emissions.

We will study the use of sustainable aviation fuels (SAFs). SAFs can reduce emissions by up to 80% over the lifecycle compared to traditional jet fuels, but are two to five times more expensive today. Singapore Airlines, in partnership with CAAS, operated a series of 12 "green package" flights in 2017 using sustainable biofuel, which saved 320 tonnes of carbon emissions. The Government and industry players are studying various options to find the right business and technological models to enable economically viable and sustainable SAF supply chains in Singapore.



As a member of ICAO and IMO, Singapore participates in and contributes to their efforts to address international transport emissions.

Addressing international maritime emissions

On the maritime front, Singapore is committed to environmentally sustainable international shipping under IMO's leadership. We actively support IMO's efforts on its *Initial Strategy on Reduction of Greenhouse Gas (GHG) Emissions from Ships* and its key target to reduce the total annual GHG emissions from international shipping by at least 50% by 2050 compared to 2008 levels. In addition to supporting IMO's work, we are implementing additional measures to address maritime emissions.

Singapore launched the Maritime Singapore Green Initiative (MSGI) in 2011 with the objective of reducing the environmental impact of shipping and shipping-related activities in the coastal and marine environment. The Maritime and Port Authority of Singapore (MPA) has pledged S\$100 million under the MSGI, which comprises four programmes:

- i) the Green Port Programme encourages ships to burn cleaner fuels in Singapore through a reduction in port dues;
- ii) the Green Ship Programme incentivises green ship design beyond IMO's requirements through tax rebates;
- iii) the Green Energy and Technology Programme promotes pilot trials and technology development for maritime emissions reduction; and
- iv) the Green Awareness Programme promotes awareness of green shipping.

Singapore is LNG bunkering-ready. While the maritime sector is developing measures that can meet the IMO's 2050 target, LNG is a cleaner and greener fuel than existing available options,

and the only viable and scalable solution for the shipping industry currently. To facilitate the greater adoption of LNG for global shipping, we are promoting the use of LNG as a marine fuel in Singapore, growing demand for LNG and driving readiness for LNG bunkering. Singapore is also working closely with other international port authorities and maritime administrations to build a network of LNG bunker-ready ports. Beyond promoting LNG, we are embarking on trials of electric vessels and other potential low-emissions fuel types.

Singapore is encouraging R&D in new low-carbon technologies and clean energy sources. To encourage the maritime industry to pursue innovation, we are collaborating with technology start-ups and start-up accelerators. We are committed to provide an enabling environment and regulatory sandboxes for the test-bedding of innovative solutions and new concepts of maritime operations.

To position Singapore for long-term maritime sustainability, the Government will develop a *Maritime Singapore Decarbonisation Blueprint 2050*. The blueprint will chart out strategies to achieve a sustainable Maritime Singapore. Additionally, the Singapore Maritime Foundation will set up an International Advisory Panel, comprising local and international industry and business leaders, to recommend strategies to support global maritime decarbonisation goals. Singapore will also set aside an initial funding of S\$40 million under the Maritime Green Future Fund to foster R&D in low-carbon technologies.

As climate change is a global challenge that requires coordinated global action, Singapore will continue to work with international stakeholders to strengthen collaborations and action on climate change.

Conclusion

Moving to a Low-Emissions and Climate Resilient Future

Climate change presents an existential challenge for all of us – nationally, regionally and globally. Singapore is committed to reduce our emissions in support of achieving the long-term temperature goal of the Paris Agreement.

Ensuring a liveable environment for the present and future will require the Government, businesses and individuals to work closely to effect the necessary transformations of our infrastructure, economy and society towards a low-carbon future.

First, we will strive to achieve our long-term low-emissions aspiration through the three thrusts of transformation, technology and collaboration, as outlined in this document. We will comprehensively decarbonise our power sector, transform our industries to raise energy efficiency, and deploy at a national level low-carbon solutions for buildings, transport and waste management. We will also adopt cross-sectoral policies to achieve comprehensive climate action across multiple sectors. Second, we will undertake significant adaptation measures to strengthen our climate resilience as a vulnerable island-state. Third, we will go beyond mitigation and adaptation measures

within our borders to share our experiences and solutions with other countries facing similar challenges to help advance global climate action.

Given Singapore's geographical constraints, our ability to realise a low-carbon future will be contingent on two key factors: the deployment maturity of technologies currently still in developmental phase, e.g. carbon capture, utilisation and storage (CCUS) and hydrogen; and effective international cooperation, in areas such as carbon storage, energy imports via regional power grids and other innovative platforms, and market-based mechanisms that support environmental integrity. We aim to work with like-minded partners to overcome these challenges over time.

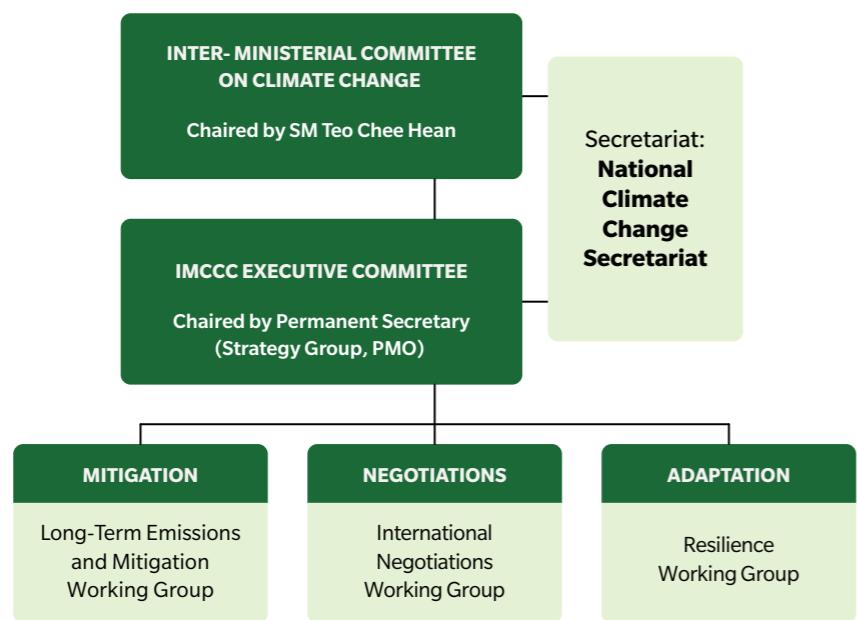
Singapore's LEDS is our commitment to global climate action. We recognise that the actions of any one country, on their own, will not be enough. A global response is needed to deliver a better and more sustainable future for all of us. We will press ahead on our long-term low-emissions aspiration and strategies, and implement the Paris Agreement in good faith, in the spirit of collaboration and collective action with all countries.



Annex

Structure of the Inter-Ministerial Committee on Climate Change

The IMCCC oversees the Whole-of-Government coordination on climate change policies to ensure that Singapore is prepared to address climate change. Established in 2007, IMCCC is chaired by Mr Teo Chee Hean, Senior Minister and Co-ordinating Minister for National Security.



IMCCC Executive Committee

IMCCC is supported by an Executive Committee (Exco) comprising the permanent secretaries of the respective Ministries. The IMCCC Exco oversees the work of the International Negotiations Working Group (INWG), Long-Term Emissions and Mitigation Working Group (LWG) and Resilience Working Group (RWG).

Long-Term Emissions and Mitigation Working Group

LWG examines options for emission reduction and identifies the capabilities, infrastructure and policies needed for long-term mitigation.

International Negotiations Working Group

INWG develops Singapore's international climate change negotiations strategy under the UNFCCC.

Resilience Working Group

RWG studies Singapore's vulnerability to the effects of climate change and recommends long-term plans that ensure the nation's adaptation to future environmental changes.

Relevant Legislation

Building Control Act: <https://sso.agc.gov.sg/Act/BCA1989>

- Building Control Regulations: <https://sso.agc.gov.sg/SL/BCA1989-S666-2003>
- Building Control (Accredited Checkers And Accredited Checking Organisations) Regulations: https://www.bca.gov.sg/BuildingControlAct/BUILDING_CONTROL_AC_REGULATIONS.html
- Building Control (Buildability) Regulations: https://www.bca.gov.sg/BuildingControlAct/others/building_control_buildability_regulations.pdf
- Building Control (Buildable Design) Regulations: https://www.bca.gov.sg/BuildingControlAct/building_control_buildable_design_regulations.html
- Building Control (Temporary Buildings) Regulations: https://www.bca.gov.sg/BuildingControlAct/building_control_temp_bldg_regulations.html
- Building Control (Environmental Sustainability) Regulations 2008: https://www.bca.gov.sg/BuildingControlAct/others/building_control_env_sus_regulations.pdf
- Approved Document – Acceptable Solutions: <https://www.bca.gov.sg/BuildingControlAct/others/Approveddocument.pdf>

Building Maintenance and Strata Management Act:

<https://sso.agc.gov.sg/Act/BMSMA2004>

Carbon Pricing Act 2018:

<https://sso.agc.gov.sg/Acts-Supp/23-2018/Published/20180601?DocDate=20180601>

- Carbon Pricing (Measurement, Reporting and Verification) Regulations 2018: <https://sso.agc.gov.sg/SL/CPA2018-S857-2018?DocDate=20181221>
- Carbon Pricing (Registration and General Matters) Regulations 2018: <https://sso.agc.gov.sg/SL/CPA2018-S858-2018?DocDate=20181221>
- Carbon Pricing (Composition of Offences) Regulations 2018: <https://sso.agc.gov.sg/SL/CPA2018-S859-2018?DocDate=20181221>
- Carbon Pricing Act 2018 (Commencement) Notification 2018: <https://sso.agc.gov.sg/SL-Supp/S856-2018/Published/20181221?DocDate=20181221>

Commodity Trading Act (Cap. 48A): <https://sso.agc.gov.sg/Act/CTA1992>

Development Fund Act: <https://sso.agc.gov.sg/Act/DFA1959>

District Cooling Act: <https://sso.agc.gov.sg/Act/84A>

Economic Development Board Act (Cap. 85): <https://sso.agc.gov.sg/Act/EDBA1961>

Relevant Legislation (Continued)**Energy Conservation Act 2012 (Cap. 92C):** <https://sso.agc.gov.sg/Act/ECA2012>

- Energy Conservation (Composition of Offences under Part IV) Regulations 2012:
<https://sso.agc.gov.sg/SL/ECA2012-S308-2012?DocDate=20180117>
- Energy Conservation (Composition of Offences) Regulations 2013:
<https://sso.agc.gov.sg/SL/ECA2012-S247-2013?DocDate=20171222>
- Energy Conservation (Energy Labelling and Minimum Performance Standards for Registrable Goods) Regulations 2013: <https://sso.agc.gov.sg/SL/ECA2012-S807-2013>
- Energy Conservation (Energy Management Practices for Transport Facilities Operators) Regulations 2013:
<https://sso.agc.gov.sg/SL/ECA2012-S807-2013>
- Energy Conservation (Energy Management Practices) Regulations 2013:
<https://sso.agc.gov.sg/SL/ECA2012-S246-2013?DocDate=20171222&ViewType=Advance&Phrase=Energy+Conservation+Energy+Management+Practices+Regulations+2013&WiAI=1>
- Energy Conservation (Fuel Economy Labelling) Regulations 2012:
<https://sso.agc.gov.sg/SL/ECA2012-S307-2012>
- Energy Conservation (Motor Vehicles Subject to Fuel Economy Requirements) Order 2012:
<https://sso.agc.gov.sg/SL/ECA2012-S309-2012>
- Energy Conservation (Registrable Corporations) Order 2013:
<https://sso.agc.gov.sg/SL/ECA2012-S248-2013>
- Energy Conservation (Registrable Goods) Order 2013:
<https://sso.agc.gov.sg/SL/S556-2013/Revoked/20180101?DocDate=20171222>
- Energy Conservation (Transport Facility Operators) Order 2013:
<https://sso.agc.gov.sg/SL/ECA2012-S806-2013>
- Energy Conservation Act 2012 (Commencement) (No. 3) Notification 2013:
<https://sso.agc.gov.sg/SL/ECA2012-S805-2013?DocDate=20131227&ValidDate=20150308&TransactionDate=20150308>
- Energy Conservation (Exemption for Regulated Lamps) Order 2015:
<https://sso.agc.gov.sg/SL/ECA2012-S399-2015>

Energy Market Authority of Singapore Act (Cap. 92B): <http://sso.agc.gov.sg/Act/EMASA2001>**Environmental Protection and Management Act (Cap. 94A):** <https://sso.agc.gov.sg/Act/EPMA1999>

- Environmental Protection and Management (Boundary Noise Limits for Factory Premises) Regulations, Reg 1:
<https://sso.agc.gov.sg/SL/EPMA1999-RG1>
- Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, Reg 2:
<https://sso.agc.gov.sg/SL/EPMA1999-RG2>

Relevant Legislation (Continued)

- Environmental Protection and Management (Fees for Licenses) Regulations, Reg 3:
<https://sso.agc.gov.sg/SL/EPMA1999-RG3>
- Environmental Protection and Management (Hazardous Substances) Regulations, Reg 4:
<https://sso.agc.gov.sg/SL/EPMA1999-RG4>
- Environmental Protection and Management (Trade Effluent) Regulations, Reg 5:
<https://sso.agc.gov.sg/SL/EPMA1999-RG5>
- Environmental Protection and Management (Vehicular Emissions) Regulations, Reg 6:
<https://sso.agc.gov.sg/SL/EPMA1999-RG6>
- Environmental Protection and Management (Composition of Offences) Regulations, Reg 7:
<https://sso.agc.gov.sg/SL/EPMA1999-RG7>
- Environmental Protection and Management (Air Impurities) Regulations, Reg 8:
<https://sso.agc.gov.sg/SL/EPMA1999-RG8>
- Environmental Protection and Management (Prohibition on the Use of Open Fires) Order 1999, Order 1:
<https://sso.agc.gov.sg/SL/EPMA1999-OR1>
- Environmental Protection and Management (Ozone Depleting Substances) Regulations, Reg 9:
<https://sso.agc.gov.sg/SL/EPMA1999-RG9>
- Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations 2012:
<https://sso.agc.gov.sg/SL/EPMA1999-S299-2012>

Environmental Public Health Act (Cap. 95): <https://sso.agc.gov.sg/Act/EPA1987>

- Environmental Public Health (Toxic Industrial Waste) Regulations, Reg 11:
<https://sso.agc.gov.sg/SL/EPA1987-RG11>
- Environmental Public Health (General Waste Collection) Regulations, Reg 12:
<https://sso.agc.gov.sg/SL/EPA1987-RG12>

Electricity Act (Cap. 89A): <http://sso.agc.gov.sg/Act/EA2001>**Fisheries Act:** <https://sso.agc.gov.sg/Act/FA1966>**Gas Act (Cap. 116A):** <https://sso.agc.gov.sg/Act/GA2001>**Hazardous Waste (Control of Export, Import and Transit) Act (Cap. 122A):**<https://sso.agc.gov.sg/Act/HWCEITA1997>

- Hazardous Waste (Control of Export, Import and Transit) Regulations, Reg 1:
<https://sso.agc.gov.sg/SL/HWCEITA1997-RG1>

Relevant Legislation (Continued)

Housing and Development Act (Cap. 129): <https://sso.agc.gov.sg/Act/HDA1959>

Jurong Town Corporation Act (Cap. 150): <https://sso.agc.gov.sg/Act/JTCA1968>

National Environment Agency Act (Cap. 195): <https://sso.agc.gov.sg/Act/NEAA2002>

National Parks Board Act (Cap. 198A): <https://sso.agc.gov.sg/Act/NPBA1996>

Parks and Trees Act (Cap. 216): <https://sso.agc.gov.sg/Act/PTA2005>

Protection of Public Sewerage System: <https://sso.agc.gov.sg/SL/SDA1999-S338-2017?DocDate=20170629>

Radiation Protection Act (Cap. 262): <https://sso.agc.gov.sg/Act/RPA2007>

Resource Sustainability Act 2019 (Cap. 262): <https://sso.agc.gov.sg/Act/RSA2019>

- Resource Sustainability (Composition of Offences) Regulations 2019:
<https://sso.agc.gov.sg/SL/RSA2019-S901-2019?DocDate=20191231>
- Resource Sustainability (Exemption for Incidentally Supplied Batteries) Order 2019:
<https://sso.agc.gov.sg/SL/RSA2019-S902-2019?DocDate=20191231>
- Resource Sustainability (Prescribed Regulated Products) Regulations 2019:
<https://sso.agc.gov.sg/SL/RSA2019-S900-2019?DocDate=20191231>
- Resource Sustainability Act 2019 (Commencement) Notification 2019:
<https://sso.agc.gov.sg/SL/S899-2019?DocDate=20191231>

Sewerage and Drainage Act: <https://sso.agc.gov.sg/Act/SDA1999>

Singapore Food Agency Act 2019: <https://sso.agc.gov.sg/Act/SFAA2019>

Relevant Publications**Other UNFCCC Submissions³⁴**

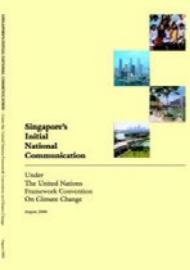
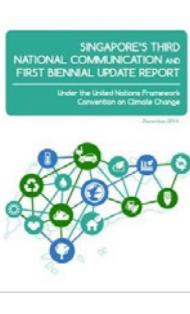
Singapore, as a Party to the UNFCCC, is required to submit National Communication (NC) reports and Biennial Update Reports (BUR) periodically to the UNFCCC.

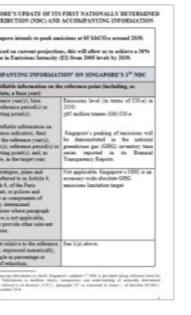
NCs, to be submitted every 4 years, provide information on Singapore's national circumstances, greenhouse gas inventory, mitigation measures, vulnerability and adaptation measures, and international cooperation. BURs, to be submitted biennially, provide an update of the information presented in NCs, particularly on the national greenhouse gas inventories and mitigation actions.

In support of the Copenhagen Accord, Singapore submitted a pledge in 2010 to reduce emissions by 16% below business-as-usual (BAU) level in 2020.

As required under the Paris Agreement, Singapore communicated an Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015. We subsequently communicated an enhanced NDC to the UNFCCC in 2020.

³⁴ National Environment Agency, National Communications and Biennial Update Reports, accessed at <https://www.nea.gov.sg/our-services/climate-change-energy-efficiency/climate-change/national-communications-and-biennial-update-reports>

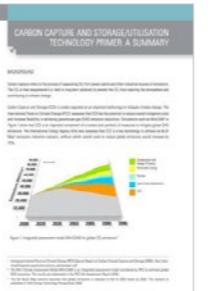
Publication	Year	Details
First NC 	2000	Singapore's initial NC was submitted on 21 August 2000.
Copenhagen pledge 	2010	Singapore pledged to reduce emissions by 16% below business-as-usual (BAU) levels in 2020.
Second NC 	2010	Singapore's second NC was submitted on 12 November 2010
Third NC and First BUR 	2014	Singapore's third NC and first BUR was submitted on 8 December 2014. <i>(As the submission year for Singapore's third NC coincided with the submission year of the first BUR, a combined report was submitted to UNFCCC.)</i>

Publication	Year	Details
Intended Nationally Determined Contribution (INDC) 	2015	Singapore's INDC pledged to reduce our emissions intensity by 36% from 2005 levels by 2030, and to stabilise emissions with the aim of peaking around 2030
Second BUR 	2016	Singapore's second BUR was submitted on 16 December 2016
Fourth NC and Third BUR 	2018	Singapore's fourth NC and third BUR was submitted on 27 December 2018. <i>(As the submission year for Singapore's fourth NC coincided with the submission year of the third BUR, a combined report was submitted to UNFCCC.)</i>
Enhanced Nationally Determined Contribution 	2020	Singapore's enhanced NDC pledged to peak our emissions at no higher than 65 MtCO ₂ e around 2030.

Masterplans and Roadmaps

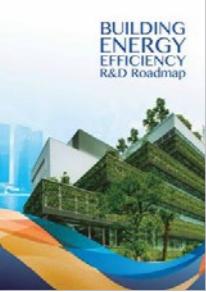
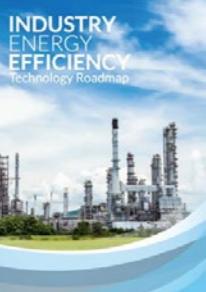
Singapore has published various masterplans targeting various areas of sustainable development and ways to mitigate and adapt to climate change. Additionally, NCCS and the National Research Foundation (NRF) have jointly commissioned a series of Technology Roadmaps to accelerate research to deployment of energy and low-carbon technologies in Singapore. Many of these Roadmaps were informed by the Technology Primers developed earlier in 2011, as referenced below.

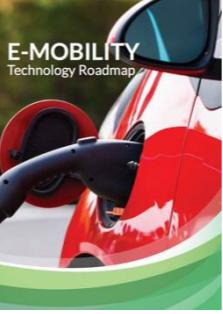
Publication	Year	Details
Singapore Green Plan 	1992 (Updated in 2012)	The Singapore Green Plan highlights our commitment and plans to ensure Singapore's environmental sustainability.
Sustainable Singapore Blueprint  	2009 (Updated in 2015 and 2016)	The Sustainable Singapore Blueprint outlines Singapore's vision and plans for a more liveable and sustainable Singapore to support the diverse needs and growing aspirations of Singaporeans through various initiatives.

Publication	Year	Details
Air-conditioning System Efficiency Technology Primer 	2011	The Air-conditioning System Efficiency Primer outlines Singapore's policies on air-conditioning efficiency, the available technology, and opportunities to improve energy efficiency.
Biorenewables Technology Primer 	2011	The Biorenewables Primer sets out the biorenewable conversion technologies used in Singapore at the time and elsewhere, the application of biofuels for transport, and the areas of R&D for Singapore.
Carbon Capture and Storage/Utilisation Technology Primer 	2011	The CCS/U Primer describes the potential application of CCS/U technologies in Singapore and the process involved in their deployment.
Energy Storage Technology Primer 	2011	The Energy Storage Primer sets out the means of energy storage, stages of commercial maturity, its potential applications in Singapore including electric vehicles and smart grids.

Publication	Year	Details
Smart Grid Technology Primer	2011	The Smart Grid Technology Primer proposes the key drivers for smart grid implementation, current projects, and areas for R&D in Singapore.
Solar Energy Technology Primer	2011	The Solar Energy Technology Primer describes the potential of solar electricity generation in Singapore, potential storage possibilities, and areas for R&D in this domain.
Green Data Centre Technology Prime	2011	The Green Data Centre Technology Primer reviews existing and emerging technologies for improving data centre efficiency and areas for R&D for Singapore.
National Climate Change Strategy	2012	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.

Publication	Year	Details
Second National Climate Change Study – Climate Projections to 2100 Science Report	2014	The Second National Climate Change Study for Singapore provides information on anticipated climate change.
Carbon Capture and Storage / Utilisation Roadmap	2014	The Carbon Capture and Storage/Utilisation (CCS/U) Roadmap identifies and studies various options of CCS/U relevant for Singapore, the potential of CCS/U technologies for carbon abatement and the R&D strategies that would accelerate the deployment of CCS/U in Singapore in the longer term.
Solar Photovoltaic Roadmap	2014	The Solar Photovoltaic Roadmap presents the development of photovoltaic scenarios for Singapore and pathways to increase the contribution of solar energy to Singapore's energy mix.
Green Data Centre Roadmap	2014	The Green Data Centre Technology Roadmap sets out a framework to improve data centre sustainability. The Roadmap aims to reduce energy consumption and improve the energy efficiency of data centre facilities and information technology.

Publication	Year	Details
Building Energy Efficiency Roadmap 	2014	The Building Energy Efficiency Roadmap outlines R&D pathways to improve energy efficiency within the building stock via technology improvements and policy recommendations.
Climate Action Plan: Take Action Today, for a Sustainable Future 	2016	The latest publication of Singapore's <i>Climate Action Plan: Take Action Today, for a Sustainable Future</i> comprises two complementary publications on Singapore's mitigation and adaptation plans. The first publication sets out how Singapore intends to reduce greenhouse gas emissions and increase our energy efficiency to meet our 2030 climate pledge. The second explains how Singapore may be affected by climate change and our strategy to prepare for them.
Our Water, Our Future 	2016 (Updated in 2017)	This publication sets out Singapore's water strategies and plans that will be undertaken in the next 50 years. It shares how Singapore plans to expand our capacities on water supply, used water management and drainage against the challenges of urbanisation, climate change and the rising cost of energy.
Industry Energy Efficiency Roadmap 	2016	The Industry Energy Efficiency Roadmap identifies and describes the technological potential and opportunities to reduce energy use from business-as-usual levels up to 2030. The Roadmap addresses the petrochemical and chemicals sector, petroleum refining, semiconductors, pharmaceuticals, and cross-sectoral technologies.

Publication	Year	Details
Waste Management Roadmap 	2016	The Waste Management Roadmap reviews developing and emerging trends in waste management technologies worldwide addressing waste processes from collection and sorting, to upcycling and treatment. The Roadmap proposes a set of technological pathways to address the identified implications.
E-Mobility Roadmap 	2016	The E-Mobility Roadmap serves as a blueprint to guide the formulation of policies and infrastructure plans that could enable successful electromobility deployment in Singapore.
Public Sector Sustainability Plan 2017 - 2020 	2017	The Public Sector Sustainability Plan 2017-2020 charts the Singapore Government's path towards achieving environmental sustainability, as part of our nationwide Sustainable Singapore Movement.
Zero Waste Masterplan 	2019	The Zero Waste Masterplan sets a new waste reduction target for Singapore – to reduce the waste sent to Semakau Landfill each day by 30% by 2030. This will help to extend Semakau Landfill's lifespan beyond 2035, when it is estimated to reach capacity.

Acknowledgements

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