SINGAPORE'S FIFTH NATIONAL COMMUNICATION AND FIFTH BIENNIAL UPDATE REPORT

2022

UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

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FRONT COVER IMAGE
Commercial buildings along Marina Catchment

BACK COVER IMAGE
Esplanade and the Marina Bay Waterfront

NOTES ON USING THIS DOCUMENT

As a non-Annex I Party to the United Nations Framework Convention on Climate Change (UNFCCC), Singapore is obliged to submit our National Communication (NC) every four years[1] and our Biennial Update Report (BUR) every two years.[2]

Singapore submitted our 4th NC in 2018 and our 4th BUR in 2020. As the submission year for Singapore's 5th NC coincides with the submission year of our 5th BUR, this document presents both Singapore's 5th NC and 5th BUR.

The following chapters are common to both the NC and BUR. The narratives in the NC for these chapters serve as a summary of the detailed information presented in the corresponding chapters in the BUR.

- National Circumstances
- National Greenhouse Gas Inventory
- Mitigation Measures

The BUR presents Singapore's ongoing and planned mitigation actions till 2020.

This document was prepared in accordance with:

- UNFCCC Guidelines for the Preparation of National Communications from non-Annex I Parties (decision 17/CP.8); and
- UNFCCC Biennial Update Reporting Guidelines (decision 2/CP.17 annex III).

As a component of our 5th NC, Chapter 4 on "Vulnerability and Adaptation Measures" is concurrently submitted as Singapore's first Adaptation Communication, pursuant to the Paris Agreement, and prepared taking into account Decision 9/CMA.1.

[1]UNFCCC decision 1/CP.16
[2]UNFCCC decision 2/CP.17

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FOREWORD

MR TEO CHEE HEAN

SENIOR MINISTER
CHAIRMAN OF THE INTER-MINISTERIAL
COMMITTEE ON CLIMATE CHANGE (IMCCC)

The window for decisive international action on climate change is narrowing. The recently completed Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) cycle concluded that the effects of climate change are widespread, rapid and intensifying.

As a low-lying island city-state, climate change is an existential threat for Singapore. While we account for only 0.1% of global emissions, Singapore has taken important steps to contribute to the global effort to tackle climate change and is continually working to overcome our constraints to raise our climate ambition.

At the Copenhagen Conference in 2009, Singapore pledged to reduce emissions by 16% below our business-as-usual (BAU) level in 2020. We are happy to announce that Singapore has achieved this target. This was achieved through sustained efforts in improving energy efficiency across various sectors of our economy, including an early switch from fuel oil to natural gas for power generation, among many other environmentally friendly measures. Yet, more work needs to be done. According to AR6 by the IPCC, the world needs to achieve net zero by around 2050 in order to limit global warming to 1.5 °C.

In October 2022, Singapore announced that it will enhance its climate pledge by committing to achieve net zero emissions by 2050, contingent on technological maturity and effective international cooperation. Our ability to fulfil our pledges, like all Parties, will depend on the continued international commitment by Parties to the Paris Agreement and their climate pledges.

We also announced that we will enhance our 2030 Nationally Determined Contribution (NDC) to reduce emissions to around 60 $MtCO_2e$ in 2030 after peaking emissions earlier. With this enhanced ambition, we have further aligned our long-term emissions trajectory with the Paris Agreement.

This is a significant and ambitious commitment for Singapore, a country that has limited potential for alternative energy sources. Our climate commitments are backed by concrete strategies, policies and actions, starting from this current crucial decade. A key measure we are taking is to raise our domestic carbon tax progressively from the current S$5 per tonne to around S$50 to S$80 per tonne[3] by 2030. We have also launched a comprehensive Singapore Green Plan 2030 (Green Plan), to make a collective whole-of-nation effort to achieve our sustainability and climate goals. The Green Plan is a living plan which will continue to evolve as technology develops and we review our strategies over time.

Singapore's decisive shift to net zero will require significant transformation in all aspects of daily life, economy, and society. There will be costs to bear and trade-offs to be made. At the same time, it will reposition Singapore and bring about a cleaner, greener world for our future generations.

Singapore's Fifth National Communication – which includes our first Adaptation Communication – and Fifth Biennial Update Report highlight the measures that we have taken as a nation to address climate change and our commitment to meet our 2020 emissions reduction pledge.

[3]This is equivalent to US$36.90 to US$59.00. Conversion from S$ to US$ is based on the monthly exchange rate as of Jan 2022.

Opposite page: Gardens by the Bay is a horticulture and garden artistry showpiece that engages and educates visitors with plants seldom seen in this part of the world, ranging from species in cool, temperate climates to tropical forests and habitats.

Kallang River at Bishan-Ang Mo Kio park is PUB's flagship project under the Active, Beautiful, Clean Waters (ABC Waters) programme. Previously a concrete canal, it was transformed into a 3 km naturalised river that meanders through the park so people can get closer to the water. Besides increasing the conveyance capacity of the waterway, this drainage project has also creatively added more green spaces for the public to enjoy.

EXECUTIVE SUMMARY

Singapore continues 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

Singapore is a small, low-lying, island city-state vulnerable to the effects of climate change. With a total land area (including that of smaller surrounding islands) of about 733.1 km², Singapore's population density of about 7,485 persons per km² is one of the highest in the world.

Due to Singapore's small size and dense urban landscape, there are challenges to using alternative energy sources such as solar, nuclear and wind energy. These difficulties in transitioning to alternative energy sources are recognised by the UNFCCC. Solar remains the most viable source of renewable energy in Singapore, and we aim to accelerate the deployment of solar energy despite challenges arising from our national circumstances.

Institutional Arrangements

Climate change is an issue with many dimensions that cut across the responsibilities of several ministries. The IMCCC, chaired by Mr Teo Chee Hean, Senior Minister and Coordinating Minister for National Security, oversees the whole-of-government (WOG) coordination on climate change policies. The National Climate Change Secretariat (NCCS) is a dedicated unit under the Prime Minister's Office (PMO) Strategy Group that serves as the secretariat to the IMCCC.

Greenhouse Gas (GHG) Inventory

Singapore's GHG emissions for 2018 totalled 53,312.68 gigagram (Gg) CO_2 equivalent. Carbon dioxide (CO_2) accounted for 94.3% of total emissions. Non-CO_2 gases such as methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) accounted for the remaining 5.7% of total emissions. This excludes an estimate of HFCs emissions from the refrigeration and air conditioning (RAC) sector, for which we are in the process of finalising.

Mitigation Measures

Singapore has achieved our Copenhagen pledge to reduce our emissions by 16% below our BAU level in 2020.

A key pillar of Singapore's strategy to mitigate GHG emissions is to improve energy efficiency across different sectors of the economy. Singapore does not subsidise energy costs, and has taken steps to use a cleaner fuel mix for electricity generation, switching from fuel oil to natural gas. However, there are limits to how much more emissions can be reduced by switching fuels, as natural gas, the cleanest fossil fuel, already constitutes about 95% of our fuel mix for electricity generation. To further decarbonise the power sector, we will harness and tap on the "Four Switches": natural gas, solar, regional power grids, and emerging low-carbon technologies.

Singapore will continue to push ahead with mitigation efforts in the different sectors as part of the Green Plan, which is a whole-of-nation movement to advance Singapore's national agenda on sustainable development.

In addition, Singapore has implemented a carbon tax of S$5 or US$3.70 per tonne of CO_2 equivalent (tCO_2 eq) of GHG emissions in the first instance, between 2019 and 2023, as a transition period. The carbon tax will be increased to S$25 or US$18.40/tCO_2 eq in 2024 and 2025, and S$45 or US$33.20/tCO_2 eq in 2026 and 2027, with a view to reaching S$50–80 or US$36.90–59.00/tCO_2 eq by 2030. The carbon tax will complement our existing mitigation efforts to meet our climate pledge under the Paris Agreement.

Innovative greening solutions on the rooftops of Housing & Development Board (HDB) flats help to reduce heat emissions from building surfaces and improve the appearance of HDB estates, making the living environment more conducive for residents.

Vulnerability and Adaptation Measures

As a relatively low-lying, densely populated island in the tropics, Singapore is naturally vulnerable to the impacts of climate change. Singapore takes a proactive, long-term approach towards climate change adaptation. Climate change resilience goes beyond physical adaptation, and must include building resilient mindsets as well as collective action to safeguard our environment. Additionally, our trade-dependent economy increases our exposure and vulnerability to the volatilities induced by climate change. Climate resilience and adaptation plans will be continuously reviewed and adjusted as new knowledge and information on the effects of climate change become available.

Concluding Remarks

Singapore remains committed to doing our part in this global crisis. We will advance on this sustainability journey together as a nation, making a decisive move to achieve net zero by 2050 and at the same time building up our climate resilience and adaptation. As a responsible member of the global community, Singapore will continue to work at the international, regional and bilateral levels to support collective global efforts to address the challenges of climate change.

NATIONAL CIRCUMSTANCES

As a small island developing state, sustainable development is at the core of Singapore's development plans and priorities.

Aerial view of the Helix Bridge, Bayfront Bridge and Benjamin Sheares Bridge at Marina Bay. Marina Bay is part of the Marina Reservoir, Singapore's 15th reservoir and the first in the heart of the city.

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.

There are over one million HDB flats in Singapore, spread over 24 towns and three estates. Majority of Singaporeans – over 80% – live in this form of public housing.

National Circumstances and Constraints

Singapore is a small island-state with a total land area (including that of smaller surrounding islands) of about 733.1 km². Much of the island is flat and relatively low-lying. As of June 2021, Singapore's total population, including foreigners working in Singapore, is estimated at 5.46 million. Singapore's population density of about 7,485 persons per km² is one of the highest in the world.

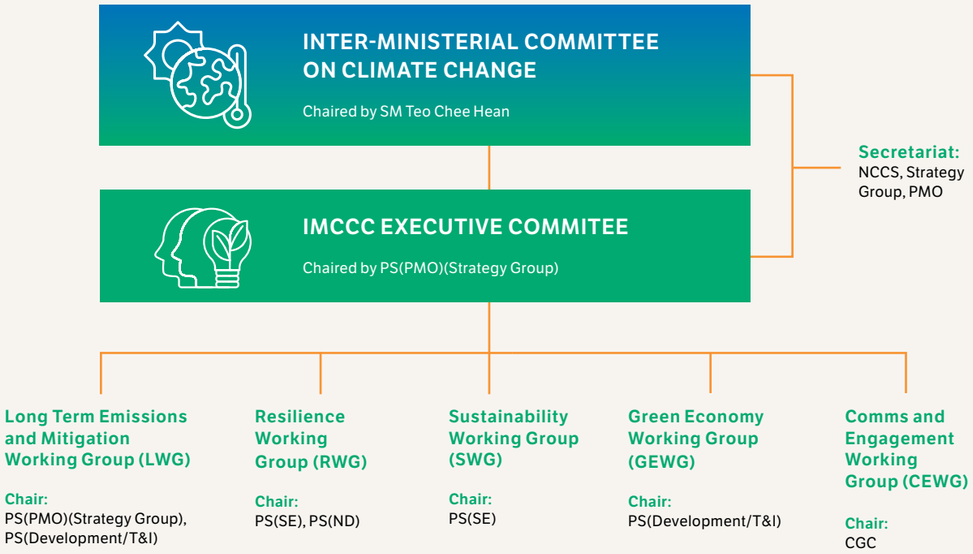
Given Singapore's small land area and dense urban landscape, there are competing uses for land which greatly limit our access to alternative energy sources at scale using current technologies. Moreover, Singapore's geographical features make harnessing conventional geothermal, hydroelectric, wind, nuclear, tidal, and wave power a major challenge. These difficulties in transitioning to alternative energy sources are recognised by the UNFCCC.[4]

Solar remains the most viable source of renewable energy in Singapore, and we aim to accelerate the deployment of solar energy through innovative ways, despite challenges arising from our space constraints and presence of high cloud cover and urban shading. In addition, the Government is exploring other means to decarbonise our energy supply, such as low-carbon electricity imports and other low-carbon solutions (e.g. hydrogen).

Institutional Arrangements

The IMCCC oversees the WOG coordination on climate change policies to ensure that Singapore is prepared to address climate change. Established in 2007, the IMCCC is chaired by Mr Teo Chee Hean, Senior Minister and Coordinating Minister for National Security, and includes the Ministers from the following Ministries: Finance, Foreign Affairs, National Development, Sustainability and the Environment, Transport, and Trade and Industry.

In July 2010, the NCCS was established as a dedicated unit under the PMO to ensure the effective coordination of Singapore's domestic and international policies, plans, and actions on climate change.



More information on Singapore's national circumstances, including details of Singapore's geographical features, climate, and economy, as well as our institutional arrangements is presented in Chapter 1 of the BUR.

[4]Articles 4.8 and 4.10 of the UNFCCC take into consideration the national circumstances of developing countries, especially small island countries, countries with low-lying coastal areas, land-locked and transit countries, and countries disadvantaged in the use of alternative energy sources, amongst others. Article 4.10 recognises the circumstances of such countries with "serious difficulties in switching to alternatives."

CHAPTER 2

NATIONAL GREENHOUSE GAS INVENTORY

The IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories were applied to improve the transparency, consistency, comparability, completeness and confidence in the national GHG inventory of emissions estimates.

The School of Art, Design and Media at Nanyang Technological University, featuring the eye-catching sloped 'grass roof', was awarded the Singapore Green Mark Platinum Award in 2011 by the Singapore Building and Construction Authority (BCA) for adopting best practices in environmental sustainability.

The most significant GHG emitted in Singapore is CO_2, primarily produced from the burning of fossil fuels to generate energy used by the industry, building, household, and transport sectors. The main contributor to GHG emissions (32.2%) is the combustion of natural gas to generate electricity.

Singapore's emissions comprises CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3. These emissions were estimated using the:

- 2006 IPCC Guidelines for National GHG Inventories
- IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories
- IPCC 2014, 2013 Supplement to the 2006 IPCC Guidelines for National GHG Inventories: Wetlands

Emission estimates were based on the sectoral approach and were calculated using the default conversion and emission factors provided in the 2006 IPCC Guidelines, unless otherwise stated.

Tier 1 methodology was used for about 90% of our emission estimates. Tier 2 methodology was used for estimating fugitive emissions from oil and natural gas, emissions from some categories of industrial processes and product use (IPPU), CH_4 emissions from solid waste disposal and CO_2 emissions from incineration of solid waste. Emission estimates from the Land Use, Land-Use Change and Forestry (LULUCF) sector were obtained mainly from using Tier 2 and 3 methodologies.

Singapore's GHG Emissions in 2018

Singapore's GHG emissions for 2018 totalled 53,312.68 $GgCO_2$ eq. This excludes the interim Tier 1b estimate of HFCs emissions from the RAC sector of 6,398.15 $GgCO_2$ eq in 2018. A breakdown of the total GHG emissions by sources in $GgCO_2$ eq is shown in the tables on pg 74–75.[5,6] The estimated CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3 emissions were converted to CO_2-equivalent using the 100-year time-horizon global warming potential (GWP) values from the IPCC Fifth Assessment Report (AR5).

Greenhouse Gas	Emissions ($GgCO_2$ eq)	% of Total Emissions
CO_2	50,260.88	94.28%
PFCs	1,437.92	2.70%
HFCs	507.29	0.95%
N_2O	484.88	0.91%
NF_3	381.25	0.72%
SF_6	127.06	0.24%
CH_4	113.39	0.21%

The compilation of the GHG inventory is coordinated by the National Environment Agency (NEA) with data from other agencies and companies. Quality control checks for the computation of GHG emissions were developed based on the IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories to improve the transparency, consistency, comparability, completeness and confidence in the national GHG inventory of emissions estimates. The multi-agency GHG inventory team uses a four-stage inventory preparation process to facilitate continuous improvement to the national GHG inventory for subsequent inventory compilation cycles.

More information on the National GHG Inventory is presented in Chapter 3 of the BUR.

Opposite page: Aerial view of the man-made Supertrees at Gardens by the Bay that tower over visitors. These are home to numerous plant types which grow on the vertical planting panels on their 'trunks'.

[5]As some figures are considerably small, they may be presented as "0.00" due to rounding.
[6]Figures may not add up to the totals due to rounding.

CHAPTER 3

MITIGATION MEASURES

Singapore is committed to transitioning towards a greener, more sustainable future.

Rooftops of HDB flats turned into lush gardens using prefabricated Roof Tray Systems. These reduce surface/ambient temperatures, add a protective layer for the roof membrane, and help reduce glare to surrounding blocks.

Singapore has met our 2020 pledge of reducing emissions by 16% below 2020 BAU[7] levels. Building on our 2020 pledge, Singapore has also enhanced our 2030 NDC to reduce emissions to around 60 $MtCO_2$ eq in 2030 after peaking our emissions earlier.

Singapore has one of the world's largest floating solar panel farms, about the size of seven football fields.

Singapore's Approach to Reducing Emissions

Energy is a strategic resource for Singapore. As an alternative energy-disadvantaged country, Singapore is highly reliant on imports for our energy needs. Recognising that energy is a scarce resource, Singapore allows for market pricing of fuel and electricity without any direct subsidy. This results in firms and households making appropriate energy consumption choices, such as minimising energy wastage and over-consumption, which contributes to emissions reduction.

Singapore has also moved towards a cleaner fuel mix for electricity generation, switching from fuel oil to natural gas, which has a lower carbon content per unit of electricity generated.

However, there are limits as to how much more emissions we can reduce by switching fuels, since natural gas already constitutes 95% of our fuel mix for electricity generation in 2016. To further decarbonise the power sector, as part of our energy transition, we will harness and tap on the "Four Switches": natural gas, solar, regional power grids, and emerging low-carbon technologies. While we invest actively in research on low-carbon technologies, there are also limits to the deployment of alternative or renewable energy sources in Singapore.

Energy efficiency is a core carbon emissions mitigation strategy. This will require our households and businesses to be more energy-conscious and make adjustments to their daily activities, choices and processes.

As an open economy without natural resources, we need to reduce carbon emissions in a cost-effective way. Hence, the Government has identified the following areas as part of a comprehensive strategy to promote energy efficiency in Singapore:

- Promoting the adoption of energy-efficient measures and technologies by addressing market barriers to energy efficiency.
- Building capabilities to sustain and drive energy efficiency efforts and to develop the local knowledge base and expertise in energy management.
- Raising awareness by reaching out to the public and businesses so as to promote energy-efficient behaviour and practices.
- Supporting research and development to enhance Singapore's capabilities in energy-efficient technologies.

We will also harness emerging low-carbon technologies to decarbonise the industry sector. For example, under the "Sustainable Jurong Island" plan that aims to transform Jurong Island into a Sustainable Energy and Chemicals (E&C) Park, the E&C sector will enable sustainable production through Carbon Capture, Utilisation and Storage (CCUS), increasing energy efficiency, and use of renewable energy in company operations. These plans will realise at least two million tonnes of carbon capture potential by 2030 and achieve more than six million tonnes of carbon abatement per annum from low-carbon solutions by 2050. The E&C sector will also increase its output of sustainable products, such as bio-based fuels and chemicals, and pyrolysis oil from plastics recycling, by four times from 2019 levels.

We will continue to push ahead with mitigation efforts in the different sectors as part of the Green Plan, which is a whole-of-nation movement to advance Singapore's national agenda on sustainable development. For example, under the building sector, we aim to green 80% of the total gross floor area (GFA) of our buildings by 2030. For the transport sector, we already have a high public transport mode share.

To further encourage the use of public transport, the length of the rail network in Singapore will increase from about 245 km today to about 360 km in early 2030s. This will enable eight in 10 households to be within a 10-minute walk of a train station, and 85% of public transport journeys of less than 20 km to be completed within 60 minutes.

We also have one of the most stringent and innovative systems in the world for controlling vehicle ownership and usage, through a vehicular quota and road pricing system. Since February 2018, the permissible growth rate of our private vehicle population has been reduced to 0% from 0.25%, effectively capping the growth of private vehicles. Singapore is working on the large-scale adoption of green vehicles. By 2040, we aim to phase out internal combustion engines and have all vehicles running on cleaner energy.

Carbon tax provides a strong price signal and impetus for businesses and individuals to reduce their carbon footprint in line with national climate goals. From 2019, Singapore implemented a carbon tax starting at S$5 or US$3.70 per tonne of CO_2-equivalent (tCO_2 eq) of GHG emissions in the first instance, between 2019 and 2023, as a transition period. To support the transition to a low-carbon future, we will raise the carbon tax levels to S$25 or US$18.40/tCO_2 eq in 2024 and 2025, and S$45 or US$33.20/tCO_2 eq in 2026 and 2027, with a view to reaching S$50–80 or US$36.90–59.00/tCO_2 eq by 2030. The carbon tax will complement our comprehensive suite of mitigation measures to help us achieve our climate pledges.

More information on Singapore's mitigation measures are presented in Chapter 4 of the BUR.

Over three million rides take place daily on the 245 km long Mass Rapid Transit (MRT) system in Singapore.

[7]Projecting from 2005, Singapore's BAU emissions are expected to reach 77.2 million tonnes (Mt) in 2020.

Built across the mouth of the Marina Channel, the Marina Barrage creates Singapore's 15th Reservoir. The first in the heart of the city, the Marina Barrage is built as an integrated facility that serves multiple purposes – a source of water, a coastal protection measure, and a recreational space for the community.

CHAPTER 4

VULNERABILITY AND ADAPTATION MEASURES

It is important for Singapore to prepare for and adapt early to climate change.

As a component of our 5th NC, Chapter 4 on "Vulnerability and Adaptation Measures", is concurrently submitted as Singapore's first Adaptation Communication, pursuant to the Paris Agreement, and prepared taking into account Decision 9/CMA.1

As a small, low-lying island city-state, Singapore is highly vulnerable to the impacts of climate change. Singapore is also one of the most densely populated countries in the world. It is thus important for Singapore to prepare for and adapt early to climate change.

Effects of Climate Change

The IPCC Working Group I Report for the AR6 cycle has warned us that the global climate will change significantly unless rapid and drastic reductions in emissions are taken. Global temperatures are projected to *very likely* rise by 1.0–5.7 °C by the end of the century from pre-industrial levels, while global mean sea levels are likely expected to increase by 0.28 m to 1.01 m over the same period, relative to 1995–2014 sea levels. Extreme weather events (such as heavy rainfall) over the region are also projected to be more intense and frequent. The IPCC Working Group II Report further cautions that widespread climate impacts are already being felt across the world, with some of these effects irreversibly and disproportionately affecting vulnerable countries, notably small island developing states (SIDS). The window for securing a liveable future is rapidly closing.

The Centre for Climate Research Singapore (CCRS), in partnership with the UK Meteorological Office, concluded Singapore's Second National Climate Change Study (V2) in 2015, which made use of data and scenarios from the IPCC's Fifth Assessment Report (AR5) to examine the long-term effects of climate change in Singapore. The study found that by 2100, the mean sea level around Singapore could rise by up to a metre and mean temperatures could increase by up to 4.6 °C. The CCRS has embarked on the Third National Climate Change Study (V3) to provide updated climate projections by 2023, which will incorporate the latest findings from IPCC AR6.

Preparing Singapore for the Impact of Climate Change

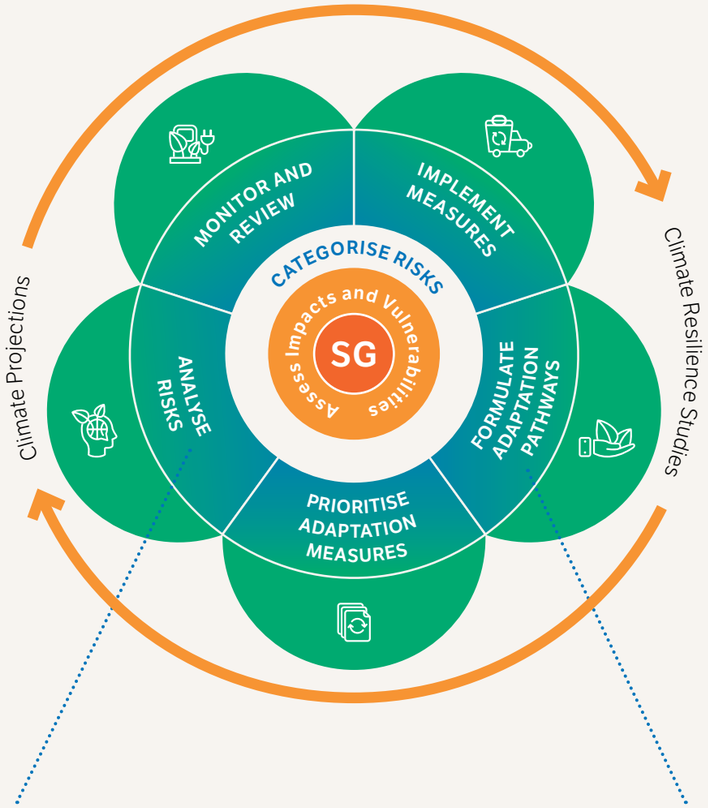
The impacts of climate change are already being felt in Singapore. 2012 to 2021 was Singapore's warmest decade since Singapore began local temperature recordings in 1929. In 2021, Singapore also experienced record rainfalls in January, April and August, leading to flash floods in various parts of Singapore. Sea levels around the island rose by 14 cm from 1979 to 2019.

Even with international efforts to limit the rise in global temperatures, there is a need to prepare Singapore for the impacts of climate change. Some adaptation measures require longer lead times to implement and have to be undertaken early. Adaptation plans must also be adaptive to climate uncertainties and evolving climate science.

To coordinate such efforts, a multi-agency Resilience Working Group (RWG), led by the Ministry of Sustainability and the Environment (MSE) and the Ministry of National Development (MND), was set up in 2010 under the IMCCC. The RWG assesses Singapore's physical vulnerabilities to climate change based on a Resilience Framework, which guides the formulation of adaptation plans up to 2100 (see the next page for Singapore's Resilience Framework).

Singapore's Resilience Framework

CCRS, set up in 2013, conducts research and studies to improve scientific understanding of local climate and the effects of climate change on Singapore. Findings from these studies form the basis for Singapore's long-term adaptation plans.



Risk Assessment
to identify and categorise climate change risks in tandem with advances in climate science.

Adaptation Planning
by formulating options to tackle the risks identified in a dynamic and flexible manner.

The RWG comprises 20 agencies which oversee key sectoral risks and efforts in enhancing Singapore's adaptive capacity, strengthening resilience capabilities, and reducing vulnerability to climate change. The inter-agency effort ensures that adaptation plans are coordinated across the Government. The agencies involved are:

- Building and Construction Authority (BCA);
- Civil Aviation Authority of Singapore (CAAS);
- Centre for Liveable Cities (CLC);
- Energy Market Authority (EMA);
- Housing & Development Board (HDB);
- Info-comm Media Development Authority (IMDA);
- JTC Corporation (JTC);
- Land Transport Authority (LTA);
- Maritime and Port Authority of Singapore (MPA);
- Ministry of Finance (MOF);
- Ministry of Health (MOH);
- Ministry of National Development (MND);
- Ministry of Sustainability and the Environment (MSE);
- National Environment Agency (NEA);
- National Parks Board (NParks);
- Prime Minister's Office - Strategy Group, National Climate Change Secretariat (PMO-SG/NCCS);
- PUB, Singapore's National Water Agency;
- Singapore Food Agency (SFA);
- Singapore Land Authority (SLA); and
- Urban Redevelopment Authority (URA)

RWG has identified six key adaptation risk areas for Singapore.

A — Adapting to Sea Level Rise and Building Flood Resilience

As a low-lying, tropical island state, Singapore is particularly vulnerable to sea level rise. Singapore is also projected to experience more frequent and intense heavy rainfall events, which can lead to inland flooding. Since April 2020, PUB has been appointed the national coastal protection agency to address inland and coastal flooding holistically.

To mitigate the impact of sea level rise, the minimum reclamation levels for new developments have been raised from 3 m to at least 4 m above the mean sea level since 2011. New critical infrastructure such as Tuas Mega Port and Changi Airport Terminal 5 will be built at least 5 m or more above the current mean sea level.

PUB is progressively conducting site-specific studies across Singapore's varied coastline of more than 300 km to examine various coastal adaptation solutions. Where feasible, they will be co-located with amenities or recreational spaces for the community to enhance the living environment. PUB will also explore hybrid solutions that combine nature-based elements with hard engineering measures. Land reclamation is also a viable measure to protect our coasts, while creating more land for housing and other needs.

Along a restored freshwater swamp, the Rasau Walk is a 300 m boardwalk within the Jurong Lake Gardens that meanders through clusters of Nibong (*Oncosperma tigillarium*), Sealing Wax Palm (*Cyrtostachys renda*), and Rasau (*Pandanus spp.*), just some of over 50 native plant species that can be found in our freshwater swamps.

Seawalls at Vivo City Promenade, an example of a hard engineering solution to adapt to rising sea levels.

To holistically assess the combined effects of extreme coastal sea levels and intense rainfall, PUB is also developing a Coastal-Inland Flood Model. This model will support the planning and operations of coastal adaptation measures.

To enhance inland flood resilience, PUB adopts a "Source-Pathway-Receptor" approach, which looks at catchment-wide solutions to build in flexibility and adaptability to cope with higher intensity storms. This comprehensive approach covers the entire drainage system, addressing not just the pathway over which the stormwater travels (i.e. "Pathway"), but also in areas generating stormwater run-off (i.e. "Source") and the areas where floods may occur (i.e. "Receptor").

PUB raised the drainage design standards in 2011 so that our drains can handle up to 50% higher rainfall intensities (i.e. "Pathway"). All new developments and re-developments of 0.2 hectares (ha) or more are required to implement measures to slow down surface run-off and reduce the peak flow of stormwater into the public drainage system, by implementing on-site detention measures (i.e. "Source") since 2014.

Developments are also required to adhere to the minimum platform and crest levels or install flood barriers to prevent floodwaters from entering buildings (i.e. "Receptor"). These structural measures are complemented by the use of technology such as X-band radars and an extensive network of water level sensors and CCTVs installed island-wide, to better predict and respond to floods. Public alerts can also be issued earlier, enabling residents in areas at risk of flash floods to take preventive measures such as deploying portable flood barriers.

B — Ensuring Water Sustainability

Climate change could lead to more frequent and prolonged droughts, which may threaten Singapore's water supply. To ensure a sustainable water supply and enhance water resilience for Singapore, PUB has built a robust and diversified water supply through the "Four National Taps", namely, local catchment water, imported water, desalinated water, and NEWater.[8] NEWater and desalinated water are weather-resilient sources that can cushion Singapore against the uncertainties in water supply brought about by climate change.

[8]NEWater is high-grade reclaimed water, produced from treated used water that is further purified using advanced membrane technologies and ultraviolet disinfection, making it clean and safe to drink.

The male Orange-bellied Flowerpecker (*Dicaeum trigonostigma*), with its slaty-blue upperparts and a large triangular orange patch on its mantle, feeds on flowers and fruits. It is a common resident of Singapore's forested areas and forest edges.

Smooth-coated otters *(Lutrogale perspicillata)* are becoming a common sight in our mangroves, mudflats, and coastal areas. These social creatures generally live in pairs and family groups.

To promote water conservation and efficient use of water, PUB introduced a Mandatory Water Efficiency Labelling Scheme (MWELS) and minimum water efficiency standard in 2009 to help consumers make more informed choices and encourage suppliers to introduce more water-efficient fittings and appliances into the market. As part of the scheme, suppliers are required to display water efficiency labels on water fittings and appliances, as well as on their packaging and advertisements.

PUB has also rolled out the Smart Water Meter Programme to install 300,000 smart water meters in residential and commercial/industrial premises under the first phase of the programme. With smart water meters, water consumption will be read automatically and transmitted remotely back to PUB daily, improving resource efficiency and augmenting PUB's capabilities in early leak detection within the water supply network and consumers' premises. Through an online portal, customers will have easy access to their daily water usage data, empowering them to track their consumption and adopt water-saving habits. PUB will review this first phase roll-out, build up its capabilities and expertise, and consider the advances in technology before implementing it nationwide.

PUB also requires companies which use more than 60,000 m³ of water in the preceding calendar year to submit a Water Efficiency Management Plan (WEMP) for three consecutive years. Preparing the WEMPs requires companies to establish water management systems and install private water meters.

To support companies' implementation of water efficiency projects, PUB also introduced the Water Efficiency Fund in 2007 to fund water efficiency assessments, pilot studies, adoption of water efficient equipment, and recycling/use of alternate sources of water.

C — Safeguarding our Biodiversity and Greenery

Singapore is home to a large variety of animal and plant species, many of which are vulnerable to climate change. As part of ongoing plans to transform Singapore into a City in Nature, NParks will continue to implement measures to ensure that our ecosystems remain healthy and resilient.

These include:

- Adding 200 ha to the existing 450 ha of nature parks surrounding nature reserves by 2030, to serve as buffers for nature reserves, and expanded habitats for native flora and fauna to thrive beyond the nature reserves;
- Implementing habitat restoration and species recovery plans to strengthen the conservation of native plant and animal species;
- Planting an additional 1 million trees across Singapore from 2020 to 2030; and
- Strengthening ecological connectivity by (i) identifying ecological corridors between key habitats through modelling of animal movements; (ii) enhancing the network of corridors through forest restoration and habitat enhancement; and (iii) augmenting connectivity by transforming roadside greenery into Nature Ways[9] that mimic the multi-tiered structure of forests.

These nature-based measures also provide ecosystem services, such as providing shade, reducing ambient temperature, and helping to grow our carbon sinks.

To mitigate the risk of tree failure during severe weather, NParks inspects trees along major roads and areas with high human activity at least once a year, and leverages technology to monitor the stability of mature trees. If needed, trees are pruned to reduce the size and weight of their crowns to better withstand storm events. NParks is also progressively replacing storm-vulnerable trees with sturdier species and planting more drought-resistant species that can tolerate erratic weather conditions.

D — Strengthening Resilience in Public Health and Food Security

Vector-borne diseases such as dengue are endemic to Southeast Asia. Higher temperatures can create favourable conditions for mosquitoes to breed and viruses to multiply faster. NEA has deployed more than 68,000 Gravitraps, which are cylindrical traps with sticky inner surfaces that trap female *Aedes* mosquitoes looking for water sources to lay their eggs, at public and landed housing estates around Singapore. Areas with high levels of *Aedes aegypti* mosquitoes are also publicly identified to inform community action and prioritised for control measures.

[9]Nature Ways are routes planted with specific trees and shrubs to facilitate the movement of animals such as birds and butterflies between green spaces.

To further enhance dengue control, NEA has released male *Wolbachia*-carrying *Aedes aegypti* mosquitoes, which mate with female mosquitoes, causing their eggs to not hatch, and helping to curb the dengue mosquito population. So far, Project *Wolbachia* has achieved up to 98% suppression of urban *Aedes aegypti* mosquito populations at study sites, and up to 88% reduction in dengue cases. Project *Wolbachia* will be progressively expanded to include landed estates and construction sites as the Government scales up production and release capacity.

Rising temperatures and more extreme weather events can also encourage the spread of novel zoonotic diseases. NParks is monitoring the effects of climate change on animal diseases through a science-based biosurveillance programme. The programme adopts a multi-disciplinary approach involving various One Health[10] agencies to identify and monitor biosecurity threats. This includes pre-border, border and post-border checks and controls of animals, such as at centres for wildlife and animal rehabilitation.

Food security is also of critical importance to Singapore. Singapore imports 90% of its food supply and is thus vulnerable to global supply disruptions caused by disease outbreaks and climate change. To minimise the risk of food supply disruptions, SFA ensures Singapore's food security by diversifying food sources, growing local produce, and supporting agrifood companies to grow overseas. A key strategy to reduce Singapore's reliance on import sources is building the agri-food sector's capabilities and capacity to sustainably produce 30% of the country's nutritional needs by 2030.

E — Keeping Essential Services Running Well

Agencies have taken early action to ensure that Singapore's essential services such as energy, telecommunications and transport infrastructure will not be affected by climate change. For example, LTA has installed flood barriers at entrances and openings of low-lying underground Mass Rapid Transit (MRT) stations, and CAAS is upgrading the drainage system at Changi Airport with new detention tanks and pumps.

Future network infrastructure developments are also built to higher standards to account for climate change impacts such as sea level rise. For example, the future Changi Airport Terminal 5 will be built 5.5 m above mean sea level and the new Tuas Mega Port is currently being built 5 m above mean sea level.

EMA and IMDA also account for climate impacts in strengthening the resilience of Singapore's energy supply and telecommunication services.

F — Keeping Buildings and Infrastructure Safe

Singapore's building codes are continually updated to ensure that the projected changes in temperature, rainfall, and wind speeds arising from climate change will not affect the structural integrity of buildings. To better understand how climate change may affect the long-term maintenance of building façades, BCA is conducting a study to evaluate the impact of climate change on the service life of façade materials. BCA has also introduced a periodic façade inspection regime to facilitate the early detection and timely repair of façade deterioration, which may be accelerated by climate change.

More frequent and heavier rainfall arising from climate change can affect slope stability. To address this, agencies that manage public land conduct regular inspections on slopes that may pose a risk to public safety, and implement appropriate mitigation measures to stabilise slopes as required. BCA also conducts public education campaigns for owners of land or buildings in areas that may be susceptible to slope failure, and advises them to regularly inspect and maintain their slopes and retaining structures.

G — Mitigating the Urban Heat Island Effect

According to the Meteorological Service Singapore, it is almost 1 °C hotter today in Singapore than it was in the 1950s. This is in part driven by the Urban Heat Island (UHI) effect – where a built-up area is warmer than its surroundings because of urbanisation. If left unaddressed, urban heat can significantly affect urban liveability and human health. Singapore's Urban Heat Island Mitigation Workgroup (UHI WG), comprising infrastructure and public health agencies, was hence formed in 2019 to coordinate WOG efforts to study and mitigate UHI effects.

The UHI WG is developing capabilities to measure and model the UHI effect, through the deployment of climate sensors to collect data on the UHI effect. To further investigate the effectiveness of potential UHI mitigation strategies, the UHI WG is also

[10]One Health is an approach that emphasises the interconnectedness of the health of people, animals and the environment. It encourages professionals in different fields to collaborate and tackle emerging infectious diseases through research, biosurveillance, detection and containment. Agencies involved in One Health include MOH, NParks, NEA, SFA and PUB.

Release of male Wolbachia-carrying *Aedes aegypti* mosquitoes to suppress the urban *Aedes aegypti* mosquito population in the community.

coordinating research on the impact of the UHI effect and possible mitigation measures. For example, the Cooling Singapore 2.0 research project aims to create a Digital Urban Climate Twin to holistically model the UHI effect in Singapore. These initiatives contribute to the development of a UHI mitigation action plan to pilot and scale measures such as increasing urban greenery and the use of cool materials.

Potential Barriers and Challenges to Implementation[11]

While much has been done to develop plans and measures to adapt to climate change, there remain challenges in implementation.

A — Impact of COVID-19

The COVID-19 pandemic has disrupted global supply chains, resulting in higher material costs. Parties may face challenges meeting immediate spending needs, such as regular infrastructure maintenance, while continuing to make longer-term investments to adapt to climate change.

B — Tracking the latest Climate Science and Cost-Effective Technologies

Singapore's climate resilience efforts will need to evolve with the latest science, with each iteration of the IPCC report and the accompanying National Climate Change Study. Hence, while measures are put in place to defend against the effects of climate change, Singapore must ensure our plans are adaptable and incorporate the latest climate change projections.

The availability and affordability of new technologies are also crucial in supporting Singapore's climate adaptation efforts. Singapore will need to continue to invest in Research and Development (R&D), and to cater sufficient time for the technologies to mature before they can be deployed at scale and at reasonable cost. For example, CCRS has launched a US$16.7 million Climate Impact Science Research (CISR) Programme to better understand the long-term impact of climate change on Singapore. The CISR Programme will focus on five key priority areas – sea level rise; water resource and flood management; biodiversity and food security; human health and energy; and cross-cutting research to bridge science-policy translation. The programme will enable policy makers to make informed decisions on climate adaptation measures and pathways.

C — Financing

Significant financing resources are required for climate adaptation. To ensure the judicious use of resources, Singapore has adopted a phased approach to the implementation of climate adaptation measures. For example, coastal protection measures are being implemented progressively, beginning in more vulnerable areas, to prevent bunching of resources. These projects are also supported by various funding

[11]The subsequent sections have been prepared in accordance with "Elements of an adaptation communication" as per Decision 9/CMA.1.

sources, with the cost spread over many years across generations, such as through the Coastal and Flood Protection Fund (CFPF)[12] and green bonds under the Significant Infrastructure Government Loan Act. Furthermore, pilot projects and test beds are used to test the efficiency of solutions prior to large scale implementation, such as nature-based enhancements to coastal protection solutions and cool materials for UHI mitigation.

D — Strengthening Community Resilience

Given the cross-cutting nature of climate change, close collaboration between different agencies is required to ensure climate resilience. This has underscored the need for inter-agency platforms, such as the IMCCC, to resolve trade-offs across various domains.

The Government alone cannot achieve climate resilience, and will need to galvanise collective action by corporations, communities, households, and individuals. For instance, PUB engages building owners and residents in low-lying areas on the loan and deployment of portable flood protection barriers in case of flash floods caused by heavy rainfall. Members of the public can also stay updated on flooded sites, through radio broadcasts, PUB's Facebook and Twitter pages, mobile apps such as "myENV", as well as LTA's Expressway Monitoring Advisory System. PUB also encourages the implementation of innovative solutions in water recycling projects through the Industrial Water Solutions Demonstration Fund (IWSDF) (part of WEF), and National Research Foundation's (NRF) Living Lab (Water) Fund.

As part of the Green Plan — a whole-of-nation movement to advance Singapore's sustainable development — the Government will continue to engage the public. Such efforts include raising awareness around climate change risks, building public acceptance of the trade-offs, and encouraging the public to co-create solutions by funding community projects through the US$37 million SG Eco Fund. The government will continue to pursue different avenues and engage the various stakeholders to strengthen Singapore's climate resilience capabilities.

Monitoring and Evaluation of Progress and Results Achieved

Monitoring and evaluation are critical to ensure transparency, manage the progress, and measure the results of Singapore's national adaptation plans. The RWG Secretariat oversees and takes stock of the data collection and reporting mechanisms across various government agencies for the focus areas mentioned in this chapter.

Under the Green Plan, the "Resilient Future" Pillar maps out specific targets set to enhance food security, adapt to sea level rise, and strengthen flood resilience. Under the "City in Nature" Pillar, there are also specific targets set towards creating a green, liveable and sustainable home for Singaporeans. The last progress update was made at the 2022 Committee of Supply debate, and details can be found on the Green Plan website.

Capability Support and Sharing of Good Practices

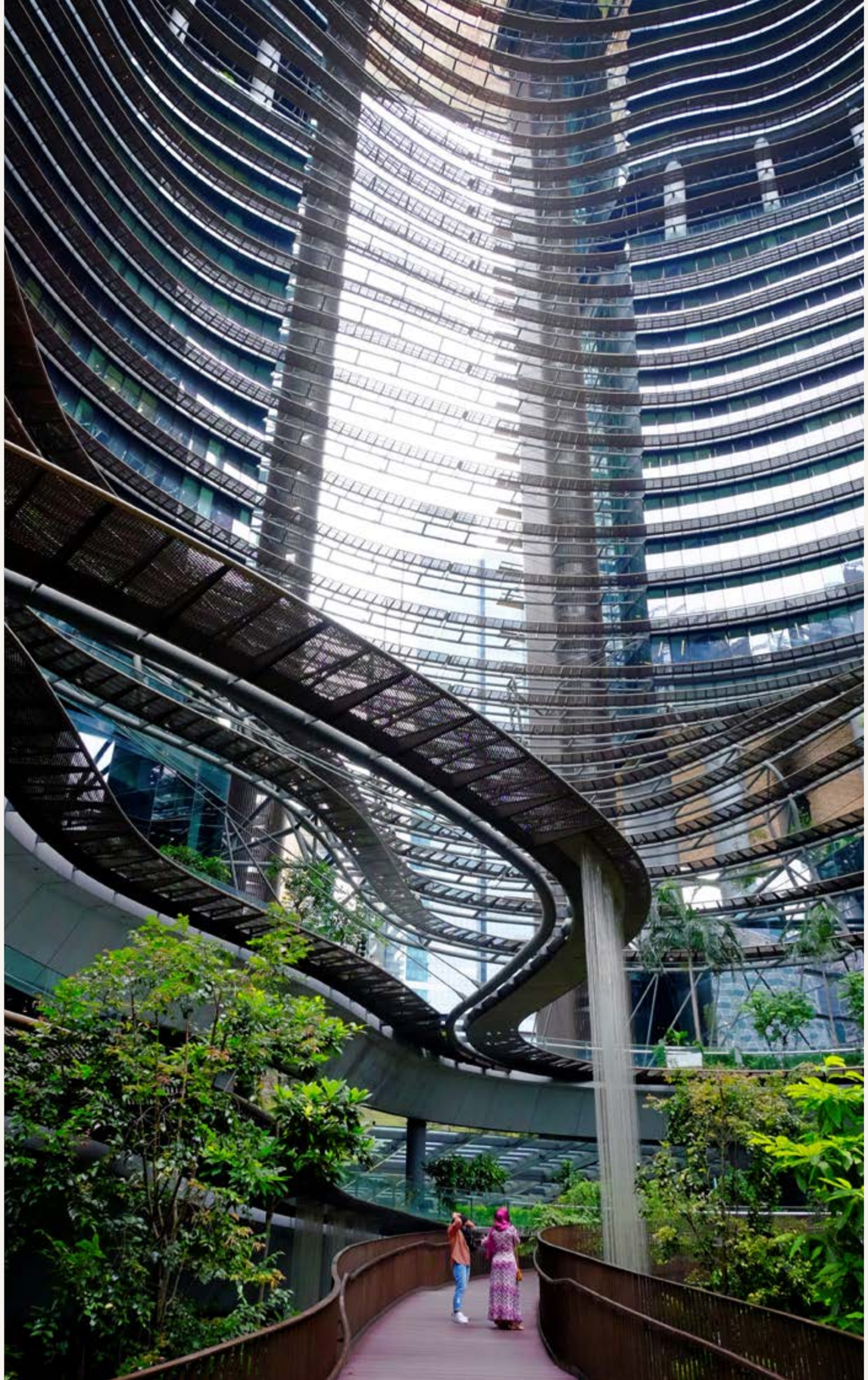
A — Capacity Building

Singapore is committed to supporting fellow developing countries in their efforts to address climate change through capacity-building assistance. Singapore believes that the sharing of best practices and expertise can have a meaningful, multiplier effect in passing on relevant skills and knowledge to other developing countries in addressing the challenges of climate change. Countries would also be able to adapt these best practices to suit their unique national circumstances.

Under the Singapore Cooperation Programme (SCP), our flagship technical assistance programme, and its Climate Action Package (CAP), more than 137,000 officials from over 180 countries and territories have been trained in topics such as climate adaptation and mitigation, disaster risk management, and green finance. Singapore has also worked with external partners, including third world countries and international organisations, to undertake these courses, as well as implement courses that address the cross-cutting impacts and risks of climate change and COVID-19. Following positive feedback, the CAP has been

Opposite page: Greenery within Marina One, an award-winning integrated development within the Marina Bay financial district.

[12]The CFPF is a statutory fund established within PUB to fund eligible coastal protection and drainage infrastructure.



extended to 2023. A non-exhaustive list of courses offered under the CAP can be found below:

Course Name	Course Description
Environmental Conservation and Sustainability	The course equips participants with knowledge on environmental conservation, coastal protection, and urbanisation.
Climate Change Adaptation and Mitigation Strategies	Topics include adaptation strategies in urban environments, with a focus on access to fresh water and food, health, and transportation.
Introduction to Disaster Risk Reduction (DRR)	This course examines the key principles of DRR, and the hardcoding of resilience into policy.
Understanding Risk Management and Risk Financing for Disaster Resilience	The course aims to support the efforts of Caribbean SIDS to enhance their planning for future large-scale disasters, and strengthen the cadre of trained professionals for DRR in the Caribbean region.
Green Climate Financing	This course discusses the financial support available for climate change projects, the monitoring, reporting and verifying of financial flows, and Singapore's experience in catalysing green investments.
Sustainable Integrated Water Resources and Stormwater Management, in conjunction with United Nations Children's Fund (UNICEF)	The course discusses approaches for managing stormwater and water resources to deal with climate impacts.
Singapore Water Management Series on Water Reuse	Topics include Singapore's used water management infrastructure and technology, such as the Deep Tunnel Sewerage System (DTSS) and NEWater plants; policies, legislation, and enforcement strategies for used water source control; and the resiliency and reliability of wastewater treatment operations.
Managing Coastal Biodiversity under Urbanisation Pressures	The course discusses the impact of climate change on coastal ecosystems, and Singapore's approach to protecting coastal biodiversity.

Additionally, Singapore is supporting regional efforts to build and enhance climate resilience. Singapore has committed US$3.7 million over five years (2018 to 2022) through the Association of Southeast Asian Nations (ASEAN) Specialised Meteorological Centre (ASMC) to help build capabilities in weather and climate forecasting. Through the ASMC, Singapore has contributed to many capacity-building workshops, such as the ASEAN Regional Climate Data Analysis and Prediction (ARCDAP) workshop series.

B — Technology Collaboration

Singapore is keen to collaborate with ASEAN and Asia-Pacific neighbours on climate science, as well as on the implementation of climate adaptation solutions. One potential area for collaboration is in studying sea level rise. Sea level rise varies from region to region, and ASEAN countries will benefit by building up capabilities in understanding regional sea level rise. Singapore currently runs a National Sea Level Programme (NSLP), which coordinates research among Institutes of Higher Learning in Singapore, and partners with overseas research partners, to model regional sea level rise. The NSLP's findings could guide coastal protection efforts within the region.

Singapore will contribute data from the Third National Climate Change Study to the Coordinated Regional Downscaling Experiment for the Southeast Asia Region (CORDEX-Southeast Asia), a World Climate Research Programme (WCRP) framework to evaluate regional climate model performance through a set of experiments. This will be done through sharing downscaled climate projections over the CORDEX-Southeast Asia domain at 8 km resolution within the region, which will provide useful climate parameters for regional countries for use in their climate adaptation planning.

C — Financial Assistance

Together with Japan and the World Bank, Singapore supported the establishment of the Southeast Asia Disaster Risk Insurance Facility (SEADRIF) under the ASEAN+3 finance process, to enable ASEAN countries to access disaster risk financing solutions and increase financial resilience to climate and disaster risks. SEADRIF launched its first product in February 2021, a sovereign flood risk insurance product that provides cover against flood risks in Lao People's Democratic Republic (Lao PDR).

Finally, Singapore seeks to support the channelling of capital towards climate-resilient development. Presently, Singapore is Southeast Asia's largest market for green and sustainability-linked bonds and loans, accounting for about half the market. The Singapore public sector is set to issue up to S$35 billion of green bonds to finance its sustainable infrastructure projects by 2030, including the recent issuance of Singapore's inaugural S$2.4 billion sovereign green bond in August 2022. The Monetary Authority of Singapore (MAS) has launched the Green Finance Action Plan which supports strategies such as the mainstreaming of green and sustainable financing and development of capabilities to originate sustainable financing solutions. MAS also has a US$2 billion Green Investments Programme to catalyse sustainable investment capabilities in the region.

Climate Resilience and Sustainable Development Goals

The IPCC Working Group II Report on Impacts, Adaptation and Vulnerability laid out a clear framework for achieving Climate Resilient Development (CRD). The report identified five key system transitions and transformations in (i) energy, (ii) industry, (iii) urban, rural and infrastructure, (iv) land, ocean, coastal, and freshwater ecosystems, and (v) societal systems, needed for CRD, with participation from all stakeholders.

The report also clearly highlighted the strong links between different climate responses and adaptation options with the 17 Sustainable Development Goals (SDGs). For example, adaptation measures like integrated coastal zone management have strong co-benefits with achieving multiple SDGs.

Adaptation actions, capability support and sharing of good practices through multilateral or bilateral agreements can improve knowledge and awareness of how to better mitigate and adapt to climate change. These efforts can further enhance international frameworks such as the Sendai Framework for DRR.

Future Plans

Singapore takes a proactive, long-term approach towards climate change adaptation – our adaptation efforts help us fulfil our obligations under the Paris Agreement and achieve the goals of the 2030 Agenda for Sustainable Development. Singapore will build on current efforts and review and adjust our policies and plans as new knowledge and information on the effects of climate change become available. With the release of future Assessment Reports by IPCC, it is necessary to leverage global and regional-level findings and translate them at the national level to update our knowledge and resilience plans. Singapore will do this through the future National Climate Change Studies.

Climate change resilience goes beyond physical adaptation, and must involve the entire community. The private sector will need to review their business continuity plans to cater for short-term disruptions caused by extreme weather events, while Singaporeans need to be mentally prepared for a changing environment. Making early adjustments will make this transition easier.

Singapore expresses support for Egypt's presidency and its efforts to achieve a successful COP-27, during Senior Minister Teo Chee Hean meeting with Egypt's Minister for the Environment, Dr. Yasmin Fouad in September 2022, Cairo, Egypt.

INTERNATIONAL COOPERATION

Singapore strongly believes that the sharing of best practices has a multiplier effect, and we do so through the Singapore Cooperation Programme.

Climate change is an existential threat to mankind. The international community must work together if we are to effectively address the impact of climate change, and every country will need to play its part. As a responsible global citizen, Singapore is actively working at the international, regional, and bilateral levels to support efforts to address the challenges of climate change.

International Cooperation

The UNFCCC and the Paris Agreement provide the basis for governments to cooperate and address climate change. Singapore is a strong advocate for the multilateral rules-based system, which the UNFCCC and the Paris Agreement are part of. We ratified the UNFCCC in 1997, acceded to the Kyoto Protocol in 2006, and ratified the Paris Agreement in September 2016. We were one of the first 55 Parties to ratify the Paris Agreement, thereby contributing to its early entry into force on 4 November 2016.

Under the Paris Agreement, we submitted our enhanced 2030 NDC and LEDS to the UNFCCC Secretariat on 31 March 2020, notwithstanding the challenging circumstances posed by the COVID-19 pandemic. We were one of the first 20 countries to do so.

Following the adoption of the Glasgow Climate Pact last year, Singapore will raise our ambition to achieve net zero emissions by 2050. To enable the transition to a low-carbon future, we will raise our carbon tax levels progressively from 2024, from S$5 or US$3.70 per tonne of emissions currently to S$25 or US$18.40 per tonne in 2024 and 2025, and S$45 or US$33.20 per tonne in 2026 and 2027, with a view to reaching S$50–80 or US$36.90–59.00 per tonne by 2030.

We participate actively and constructively in negotiations at the annual UNFCCC Conference of the Parties (COP) and work with all Parties to push for ambitious, balanced, and mutually acceptable outcomes. This includes co-facilitating Ministerial negotiations on key issues at COP at the request of COP Presidencies. For instance, Singapore co-facilitated Ministerial consultations on the topic of 'differentiation' at COP-21 in Paris, on 'mitigation' at COP-24 in Katowice, and the overarching cover decisions at COP-25 in Madrid. At COP-26 in Glasgow, Singapore co-facilitated Ministerial consultations on the key issue of Article 6 of the Paris Agreement on carbon market rules and helped guide discussions towards a successful outcome. Singapore joined the following global initiatives at COP-26, in support of global climate action: Powering Past Coal Alliance, Global Methane Pledge, Greening Government Initiative, Agriculture Innovation Mission for Climate, and the Glasgow Leaders' Declaration on Forests and Land Use.

As part of our support for a multilateral response to climate change, Singapore has participated in, and contributed experts to the working groups convened by other multilateral organisations.

As a member of the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO), and their Councils, Singapore contributes to their efforts to mitigate international aviation and maritime transport emissions. We actively support the development of ICAO's holistic strategy and measures to mitigate international aviation emissions, including technologies, operational improvements, ICAO's market-based measure (CORSIA)[13], and sustainable aviation fuels. Singapore also actively supports the development of the IMO Strategy on the Reduction of GHG Emissions from Ships, and the work on short, medium and long-term technical, market-based and other measures.

[13]CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation.

In addition to implementing IMO and ICAO's standards and requirements on international transport emissions, the Singapore aviation and maritime transport sectors voluntarily take measures to mitigate these emissions.

On international aviation, Singapore submitted early our State Action Plan to ICAO, and regularly updates it. Singapore's air navigation service provider implements air traffic management (ATM) measures, with state-of-the-art technologies and through partnerships, which enhance the efficiency and reduce the emissions of over 660,000 aircraft movements in the Singapore Flight Information Region. Singapore carriers are modernising their fleets with more fuel-efficient aircraft and engines, conducting more efficient flight operations and flight trials using sustainable aviation fuels, and adopting best practices in aircraft and engine maintenance. Singapore is currently developing a Sustainable Air Hub Blueprint, which will be published next year.

On maritime transport, Singapore launched the 'Maritime Singapore Decarbonisation Blueprint: Working Towards 2050' in March 2022. The Blueprint, developed in consultation with industry leaders, charts ambitious and concrete strategies to build a sustainable Maritime Singapore.

Singapore earlier launched the Maritime Singapore Green Initiative (MSGI) to reduce the environmental impact of shipping and shipping-related activities on the coastal and marine environment, with an initial funding pledge by the Maritime and Port Authority (MPA) of S$100 million (US$74 million) over five years. The MSGI has since been extended and further enhanced. Stakeholders are encouraged to adopt environmentally-friendly practices and reduce the environmental impact of operations through voluntary programmes. The MSGI also supports local maritime technology companies in developing and deploying green technologies through co-funding grants. MPA has set aside S$6 million (US$4.44 million) to support the building of liquefied natural gas (LNG) bunker vessels to enable ship-to-ship LNG bunkering operations.

MPA, the Port of Rotterdam and the Ministry of Land, Infrastructure, Transport and Tourism of Japan signed a Memorandum of Cooperation in October 2020 to form the Future Fuels Port Network (FFPN). The FFPN aims to explore the harmonisation of standards for future marine fuels, such as ammonia, including by coordinating joint bunkering pilot runs with identified shipping lines between ports.

We have also engaged and collaborated with other UN agencies and programmes on initiatives to address climate change. For example, BCA has been working closely with UN Environment Programme (UNEP) to promote standards for sustainable buildings in the region. The Global Alliance for Buildings and Construction for Climate (GlobalABC) is a joint initiative by the French Government and UNEP in 2015 to work towards the Paris Agreement goals. Launched at COP-21, GlobalABC is a major international initiative that aims to increase the pace and scale of this transformation through scaling up climate actions in the sector by mobilising all stakeholders, including member states and non-state actors from the buildings and construction sector.
As part of knowledge exchange and efforts to shape the global green agenda, BCA has been contributing to GlobalABC's Global Status Report, which keeps track of progress in climate change policies and initiatives. At the invitation of UNEP, BCA and the Singapore Green Building Council also joined a discussion in July 2021 on the role of finance in making the construction value chain more sustainable as part of UNEP's series of expert workshops focusing on the construction sector, and shared briefly on the Singapore Green Building Masterplan (SGBMP) and green financing.

Singapore's NRF set up the Campus for Research Excellence and Technological Enterprise (CREATE) in 2007 as an international campus to forge partnerships between Singapore's universities and research institutions, and leading overseas research institutions. Today, the campus co-locates researchers from the Massachusetts Institute of Technology (MIT), University of California Berkeley (UCB), Cambridge University, ETH Zurich, Technical University of Munich (TUM), Hebrew University of Jerusalem (HUJ), Shanghai Jiao Tong University (SJTU), University of Illinois at Urbana Champaign (UIUC), CNRS (the French National Centre for Scientific Research), National University of Singapore (NUS), and Nanyang Technological University (NTU) to conduct interdisciplinary research in areas such as urban design and mobility, environmental sensing and modelling, and low-carbon research.

Participants visiting the Earth Observatory of Singapore to gain a deeper understanding of climate change, and natural hazards and threats during the “Climate Change and Emerging Threats” course under the SCP.

Promoting Standards for Environmentally Friendly Buildings

The Green Mark (GM) certification programme was initiated by BCA in 2005 to encourage the design and construction of more environmentally friendly buildings. Since then, GM has become one of the benchmarks for sustainable building designs and operational practices in Southeast Asia and beyond.

As of 31 December 2021, close to 340 applications for GM certification have been received from 16 countries. In recognition of Singapore's leadership in promoting green building policies and sustainable built environments, BCA has been accorded several international awards:

i. The Aspen Institute Energy and Environment Award (Government) – 2010;
ii. The World Green Building Council Government Leadership Award (Regional Leadership) – 2011; and
iii. The International (I-Star) Energy Efficiency Award – 2013.

In a study conducted by Solidiance (a consultancy firm) in 2016, Singapore was ranked 2nd among global cities, including Paris, London, New York and Sydney, when assessed for green building performance across a range of categories, such as building efficiency and performance, and green building policies and targets. Moving forward, we will pursue more ambitious sustainability standards under the SGBMP to pave the way for a low-carbon built environment.

Regional Cooperation

ASEAN Member States continue to be particularly vulnerable to the impact of climate change. Emerging from the COVID-19 pandemic, the region has been working towards a green economic recovery and intensifying efforts to address climate change. At the 37th ASEAN Summit in 2020, ASEAN Leaders adopted the ASEAN Comprehensive Recovery Framework (ACRF) and its Implementation Plan, which placed green recovery front and centre in the region's economic recovery.

Key focus areas in the ACRF include energy transition, green infrastructure, sustainable/responsible investment, disaster risk and management, and sustainable consumption and production. In addition, existing efforts and initiatives such as the ASEAN Sustainable Consumption Framework and the establishment of the ASEAN Circular Economy Stakeholder Platform have also been accelerated.

An example of ASEAN+3 cooperation in disaster risk management is SEADRIF, which provides ex-ante climate and disaster risk solutions to ASEAN Member States. SEADRIF, an ASEAN+3 initiative in partnership with the World Bank, is the first regional catastrophe risk facility established in Asia.[14] The SEADRIF Insurance Company, domiciled and licensed in Singapore, issued its first product in February 2021. SEADRIF is conceptualising its second product, a Public Asset Financial Protection Programme which will allow SEADRIF member countries to better manage the financial risk from damage to public assets and infrastructure.

ASEAN Member States are committed to working towards a climate-resilient ASEAN through the implementation of the updated ASEAN Working Group on Climate Change (AWGCC) Action Plan 2019–2025 (AAP), which aims to deliver capacity-building programmes and technical exchanges in eight core themes, namely: (a) climate change adaptation; (b) long-term planning and assessment of NDCs; (c) climate change mitigation; (d) climate modelling and assessment; (e) measurement, reporting and verification (MRV) and stocktake of GHG emissions; (f) climate financing and market; (g) cross sectoral coordination; and (h) technology transfer.

Some of the expected outcomes from these projects and activities include: (a) strengthening ASEAN Member States' capacity to implement NDCs; and (b) building ASEAN Member States' capacity on carbon pricing, and laying the foundation for possible cooperation on carbon pricing at the regional level. Singapore is working with implementing agencies on the following projects in the AAP:

Project Title	Implementation Agency	Status	Description
Southeast Asia Network for Enhancing Climate Transparency	UNEP Copenhagen Climate Centre	Completed in 2021	This project was part of the Global Support Programme (GSP), a Global Environment Facility (GEF) project jointly implemented by UNEP and the United Nations Development Programme (UNDP), to support developing countries on NCs, GHG inventories, Mitigation and Vulnerability and Adaptation (V&A) analysis, and BURs. The scope of this project in Southeast Asia was to: • Develop a Southeast Asian network for climate transparency • Provide technical backstopping, tools and targeted guidance, training on transparency reporting • Support Southeast Asian countries in preparing NCs, BURs and Biennial Transparency Reports (BTRs) • Provide peer reviews of NCs, BUR and GHG inventories • Provide assistance to strengthen national institutional arrangements on MRV. UNEP Copenhagen Climate Centre, in collaboration with Singapore's NEA, accomplished the deliverables in 2021 through the AWGCC platform.
Partnership to Strengthen Transparency for co-Innovation (PaSTI) and the Japan-ASEAN Integration Fund (JAIF) Phase 2 – Development and implementation of facility level Monitoring and Reporting (M&R) framework for GHG emissions in ASEAN Member States	Overseas Environmental Cooperation Centre (OECC) Japan	Ongoing	Phase 1 of the project conducted a needs assessment and developed an implementation roadmap for harmonised facility-level M&R systems across ASEAN Member States. Phase 1 was completed in Sept 2020. Phase 2 of the project entails establishing the M&R system and testing it at selected facilities in interested ASEAN Member States. This is expected to be a 12-month project, and was launched at the PaSTI side event at the Japan pavilion at COP-26 on 12 November 2021.

As ASEAN-EU (European Union) Country Coordinator for the period 2018–2021, Singapore has worked with the EU to launch a High-Level Dialogue on Environment and Climate Change in July 2019 to enhance cooperation between ASEAN and the EU on shared regional and global challenges related to the protection of the environment and climate change. The areas of cooperation discussed include climate mitigation and adaptation, long-term strategies, and sustainable finance.

As country coordinator for the ASEAN-US Energy Cooperation, Singapore works closely with the US to enhance regional energy cooperation in areas such as energy security and resiliency,

Singapore Minister for Sustainability and the Environment, Ms Grace Fu, co-facilitating Ministerial consultations on Article 6 of the Paris Agreement at COP-26 in Glasgow.

renewable energy technologies, and energy market integration to support the goals set out in the ASEAN Plan of Action on Energy Cooperation (APAEC) 2016–2025. To this end, the US and Singapore draw on each other's expertise and experience to develop innovative capacity-building programmes such as the ASEAN-US Workshop on Decarbonisation and the Renewable Energy Workshop under the Singapore-US Third Country Training Programme (TCTP), to promote and facilitate the sharing of best practices.

As Chairman of the ASEAN Working Group on Chemicals and Waste for the period 2019–2022, Singapore has been working closely with ASEAN Member States to develop technical guidelines on plastic waste in the ASEAN region. Singapore shepherded the submission of an ASEAN Joint Statement on Chemicals and Waste for the 2021 Meetings of the Conferences of the Parties to the Basel, Rotterdam and Stockholm Conventions, which took place between 26 and 30 July 2021.

As a small city-state, Singapore faces challenges common to cities in adapting to climate change. To share our experience and facilitate discussions on these issues, Singapore has initiated and hosted the World Cities Summit (WCS), Clean Enviro Summit Singapore (CESG), the Singapore International Water Week (SIWW), and the Singapore International Energy Week (SIEW). These international conferences are part of our efforts to bring policy makers and stakeholders in city planning, environment, water and energy management together to examine urban challenges, and identify shared solutions and best practices in areas such as sustainable urban planning, water and waste management, climate resilience and energy transitions.

The 9th edition of SIWW and 5th edition of CESG were jointly organised in April 2022 to foster collaboration and partnership amongst environment and water leaders. Both events hosted over 15,000 delegates and visitors from 65 countries, and 300 participating exhibitors. Key topics such as climate mitigation and adaptation, resource circularity, net zero and decarbonisation, waste as a resource, sustainable energy, climate resilience and enhanced hygiene standards were discussed at the Water Leaders Summit, Clean Environment Leaders Summit and other co-located events. The 8th edition of the WCS in August 2022 attracted around 2,500 mayors and city leaders, senior government officials, industry experts, and trade visitors. 72 senior delegates representing 65 cities discussed how cities could emerge stronger from disruptions like the pandemic and the impact of climate change. Dedicated sessions focused on the challenges from climate change and facilitated exchange of knowledge and system-wide solutions to decarbonisation and climate change adaptation in cities.

Now in its 15th year, SIEW brings together key government and industry leaders through sessions such as the Singapore Energy Lecture and the Singapore Energy Summit to share best practices and solutions to move towards global energy transition.

Singapore actively participates in the C40 Cities Climate Leadership Group (C40). The C40 is a network of 97 cities committed to addressing climate change globally by implementing sustainable climate-related actions locally. Our involvement in the C40 allows us to share our experience in sustainable development through webinars, by hosting study trips, and through actively participating at mayor-level forums. Likewise, C40 enables Singapore to learn from the best practices of other major cities.

In 2016, Singapore hosted a high-level C40 event, "From Ambition to Action: The Vital Role of Cities in Achieving the Paris Agreement," which brought together C40 mayors and city experts from around the world to discuss the climate actions they were taking and the key challenges they faced. In 2019, then-Minister of State (National Development) and Minister of State (Manpower) Zaqy Mohamad led the Singapore delegation at the C40 World Mayors Summit in Copenhagen.

To advance scientific understanding of the tropical climate variability affecting Singapore and the wider Southeast Asia region, Singapore established the CCRS in 2013. The CCRS builds local capabilities in tropical weather and climate science research, and fosters research partnerships at the national, regional, and broader international levels. CCRS, in collaboration with the ASMC, has organised capability-building programmes for ASEAN Member States on seasonal prediction and climate change projection. This includes the ARCDAP workshop series, which has supported ASEAN Member States in making climate assessments, and in turn informs policy formulation and decision-making processes. The ASMC has also been organising biannual runs of the ASEAN Climate Outlook Forum (ASEANCOF), which provides National Meteorological and Hydrological Services in Southeast Asia and offers international experts a platform to discuss the regional climate outlook for the two main monsoon seasons in Southeast Asia.

As of March 2022, three ARCDAP workshops involving more than 130 participants and 17 runs of ASEANCOF have been conducted. In February 2022, CCRS became a core member of the 'Unified Model' Consortium, contributing to the collaborative development of weather and climate modelling capabilities alongside partners such as the United Kingdom and Australia.

Bilateral Cooperation

Singapore actively collaborates with countries to build on one another's strengths in addressing climate change, and to provide capacity building to developing countries on related issues. At the

bilateral level, Singapore has provided technical assistance and capacity-building support to officials from fellow developing countries since 1992 on various climate-related issues. These programmes are organised under the SCP, our flagship technical assistance programme. To date, over 137,000 participants from more than 180 countries, territories, and intergovernmental organisations have attended SCP training courses on topics such as sustainable urban development, water management, emissions reduction, and DRR.

Renewing our commitment to support efforts in addressing climate change and its impact, Singapore launched a CAP at the Special ASEAN Ministerial Meeting on Climate Action in July 2018. This package is tailored for fellow developing countries, in particular the SIDS and the Least Developed Countries (LDCs), and focuses on climate-related areas such as climate science, climate adaptation and mitigation strategies, DRR, green finance, and the implementation of the Paris Agreement.

Where possible, Singapore works with developed country partners and international organisations under the CAP to pool expertise and resources. For example, we partnered New Zealand to organise a CAP workshop on decoding the Paris Rulebook in Southeast Asia and collaborated with the NDC Partnership, the UNFCCC Secretariat, and the 2050 Pathways Platform to organise a workshop for ASEAN Member States to discuss opportunities, challenges, and options to enhance and implement their NDCs. Following positive feedback, the CAP was extended to 2023.

To strengthen our global collaboration efforts, we have commenced negotiations on a bilateral Green Economy Agreement (GEA) with Australia, which will be a world-first agreement that combines trade, economic, and environment objectives. Singapore has also signed Memoranda of Understanding (MOU) with countries such as Australia, Chile, New Zealand, Indonesia, and Japan to collaborate on areas such as regional power grids, and low-carbon solutions such as hydrogen and carbon capture, utilisation and storage (CCUS).

Regional Capacity Building Workshop on ‘Enhancing Nationally Determined Contributions’

Singapore, in collaboration with the NDC Partnership, UNFCCC Secretariat, and the 2050 Pathways Platform, organised a workshop on ‘Enhancing NDCs’ from 13 to 15 January 2020. The workshop, an initiative under our Singapore Cooperation Programme’s CAP, was attended by representatives from ASEAN Member States. Participants benefitted from the practical sharing and hands-on training sessions led by the UNFCCC Secretariat to implement and enhance their countries’ NDCs in accordance with the Katowice guidance on information to facilitate clarity, transparency and understanding (ICTU), as well as the accounting and tracking of progress in implementing the countries’ NDCs. The workshop also provided a platform for participants to discuss opportunities, challenges, and options to enhance and implement their NDCs and prepare their LEDS.

Highlights of the Climate Action Package

No.	Course Name	Partnerships	Course dates/ duration	Course Description
1	Workshop on Introducing Impact-Based Forecast and Warning Service	Singapore-US TCTP	Week-long programme in December 2021	The course aimed to introduce the concepts and demonstrate the value of implementing a country-coordinated impact-based forecast and warning service (IBFWS) to mitigate risk from weather and climate related hazards.
2	Introduction to DRR	UNDRR	Two-week long programme in April/May 2021	The course examined key principles of DRR and the hardcoding of resilience into policy, implementation action and human behaviour. The course also covered Singapore’s experiences in DRR and its WOG approach in formulating adaptation measures and building resilience in the community.
3	Sustainable Integrated Water Resources and Stormwater Management	UNICEF	Two-week long programme in November 2021	The course discussed approaches to integrated water resources and stormwater management, urban sanitation, drinking water quality monitoring, innovative financing, and knowledge management to deal with the extreme weather conditions brought on by climate change.
4	Managing Coastal Biodiversity under Urbanisation Pressures	SCP Training Award	Week-long virtual programme in October 2019 and July 2021	The course shared Singapore’s approach to the protection and management of coastal biodiversity in the face of intense urbanisation. It also discussed the impact of climate change on achieving SDGs in the context of coastal ecosystem services.
5	Environmental Conservation and Sustainability	SCP Training Award	Week-long programme in May 2019 and August 2021	The course aimed to equip the participants with knowledge on addressing issues on environmental conservation, coastal population, and urbanisation.
6	Clean Energy and Emission Reduction	SCP Training Award	Week-long programme in September 2019 and May 2021	The course enabled the participants to gain an understanding of Singapore’s multi-agency engagement in formulating energy solutions to climate change; to achieve a better appreciation of issues surrounding climate change and the importance of collective mitigating actions taken on a global scale; and to understand the types of clean and renewable sources of energy and the related technical principles.
7	Sustainable Waste Management and Smart Urbanisation	SCP Training Award	Week-long programme in January 2021 and February 2022	This course provided insights to Singapore’s multi-agency collaboration in formulating and implementing nature-based solutions (NBS) and closing the waste loop to enhance urban resilience. It also addressed issues related to urbanisation in the context of evolving challenges brought about by climate change.
8	Climate Change Adaptation and Mitigation Strategies	SCP Training Award	Week-long programme in September 2019 and March 2022	The course enabled the participants to focus on ways to mitigate environmental challenges that arise from climate change, and to gain insights into the various adaptation and mitigation strategies that could be adopted to tackle climate change.

NATIONAL CIRCUMSTANCES

Under the Singapore Green Plan 2030, Singapore is implementing innovative measures to develop a green and more sustainable home for our people. The Green Plan also sets out our approach on adapting to the impact of climate change, as well as reducing emissions.

COUNTRY PROFILE

Singapore is a small, low-lying island-state in Southeast Asia and consists of one main island and more than 60 smaller ones. It is located between latitudes 1°09'N and 1°29'N and longitudes 103°36'E and 104°25'E, approximately 137 km north of the Equator. It is separated from Peninsular Malaysia by the Straits of Johor, and the Indonesian islands by the Straits of Singapore.

Land Area

The main island of Singapore is about 49 km east to west and 28 km from north to south. The total land area (including that of smaller islands) is about 733.1 km^2. Among the smaller islands, the larger ones are Pulau Tekong (26.7 km^2), Pulau Ubin (10.2 km^2), and Sentosa (4.8 km^2). Singapore's surface reaches 163 m at our highest point. Much of Singapore is generally flat and less than 15 m above sea level, as defined by the Singapore Height Datum (SHD).[14]

Climate

Singapore is situated near the equator and has a tropical climate, with relatively high and uniform temperatures, abundant rainfall, and high humidity throughout the year. Singapore's climate is characterised by two monsoon seasons separated by inter-monsoon periods. The Northeast Monsoon occurs from December to early March, and the comparatively drier Southwest Monsoon from June to September. The early part of the Northeast Monsoon (December to January) is the wetter period of the year when monsoon surges occur, which can bring prolonged heavy rain to Singapore. The later part of the Northeast Monsoon (February to early March) is usually much drier, with February being the driest month of the year. Afternoon thunderstorms with frequent lightning are common throughout the year, especially during the inter-monsoon periods from late March to May, and October to November. During the Southwest Monsoon and inter-monsoon periods, widespread heavy rain and gusty winds associated with Sumatra squalls also occur occasionally. Singapore's long-term (1991–2020)[15] annual mean temperature is 27.8 °C, with average daily maximum and minimum temperatures of 31.6 °C and 25.0 °C respectively. The long-term average annual rainfall is 2,113.3 mm.

Recent Trends

Observations by MSS showed that Singapore's annual mean temperature has risen at an average rate of 0.2–0.3 °C per decade since 1980. Four of the past seven years (2015, 2016, 2018, and 2019) are also among the top 10 warmest years on record with respect to the annual mean temperature. In the last two years, there was a slight moderation in Singapore's annual mean temperature (28.0 °C and 27.9 °C in 2020 and 2021 respectively) due to wetter weather conditions. Well-above average annual total rainfall of 2,809.6 mm was recorded in 2021, resulting in the second wettest year since 1980.

Population

As of June 2021, Singapore's total population, including foreigners working in Singapore, was estimated at 5.46 million. In total, there were 3.99 million residents. Non-residents totalled 1.47 million, and include our foreign workforce across all pass types, dependants, and international students. Singapore's small land area also means that our population density of about 7,485 persons per km^2 is one of the highest in the world.

Economy

Singapore is an export-oriented economy that is highly dependent on international trade.In 2021, in nominal terms, Singapore's external merchandise trade amounted to S$1,160 billion or US$863 billion, more than two times its gross domestic product (GDP) (S$533 billion or US$397 billion). Over several decades, Singapore has built up a strong economy where manufacturing, wholesale trade, and finance and insurance sectors each comprised around 22.3%, 17.9%, and 14.6% of the economy respectively, in 2021. Singapore's small domestic market has necessitated an export-oriented economy, with the bulk of our industries manufacturing products for export rather than local consumption. For example, Singapore is one of the five largest export refining centres in the world, and our three refineries produce primarily for global export. Oil made up around 14% of our total merchandise exports in 2021. Singapore's strategic geographical location has also enabled it to develop into a major air and sea transportation hub. The economic structure in 2021 is as shown.

Economic Structure, 2021
(Nominal Value Added Share, %)

	%
Manufacturing	22.3
Construction	2.9
Utilities	1.2
Other Goods Industries	0.0
Wholesale Trade	17.9
Retail Trade	1.4
Transportation & Storage	6.1
Accommodation	0.5
Food & Beverage Services	0.9
Information & Communications	5.6
Finance & Insurance	14.6
Real Estate	2.9
Professional Services	5.8
Administrative & Support Services	3.6
Other Service Industries	10.5
Ownership of Dwellings	3.8

Water

To ensure water sustainability, Singapore has developed a diversified and robust supply of water from four sources known as the "Four National Taps", namely water from local catchment, imported water, high-grade reclaimed water known as NEWater, and desalinated water.

Since 2011, the total water catchment area has increased from half to two-thirds of Singapore's land surface with the completion of three reservoirs in urbanised areas. Despite our best efforts to maximise water supply from our local catchments, Singapore is still physically limited by our small land area, while demand for water continues to increase in tandem with economic and population growth. Water demand is expected to almost double by 2060.

NEWater and desalinated water are independent of rainfall, and thus greatly enhance the resiliency of our water sources against dry weather. However, the production of these two sources is more energy-intensive than treating raw water from local catchment. PUB has been investing in R&D to improve the energy efficiency of our water production. For instance, biomimetic membrane technology (which mimics the way plants and animals extract freshwater from saline water), is being engineered and scaled up to reduce the energy needed for membrane-based water purification processes. Another research priority is pressure-retarded osmosis, which recovers energy from the waste streams of seawater desalination and NEWater production. Combining these technologies will lower the energy demand for water production at a systems level. These low-energy solutions will take time to develop and mature before they can be fully deployed.

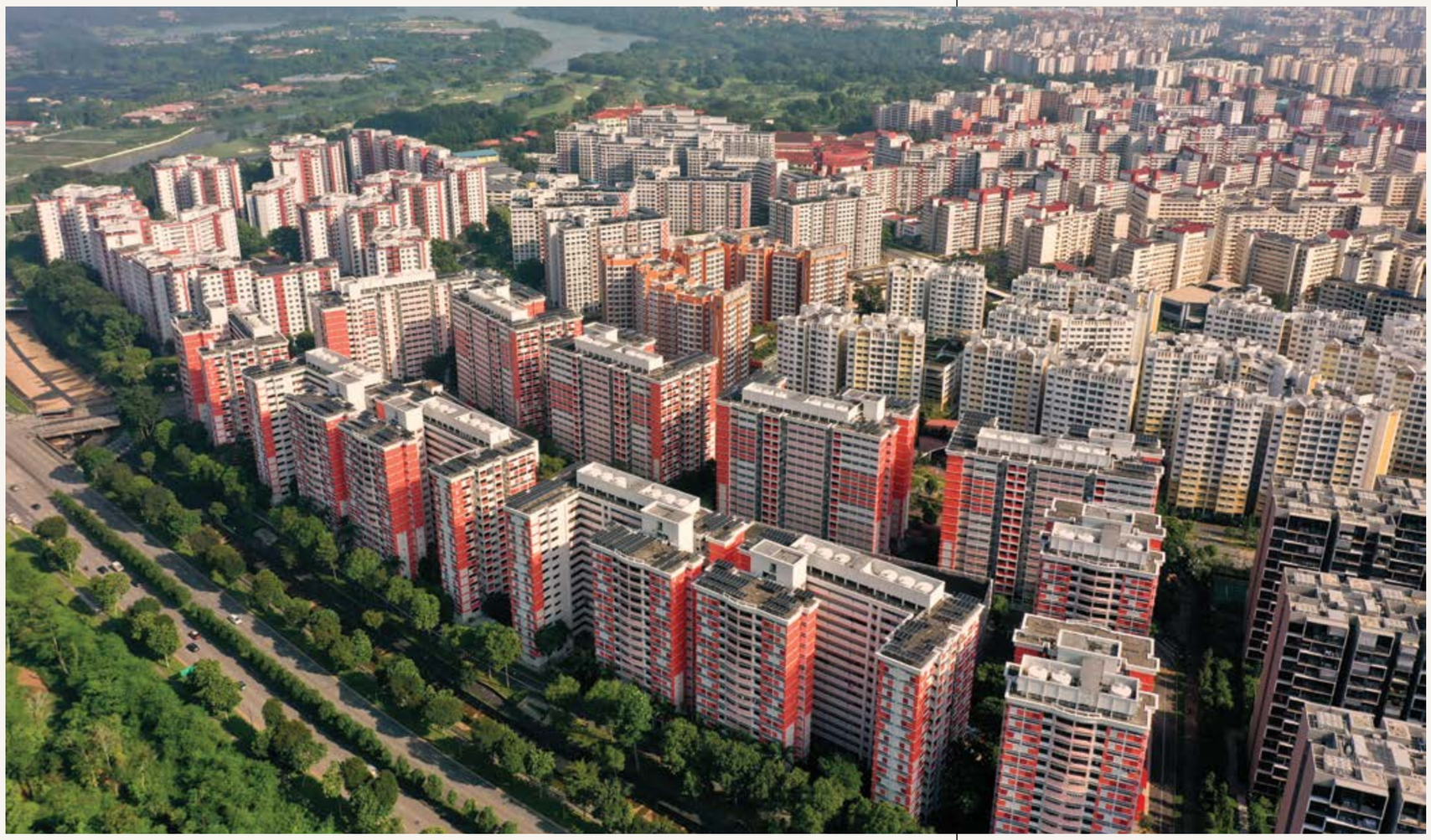
Managing demand is equally essential to ensuring a sustainable water supply. Singapore adopts a multi-pronged approach in managing its water demand: pricing water to reflect its scarcity value, mandating water efficiency standards, and public education on water conservation practices. Through these wide-ranging measures, Singapore's per capita domestic water consumption was reduced from 165 litres per day in 2000 to 141 litres per day in 2019.[16] Through PUB's efforts in water network management, Singapore had a distribution loss of 8.0% in 2020. The number of water pipeline leaks in Singapore, at 3.8 leaks/100 km of pipelines per year, is low compared to other countries.

NATIONAL CIRCUMSTANCES AND CONSTRAINTS

For small island-states 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 impact of climate change on us is disproportionately large.

[14]The SHD is defined as the mean sea level determined at Victoria Dock in Singapore between 1935 and 1937.
[15]The World Meteorological Organization defines climate as the average state of the weather over a period of 30 years or more. Climate statistics are based on a 30-year reference period that is updated every 10 years, with 1991–2020 as the current reference period.

[16]This figure rose to 154 litres per day in 2020 due to the COVID-19 pandemic, which resulted in people spending more time at home because of work from home and home-based learning arrangements, and increase in frequency of cleaning in homes.



High-rise, high-density developments are a common feature of Singapore's public housing. 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.

Despite the unique challenges and constraints faced as a dense built-up city-state with no hinterland and limited resources, Singapore is committed to doing our part in the global fight against climate change. We will continue to build on a long-standing and comprehensive national approach that seeks to achieve sustainable growth alongside environmental protection. As we work towards a low-carbon future, the extent of emissions reduction from our climate strategy will depend on our national circumstances, past mitigation efforts, and geographical constraints which limit our access to renewable energy at scale.

Historically, our strategic geographical position along the East-West trade routes has made Singapore a natural location for oil storage and refining facilities serving the region. Building on our position as a key regional port, the refining and petrochemical plants help create synergies and are part of a business supply network in Southeast Asia, the Western Pacific, South Asia, and Australasia. The refining and petrochemical export sector is a large source of our carbon emissions and Singapore has been working to improve energy efficiency in this sector. This is an ongoing effort.

CLIMATE VULNERABILITIES

The IPCC AR6 on the Physical Science Basis of Climate Change released in August 2021 states that Southeast Asia as a broad region will experience an increase in mean temperature, increase in extreme heat, increase in mean precipitation, and flooding caused by extreme rainfall events. According to the subsequent IPCC AR6 on Impacts, Adaptation and Vulnerability released in February 2022, coastal cities and settlements, like Singapore, are at the forefront of climate risk. The report highlighted the increased exposure to climate-driven hazards, such as rising temperatures and the UHI, and distinctive ocean-driven hazards such as rising mean sea levels, exposure to storm surges, and flooding from extreme tides.

Although our impact on global emissions is small, our exposure to climate risks and climate change impacts is disproportionately large, as a result of our geography.

Singapore's vulnerability to climate change will require the Government to pursue a comprehensive adaptation programme to protect our coasts, low-lying areas, and communities.[17] These adaptation actions will impose significant fiscal costs.

ALTERNATIVE ENERGY CONSTRAINTS

Singapore has limited land area, relatively flat land, a high urban density, low wind speeds, and lacks conventional geothermal resources. Therefore, harnessing alternative energy sources such as hydroelectric, wind or geothermal power is a major challenge. While solar energy is Singapore's most viable alternative energy option, competing uses for land greatly limit our access to solar energy at scale. It is necessary for us to explore low-carbon alternatives such as hydrogen, CCUS technologies, as well as electricity imports by working with other countries through international collaborations.

Biomass

Biomass, which is used by many countries with available land mass as an alternative to fossil fuel, is not viable as a significant energy resource for Singapore. In addition, combustion of imported solid biomass generates large quantities of ash that need to be repurposed or disposed of. Singapore already converts much of our waste to energy, providing about 2.3% of the total electricity generated in 2020. Nonetheless, we will continue to monitor developments in this area.

Geothermal

Geothermal energy is currently not commercially viable in Singapore, given the lack of conventional geothermal resources. However, there is a possibility for Singapore to harness quality geothermal resources at greater depths.[18] Singapore is embarking on studies to better assess our deep geothermal resource potential. If the studies yield positive results, EMA will explore undertaking further research to determine the viability of deploying advanced or enhanced geothermal systems that utilise deep geothermal heat in Singapore.

[17]Singapore's Climate Action Plan: Take Action Today for a Sustainable Future outlines the impact of climate change on Singapore and Singapore's strategy in reducing GHG emissions.
[18]Source: Academic papers/studies by Graham J.H. Oliver and J. Zhao.

Recognition of National Circumstances in the UNFCCC

The UNFCCC Articles 4.8 and 4.10 call for Parties to take into consideration developing countries' national circumstances – especially small island countries, countries with low-lying coastal areas, land-locked and transit countries, and countries disadvantaged in the use of alternative energy sources, amongst others.

Article 4.8: "Parties shall give full consideration to actions to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of response measures." Three sub-clauses in the article are of specific relevance to Singapore, namely:

4.8 (a) Small island countries
4.8 (b) Countries with low-lying coastal areas
4.8 (h) Countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energy-intensive products

Article 4.10: "The 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.**"

Hydroelectric Power

Hydroelectricity harnesses the energy of flowing water for the generation of electricity. Much of Singapore is generally flat and less than 15 m above sea level, as defined by the SHD. The absence of major river systems means that hydroelectricity is not a viable option in Singapore.

Marine (Tidal and Wave Power)

The tidal range (difference between high and low tide) is about 1.7 m, well below the 4 m tidal range that is typically required for commercial tidal power generation. The availability of wave power is determined by the height and frequency of waves, but the waters around Singapore are relatively calm as we are surrounded by land masses. In addition, wave, tidal and ocean thermal energy have limited application as much of our sea space is used for ports, anchorage, and international shipping lanes.

Nuclear

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

Since the conclusion of the Pre-FS, we have been monitoring the development of safer nuclear energy technologies. Advanced nuclear power plant technologies and designs that are being developed globally have the potential to be much safer than many of the plants that are in operation today. Some of these designs could potentially be suitable for deployment in small and densely populated cities. However, most of these technologies are still undergoing R&D and have not begun commercial operation. Any decision to deploy new technologies will need to be considered against the technology's safety and reliability, affordability, and environmental sustainability. We will continue to monitor developments in nuclear energy, and build capabilities to assess their implications for Singapore.

Wind

Harnessing wind energy is also not viable, given our low average wind speeds of about 2 m/s to 3 m/s and lack of land for large-scale application of wind turbines. Most commercial wind farms leverage average wind speeds of at least 4.5 m/s, while prime wind sites require annual average wind speeds in excess of 7.5 m/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. Singapore has taken proactive steps to facilitate solar deployment through regular reviews to streamline existing regulations and compliance requirements.

The Government has also embarked on the SolarNova Programme, which aggregates demand for solar deployment across public sector buildings and spaces to catalyse the growth of solar energy. The lead demand generated has also helped and will continue to support the solar industry to develop its capabilities. In addition, the Government is actively investing in R&D and test-bedding to lower costs, optimise space utilisation, and improve the efficiency and durability of solar technologies.

As solar deployment increases, we are pursuing solutions to manage the intermittency of solar PV in Singapore's context, to ensure a stable and reliable grid. We will deploy at least 200 MW of energy storage systems (ESS) beyond 2025, and are working with the industry and research community to develop policies and regulations, as well as embark on R&D initiatives and test-beds to grow a vibrant ecosystem and facilitate widespread ESS deployment in Singapore.

PURSUING EMERGING LOW-CARBON SOLUTIONS

CCUS and Hydrogen

Singapore will look into emerging low-carbon solutions such as CCUS and low-carbon hydrogen (as alternative fuel and industrial feedstock), which have the potential to help reduce our carbon footprint.

Large-scale deployment of these low-carbon solutions (LCSs) is currently limited by techno-economic constraints. We will continue to evaluate such technologies, explore possible deployment pathways, and invest in R&D initiatives to accelerate the adoption of potentially viable technologies. For instance, Singapore has launched a S$55 million or US$40.69 million Low-Carbon Energy Research (LCER) Funding Initiative (FI) to support the R&D and piloting of low-carbon technologies, with a focus on CCUS and low-carbon hydrogen, which is part of the Research, Innovation & Enterprise Plan, and we look forward to collaborations with other countries to explore the development of hydrogen.

In 2021, Keppel Data Centres, Chevron, Pan-United, and Surbana Jurong, with the support of our NRF, signed an MOU to accelerate the development of CCUS technologies, such as technologies that utilise cryogens, membranes, and hydrogen. Shell signed a S$4.6 million or US$3.40 million research agreement with NUS, with support from NRF and tthe Economic Development Board (EDB) to jointly develop processes to use CO_2 in the production of ethanol and n-propanol for cleaner fuels.

We have also strengthened international partnerships on the energy front. Singapore is actively forging international partnerships such as with Australia, Chile, China, Indonesia, Japan, Kingdom of Saudi Arabia, New Zealand and the US to advance our collaborations in low-carbon solutions and technologies. Through such partnerships, we aim to collaborate on areas such as the development of standards and certifications for low-carbon hydrogen and joint RD&D (research, development, and deployment) to improve the techno-economic viability of low-carbon technologies.

PURSUIT OF SUSTAINABLE DEVELOPMENT

Singapore has always prioritised environmental issues and pursued the goals of growing the economy and protecting the environment concurrently.

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 2020, natural gas accounted for 95.8% of our electricity generation, with the remainder mainly from waste-to-energy plants and solar PVs. We 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.

To maximise the potential of emission reduction from sectoral measures, Singapore implemented a carbon tax, the first carbon pricing scheme in Southeast Asia, in 2019. In October 2022, we announced that we will raise our ambition to achieve net-zero emissions by 2050, contingent on technological maturity and effective international cooperation. Our ability to fulfil our pledges, like all Parties, will depend on the continued international commitment by Parties to the Paris Agreement and their climate pledges. To enable the transition to a low-carbon future, we will raise the carbon tax levels progressively from 2024, from the current S$5 or US$3.70/tCO_2 eq, to S$25 or US$18.40/tCO_2 eq in 2024 and 2025, and S$45 or US$33.20/tCO_2 eq in 2026 and 2027, with a view to reaching S$50–80 or US$36.90–59.00/tCO_2 eq by 2030.

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 and low-carbon economy. We aim to quadruple our solar deployment by 2025 and plan to import up to four gigawatt (GW) of electricity by 2035, which will make up 30% of our power supply. We also safeguard more than 7,800 ha of green spaces – nature reserves, gardens and parks – across Singapore, and integrate greenery throughout the city.

For Singapore to achieve net zero, we are embarking on a long-term energy transition plan to achieve deep decarbonisation.

Singapore's long-standing pursuit of sustainable development has enabled our carbon intensity to be one of the lowest in the world today. We ranked among the 18 best-performing out of 178 countries in terms of carbon intensity in 2019.[19] We are recognised as Asia's most sustainable city and the fourth most sustainable city globally according to the 2018 Sustainability Cities Index. The Sustainability Cities Index recognises that Singapore is undertaking sustainability initiatives that will create a high-quality living environment, which is resilient and in line with the broader climate change agenda. Singapore has also ranked first in the Global Competitiveness Index in the World Economic Forum (WEF)'s Global Competitiveness Report 2019, underscoring how our sustainability efforts have helped Singapore maintain its competitiveness.

Innovation will be key for Singapore to continue to develop sustainably. We aim to develop an ecosystem of 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.

Despite our constraints and unique circumstances, Singapore is committed to reducing our emissions across all sectors to support global climate action. Details of our mitigation actions are provided in Chapter 4.

The Singapore Green Plan 2030

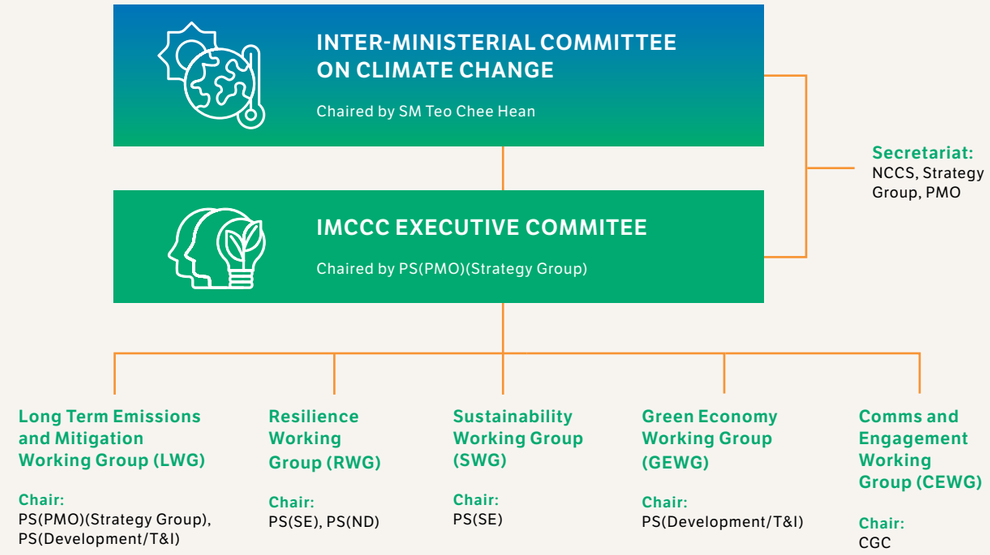
The Green Plan was launched in February 2021, building on past and ongoing sustainability efforts. It is Singapore's roadmap and whole-of-nation movement towards sustainable development and net zero emissions, with concrete sectoral plans and targets that take our commitment to sustainable development to a higher level. It brought together multi-sectoral sustainability efforts, giving focus and momentum to building back greener and stronger.

[19]World CO_2 Indicators, International Energy Agency, 2021.

Green Government and **Green Citizenry** are enablers under the Green Plan. Under Green Government, the Singapore public service is leading the way in Singapore's sustainability journey by setting more ambitious targets and measures for its offices and public infrastructure, and embedding sustainability into core business areas such as procurement. Green Citizenry involves creating space for Singaporeans to participate in the sustainability journey, co-creating and co-delivering solutions for the Green Plan.

The Green Plan is a long-term plan that will evolve, with more ambitious targets and aspirations over time as key technologies mature. The Government will partner businesses, civil society, communities and individuals to make the Green Plan a reality.

INSTITUTIONAL ARRANGEMENTS



The IMCCC oversees the WOG coordination on climate change policies to ensure that Singapore is prepared to address climate change. Established in 2007, the IMCCC is chaired by Mr Teo Chee Hean, Senior Minister and Coordinating Minister for National Security, and includes the Ministers from the following Ministries: Sustainability and the Environment, Finance, Foreign Affairs, National Development, Trade and Industry, as well as Transport.

The IMCCC is supported by an Executive Committee (Exco) comprising Senior Officials from relevant government agencies. The IMCCC Exco oversees the following working groups:

- Long-Term Emissions and Mitigation Working Group (LWG), which develops and oversees the implementation of plans to reduce Singapore's long-term emissions, examines mitigation options, and identifies the capabilities, infrastructure and policies needed for long-term emissions reduction;
- Resilience Working Group (RWG), which studies Singapore's vulnerability to the effects of climate change and develops long-term plans that ensure the nation's resilience to future environmental changes;
- Sustainability Working Group (SWG), which develops the national sustainability agenda to strengthen Singapore's resource resilience, and addresses emerging and cross-cutting issues on sustainability;
- Green Economy Working Group (GEWG), which coordinates and enables the growth of Singapore's green economy, to seize new economic opportunities in sustainability and create good jobs for our workforce; and
- Communications and Engagement Working Group (CEWG), which establishes communications priorities to achieve greater WOG coordination in climate change communications and engagement efforts, and to build consensus on Singapore's climate change plans and targets.

To ensure the effective coordination of Singapore's domestic and international policies, plans, and actions on climate change, NCCS was established as a dedicated unit in July 2010 under PMO. NCCS is part of the Strategy Group which supports the Prime Minister and his Cabinet to establish priorities and strengthen strategic alignment across the Government. The positioning of NCCS underscores the importance that Singapore places on climate change.

Opposite page: A poster about Singapore's Green Plan 2030.

CHAPTER 2

ENHANCING CAPACITIES

Climate change is a global challenge that requires global solutions. Singapore will continue to contribute to this global effort by sharing our experience, practices and expertise in climate change and sustainable development with other countries.

Rays of sunlight filter through glass panes of the Cloud Forest conservatory dome at Gardens by the Bay. The conservatories feature sustainable engineering and advanced energy efficient solutions for cooling.

Singapore recognises the importance of enhancing our capacity for MRV processes, and pursuing ambitious climate actions. Enhancing our technical expertise is an ongoing process, taking into consideration the best available science and technology, as well as our experience from implementing previous programmes.

Given Singapore's unique circumstances and evolving needs, we constantly seek new opportunities to leverage innovative technologies and solutions to address our climate change adaptation and mitigation needs. While Singapore does not rely exclusively on external sources for financial, technical, technological or capacity-building support to address climate change, the Government pursues partnerships with civil society, academia, businesses, and other like-minded countries to co-create solutions that can support Singapore's transition towards a low-carbon, climate-resilient future. We also participate in technical workshops and consult subject experts at the UNFCCC Secretariat, think-tanks, academia, and international organisations to further enhance our MRV processes and climate policies. Having learnt much from these efforts, we continue to pay it forward by sharing our experiences and best practices with fellow developing countries.

MRV CAPACITIES

Singapore has been building its MRV capacities by participating in training programmes organised by the UNFCCC Secretariat, the IPCC, and other expert organisations.

Efforts were undertaken to enhance the transparency of GHG inventory reporting in the following areas:

1 – Inclusion of GHG emissions from Agriculture sector

In 2020, Singapore commissioned a study to develop a Tier 1 estimate of GHG emissions from the Agriculture sector for the year 2018, using default parameter values such as emission and stock change factors prescribed in the 2006 IPCC Guidelines for National GHG Inventories. The estimate is 8.04 $GgCO_2$ eq. More details are provided in Chapter 3 and in the Annex.

2 – Recalculation of GHG time series

In line with the IPCC Good Practice Guidance, Singapore's GHG inventory has been updated in a consistent manner. Where historical data is unavailable, the splicing techniques prescribed in the 2006 IPCC Guidelines, such as extrapolation and the surrogate method, were applied to ensure time series consistency. More details are provided in Chapter 3.

3 – Inclusion of new sectoral reporting tables

For enhanced transparency, Singapore will also be including more sectoral and background reporting tables under Waste and Agriculture, Forestry and Other Land Use (AFOLU) sectors to reflect the guidance from the Team of Technical Experts' (TTE) feedback arising from the Technical Analysis Summary Report (TASR) of our 4th BUR.

Singapore will continue efforts to enhance our MRV capabilities to improve the transparency of our reports. We will continue to build our capacities through participation in technical workshops and the outcomes will be included in future BURs/BTRs.

LAND USE, LAND-USE CHANGE AND FORESTRY

Singapore continues to monitor GHG emissions and removals from the LULUCF sector via wall-to-wall assessment of the land use and land-use changes derived through very high-resolution satellite images, encompassing all land-use categories as well as activity data on the five carbon pools, in accordance

Photovoltaic (PV) panels will be installed on the rooftops of as many HDB blocks as possible to help reduce Singapore's carbon footprint and mitigate the effects of climate change.

with the guidelines defined by the IPCC. Most of the emission factors are obtained from field measurements and modelling. As we proceed to build on the refinements reported in previous BURs, we continue to enhance our data collection and analysis for this sector. In doing so, we have completed our next cycle of field measurements for the national forest inventory, which provides an update to the emission factors and are used in the preparation of this BUR. We have also taken a closer look at processing our satellite images to refine the estimates of our activity data. We continue to build our capacity by providing regular internal training opportunities for technical staff as well as participating in capacity-building workshops to further develop our technical capabilities.

DEVELOPING AN EMISSIONS INVENTORY FOR HFCs BASED ON IPCC TIER 2 METHODOLOGY

In 2018, Singapore developed an interim Tier 1b estimate of HFCs emissions from the RAC sector for the year 2014. The same methodology was used to obtain an estimate for 2018. The estimate is 6.40 $MtCO_2$ eq.[20]

On 1 January 2019, Singapore implemented licensing controls on the HFCs regulated under the Kigali Amendment of the Montreal Protocol. The licensing regime has enabled Singapore to collect more accurate import and export trade data on HFCs. With the new licensing condition, Singapore has been working to develop a Tier 2 estimate of HFCs emissions for data from 2019 onwards, to be included in the national GHG inventory in future reports.

REFERENCE APPROACH AND SECTORAL APPROACH EMISSIONS

As a global trading hub with a high trade to GDP ratio, Singapore experiences volatility in trade data as a direct result of our large and varying trade volumes coupled with the presence of a large refining and petrochemical sector. This gives rise to large discrepancies between emissions calculated using the reference approach and the sectoral approach. As such, emissions calculated using the sectoral approach would be more accurate than using the reference approach in Singapore's context. Singapore is building its capacity to understand the discrepancies through an ongoing study. The results will be included in future reports.

[20] The estimate includes a minute quantity (0.0007 $MtCO_2$ eq) of PFC-116 emissions.

PARKROYAL COLLECTION Pickering Hotel is a lush green oasis in the heart of the business district. Designed by Singapore-based WOHA architects, it contains eco-friendly features such as solar powered systems and rain harvesting, and has achieved the Green Mark Platinum rating.

The "Enhancing Nationally Determined Contributions" workshop held from 13 to 15 January 2020 was attended by representatives from ASEAN Member States and provided a platform for participants to discuss opportunities, challenges, and options to enhance and implement their NDCs and prepare their LEDS.

INTERNATIONAL COOPERATION EFFORTS

Climate change is a global challenge that requires global solutions. Singapore believes that the most effective way we can contribute is through sharing our best practices and expertise in climate change and sustainable development with fellow developing countries. We do this primarily through the SCP, which is our flagship technical assistance programme. Since its establishment in 1992, more than 137,000 officials from over 180 countries and territories have participated in our capacity building programmes. Our SCP programmes are aimed at strengthening countries' ability to implement the 17 SDGs of the 2030 Agenda and the Paris Agreement.

Recognising the difficulties faced by many developing countries in countering the growing challenge of climate change, we have offered courses related to sustainable development and climate change since 2012. Our newest package, the CAP, was launched in 2018. Courses under the CAP aim to support all developing countries, in particular the SIDS and LDCs, in building climate resilience while achieving their Paris Agreement pledges. The CAP covers topics such as climate adaptation and mitigation strategies, DRR, energy efficiency, and emission reduction. Following positive feedback, we extended the CAP to 2023.

Singapore also works with developed and developing country partners and international organisations to synergise expertise and pool resources to implement capacity-building programmes. In June 2019, we worked with the UN Office for Disaster Risk Reduction (UNDRR) on a "train-the-trainers" workshop in disaster resilience for the Caribbean. In January 2020, we co-hosted a workshop on "Enhancing Nationally Determined Contributions" with the NDC Partnership, which was supported by the UNFCCC Secretariat and the 2050 Pathways Platform. Participants found the workshop helpful in guiding their application of UNFCCC reporting guidelines, as well as in the accounting and tracking of the progress of their countries' NDCs. The workshop also provided an encouraging platform for NDC administrators to share valuable experiences.

Sentosa, Singapore's premier island resort getaway, targets to achieve carbon neutrality by 2030 and become a globally recognised, certified sustainable tourism destination. In July 2022, Sentosa Development Corporation was the first island destination in Asia to meet the Global Sustainable Tourism Council – For Destinations criteria, affirming the organisation's strong push for collective and collaborative whole-of-island efforts towards achieving a more sustainable Sentosa.

NATIONAL GREENHOUSE GAS INVENTORY

The multi-agency GHG inventory team uses a four-stage inventory process to facilitate continuous improvement to the national GHG inventory.

The most significant GHG emitted in Singapore is CO_2, primarily produced by the burning of fossil fuels to generate energy used by the industry, building, household, and transport sectors. Given Singapore's small land size and highly urbanised landscape, GHG emissions from the AFOLU sector are negligible in comparison with other economic sectors and the size of carbon stocks.

SINGAPORE'S GHG EMISSIONS FOR 2018

Singapore's GHG emissions for 2018 totalled 53,312.68 $GgCO_2$ eq. This excludes the interim Tier 1b estimate of HFCs emissions from the RAC sector of 6,398.15 $GgCO_2$ eq in 2018. A breakdown of the total GHG emissions by sources in $GgCO_2$ eq is shown in the tables on pages 74–75.[21, 22]

The breakdown of emissions by type of gas is as shown.

Greenhouse Gas	Emissions ($GgCO_2$ eq)	% of Total Emissions
CO_2	50,260.88	94.28%
PFCs	1,437.92	2.70%
HFCs	507.29	0.95%
N_2O	484.88	0.91%
NF_3	381.25	0.72%
SF_6	127.06	0.24%
CH_4	113.39	0.21%

METHODOLOGY USED

2006 IPCC Guidelines

Singapore's emissions were estimated using the 2006 IPCC Guidelines for National GHG Inventories. Emissions estimates were based on the sectoral approach. Most emissions estimates were derived using Tier 1 methodology provided in the 2006 IPCC Guidelines. Where default conversion and emission factors were used, they were taken from the 2006 IPCC Guidelines as well, unless otherwise stated.

Higher tier methodology was used where data was available. Specifically, higher tiers and country/plant-specific emission factors were used for estimating fugitive emissions from oil and natural gas, emissions from some categories of IPPU, CH_4 emissions from solid waste disposal and CO_2 emissions from the incineration of solid waste. Emissions from the LULUCF sector were also obtained mainly from using Tier 2 and Tier 3 methodologies based on the 2006 IPCC Guidelines and the 2013 Supplement to the 2006 IPCC Guidelines: Wetlands (Wetlands Supplement), where applicable.

IPCC Good Practice Guidance

The CO_2 emissions from hazardous waste incineration were estimated using Tier 1 methodology from the 2006 IPCC Guidelines, with default emission factors from the IPCC Good Practice Guidance due to unavailable factors in the 2006 IPCC Guidelines.

In addition, the IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories were applied to improve the transparency, consistency, comparability, completeness and confidence in the national GHG inventory of emissions estimates.

The tables on pages 67–71 provide the report for methods and emission factors used for the emissions estimation.

[21] As some figures are considerably small, they may be presented as "0.00" due to rounding.
[22] Figures may not add up to the totals due to rounding.

Greenhouse Gas Source and Sink Categories	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6		NF_3	
	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1 — ENERGY														
1A - Fuel Combustion Activities														
1A1 Energy Industries	T1	D	T1	D	T1	D								
1A2 Manufacturing Industries and Construction	T1	D, CS	T1	D	T1	D								
1A3 Transport	T1	D	T1	D	T1	D								
1A4 Other Sectors	T1	D, CS	T1	D	T1	D								
1A5 Non-Specified	NO	NO	NO	NO	NO	NO								
1B - Fugitive Emissions from Fuels														
1B1 Solid Fuels	NO	NO	NO	NO	NO	NO								
1B2 Oil and Natural Gas	T2, T3	PS	T2, T3	PS	T1	D								
1B3 Other Emissions from Energy Production	NO	NO	NO	NO	NO	NO								
1C - Carbon Dioxide Transport and Storage														
1C1 Transport of CO_2	NO	NO												
1C2 Injection and Storage	NO	NO												
2 — INDUSTRIAL PROCESSES AND PRODUCT USE														
2A - Mineral Industry														
2A1 Cement Production	NO	NO												
2A2 Lime Production	NO	NO												
2A3 Glass Production	NO	NO												
2A4 Other Process Uses of Carbonates	NO	NO												
2A5 Other (please specify)	NO	NO	NO	NO	NO	NO								

Notation keys:
T1 = Tier 1, T2 = Tier 2 and T3 = Tier 3 D = IPCC default, CS = Country specific and PS = Plant specific NO = Not Occurring

Greenhouse Gas Source and Sink Categories	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6		NF_3	
	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
2B - Chemical Industry														
2B1 Ammonia Production	NO	NO	NO	NO	NO	NO								
2B2 Nitric Acid Production					NO	NO								
2B3 Adipic Acid Production	NO	NO			NO	NO								
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production	NO	NO			NO	NO								
2B5 Carbide Production	NO	NO	NO	NO										
2B6 Titanium Dioxide Production	NO	NO												
2B7 Soda Ash Production	NO	NO												
2B8 Petrochemical and Carbon Black Production	T3	PS	NO	NO										
2B9 Fluorochemical Production							NO	NO	NO	NO	NO	NO	NO	NO
2B10 Other (please specify)	NO	NO	NO	NO	NO	NO								
2C - Metal Industry														
2C1 Iron and Steel Production	T3	PS	NO	NO										
2C2 Ferroalloys Production	NO	NO	NO	NO										
2C3 Aluminium Production	NO	NO							NO	NO	NO	NO		
2C4 Magnesium Production	NO	NO					NO	NO	NO	NO	NO	NO		
2C5 Lead Production	NO	NO												
2C6 Zinc Production	NO	NO												
2C7 Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2D - Non-Energy Products from Fuels and Solvent Use														
2D1 Lubricant Use	T1	D	NO	NO	NO	NO								
2D2 Paraffin Wax Use	T1	D	NO	NO	NO	NO								
2D3 Solvent Use	NO	NO	NO	NO	NO	NO								
2D4 Other (please specify)	NO	NO	NO	NO	NO	NO								

Notation keys:

T1 = Tier 1, T2 = Tier 2 and T3 = Tier 3 D = IPCC default, CS = Country specific and PS = Plant specific NO = Not Occurring

Greenhouse Gas Source and Sink Categories	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6		NF_3	
	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
2E - Electronics Industry														
2E1 Integrated Circuit or Semiconductor	NA	PS	NA	PS	NA	PS	T2a, T2b, T3	D, PS	T2a, T2b, T3	D, PS	T2a, T2b, T3	D, PS	T2a, T2b, T3	D, PS
2E2 TFT Flat Panel Display					NA	PS	NO	NO	T3	PS	T3	PS	T3	PS
2E3 Photovoltaics							NO	NO	NO	NO	NO	NO	NO	NO
2E4 Heat Transfer Fluid							NO	NO	NO	NO	NO	NO	NO	NO
2E5 Other (please specify)							NO	NO	NO	NO	NO	NO	NO	NO
2F - Product Uses as Substitutes for Ozone Depleting Substances														
2F1 Refrigeration and Air Conditioning							T2b	NA	NO	NO	NO	NO	NO	NO
2F2 Foam Blowing Agents							NO	NO	NO	NO	NO	NO	NO	NO
2F3 Fire Protection							T2b	NA	NO	NO	NO	NO	NO	NO
2F4 Aerosols							NO	NO	NO	NO	NO	NO	NO	NO
2F5 Solvents							T2b	NA	NO	NO	NO	NO	NO	NO
2F6 Other Applications							NO	NO	NO	NO	NO	NO	NO	NO
2G - Other Product Manufacture and Use														
2G1 Electrical Equipment							NO	NO	NO	NO	T3	PS	NO	NO
2G2 SF_6 and PFCs from Other Product Uses									NO	NO	NO	NO		
2G3 N_2O from Product Uses					NO	NO								
2G4 Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Notation keys:

T1 = Tier 1, T2 = Tier 2 and T3 = Tier 3 D = IPCC default, CS = Country specific and PS = Plant specific NA = Not Applicable and NO = Not Occurring

Greenhouse Gas Source and Sink Categories	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6		NF_3	
	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
2H - Other														
2H1 Pulp and Paper Industry	NO	NO	NO	NO	NO	NO								
2H2 Food and Beverages Industry	NA	PS	NA	PS	NA	PS								
2H3 Other (please specify)	NA	PS	NA	PS	NA	PS	NO	NO	NO	NO	NO	NO	NO	NO
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE														
3A - Livestock														
3A1 Enteric Fermentation			T1	D										
3A2 Manure Management			T1	D	T1	D								
3B - Land														
3B1 Forest land	T3	CS	NO	NO	T1	D								
3B2 Cropland	T1	D	NO	NO	T1	D								
3B3 Grassland	NO	NO	NO	NO	NO	NO								
3B4 Wetlands	T1	D	NO	NO	NO	NO								
3B5 Settlements	T3	CS	NO	NO	T1	D								
3B6 Other land	NO	NO	NO	NO	NO	NO								
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land														
3C1 Burning	NO	NO	NO	NO	NO	NO								
3C2 Liming	T1	D												
3C3 Urea Fertilisation	T1	D												
3C4 Direct N_2O Emissions from managed soils					T1	D								
3C5 Indirect N_2O Emissions from managed soils					T1	D								
3C6 Indirect N_2O Emissions from manure management					NO	NO								
3C7 Rice Cultivations			NO	NO	NO	NO								
3C8 Other (please specify)	NO	NO	NO	NO	NO	NO								

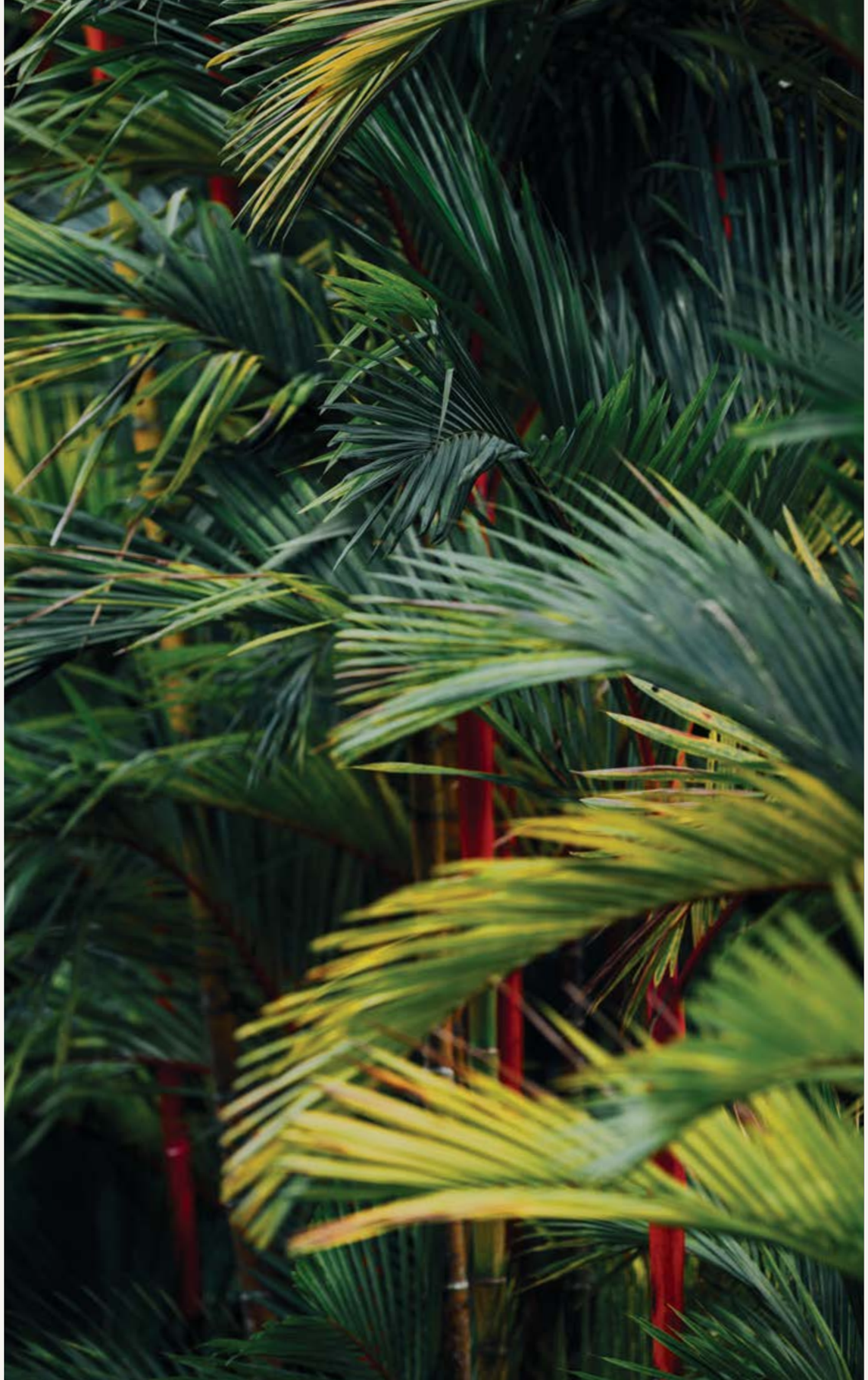
Notation keys:

T1 = Tier 1, T2 = Tier 2 and T3 = Tier 3 D = IPCC default, CS = Country specific and PS = Plant specific NA = Not Applicable and NO = Not Occurring

Greenhouse Gas Source and Sink Categories	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6		NF_3	
	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
3D - Other														
3D1 Harvested Wood Products	NO	NO			NO	NO								
3D2 Other (Sea)	T3	CS	NO	NO	NO	NO								
4 — WASTE														
4A - Solid Waste Disposal			T2	D										
4B - Biological Treatment of Solid Waste			NO	NO	NO	NO								
4C - Incineration and Open Burning of Waste	T1, T2a	D	T1	D	T1	D								
4D - Wastewater Treatment and Discharge			NE	NE	T1	D								
4E - Other (please specify)	NO	NO	NO	NO	NO	NO								
5 — OTHER														
5A - Indirect N_2O emissions from the Atmospheric Deposition of Nitrogen in NO_x and NH_3					NO	NO								
5B -Other (please specify)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
INFORMATION ITEMS														
CO_2 from Biomass Combustion for Energy Production	T2a	D												

Notation keys:

T1 = Tier 1, T2 = Tier 2 and T3 = Tier 3 D = IPCC default, CS = Country specific and PS = Plant specific NE = Not Estimated and NO = Not Occurring



Marina Bay area, with a catchment area of 10,000 ha, is Singapore's largest and most urbanised catchment.

Global Warming Potentials

The estimated CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3 emissions were converted to CO_2 equivalent (CO_2 eq) using the 100-year time-horizon GWP values from the IPCC AR5, as presented in the table below.

Greenhouse Gas	Chemical Formula	GWP
Carbon dioxide	CO_2	1
Methane	CH_4	28
Nitrous oxide	N_2O	265
Hydrofluorocarbons	HFCs	116–12,400
Perfluorocarbons	PFCs	6,630–11,100
Sulphur hexafluoride	SF_6	23,500
Nitrogen trifluoride	NF_3	16,100

Precursors

Emissions of precursors such as carbon monoxide (CO), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs) and other gases such as sulphur dioxide (SO_2) are not included in the inventory. The levels of these gases in the air are currently monitored by a network of ambient air quality monitoring stations. CO, NO_x and SO_2 are considered air pollutants and are regulated under the Environmental Protection and Management Act (EPMA) which stipulates emission standards for these pollutants. Strict enforcement programmes and air quality monitoring have helped to ensure that the emissions of all these precursors are minimised and that air quality remains good.

Opposite page: The Lipstick Palm (Cyrtostachys renda), which has characteristically bright red leaf sheaths, is a symbol of the Singapore Botanic Gardens, our very first UNESCO World Heritage Site.

Greenhouse Gas Source and Sink Categories	Net CO_2	CH_4	N_2O	HFCs
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**50,260.88**	**113.39**	**484.88**	**507.29**
1 — ENERGY	**49,533.34**	**91.65**	**222.74**	
1A - Fuel Combustion Activities	48,307.43	54.73	219.94	
1A1 Energy Industries	20,220.81	9.06	63.91	
1A2 Manufacturing Industries and Construction	20,056.92	11.79	14.63	
1A3 Transport	7,383.34	32.33	141.11	
1A4a Commercial / Institutional	430.55	1.02	0.19	
1A4b Residential	215.81	0.52	0.10	
1B - Fugitive Emissions from Fuels	1,245.91	36.92	2.80	
1B2 Oil and Natural Gas	1,245.91	36.92	2.80	
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**380.81**	**0.16**	**178.60**	**507.29**
3 — AGRICULTURE	**0.09**	**2.22**	**5.73**	
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	**106.36**	**NO**	**5.81**	
4 — WASTE	**220.27**	**19.36**	**72.00**	
4A - Solid Waste Disposal		19.36		
4C - Incineration and Open Burning of Waste	220.27	0.00	1.81	
Clinical Waste Incineration	2.80	0.00	0.06	
Hazardous Waste Incineration	217.47	0.00	1.75	
4D - Wastewater Treatment and Discharge		NE	70.19	
INFORMATION ITEMS[23]				
CO_2 from Biomass Combustion for Energy Production	1,660.95			

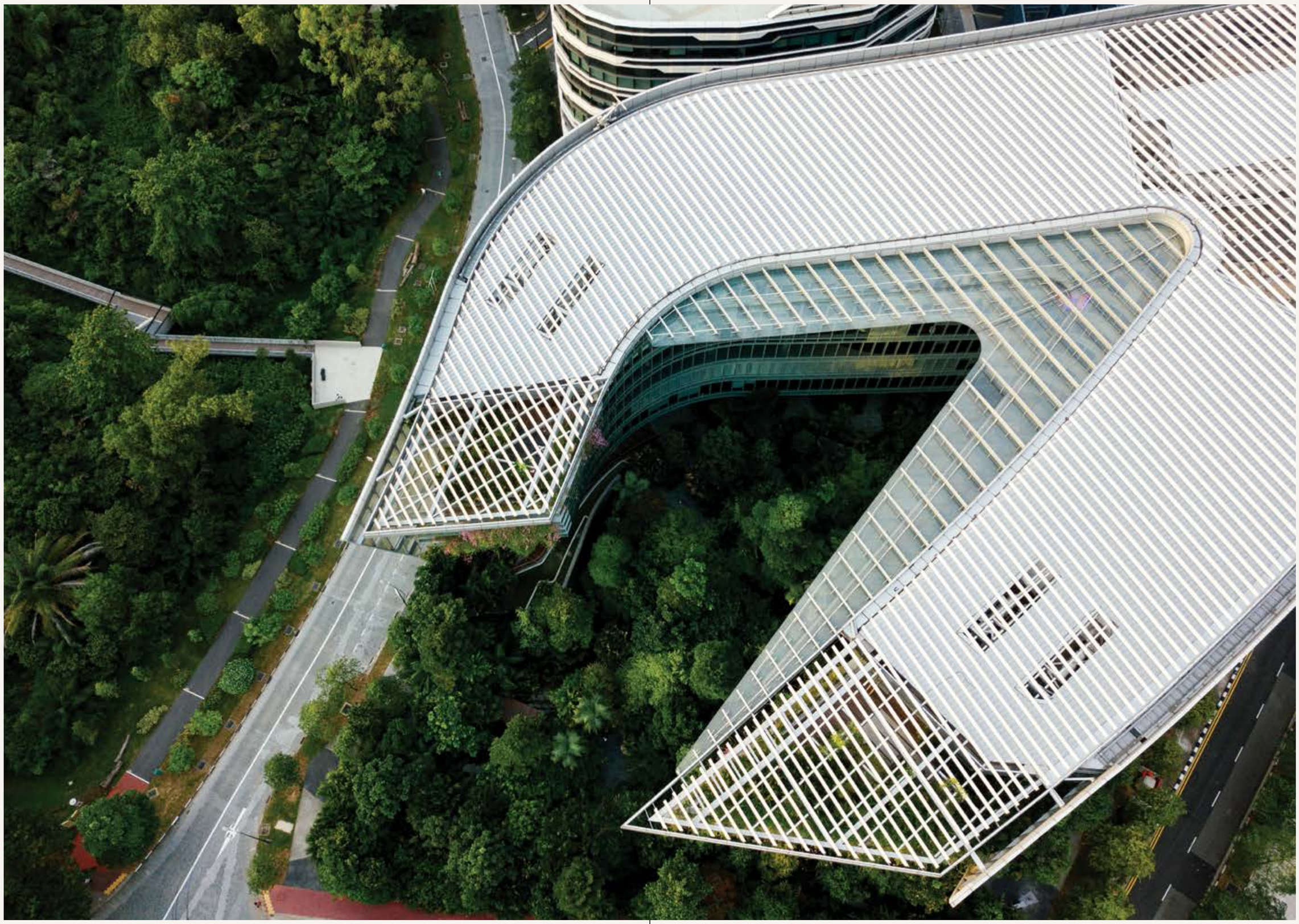
Notation keys:

NE = Not Estimated and NO = Not Occurring

[23]According to the 2006 IPCC Guidelines, information items are not included in the national total GHG emissions.

Greenhouse Gas Source and Sink Categories	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**1,437.92**	**127.06**	**381.25**	**53,312.68**
1 — ENERGY				**49,867.74**
1A - Fuel Combustion Activities				48,582.11
1A1 Energy Industries				20,293.79
1A2 Manufacturing Industries and Construction				20,083.35
1A3 Transport				7,556.78
1A4a Commercial / Institutional				431.76
1A4b Residential				216.43
1B - Fugitive Emissions from Fuels				1,285.63
1B2 Oil and Natural Gas				
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**1,437.92**	**127.06**	**381.25**	**3,013.09**
3 — AGRICULTURE				**8.04**
3 — LAND USE, LAND-USE CHANGE AND FORESTRY				**112.18**
4 — WASTE				**311.63**
4A - Solid Waste Disposal				19.36
4C - Incineration and Open Burning of Waste				222.08
Clinical Waste Incineration				2.86
Hazardous Waste Incineration				219.22
4D - Wastewater Treatment and Discharge				70.19
INFORMATION ITEMS[24]				
CO_2 from Biomass Combustion for Energy Production				1,660.95

[24]According to the 2006 IPCC Guidelines, information items are not included in the national total GHG emissions.



The Sandcrawler building at Fusionopolis was awarded the BCA Green Mark Award (Platinum) in 2019.

Worksheets

The 2018 GHG inventory worksheets are appended in the Annex.

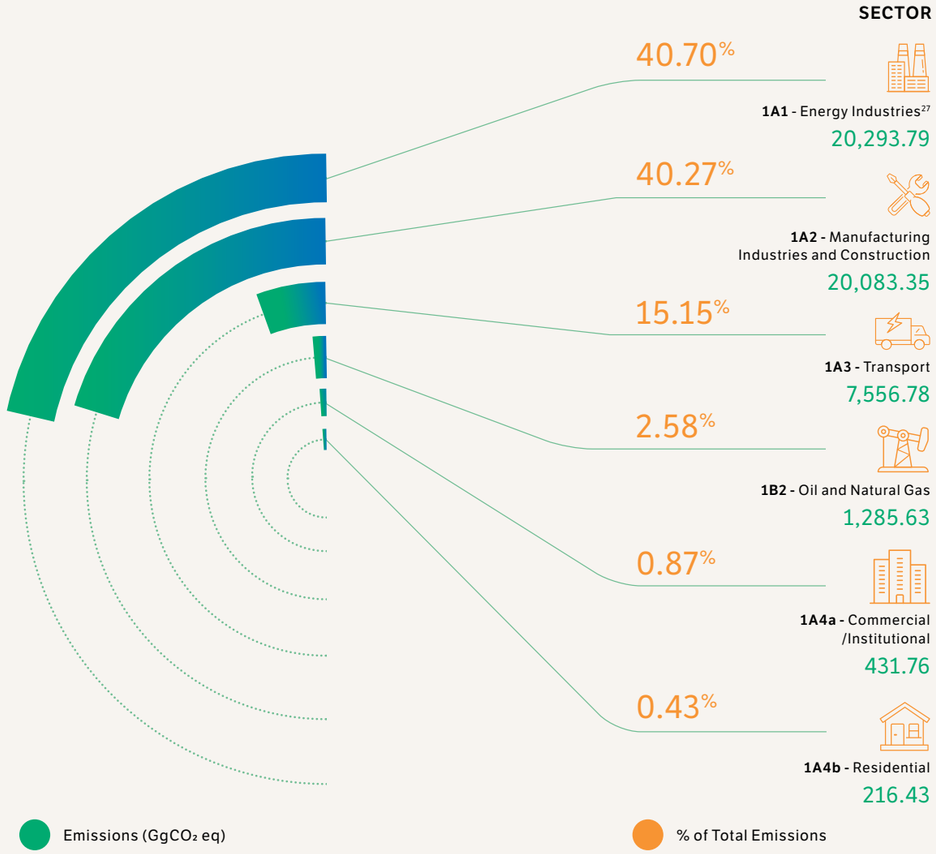
Previously Reported GHG Emissions

A breakdown of the total GHG emissions by sources reported in previous NCs and BURs (1994, 2000, 2010, 2012, 2014 and 2016) in $GgCO_2$ eq can also be found in the Annex.[25]

EMISSIONS FROM INTERNATIONAL BUNKERS IN 2018

International Bunkers	CO_2 emissions ($GgCO_2$ eq)[26]
Aviation	15,684.96
Marine	157,319.27

Note: As Singapore is a major international air and sea transportation hub, aviation and marine bunker fuels are uplifted in Singapore as part of the services provided to passing aircraft and ships on international routes. Emissions from international aviation and marine bunker fuels are therefore excluded from Singapore's national GHG inventory and national GHG totals. Singapore actively supports and contributes to the efforts led by the ICAO and the IMO in addressing international aviation and maritime transport emissions on a global basis.



BREAKDOWN OF EMISSIONS BY IPCC SECTOR

1 — Energy

The combustion of fossil fuels to generate energy is the major source of GHG emissions in Singapore. The amount of emissions emitted from the energy sector in 2018 was 49,867.74 $GgCO_2$ eq. The contribution of emissions from fuel combustion activities and fugitive emissions is as shown.

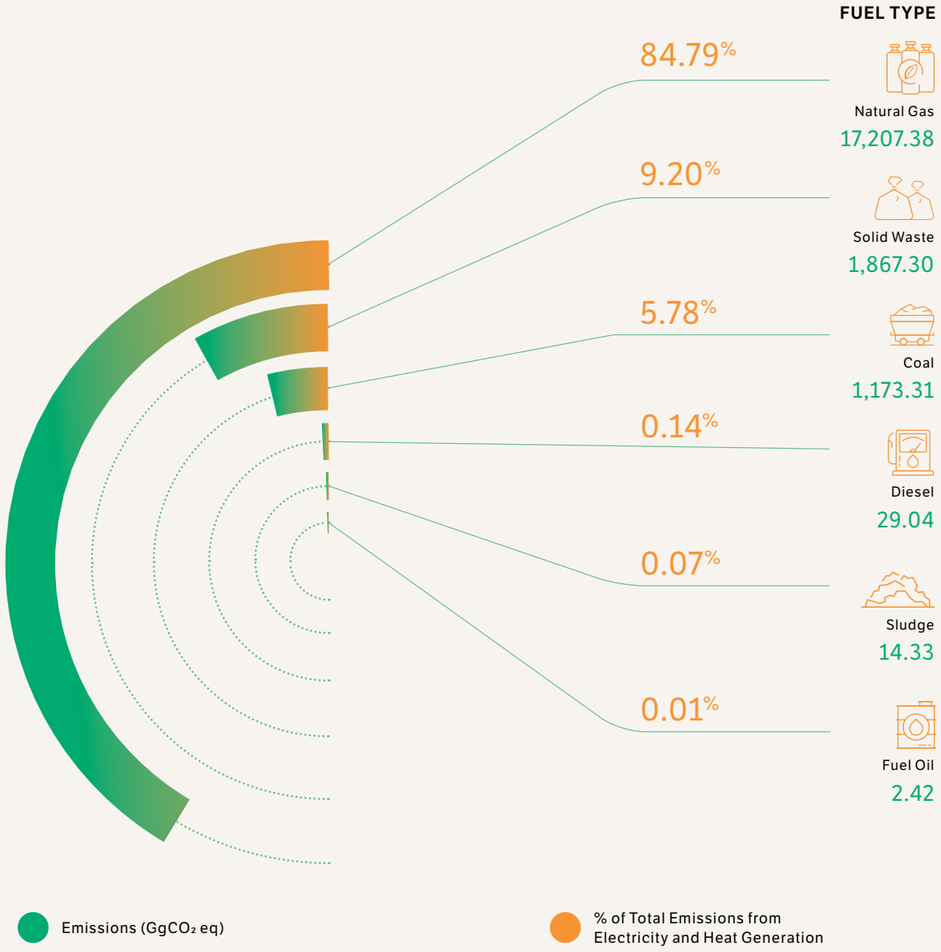
As heat from the incineration of waste is recovered to produce electricity in Singapore, CO_2, CH_4 and N_2O emissions from waste incineration are reported in the energy sector.

According to the 2006 IPCC Guidelines, CO_2 emissions from waste incineration are estimated from the portion of the waste that is fossil-based, and the non-fossil-based fraction is excluded.

Heat from the incineration of sludge from wastewater processes is also recovered in Singapore, hence CH_4 and N_2O emissions from sludge incineration are reported in the energy sector.[28]

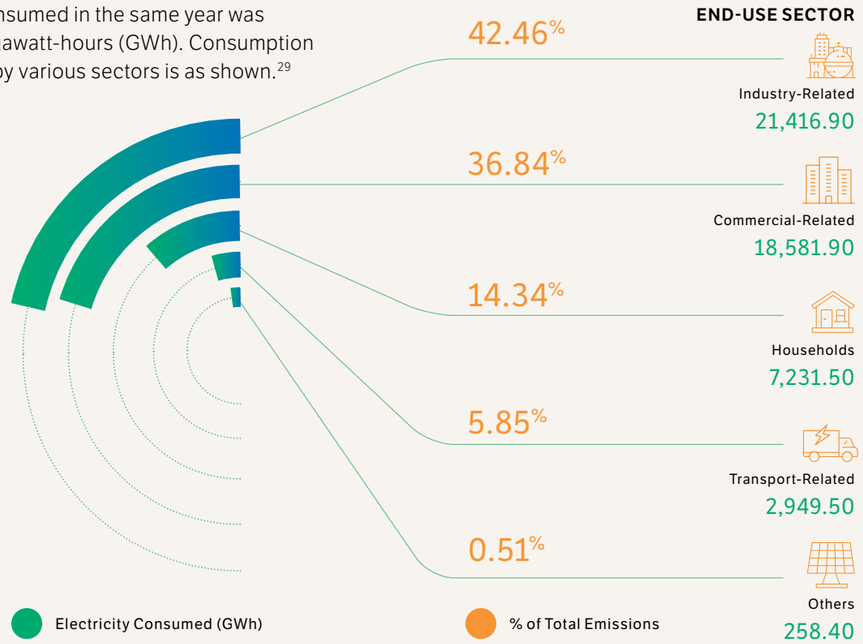
1A1 - Energy Industries

In 2018, emissions from electricity and heat generation totalled 20,293.79 $GgCO_2$ eq. The breakdown of emissions from different fuel types used for electricity and heat generation is as shown.



[25] In line with the IPCC Good Practice Guidance to continually review the GHG inventory ensuring that it is compiled in a consistent manner, emissions estimates may have been updated.
[26] Emission factors from the 2006 IPCC Guidelines were applied for the purpose of submission of data on greenhouse gas from international bunkers to the UNFCCC only.
[27] Emissions from the incineration of solid waste and incineration of sludge are included under 1A1 Energy Industries.
[28] More details on the incineration of solid waste and incineration of sludge are presented under 4 Waste section.

Electricity consumed in the same year was 50,438.20 gigawatt-hours (GWh). Consumption of electricity by various sectors is as shown.[29]

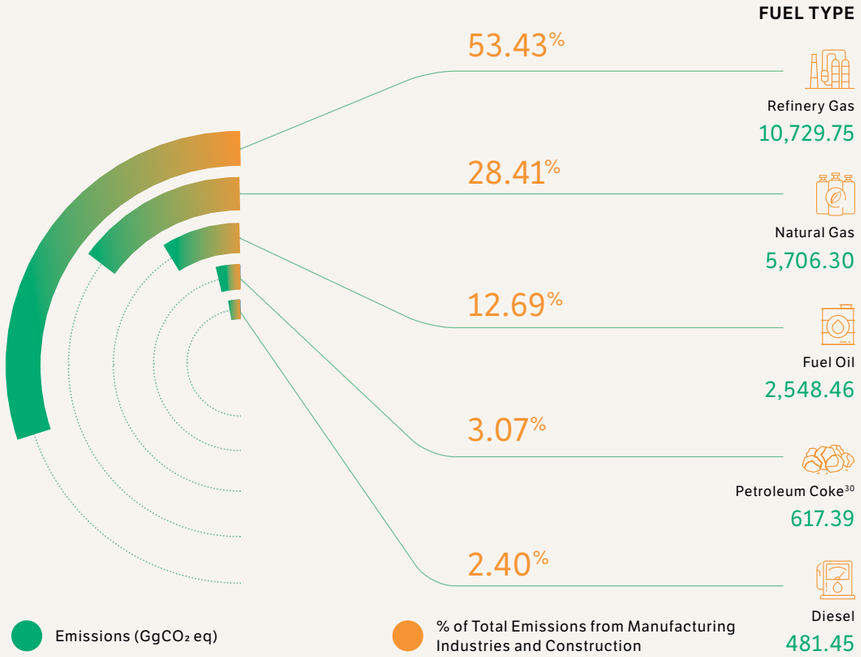


1A2 - Manufacturing Industries and Construction

The majority of the direct emissions from the Manufacturing Industries and Construction sector are from the combustion of primary fuels by the refining and petrochemical sector.

While Singapore does not produce any oil or gas, we are a major oil refining and petrochemical centre that serves the global market.

The breakdown of emissions by fuel type in the Manufacturing Industries and Construction sector is as shown.

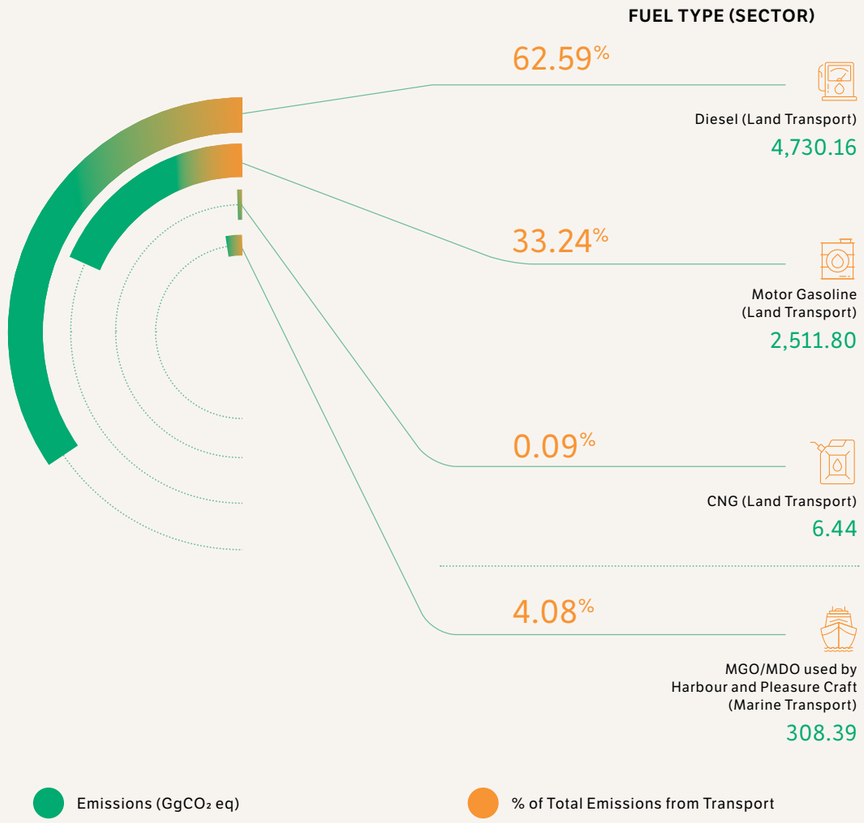


[29]Source: Energy Market Authority (EMA), Singapore Energy Statistics 2021, Table 3.2
[30]Due to confidentiality reasons, emissions from the combustion of Liquefied Petroleum Gas (LPG) and Gas Works Gas are included under Petroleum Coke.

1A3 - Transport

In 2018, Singapore had a network of 3,515 km of paved public roads and a population of 957,006 motor vehicles.[31] These motor vehicles consumed diesel, motor gasoline, and compressed natural gas (CNG). Marine Gas Oil/Marine Diesel Oil (MGO/MDO) was consumed by harbour and pleasure craft plying within the waters of Singapore.

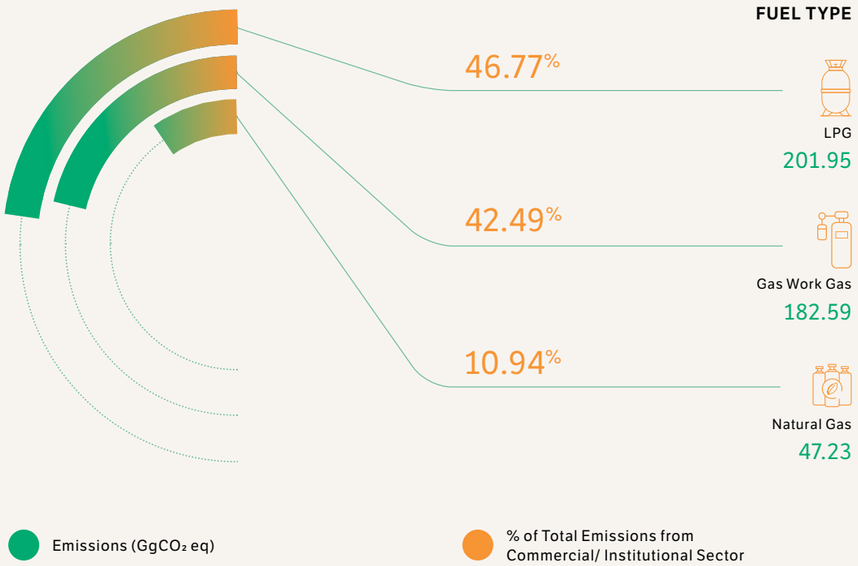
The breakdown of emissions by fuel type in the transport sector is as shown.

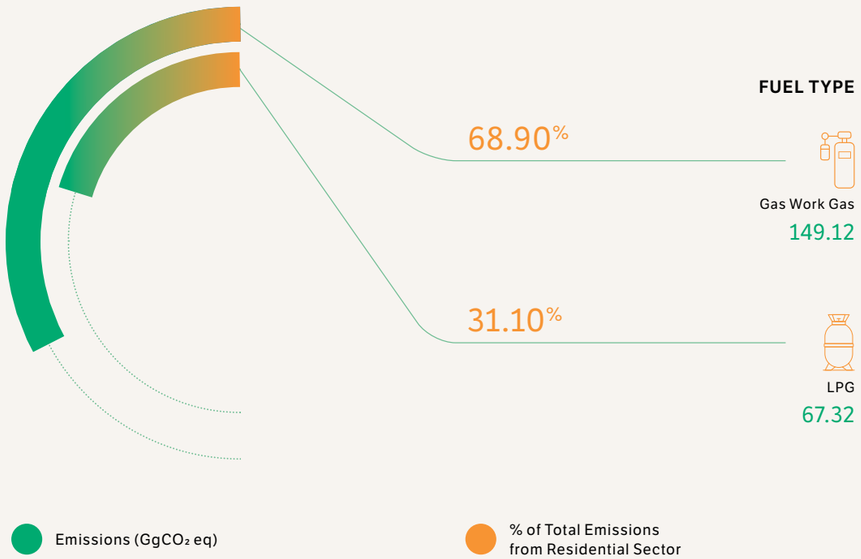


[31]Source: Motor Vehicle Population By Vehicle Type, Annual Vehicle Statistics 2021, Land Transport Authority: https://www.mytransport.sg/content/mytransport/home/dataMall.html

1A4a - Commercial/Institutional & 1A4b - Residential

Emissions from the commercial/institutional and residential sectors were from the use of LPG and Gas Works Gas,[32] mainly for cooking and hot water systems. The breakdown of emissions by fuel type in the commercial and residential sectors is as shown.





[32]Liquefied Petroleum Gas or LPG, is a mixture of hydrocarbon gases formed as part of the petroleum refining process. Gas Works Gas is primarily hydrogen gas generated through steam reforming of natural gas.

1B2 - Fugitive Emissions from Fuel and Oil and Natural Gas

The Energy Conservation Act (ECA) introduced in 2013[33] mandates energy-intensive companies in the industrial sector to monitor and report their energy use and GHG emissions on an annual basis. Companies under the ECA will compute their fugitive emissions[34] and IPPU emissions[35] based on the 2006 IPCC Guidelines and submit their GHG reports as part of their regulatory requirements.

The fugitive emissions from oil and natural gas are estimated using a mix of Tier 1, Tier 2, and Tier 3 estimation methods, incorporating plant-specific methodology, activity data and emission factors, and account for 2.41% of the national 2018 GHG inventory.

The sources of fugitive emissions compiled from the ECA include, but are not limited to, equipment leaks, evaporation and flashing losses, venting, flaring, incineration, and accidental releases. The main contributors to fugitive emissions from oil and natural gas were the flaring of waste gases from process upsets and/or maintenance activities.

2 — Industrial Processes and Product Use

As described in the "1B2 Fugitive Emissions from Fuel – Oil and Natural Gas" category, the emissions from the IPPU sector are compiled from the GHG reports submitted by energy-intensive companies in the industrial sector as part of the regulatory requirements under the ECA.

Emissions from the IPPU sector are estimated using a mix of Tier 1, Tier 2, and Tier 3 estimation methods from the 2006 IPCC Guidelines, incorporating plant-specific methodology, activity data and emission factors where data is available. Where default factors were used, they were taken from the 2006 IPCC Guidelines. The report of methods and emission factors used for the emissions estimation for each IPPU source category is as shown earlier on pages 67–71.

The main source of emissions in the IPPU sector is from the "2E Electronics Industry" category, contributing 74.41% of the IPPU emissions. In the electronics industry, CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3 were used in the manufacturing processes, with emission control technologies installed in some processes.

This is followed by emissions from the category, "2F Product Uses as Substitutes for Ozone Depleting Substances," which accounts for 12.47% of the IPPU emissions, mainly due to emissions from the usage of HFCs in the solvents application.

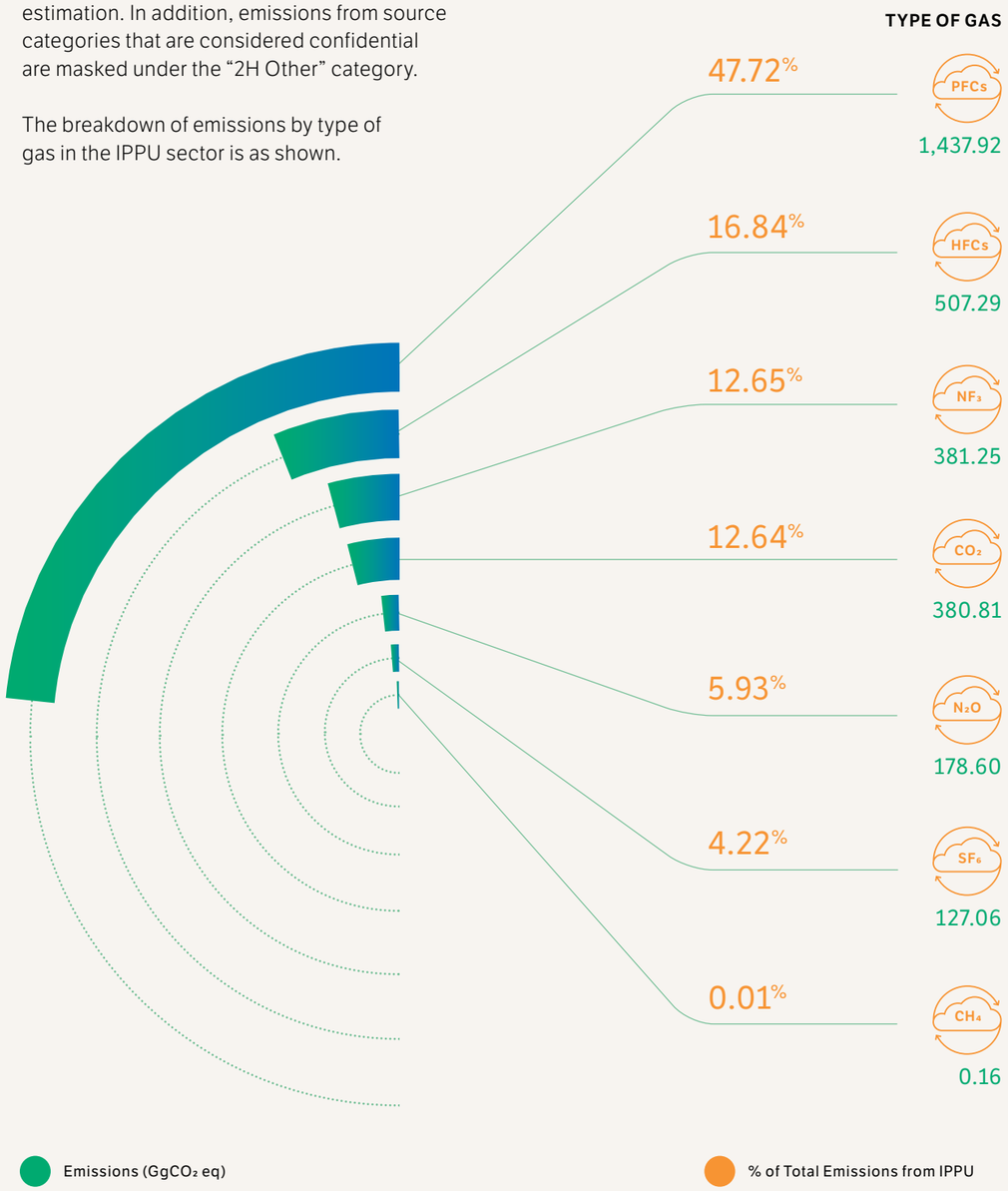
Categories	Total GHG Emissions ($GgCO_2$ eq)	% of Total Emissions from IPPU
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	3,013.09	100%
2A - Mineral Industry	NO	
2B - Chemical Industry	325.44	10.80%
2C - Metal Industry	C	
2D - Non-Energy Products from fuels and Solvent Use	1.43	0.05%
2E - Electronics Industry	2,242.17	74.41%
2F - Product Uses as Substitutes for Ozone Depleting Substances	375.63	12.47%
2G - Other Product Manufacture and Use	14.67	0.49%
2H - Other	53.75	1.78%

Notation keys:
C = Confidential and NO = Not Occurring

[33]From 1 January 2019, measurement and reporting requirements for GHG emissions are imposed under the Carbon Pricing Act.
[34]Prior to 2013, fugitive emissions from oil and natural gas were based on company-level surveys.
[35]More details on IPPU emissions are presented in the next section, 2 – Industrial Processes and Product Use.

The "2H Other" category includes estimated emissions where there is no methodological guidance provided in the 2006 IPCC Guidelines, such as the Food and Beverages industry, Chemical industry – Other, and Other – Shipbuilding industry. For such emissions, plant-specific methodology, activity data and emission factors were used for emissions estimation. In addition, emissions from source categories that are considered confidential are masked under the "2H Other" category.

The breakdown of emissions by type of gas in the IPPU sector is as shown.



3 — Agriculture, Forestry and Other Land Use

Agriculture

The GHG emissions from agriculture for the reporting year 2018 are negligible, contributing only 0.02% of Singapore's total GHG inventory. The small agricultural sector only occupies about 1% of land in Singapore and mainly produces eggs, food fish, and leafy vegetables for local consumption to supplement our imports of these items. Some quail eggs are produced, and a small number of dairy cows and goats are reared for milk for local consumption. Some orchids and ornamental fish are also grown and reared for export, but this made up a small and insignificant subset of the agriculture sector in Singapore.

The emissions from the agriculture sector for the reporting year 2018 are estimated to be 8.04 $GgCO_2$ eq as presented in the table below. Estimates from the agriculture sector are included for the first time through this BUR. The emissions from agriculture sector were estimated using the Tier 1 approach, with default emission factors from the 2006 IPCC Guidelines. The activity data was derived from census data and customised surveys. Considerable amount of effort was spent to collect data required from farms for reporting the BUR and most emissions were insignificant.

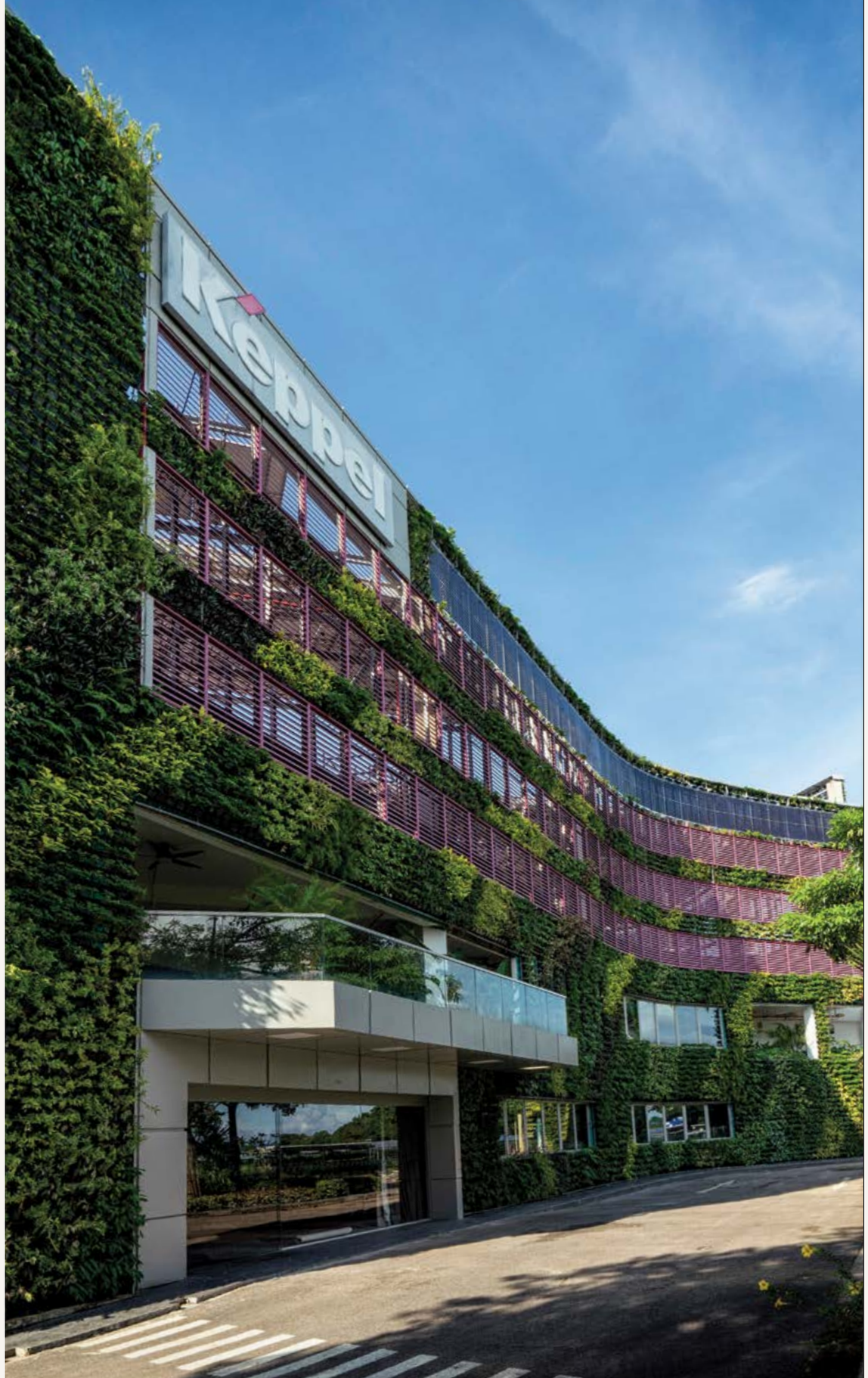
Land Use, Land-Use Change and Forestry

Singapore continues to maintain a system to capture removals and emissions from the LULUCF sector, ensuring compliance in accordance to the 2006 IPCC Guidelines on LULUCF.

Categories	Activity data	Emissions (Gg)			
	Number of animals, or Total amount of urea/ lime/nitrogen applied (Gg/yr)	CO_2	CH_4	N_2O	Total 2018 CO_2 eq emissions
3A1 - Enteric Fermentation			0.01		0.32
3A1ai Dairy Cows	47		0.00		
3A1aii Other Cattle	128		0.01		
3A1d Goats	478		0.00		
3A2 - Manure Management			0.07	0.01	4.59
3A2ai Dairy Cows	47		0.00	^NO	
3A2aii Other Cattle	128		0.00	^NO	
3A2d Goats	478		0.00	0.00	
3A2i Poultry	2,179,078		0.07	0.01	
3A2j Other (quails)	136,870		0.00	0.00	
3C2 - Liming	0.19	0.09			0.09
3C3 - Urea Fertilisation	0.00	0.00			0.00
3C4 - Direct N_2O Emissions from Managed Soils	0.51			0.01	2.13
3C5 - Indirect N_2O Emissions from Managed Soils (Cropland)				0.00	0.90
3C6 - Indirect N_2O Emissions from Manure Management				^^NO	^^NO
	Total emissions from agriculture sector	0.09	0.08	0.02	8.04

Notation key:
NO = Not Occurring

^Based on anaerobic digestion
^^ Based on anaerobic digestion and composting
Figures may not add up to the totals due to rounding.
As some figures are considerably small, they may be presented as "0.00" due to rounding.



Estimation and reporting of the GHG removals and emissions were carried out for all land use and land-use change categories in Singapore, and assessed for all five carbon pools. The main land-use categories (Forest Land, Cropland, Wetlands and Settlements) were further subdivided into subcategories for assessment of their respective contributions to the removals and emissions. The category Grassland is not relevant for Singapore, as lawns and grassland patches are located in between infrastructure, in urban parks and stocked forests, and subsumed under the Forest Land category or under Settlements using specific emission factors for such low vegetation. The category Other Land does not occur in Singapore. However, a unique land category "Other" is included to capture emissions/removals mainly from activities such as land reclamation projects.

For all land-use change categories, the IPCC approach of estimating removals and emissions in all pools for a transition period of 20 years continues to be applied. Methods employed in the assessment follow higher tier approaches, where possible, for example in Forest Land. The land use and land-use change matrix continues to be assessed based on a wall-to-wall mapping using very high-resolution satellite images. Emission factors of any significant pools of subcategories were estimated with Tier 2 or 3 approaches and using country-specific data, derived from regular ground-truthed field measurements of tree biomass and soil inventory and estimated by modelling approaches. The C stock change rates of biomass and soil in land-use change areas to the Forest Land subcategory "Mangroves" were taken from the Wetlands Supplement and complemented by country-specific C stocks from published literature. Biomass C stocks of Cropland were estimated using IPCC default values due to the insignificant share of this land-use category in Singapore. The default soil C stock and management factors for cropland were taken from the 2006 IPCC Guidelines.

Singapore is a highly dynamic country with frequent land-use changes within a short period of time. As such, land has been frequently converted to other land-use categories or subcategories more than once within a 20-year transition period. This may lead to potential overestimates of GHG emissions and removals from unrealistic fluctuations in carbon pools. By performing a series of checks to our remote sensing data, intermediate land-use changes were then corrected to ensure smoother transitions, such that each land-use change relates to a more realistic estimate of carbon stock changes. We have also completed another round of ground truthing exercise resulting in updated emission factors for significant categories and subcategories in the LULUCF sector. The corresponding estimates of removals and emissions were derived from these updated emission factors.

The total annual net emissions for the reporting year 2018 for the LULUCF sector of Singapore amounted to 112.18 $GgCO_2$ eq (including N_2O). A summary breakdown of the contributions from each land-use category is represented below.

ANNUAL CHANGE IN CARBON STOCKS, $GgCO_2$

Land-Use Category	Living Biomass (A)	Dead Organic Matter (B)	Soil (C)	CO_2 Removals/ emissions (D = A+B+C)	CH_4 ($GgCO_2$ eq)	N_2O ($GgCO_2$ eq)
3B1 - Forest Land	-33.53	-3.35	-11.24	-48.13	NO	0.16
3B2 - Cropland	0.98	0.28	-0.50	0.76	NO	0.03
3B3 - Grassland	NO	NO	NO	NO	NO	NO
3B4 - Wetlands	0.94	0.11	0.83	1.88	NO	NO
3B5 - Settlements	112.82	8.58	28.79	150.19	NO	5.63
3B6 - Other Land	NO	NO	NO	NO	NO	NO
3D - Other[36]	0.67	0.02	0.96	1.66	NO	NO
TOTAL[37]	81.88	5.64	18.84	106.36	NO	5.81

Notation key:
NO = Not Occurring

Opposite page: Keppel Infrastructure @ Changi Building, which houses an intelligent operations control centre and energy transition innovation centre, was Singapore's first Platinum Positive Energy building under the new and more stringent Green Mark Scheme. Such buildings have at least 115% of its energy consumption, including plug load, supplied from on-site renewable sources.

[36] "3D Other" category is included to capture mainly emissions from carbon losses to the sea due to land reclamation measures, while removals from land reclamation measures are included in the respective land-use subcategories.
[37] "Figures may not add up to totals due to rounding.

With social and activity spaces over four storeys of lush greenery, the Green Oasis at CapitaSpring offers opportunities to reconnect with nature in the middle of the city.

4 — Waste

4A - Solid Waste Disposal & 4C - Incineration and Open Burning of Waste

Solid Waste Management[38, 39]

Singapore has adopted waste-to-energy incineration technology to reduce the volume of waste disposed of at landfill since the 1970s. As heat from the incineration of waste is recovered to produce electricity, according to the 2006 IPCC Guidelines, CO_2, CH_4, and N_2O emissions from waste incineration are reported in the energy sector. Biogenic CO_2 emissions from the incineration of non-fossil-based waste are excluded from the national total emissions estimates and are included as an information item in the energy sector.

Today, all incinerable wastes that are not recycled are disposed of at the waste-to-energy plants. Only non-incinerable waste and ashes from the incineration process are disposed of at the offshore Semakau Landfill, which is the only active sanitary landfill in Singapore. The Lorong Halus Landfill, which was closed in 1999, has a management system and a leachate collection system. A bentonite wall and a leachate collection system were also installed adjacent to the landfill site along the riverbank to transform the river into a reservoir. These help to mitigate the risk of leachate from the landfill polluting water, as well as manage CH_4 emissions to the atmosphere. The CH_4 concentration in Lorong Halus Landfill has since reached a low concentration level and the extraction of gases was discontinued in 2017. There are also insignificant CH_4 emissions from Semakau Landfill, as it receives only incineration ash and non-incinerable waste.

CH_4 and N_2O emissions were estimated based on the amount of waste incinerated at the waste-to-energy incineration plants.

Sludge Incineration[40]

From 1985 to 2008, treated sludge was applied on reclaimed land sites as a soil conditioner. Residual CH_4 emissions were due to anaerobic decay of the organic contents in the sludge from these sites. Since 2009, direct methane emissions from sewage sludge have been significantly reduced by incinerating the sludge.[40] The CH_4 emissions from sewage sludge disposal in 2018 were 19.36 $GgCO_2$ eq.

As heat from the incineration of sludge is recovered to produce electricity, according to the 2006 IPCC Guidelines, CH_4 and N_2O emissions from incineration of sludge are reported in the energy sector.

Clinical and Hazardous Waste Incineration

Facilities engaged in the incineration of clinical and hazardous waste in Singapore are regulated by the NEA under the Environmental Public Health Act (EPHA) and its Regulations. The activity data submitted by these facilities to NEA was used to estimate the emissions of CO_2, CH_4 and N_2O.

The breakdown of emissions by type of GHG from clinical waste incineration is as shown.[41]

Type of Gas	Emissions ($GgCO_2$ eq)	% of Total Emissions from Clinical Waste Incineration
CO_2	2.80	97.74%
N_2O	0.06	2.26%
CH_4	0.00	0.00%

The breakdown of emissions by type of GHG from hazardous waste incineration is as shown.[41]

Type of Gas	Emissions ($GgCO_2$ eq)	% of Total Emissions from Hazardous Waste Incineration
N_2O	1.75	0.80%
CH_4	0.00	0.00%
CO_2	217.47	99.20%

[38]Emissions from the incineration of solid waste and incineration of sludge are included under 1A1 Energy Industries.
[39]As accurate data points on the percentage composition of individual waste streams were not available prior to 2001, the data points prior to 2001 were estimated based on an extrapolation of waste composition from 2001 to 2016. The extrapolated percentages of each waste stream were then multiplied by the total amount of waste incinerated in the corresponding years to obtain the respective waste amounts. GHG emissions were then computed based on the 2006 IPCC Guidelines.
[40]In accordance with the 2000 IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories, emissions from the incineration of sewage sludge for year 2010 were estimated by PUB based on the backward trend extrapolation of available data from September 2010 to December 2010. The emissions were from the sludge incineration plant operated by ECO-SWM which was registered as a Clean Development Mechanism (CDM) project on 13 September 2010. From 2012 onwards, emissions from the incineration of sewage sludge were estimated by PUB based on the forward trend extrapolation of available data from 2010 and 2011.
[41]As some figures are considerably small, they may be presented as "0.00" due to rounding.

The TreeTop Walk, located in the Central Catchment Nature Reserve, offers a bird's eye view of the community of plants and animals that live in the forest canopy.

4D - Wastewater Treatment and Discharge

Used water from both domestic and non-domestic sources is conveyed via sewers to water reclamation plants (WRPs) for treatment. At the WRPs, the used water is treated using the waste activated sludge process. A by-product of this treatment process is waste activated sludge which is fed into digesters for stabilisation. The biogas produced in the digesters is used as fuel to either dry dewatered sludge further or generate electricity to supplement the power requirement of the treatment facilities. CO_2 produced from the combustion of biogas is not counted in the national inventory as it is part of the natural carbon cycle of decomposition. Fugitive CH_4 emission is negligible as all unused biogas is flared. Emissions from wastewater treatment are reported at an aggregated level and not differentiated by the waste sources.

N_2O emissions were from human sewage and estimated based on annual per capita protein intake data from the UN Food and Agriculture Organisation (FAO).[42] The N_2O emissions from wastewater treatment and discharge in 2018 were 70.19 $GgCO_2$ eq.

KEY CATEGORY ANALYSIS

A key category analysis (KCA) is conducted for the GHG inventory to identify major sources of GHG emissions, so that the resources available for inventory preparation are prioritised to improve GHG emissions estimates for those major sources.

The KCA is performed for emission sources, in terms of CO_2 equivalent emissions. Key categories are identified using the Approach 1 level assessment and trend assessment from the 2006 IPCC Guidelines, whose emissions when summed in descending order of magnitude add up to 95% of the total GHG emissions. Disaggregation to lower levels was not considered necessary as it splits important aggregated categories into small sub-categories that are no longer key.

The key categories identified in the tables overleaf are performed with LULUCF. There are no changes to the key categories identified from the Approach 1 level and trend assessment, with and without LULUCF.

[42]Singapore's 2018 annual per capita protein intake is estimated from Southeast Asia's average per capita protein intake (Source: UN FAO) as Singapore-specific figures are not available.

Level Assessment

Of the 15 key categories identified, 11 key categories originate from fuel combustion activities which primarily produce CO_2 emissions. The main contributor to Singapore's 2018 GHG inventory is CO_2 emissions from the combustion of natural gas (32.2%) for electricity and heat generation. The other four key categories identified are PFCs and NF_3 from the Electronics Industry which are used and emitted by semiconductors and integrated circuits manufacturing companies, fugitive CO_2 emissions from oil and natural gas due to flaring of waste gases from process upsets and/or maintenance activities, and HFCs from Product Uses as Substitutes for Ozone Depleting Substances category which are mainly used and emitted in the solvent application.

A	B		C	D	E	F
IPCC Category Code	**IPCC Category**	**Fuel Type**	**Greenhouse Gas**	**Emissions ($GgCO_2$ eq)**	**Percentage Contribution**	**Cumulative Total of Column E**
1A1	Fuel Combustion Activities – Energy Industries	Natural Gas	CO_2	17,190.68	32.2%	32.2%
1A2	Fuel Combustion Activities – Manufacturing Industries and Construction	Refinery Gas	CO_2	10,719.60	20.1%	52.4%
1A2	Fuel Combustion Activities – Manufacturing Industries and Construction	Natural Gas	CO_2	5,700.78	10.7%	63.0%
1A3b	Fuel Combustion Activities – Transportation – Road Transportation	Diesel	CO_2	4,658.29	8.7%	71.8%
1A3b	Fuel Combustion Activities – Transportation – Road Transportation	Motor Gasoline	CO_2	2,413.58	4.5%	76.3%
1A2	Fuel Combustion Activities – Manufacturing Industries and Construction	Fuel Oil	CO_2	2,099.94	3.9%	80.2%
1A1	Fuel Combustion Activities – Energy Industries	Solid Waste[43]	CO_2	1,830.72	3.4%	83.7%
2E	Industrial processes and Product Use – Electronics Industry		PFCs	1,437.92	2.7%	86.4%
1B2	Fugitive Emissions from Fuels	Oil and Natural Gas	CO_2	1,245.91	2.3%	88.7%
1A1	Fuel Combustion Activities – Energy Industries	Coal	CO_2	1,168.05	2.2%	90.9%
1A2	Fuel Combustion Activities – Manufacturing Industries and Construction	Petroleum Coke[44]	CO_2	616.18	1.2%	92.1%
1A2	Fuel Combustion Activities – Manufacturing Industries and Construction	Diesel	CO_2	479.88	0.9%	93.0%
1A2	Fuel Combustion Activities – Manufacturing Industries and Construction	Light Fuel Oil	CO_2	440.54	0.8%	93.8%
2E	Industrial processes and Product Use – Electronics Industry		NF_3	381.25	0.7%	94.5%
2F	Industrial Processes and Product Use – Product Uses as Substitutes for Ozone Depleting Substances		HFCs	375.63	0.7%	95.2%

[43]According to the 2006 IPCC Guidelines, CO_2 emissions from solid waste incineration is estimated from the portion of waste that is fossil-based.
[44]Due to confidentiality reasons, CO_2 emissions from the combustion of LPG and Gas Work Gas are included under Petroleum Coke.

Trend Assessment

There are 13 key categories identified in the trend assessment with the highest trend seen in the decrease in fuel oil combustion for electricity and heat generation (40.2%), followed by the increase in natural gas combustion for electricity and heat generation (23.2%). This natural gas and fuel oil trend is also observed in the manufacturing industries and construction sector, where natural gas combustion increased by 9.9% while fuel oil combustion decreased by 5.9% respectively.

A	B		C	D	E	F	G	H
IPCC Category Code	**IPCC Category**	**Fuel Type**	**Greenhouse Gas**	**Year 2000 Emissions ($GgCO_2$ eq)**	**Year 2018 Emissions ($GgCO_2$ eq)**	**Trend Assessment**	**Percentage Contribution to Trend**	**Cumulative Total of Column G**
1A1	Fuel Combustion Activities – Energy Industries	Fuel Oil	CO_2	16,965.21	2.41	0.59	40.2%	40.2%
1A1	Fuel Combustion Activities – Energy Industries	Natural Gas	CO_2	2,766.79	17,190.68	0.34	23.2%	63.4%
1A2	Fuel Combustion Activities – Manufacturing Industries & Construction	Natural Gas	CO_2	NO	5,700.78	0.15	9.9%	73.3%
1A2	Fuel Combustion Activities – Manufacturing Industries & Construction	Refinery Gas	CO_2	4,781.20	10,719.60	0.11	7.2%	80.5%
1A2	Fuel Combustion Activities – Manufacturing Industries & Construction	Fuel Oil	CO_2	4,007.03	2,099.94	0.09	5.9%	86.4%
1A1	Fuel Combustion Activities – Energy Industries	Coal	CO_2	NO	1,168.05	0.03	2.0%	88.4%
1B2	Fugitive Emissions from Fuels	Oil and Natural Gas	CO_2	132.91	1,245.91	0.03	1.8%	90.2%
2E	Industrial Processes and Product Use – Electronics Industry		PFCs	519.23	1,437.92	0.02	1.3%	91.5%
1A1	Fuel Combustion Activities – Energy Industries (Waste – MSW WtE)	Solid Waste[43]	CO_2	848.81	1,830.72	0.02	1.2%	92.7%
1A3b	Fuel Combustion Activities – Transportation – Road Transportation	Motor Gasoline	CO_2	2,081.15	2,413.58	0.01	0.7%	93.4%
2F	Industrial Processes and Product Use – Use of HFCs and PFCs as Substitutes for Ozone Depleting Substances		HFCs	NO	375.63	0.01	0.7%	94.1%
1A2	Fuel Combustion Activities – Manufacturing Industries & Construction	Light Fuel Oil	CO_2	581.40	440.54	0.01	0.6%	94.7%
1A2	Fuel Combustion Activities – Manufacturing Industries & Construction	Diesel	CO_2	609.93	479.88	0.01	0.6%	95.3%

Notation key:
NO = Not Occurring

[43]According to the 2006 IPCC Guidelines, CO_2 emissions from solid waste incineration is estimated from the portion of waste that is fossil-based.

UNCERTAINTY ANALYSIS

An uncertainty analysis is conducted for the GHG inventory to prioritise national efforts to reduce the uncertainty of inventories and guide decisions on methodological choice. Currently, efforts are being undertaken to quantitatively estimate the uncertainty of the GHG inventory. The results will be included in future reports when ready.

Singapore's national GHG inventory was qualitatively assessed based on three levels of confidence: H for High confidence in estimation, M for Medium confidence in estimation, and L for Low confidence in estimation.

99.8% of the GHG data has a confidence level of either "medium" or "high". A large proportion of these emissions is from fuel combustion activities. The collection of fuel combustion, fugitive emissions, IPPU, clinical and hazardous waste data through Acts regulated by EMA and NEA strengthened the confidence in the data and formed the basis for the high confidence in the GHG emissions.

Data collected under surveys was assessed to be of medium confidence level. Quality control and quality assurance procedures outlined in the 2006 IPCC Guidelines were also applied to minimise human errors during inventory compilation and to ensure that the inventory is complete, accurate, and consistent.

The categories that were assessed to be of lower confidence accounted for about 0.2% of total GHG emissions. The conservative level of confidence reflected the uncertainties for these emissions estimates. Methodological issues such as proxy data used to estimate N_2O emissions from wastewater treatment and discharge resulted in a lower level of confidence. Additionally, as the GHG estimates from the LULUCF sector are based on subtractions between emissions and removals in pools, subcategories and across subcategories, this leads to a relatively high uncertainty even when higher tier approaches are applied, as is the case for Singapore. The highly dynamic Settlements subcategories and the subcategory land-use change to Forest Land contribute most to the total uncertainty of the LULUCF sector.

The landscape of Bishan-Ang Mo Kio Park was reconfigured to manage stormwater, prevent flooding, and support biodiversity within an urban setting.

CONFIDENCE LEVELS OF DATA[45, 46]

Greenhouse Gas Source and Sink Categories	Confidence Level	% of Total Emissions
1 — ENERGY		93.5%
1A - Fuel Combustion Activities		
1A1 Energy Industries	H	38.1%
1A2 Manufacturing Industries and Construction	M	37.7%
1A3 Transport	M	14.2%
1A4a Commercial/ Institutional	H	0.8%
1A4b Residential	H	0.4%
1B - Fugitive Emissions from Fuels		
1B2 Oil and Natural Gas	H	2.4%
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	H	5.7%
3 — AGRICULTURE	M	0.0%
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	M	0.2%
4 — WASTE		0.6%
4A - Solid Waste Disposal	L	0.0%
4C - Incineration and Open Burning of Waste		
Clinical Waste Incineration	H	0.0%
Hazardous Waste Incineration	H	0.4%
4D - Wastewater Treatment and Discharge	L	0.1%

Notation keys:
L = Low, M = Medium, H = High

[45]As some figures are considerably small, they may be presented as ''0.0'' due to rounding.
[46]Figures may not add up to the totals due to rounding.

RECALCULATIONS

Singapore's national GHG inventory time series were recalculated using the methodologies outlined in the 2006 IPCC Guidelines, with methods and emission factors used for emissions estimation summarised on pages 69–71. For source categories with new or updated activity data, emission factors and equation parameters where applicable, emissions estimates for past inventories were also recalculated. This includes emissions from the agriculture sector, updates to the LULUCF sector, updates to the United Nations' FAO annual per capita protein intake figure, and updates for activity data under the energy sector such as IPCC category 1A2 Manufacturing Industries and Construction, and 1A3 Transport. To ensure time series consistency, efforts were taken to use the prescribed splicing techniques from the 2006 IPCC Guidelines (e.g. surrogate data) to ensure that the inventories were recalculated where historical data was unavailable.

Generally, using the methodologies outlined in the 2006 IPCC Guidelines, updates to activity data and parameters resulted in an estimated 0.1% increase in GHG emissions across the time series for the earlier years. The increase in GHG emissions in the year 2016 was largely due to revision in activity data arising from efforts taken to ensure transparency, consistency, comparability and confidence in the national GHG inventory of emission estimates as prescribed in the IPCC Good Practice Guidance. The table below provides the results and comparison of the recalculated national GHG inventory for the years reported in previous NCs and BURs.

S/N	Net National Emissions	Before/After Recalculations	1994	2000	2010	2012	2014	2016
			($GgCO_2$ eq)					
1	Net National Emissions (reported in 4th BUR)	Before	28,115.53	38,952.34	46,142.83	47,909.83	49,943.35	50,702.71
2	Net National Emissions (reported in 5th NC and 5th BUR)	After	28,151.94	38,986.99	46,165.75	47,931.91	49,973.25	51,531.18
% Difference between Rows 1 and 2			0.13%	0.09%	0.05%	0.05%	0.06%	1.63%

TIME SERIES OF GREENHOUSE GAS EMISSIONS (2000–2018)

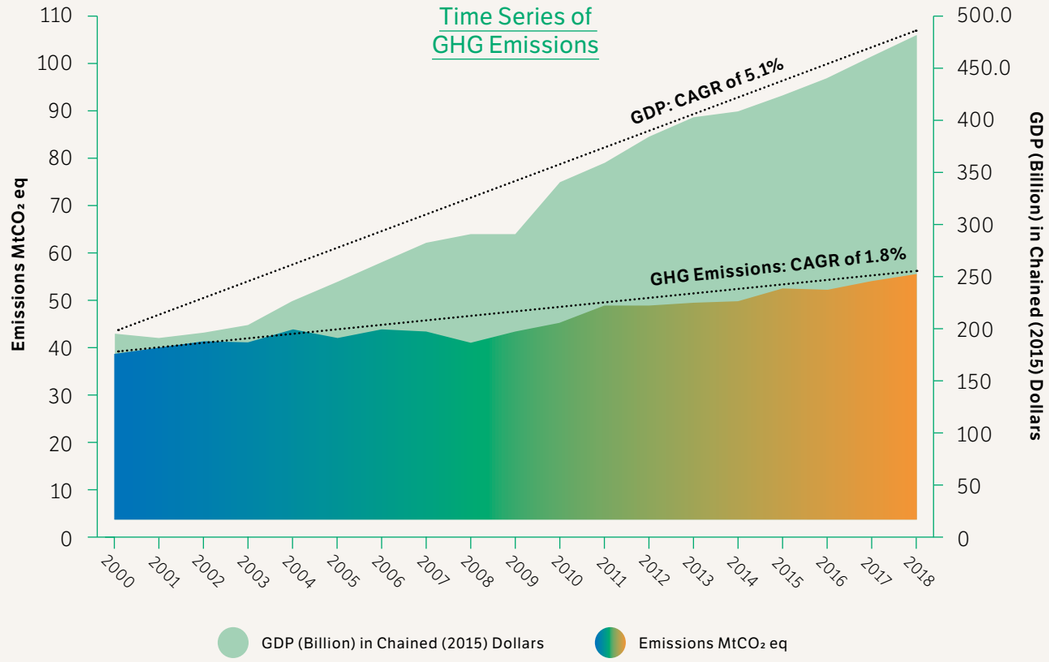
From 2000 to 2018, Singapore's economy grew at a compounded annual growth rate (CAGR) of 5.1%, while real GDP levels (in chained (2015) dollars) increased by 146% from S$193 billion in 2000 to S$476 billion in 2018. In the same period, Singapore's GHG emissions grew at a slower rate with a CAGR of 1.8%, and an increase of 36.7% (14,326 $GgCO_2$ equivalent) from 2000 to 2018.

As an open trade-oriented economy, Singapore's GDP growth volatility is much higher than that of larger economies.[47] Singapore's GDP is sensitive to changes in the global economy as emissions attributable to economic activity make up a large proportion of Singapore's emissions. Hence, our emissions trajectory can be affected by external economic conditions and events. For example, the uptick in emissions in 2010 can be attributed to Singapore's strong recovery after the Global Financial Crisis in 2008 and 2009, when GDP grew by 14.5% in 2010 after growing marginally at 0.1% in 2009.

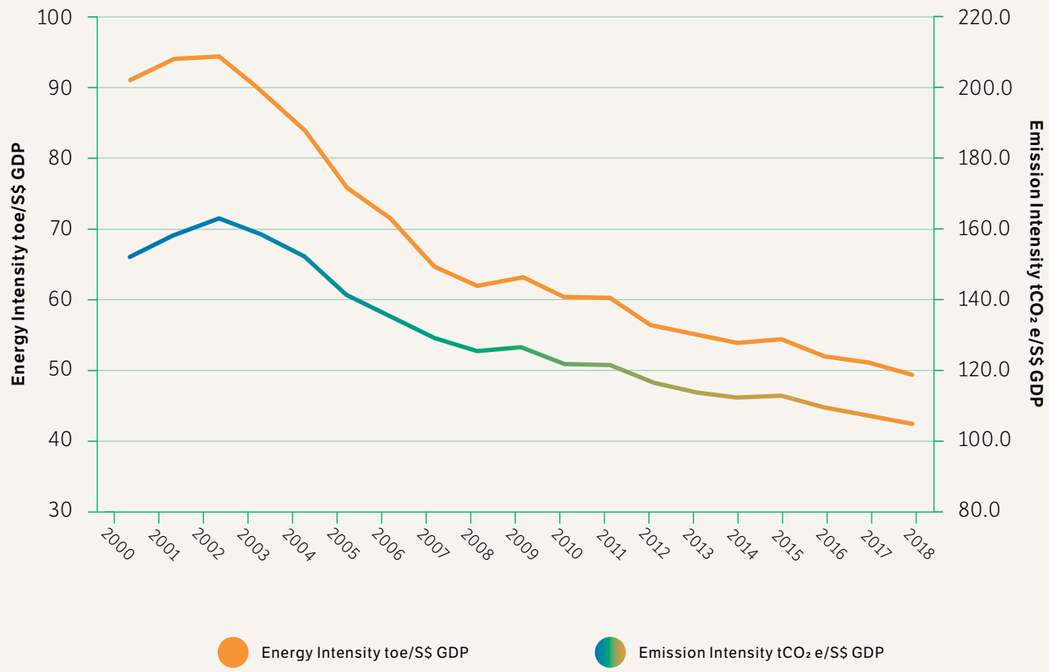
Overall, emissions intensity improved by 44.5% while energy intensity improved by 39.8% from 2000 to 2018. Some of the key policy initiatives implemented during this period include a switch in fuel mix from fuel oil to natural gas, a cleaner fuel source, as well as various schemes promoting energy efficiency. These include the BCA Green Mark Scheme, a green building rating system, and co-funding and financing schemes that promote the development of environmentally friendly buildings.

[47] Is Smoother Always Better? Understanding Singapore's Volatility-Growth Relationship, Shruthi Jayaram, Titus Lee and Thia Jang Ping, Economic Survey of Singapore 2009

Time Series of GHG Emissions



Time Series of Energy and Emissions Intensity



The Eco-Link@BKE is an ecological bridge that spans the Bukit Timah Expressway, connecting Bukit Timah Nature Reserve and Central Catchment Nature Reserve.

PREPARATION OF THE GREENHOUSE GAS INVENTORY

The preparation of the national GHG inventory is a multi-agency effort led by the NEA. An overview of the four-stage GHG inventory preparation process is shown below.

Stage 1
Collection as well as **QC** and **QA** checks conducted by data owners

Stage 2
QC checks on computation of emissions by NEA

Stage 3
QA checks on computation of emissions by an independent team within NEA

Stage 4
Endorsement by MRV Taskforce after completion of **QC**/**QA** by agencies

QC = Quality Control

QA = Quality Assurance

Quality control and quality assurance checks for the compilation of data and computation of GHG emissions were developed based on the 2006 IPCC Guidelines for National GHG Inventories.

An Emissions Data Monitoring and Analysis (EDMA) system has been developed to facilitate the inventory compilation process. The system has been designed to receive input and activity data from different data sources, generate emissions estimates, facilitate quality control checks and provide the relevant government agencies with secure access to the emissions database.

The system has been designed for efficient electronic data management and archival of all data used in the estimation of emissions to ensure the continuity and security of the national GHG inventory. The data management functions of the system include archival and storage of past activity data and emission factors, archival and storage of data source descriptions, methodology descriptions and reference materials, and one-stop integrated access to the documentation of data sources, methodology descriptions, and reference materials.

The 35-ha Singapore Sports Hub, which was awarded the Green Mark Gold Plus standard for its sustainable design.

1 — Quality Control and Quality Assurance for the Collection/Compilation of Data

Data required for the national GHG inventory is collected/compiled through legislation and surveys administered by the various government agencies (data owners). The sources of data for the national GHG inventory are as follows:

SOURCES OF DATA FOR GHG INVENTORY

IPCC Sector	Type of GHG	Data Owner
1 — ENERGY		93.5%
1A - Fuel Combustion Activities	CO_2, CH_4, N_2O	
1A1 Energy Industries		Energy Market Authority National Environment Agency PUB, Singapore's National Water Agency
1A2 Manufacturing Industries and Construction		Energy Market Authority National Environment Agency
1A3 Transport		Energy Market Authority National Environment Agency Maritime and Port Authority of Singapore
1A4a Commercial/ Institutional		Department of Statistics Energy Market Authority
1A4b Residential		
1B - Fugitive Emissions from Fuels		
1B2 Oil and Natural Gas	CO_2, CH_4, N_2O	National Environment Agency
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3	National Environment Agency
3 — AGRICULTURE	CO_2, CH_4, N_2O	Singapore Food Agency
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	CO_2, N_2O	National Parks Board
4 — WASTE		
4A - Solid Waste Disposal	CH_4	PUB, Singapore's National Water Agency
4C - Incineration and Open Burning of Waste		
Clinical Waste Incineration	CO_2, CH_4, N_2O	National Environment Agency
Hazardous Waste Incineration		
4D - Wastewater Treatment and Discharge	N_2O	PUB, Singapore's National Water Agency Food and Agriculture Organization of the United Nations (FAO)

URA's Landscaping for Urban Spaces and High Rises (LUSH) programme helps to green our built environment by requiring developments to replace their site area with an equivalent amount of greenery and communal spaces, in exchange for development incentives.

QC for Data

The quality control checks conducted by the data owners are summarised below:

	QC Activity	Actions by Data Owner
Units	Check that parameter units are correctly recorded and that appropriate conversion factors are used.	Analysed and verified data trends for potential unit or conversion errors.
Database	Check that parameter units are correctly recorded and that appropriate conversion factors are used.	Analysed data trends. Highlighted deviations and outliers and verified them for potential data input errors and reference coding errors.
	Check the integrity of database files.	Verified data processed in the database against original data files to ensure consistency and data integrity.
	Check for consistency in data between source categories.	Verified the data mapping tables and files used to ensure that mapping and data consistencies between different source categories are maintained. Data mapping tables adopt Singapore's classification.
	Undertake completeness checks.	Streamlined and aligned data sources used. Included new data streams where applicable.
	Check methodological and data changes resulting in recalculations.	Re-processed updated data in the system and recompiled sub-totals and totals from the updated data. Analysed time series of totals to ensure data quality standards are achieved. Adopted appropriate splicing techniques to ensure a consistent time series.
Compilation	Check that the movement of inventory data among processing steps is correct.	Verified and checked sub-totals against totals when computing aggregated figures.
	Internal documentation.	Conducted regular data compilation reviews and documented these processes. Archived and stored the data in the EDMA system periodically.
Comparison	Compare estimates to previous estimates.	Analysed time series of totals to ensure data quality standards are achieved.

QA for Data

Data collected is verified by an independent team within each agency, which is not involved in the data collection and compilation process. After these quality assurance checks, agencies will submit their quality control and quality assurance documentation together with their data to NEA for computation/conversion to GHG emissions.

2 — Quality Control for the Computation of Emissions

GHG emissions are computed by the GHG inventory team within NEA based on the activity data provided by agencies. The quality control checks on emissions computed from source data are verified by persons who are not involved in the emissions computation. These procedures help to minimise human errors during inventory compilation, and ensure the production of complete, accurate, and consistent inventories. The quality control procedures that were conducted by the GHG inventory team within NEA are summarised above.

Quality control checks have also been incorporated into the EDMA system. These include checks on the acceptable range of data input and factors, as well as percentage differences compared to emissions from previous years.

3 — Quality Assurance for Computation of Emissions

The quality assurance procedures comprise checking of transcription of data between databases, verification of data, emission factors, conversion factors and equations, including checking of congruence of totals and sub-totals.

The computed emissions are verified by an independent NEA team that is not involved in the computation of the GHG emissions. This quality assurance team conducts a review of the inventory compilation process. The review involves the verification of methods, data, processes, and assumptions for the preparation of the inventory, and recommendation of areas for improvement as necessary. During the review, needs for institutional strengthening and capacity building are identified and planned to improve future work on the national GHG inventory. Training is proposed as necessary for new and existing officers involved in the preparation of the national GHG inventory.

4 — Endorsement

An inter-agency working committee (MRV Taskforce) will review the quality control and quality assurance procedures conducted by agencies, and endorse the national GHG inventory.

This garden is named after Sir Stamford Raffles, an avid naturalist who spent his free time studying botany and wildlife. Inspired by his love for plants, the Raffles Garden showcases the diverse plant species that Raffles encountered in Southeast Asia.

CHAPTER 4

MITIGATION MEASURES

Shifting to cleaner energy and improving energy efficiency across sectors are some key strategies to mitigate Singapore's emissions.

Opened in April 2019, Jewel Changi Airport is an iconic mixed-used development that integrates nature, engineering innovation and human ingenuity. The dome-shaped complex houses a 40-metre high Rain Vortex – the world's largest indoor waterfall – and is made of materials and with infrastructure and systems that are energy efficient and responsive to Singapore's tropical environment.

The 60 MWp floating solar photovoltaic on Tengeh Reservoir is one of the world's largest inland floating solar farms.

INTRODUCTION

Under our 2009 Copenhagen pledge, Singapore is committed to reducing emissions by 16% below 2020 BAU levels. Having ratified the Paris Agreement on 21 September 2016, Singapore has also enhanced our NDC pledge which builds on our 2020 commitment for which we have met. Under the enhanced 2030 NDC, Singapore intends to reduce emissions to around 60 $MtCO_2$ eq in 2030 after peaking our emissions earlier.

SINGAPORE'S APPROACH TO REDUCING EMISSIONS

Energy is a strategic resource for Singapore. As an alternative energy-disadvantaged country, Singapore is highly reliant on imports for our energy needs.

Recognising that energy is a scarce resource, Singapore allows for market pricing of fuel and electricity without any direct subsidy. This results in firms and households making appropriate energy consumption choices, such as minimising energy wastage and over-consumption, which contributes to emissions reduction.

Since the early 2000s, Singapore has taken steps to use a cleaner fuel mix for electricity generation, switching from fuel oil to natural gas. To further decarbonise the power sector as part of our energy transition and other initiatives under the Green Plan, we will harness and tap on "Four Switches" to transform our energy supply:

- 1st Switch: Natural gas
- 2nd Switch: Solar
- 3rd Switch: Regional power grids
- 4th Switch: Emerging low-carbon alternatives (e.g. CCUS and hydrogen).

Given Singapore's limited options for alternative energy sources, improving energy efficiency is one of our key mitigation strategies. This will require households and businesses to be more energy-conscious and make adjustments to their daily activities, choices, and processes. In addition to reducing emissions, greater energy efficiency also leads to cost savings. The Government will continue to raise awareness and build capabilities to improve energy efficiency across sectors. A major part of this effort involves addressing sector-specific barriers using incentives or regulatory measures where appropriate.

Measures to Reduce Emissions

Measure #1 Shifting to Cleaner Energy Sources

Traditionally, Singapore has relied heavily on natural gas piped in from Malaysia and Indonesia for power generation. Since May 2013, Singapore has imported LNG from global gas markets through our LNG terminal. Having access to both LNG and piped natural gas has helped to diversify and secure our energy sources and further increase the share of clean natural gas in our fuel mix. The proportion of Singapore's electricity generated by natural gas rose from 26% in 2001 to 95.8% in 2020. The grid emission factor of the power system has improved in tandem. Today, Singapore ranks among the countries with the highest percentage use of natural gas for electricity generation. Our fuel mix makes us much less carbon-intensive than many other nations that still use coal as an important part of their power generation. Notwithstanding this, we have launched the Genco Energy Efficiency Grant Call and Advanced Combined Cycle Gas Turbines (CCGT) incentive scheme to encourage generation companies to improve energy efficiency and reduce carbon emissions of their existing natural gas units.

Despite limited land and high cloud cover, solar energy remains one of the most viable renewable energy options for Singapore.

We are also increasing our use of solar energy. Among the renewable energy options, solar energy remains the most promising option for Singapore. As of 2020, Singapore had installed 435.8 megawatt-peak (MWp) of solar PV compared to 15.3 MWp in 2013. We have also set targets to achieve 1.5 gigawatt-peak (GWp) of solar by 2025 and at least 2 GWp by 2030. To achieve this, we are increasing solar deployment on both conventional rooftop spaces and innovative solar applications (e.g. floating solar, solar on building facades). We are also actively investing in R&D and test-bedding to lower cost, optimise space utilisation, and improve the efficiency and durability of solar technologies.

To facilitate this, EDB had previously implemented solar capability building schemes such as the Solar Capability Scheme (SCS) and Clean Energy Research & Testbedding (CERT) Programme. These had built up capabilities among our local solar companies in the engineering design and installation of solar PV systems. R&D funding was also directed towards building capabilities in solar PV manufacturing, systems, and grid integration. Moving forward, Singapore will continue to invest in R&D to develop low-cost, high-efficiency cells and modules, urban solar system capabilities, and grid integration solutions for intermittent renewables.

On the demand side, the Government embarked on the SolarNova programme which aggregates demand for solar PV deployment across public sector buildings and spaces, to catalyse the growth of the solar industry in Singapore. Five leasing tenders totalling 296 MWp have been awarded since 2015, with a sixth tender awarded in 2022 for 70 MWp of solar energy. The SolarNova programme forms part of Singapore's plan to reach at least 2 GWp of installed solar PV capacity by 2030.

PUB is actively deploying solar panels on reservoirs. The clean energy generated is sufficient to power PUB's five local water treatment plants and the Marina Barrage, offsetting approximately 7% of

PUB's annual energy needs and reducing our carbon emissions by about 32 kilotonnes per year. Two floating solar PV systems of 1.5 MWp each were also deployed at Bedok and Lower Seletar Reservoirs in 2021. PUB is currently studying the feasibility of deploying 44MWp and 100MWp floating solar PV systems at Pandan and Lower Seletar Reservoirs respectively.

In addition, EMA has been enhancing the market and regulatory framework to facilitate solar deployment in a sustainable manner. Some of the key enhancements include providing greater clarity on the licensing framework for solar energy and streamlining market registration and settlement procedures to reduce compliance cost. The Government has also worked with research institutes to review and update Singapore's estimated solar technical potential.[48] This helps to increase public and industry awareness of solar energy in Singapore's context and support deployment. The Government will continue to work with the industry to facilitate greater deployment of solar energy in the power system.

To manage the intermittent nature of solar and ensure grid resilience, we have set out a target to deploy at least 200 megawatts (MW) of ESS beyond 2025. We are working with the industry and research community to evolve policies and regulations and embark on R&D initiatives and testbeds to grow a vibrant ecosystem and facilitate pervasive ESS deployment in Singapore.

For instance, EMA and Keppel Offshore & Marine (Keppel O&M) awarded a research grant to a consortium in October 2020 to pilot Singapore's first floating ESS. The consortium will deploy a 7.5 MW/7.5 MWh Li-ion battery ESS on Keppel O&M's Floating Living Lab, which will be one of Singapore's largest ESS deployments to date. As Singapore's hot and humid environment can affect ESS performance, the testbed will also use an innovative liquid-cooling solution to cool the battery cells and enhance the lifecycle of the ESS.

Singapore targets to deploy at least 200 megawatts (MW) of ESS beyond 2025 to manage solar intermittency.

[48]Technical potential refers to the estimated achievable capacity (expressed in terms of megawatt) of a renewable energy technology that is available for development after accounting for topographic limitations, usable space, system performance etc.

These measures to shift Singapore to cleaner energy sources were projected to achieve 4.18 Mt of CO_2 eq abatement by 2020. An estimated 4.55 Mt of CO_2 eq abatement was achieved in 2020.

Beyond the switch to natural gas and maximising solar deployment, Singapore is tapping on regional power grids to access cleaner energy sources beyond our borders. We are planning to import up to 4 GW of low-carbon electricity by 2035, which is expected to make up around 30% of Singapore's electricity supply in 2035. To pave the way for these electricity imports, EMA has been working with various partners on electricity import trials, which will allow us to assess and refine the technical and regulatory frameworks for importing electricity. They include a trial to import 100 MW of electricity from Peninsular Malaysia, as well as a pilot to import around 100 MW of solar-generated electricity from Pulau Bulan, Indonesia. Singapore is also a part of the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP), which facilitates cross-border power trade among the four countries.

Finally, Singapore is exploring emerging low-carbon technologies such as advanced geothermal systems, hydrogen, and CCUS that can help reduce Singapore's carbon footprint in the longer term. While such technologies are nascent, Singapore is taking active steps including investing in R&D through the LCER Funding Initiative to improve the technical and economic viability of such solutions.

Measure #2 Improving Industrial Energy Efficiency

Industry is the highest energy-consuming sector in Singapore and improving industrial energy efficiency is key to reducing our emissions. We have been actively driving energy efficiency in the industry sector by encouraging the adoption of energy-efficient technologies through a mix of incentives, capability building and regulations. In 2018, Singapore achieved an energy intensity of 38.3 ktoe/S$ billion or 52.3 ktoe/US$ billion, which was a 39.8% improvement over 2000 levels.[49]

Since 2005, the Government has been providing grants to help industrial facilities review their facility design to incorporate energy and resource efficiency measures, and carry out energy assessments to identify and implement energy efficiency opportunities. Examples of these schemes include the Productivity Grant for Energy Efficiency and the Energy Efficiency Fund (E2F) which offset part of the initial capital investments in energy-efficient technologies.

Singapore has also been conducting energy efficiency studies and putting in place national schemes for building energy efficiency capabilities within our workforce. The Energy Efficiency Opportunities (EEO) Assessor Certification Scheme jointly developed by the Government and the Institution of Engineers, Singapore (IES) in 2018 aims to certify qualified professionals to conduct energy efficiency opportunities assessments. The Energy Efficiency Technology Centre (EETC) has been set up to help companies, in particular, Small and Medium-sized Enterprises (SMEs), which may not have the resources or expertise, to uncover and implement energy efficiency opportunities, and train a pipeline of industrial energy efficiency engineers to support the future low-carbon economy. This centre is a collaboration between the Government and the Singapore Institute of Technology (SIT).

The ECA introduced in 2013 mandates energy intensive companies in the industry sector to appoint a qualified energy manager, monitor, and report their energy use and GHG emissions,[50] and submit energy efficiency improvement plans on an annual basis. The ECA has since been further enhanced. With effect from 2018, companies regulated under the ECA are required to adopt specified methodologies for GHG measurement and reporting, in line with best practices and internationally recognised standards. 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.

Overall, we achieved an estimated 1.08 Mt of CO_2 eq abatement from these energy efficiency measures in 2020, in line with our original estimated range of 1.05–1.43 Mt of CO_2 eq abatement.

[49]Figures cited are national-level figures, calculated from domestic data sources. Conversion from S$ to US$ is based on exchange rates as of July 2020.
[50]From 1 January 2019, measurement and reporting requirements for GHG emissions are imposed under the Carbon Pricing Act.

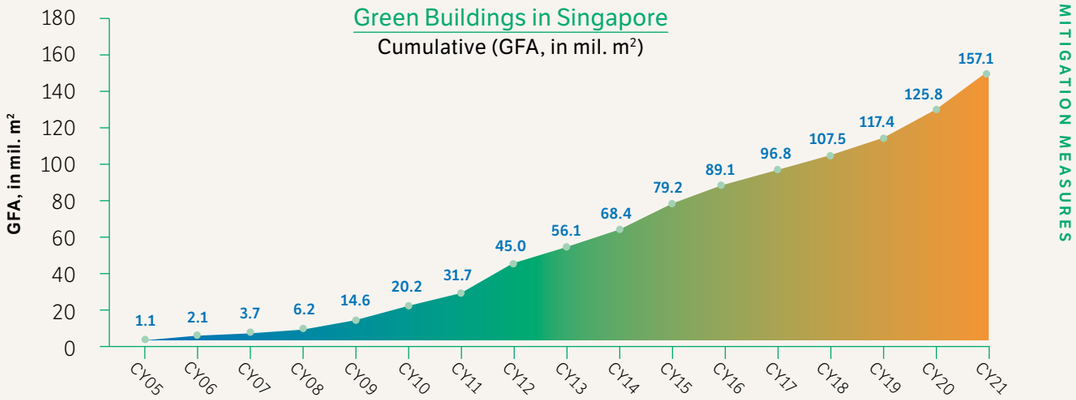
Measure #3 Greening Buildings

As a highly urbanised island state, the greening of buildings is an important part of Singapore's mitigation strategy. To address barriers to adopting energy-efficient technologies in buildings,[51] the Government launched the BCA Green Mark scheme in 2005, a green building rating system designed specifically for buildings in the tropics. This scheme formed the backbone of Singapore's first Green Building Masterplan (GBMP), which was rolled out in 2006 to encourage, enable, and engage industry stakeholders to adopt new green buildings. The first edition of the GBMP targeted new buildings to encourage developers to embed sustainability as part of a building's life cycle from the outset. Subsequent editions of the GBMP focused on greening the larger stock of existing buildings and engaging building occupants to change energy consumption behaviour. An ambitious target to green 80% of Singapore's GFA by 2030 was also set in 2009 to guide measures to drive green building adoption.

The Government has employed the use of both regulations and incentives in the past GBMPs to drive the green building movement. Developers and owners of new buildings, or existing buildings undergoing major retrofitting works, are required to achieve minimum environmental sustainability standards. Since 2010, new building projects in key strategic areas such as Marina Bay, the Downtown Core and Jurong Lake District have been required to meet even higher standards. Existing prescribed buildings[52] are required to submit building information and energy consumption data annually. To encourage building owners to consciously adopt measures to improve their buildings' energy efficiency, the information from commercial buildings, healthcare facilities, and educational institutions are publicly disclosed. In addition, all existing buildings with GFA of 5,000 square metres or more have to achieve minimum environmental sustainability standards when a cooling system is installed or retrofitted, as well as carry out three-yearly energy audits on building cooling systems. Regulation is complemented with incentives and financing schemes to encourage developers to achieve higher tier GM ratings, and to assist building owners in financing the high upfront retrofitting cost.

Rooftop spaces in HDB Multi-Storey Carparks are transformed into community gardens as part of HDB Green Towns Programme to intensify greening in public housing estates.

[51]These barriers include limited capital and split incentives between building developers and owners.
[52]Building types include commercial buildings (offices, hotels, retail buildings and mixed developments), healthcare facilities, education institutions, civic and community institutions, places of worship, and sport and recreation.



With support from Research and Innovation (R&I) efforts in green buildings, the Government launched the Super Low Energy (SLE) Programme for Buildings[53] in 2018, which included strategies to mainstream these new best-in-class energy-efficient buildings.

In 2020, the BCA worked with the Singapore Green Building Council (SGBC) to co-create the 4th edition of the SGBMP together with the industry and community to chart the next steps of Singapore's green building journey post-2020. In this co-creation process, the Government worked closely with traditional industry stakeholders and also reached out to more than 5,000 individuals in the community through various engagement channels.SGBMP was officially launched in March 2021 after one year of co-creation. The three key outcomes for the SGBMP, dubbed '80-80-80 in 2030' will accelerate our transition to a low-carbon built environment:

1. **Existing target** 80% of buildings by GFA to be green by 2030.
2. **New target** 80% of new developments by GFA to be SLE buildings from 2030
3. **New target** 80% improvement in EE (from 2005 levels) for best-in-class green buildings by 2030.

As of December 2021, we have greened more than 49% of our buildings by GFA and are on track to meeting our target of 80% by 2030 and will be implementing other measures to meet the "80-80-80" outcomes for 2030.

The mitigation measures in the building sector were projected to achieve 0.87–1.55 Mt of CO_2 eq abatement by 2020. In 2020, the abatement achieved was 0.986 Mt of CO_2 eq.

Measure #4 Shifting Travel Demand to Low-Emission Modes and Reducing Vehicular Emissions

Public transport is the most energy-efficient mode of powered transport. Singapore's target is for the mass public transport modal share during the morning and evening peak hours to reach 75% by 2030. Singapore further aims to establish Walk-Cycle-Ride (WCR) transport modes, comprising active mobility and public and shared transport modes, as the preferred way to travel. By 2040, all journeys to the nearest neighbourhood centre using WCR modes of transport will take no more than 20 minutes, while nine in 10 peak period WCR journeys will be completed in less than 45 minutes.

To encourage the use of public transport, the length of the rail network will expand from about 245 km today to about 360 km in the early 2030s. Eight in 10 households will be within a 10-minute walk from a train station. We will also progressively implement Transit Priority Corridors that serve as dedicated, continuous bus lanes, and deploy smarter traffic control solutions to reduce passengers'

[53]SLE buildings can achieve at least 60% improvements in energy efficiency (EE) over 2005 baseline levels. In 2018, the highest rating achievable under the Green Mark scheme is equivalent to 50% EE improvement over 2005 levels.

Singapore aims to establish Walk-Cycle-Ride (WCR) transport modes as the preferred way to travel.

commute times. Additionally, we will maintain an open and contestable point-to-point market that provides commuters better access to taxis and private hire cars, and encourage car sharing to give the populace more commuting choices without having to own a car.

Singapore will accelerate the building of cycling paths and active mobility infrastructure to make cycling and walking more convenient and attractive. By 2030, our cycling path network will be extended to more than 1,000 km, up from 460 km in 2020. Beyond the 200 km of sheltered walkways from transport nodes to homes and public amenities built as of now, a further 150 km of these sheltered walkways will be added by 2040.

The ownership and usage of private vehicles will continue to be managed through various taxes as well as fees and charges that reflect the competing needs for our scarce land resource. Prospective vehicle owners are required to bid and pay for a limited pool of Certificates of Entitlement, which allows a holder to purchase a vehicle and use it for 10 years. Since 2018, we have capped private car and motorcycle growth at zero. To manage car usage, charges are imposed on all vehicles for using congested roads during peak hours throughout the year.

To encourage the use of vehicles with lower emissions, the Carbon Emissions-Based Vehicle Scheme (CEVS) and the Fuel Economy Labelling Scheme (FELS) were introduced in 2013. FELS provides information on the fuel economy of vehicles for a more informed decision on vehicle purchase, while CEVS provides rebates for low-emission cars and imposes surcharges on high-emission cars. CEVS was replaced by the Vehicular Emissions Scheme (VES), with a new Vehicular Emissions label, in January 2018. In addition to CO_2, VES includes four additional pollutants (i.e. hydrocarbons, carbon monoxide, nitrogen oxides, and particulate matter) in the assessment of new cars, taxis, and newly imported used cars for rebate or surcharge based on the worst-performing pollutant. Given the promising results of VES, a similar scheme, the Commercial Vehicle Emissions Scheme, has also been introduced in April 2021 for light goods vehicles.

Singapore is working on the large-scale adoption of green vehicles. By 2040, we aim to phase out internal combustion engine (ICE) vehicles and have all vehicles running on cleaner energy. The public sector itself will take the lead and progressively procure and use cleaner energy vehicles. From 2020, all new public bus purchases will be cleaner energy buses, including electric and hybrid buses. We are introducing policies and initiatives to encourage the adoption of electric vehicles (EVs). We have introduced tax incentives to lower the upfront and running cost of owning an EV such as the Electric Vehicle Early Adoption Incentive (EEAI), the enhanced VES, and revisions to the road tax structure for mass-market EVs. We will also expand our public charging infrastructure to support the growth of the EV population, with a target of 60,000 charging points nationwide by 2030.

By making WCR modes the preferred way to travel, managing private car usage, and proliferating green vehicles, Singapore will further reduce vehicular emissions and enhance the overall carbon efficiency of our land transport system.

The mitigation measures in the transport sector achieved 1.67 Mt of CO_2 eq abatement in 2020, with an estimated 1.56 Mt of CO_2 eq abatement projected earlier.

Measure #5 Improving Energy Performance Standards of Household Appliances and Promoting Energy Efficiency to Households

The household sector accounts for about 16% of the total electricity consumed in Singapore. If households reduce their electricity consumption by using energy-efficient appliances, they will help to reduce Singapore's GHG emissions and contribute towards action to address climate change, and also enjoy reduction of their utility bills. To help consumers make more informed purchasing decisions, the Government introduced the Mandatory Energy Labelling Scheme (MELS) in 2008, which requires suppliers of energy-consuming household appliances to affix their products with energy labels to identify energy-efficient models. To date, the MELS covers air conditioners, refrigerators, TVs, clothes dryers, and lamps. In 2019, the MELS was expanded to cover more lamp types such as common compact fluorescent lamps with non-integrated ballasts (CFLni), fluorescent tubes, and their LED direct replacements. In 2021, MELS was expanded to cover Variable Refrigerant Flow (VRF) air-conditioners.

Regulations on MEPS were introduced for refrigerators and air conditioners in 2011 to raise the average energy efficiency of household appliances by removing energy-inefficient models from the market. Only appliance models that meet the MEPS are allowed for sale. This protects consumers from being locked into the high energy costs of operating energy-inefficient appliances. MEPS cover air conditioners, refrigerators, clothes dryers, lamps, and fluorescent lamp ballasts. Since the introduction of the MELS and MEPS, the average energy efficiency of

A joint initiative by NEA and PUB, the Climate Friendly Households (CFH) programme provides 1-, 2-, and 3-room households with e-vouchers to purchase energy-efficient refrigerators and LED lights and water-efficient shower fittings.

air conditioners as well as refrigerators has improved by 47% and 46% respectively. This translates to annual household energy savings of about S$320 million or US$236 million.[54]

In 2017 and 2018, the Government organised the "Energy-Saving Challenge" to encourage households to be more energy-efficient and practise energy-saving habits such as setting the air conditioner temperature at 25 °C. Participants who reduced their electricity use by 1% or more during the Challenge period stood a chance to win prizes from the campaign sponsors. The Challenge received 7,000, and more than 15,000 entries in 2017 and 2018 respectively. Participants in the two campaigns saved a total of 800,000 kWh during the contest periods.

To encourage households staying in one- or two-room public housing units to switch to using LED lights, NEA provided S$25 or US$18.50 vouchers with a Switch and Save – Use LED (SSUL) programme in 2018. About 9,000 households utilised the vouchers which resulted in an annual electricity savings of about 200,000 kWh. This was followed by the launch of the Climate Friendly Households Programme in 2020 where each one-, two-, and three-room public housing household was provided with $225 or US$166.46 worth of e-vouchers to purchase energy-efficient and climate-friendly refrigerators, LED lights, and water-efficient shower fittings. These mitigation measures have achieved about 0.72 Mt of CO_2 eq abatement in 2020, which is equivalent to taking about 220,000 cars off the road.

Measure #6 Reducing Emissions from Waste and Wastewater Treatment

The Government is also looking to reduce emissions from waste and wastewater treatment. First, we incinerate our waste and wastewater sludge, which reduces methane emissions from landfills. Second, we intend to increase our overall waste recycling rate to 70% by 2030 from the current 52%.

Third, we maximise energy efficiency in operations and increase energy production and recovery. One key initiative in progress is the co-location of a used water treatment plant (Tuas Water Reclamation Plant (TWRP)) and an Integrated Waste Management Facility (IWMF), which is expected to be completed in phases from 2026 onwards. The integration of these two facilities is collectively known as the Tuas Nexus and provides an opportunity to harness synergies in treating used water and solid waste, reaping the benefits of a Water-Energy-Waste nexus. Among the many synergies at Tuas Nexus, the additional biogas produced at TWRP through the co-digestion of food waste slurry and used water sludge will be combusted at the IWMF to enhance its overall plant thermal efficiency and increase power production. The electricity generated by IWMF will be sufficient to sustain the operations of Tuas Nexus, and excess electricity will be exported to the national grid.

The mitigation measures in the waste and water sectors were projected to achieve 0.15 Mt of CO_2 eq abatement by 2020. In 2020, the abatement achieved was 0.14 MtCO_2 eq.

Carbon Tax

Carbon tax provides a strong price signal and impetus for businesses and individuals to reduce their carbon footprint in line with national climate goals. Singapore implemented a carbon tax, the first carbon pricing scheme in Southeast Asia, on 1 January 2019. The carbon tax applies to all facilities emitting 25 ktCO_2 eq or more GHG emissions in a year across all sectors without exemption, and covers around 80% of our national emissions. The carbon tax provides a broad-based price signal to encourage GHG emission reduction where it makes the most economic sense. The carbon tax is part of Singapore's comprehensive suite of mitigation measures to spur emissions reduction, create green growth opportunities, and transition to a low-carbon economy.

The carbon tax level is set at S$5 or US$3.70/tCO_2 eq from 2019 to 2023, to provide a transitional period for emitters to adjust. To support the transition to a low-carbon future, we will raise the carbon tax levels to S$25 or US$18.40/tCO_2 eq in 2024 and 2025, and to S$45 or US$33.20/tCO_2 eq in 2026 and 2027, with a view to reaching S$50–80 or US$36.90–59.00/tCO_2 eq by 2030. This will support our raised climate ambition to achieve net zero emissions by 2050 and secure a greener and more sustainable living environment for future generations, while being economically competitive in a low-carbon future.

[54]Based on the average efficiency of air conditioners and refrigerators between 2008 and 2020. Conversion from S$ to US$ is based on exchange rates as of March 2022.

A transition framework will also be introduced to give existing emissions-intensive trade-exposed (EITE)[55] companies more time to transition to a low-carbon economy. To not unduly erode business competitiveness in the near term and mitigate the risk of carbon leakage, existing facilities in EITE sectors will receive transitory allowances for part of their emissions.

Companies may also surrender high quality international carbon credits, aligned with Paris Agreement Article 6 rules, to offset up to 5% of their taxable emissions from 2024.

International Market Mechanisms

As a non-Annex I Party, Singapore is eligible to participate in the Clean Development Mechanism (CDM) of the Kyoto Protocol which allows GHG emission reduction from registered projects implemented to generate certified emission reduction (CER) credits.

As of December 2020, Singapore has six registered CDM projects. Information on the six registered CDM projects was reported earlier in Singapore's 3rd NC and 1st BUR.

Domestic emissions abatement remains our priority, and carbon credits are only one part of our LEDS. However, due to our lack of alternative energy options, there is a limit on how much we can reduce emissions domestically. Effective international cooperation through carbon credits is part of our suite of measures to achieve our decarbonisation goals. This complements our domestic mitigation efforts and positions Singapore as a carbon services and trading hub to harness new economic opportunities.

Domestic Measurement, Reporting and Verification

The domestic measurement, reporting and verification (dMRV) of Singapore's mitigation actions is a WOG effort.[56] Each government agency is responsible for monitoring, measuring and documenting the progress of the mitigation actions under its purview.

Agencies usually utilise relevant data collected from official surveys, required under various Acts, for dMRV purposes. Data collected from companies and/or building owners is then verified by the lead agencies. For example, power generation companies are required under the Electricity Act to measure and report the quantity of fuel used for electricity generation monthly. The lead agency for the power sector, EMA, will verify the reported data through QA/QC procedures in accordance with the International Energy Agency (IEA), IPCC, and United Nations Statistics Division's guidelines and requirements. EMA uses this data to monitor emissions from the electricity generation sector. The aggregated data is also available through EMA's annual "Singapore Energy Statistics" report.

Information collected by the lead agencies is consolidated by the LWG secretariat annually. LWG will then assess the effect of the various mitigation measures and track Singapore's progress in meeting our mitigation pledge and objectives.

[55]Examples of EITE sectors include the energy and chemicals, and electronics sectors. Non-EITE sectors include domestic-oriented sectors like power generation companies, waste management companies etc.
[56]The agencies involved include MSE, MTI, MOT, NCCS, BCA, EDB, EMA, LTA, MPA, NEA, NParks and PUB.

LIST OF MITIGATION MEASURES

Table 1 — Shifting to Cleaner Energy Sources

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal ($MtCO_2$ eq)	Methodologies and Assumptions	Gas Coverage	Progress Indicators	Results Achieved
Fuel mix switch away from fuel oil	To switch fuel mix away from fuel oil, towards natural gas for power generation.	Facilitating the utilisation of natural gas for power generation. Abatement is expected from an increase in the share of natural gas in the generation mix from approximately 70% in the BAU case to 90% by 2020.	**Completed** 4.38 $MtCO_2$ eq of abatement has been achieved due to the increase in the share of natural gas in the generation mix from approximately 70% in the BAU scenario to 95.8% in 2020. Since 2005, the power generation industry's repowering to natural gas, the introduction of the LNG terminal and LNG vesting has contributed to the increase in the share of natural gas to 95.8% in 2020.	Infrastructure Development	4.0	Natural gas is expected to form more than 90% of Singapore's fuel mix for power generation in 2020 and is the basis of the projected abatement in 2020. The carbon abatement achieved by this measure is estimated based on the amount of fuel oil displaced by cleaner natural gas for power generation.	CO_2	Fuel Mix	Increase in the share of natural gas to 95.8% in 2020. Estimated abatement achieved in 2020: 4.38 Mt
Solar installation from existing schemes	To facilitate the adoption of solar photovoltaics (PVs).	Encouraging more R&D, test-bedding and deployment of solar PVs.	**Completed** Singapore has achieved our target to deploy 350 MWp by 2020. The WOG effort to facilitate solar adoption includes capability development, such as HDB's solar capability building programme for public housing; multi-agency solar-leasing tenders; and EDB's incentive schemes for R&D and test beds, such as the SCS, CERT Programme and floating PV project. EDB and HDB also launched the SolarNova programme, which aims to accelerate solar deployment in Singapore by promoting and aggregating solar demand across government buildings and spaces.	Incentive, Technology	0.18	The carbon abatement achieved by this measure is based on the emissions from CCGTs that would have resulted from generating the amount of electricity displaced by solar energy.	CO_2	Installed Solar Capacity	Estimated abatement achieved in 2020: 0.17 Mt

Table 2 — Improving Industry Energy Efficiency and Promoting Use of Cleaner Fuels

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal ($MtCO_2$ eq)	Methodologies and Assumptions	Gas Coverage	Progress Indicators	Results Achieved
Cogeneration plants	To encourage investment in cogeneration plants.	Encouraging cogeneration plant investments, which will reduce carbon emissions through increasing energy efficiency in electricity and steam generation, through the provision of incentives to encourage companies to improve their energy efficiency.	**Completed** Three cogeneration plants have been constructed.	Incentive	0.67–0.73	0.67–0.73 Mt of carbon mitigation by 2020 is assumed to be delivered by three to four cogeneration plants in the petroleum and petrochemical sector. Abatement achieved per cogeneration plant is based on technical estimates and information provided by companies. As part of the application process for incentives, companies are required to report the carbon abatement resulting from their investments. Verification checks are done by Professional Engineers, Singapore Certified Energy Managers or Qualified Energy Services Specialists after project completion.	CO_2	Number of cogeneration plants, total funding given out, abatement achieved calculated through data collection/ audits.	Estimated abatement achieved in 2020: 0.59 Mt
Manufacturing Energy Efficiency	To encourage energy efficiency and consequently reduce emissions from the manufacturing sector.	Encouraging energy efficiency retrofits in the manufacturing sector through incentives, and private sector financing of energy efficiency projects.	**Completed** Companies have been supported to improve energy efficiency. In 2017, the Energy Efficiency Improvement Assistance (EASe) and other existing incentive schemes were consolidated to form the new E2F to better support a range of energy efficiency efforts.	Incentive	0.31–0.59	Abatement calculated based on carbon abatement from the implementation of projects supported under the schemes. Abatement arising from incentives will be audited by Professional Engineers or Qualified Energy Services Specialists shortly after the commissioning period. All other incentives are verified by company voluntary reporting.	CO_2	Total funding given out, abatement achieved calculated through data collection/ audits.	Estimated abatement achieved in 2020: 0.42 Mt

Table 2 — Improving Industry Energy Efficiency and Promoting Use of Cleaner Fuels

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal ($MtCO_2$ eq)	Methodologies and Assumptions	Gas Coverage	Progress Indicators	Results Achieved
Fuel switching in industry	To encourage fuel switching in third-party utility providers.	Encouraging third-party utility providers to switch to cleaner fuel for steam generation.	**Completed** Two wood-chip boilers totalling 60 tons per hour of steam production capacity have been constructed.	Incentive	0.07	Abatement calculated based on carbon abatement achieved from the displacement of existing fuel by use of cleaner fuel types.	CO_2	Abatement achieved calculated through data collection/ audits.	Estimated abatement achieved in 2020: 0.07 Mt
Data Centre Energy Efficiency	To encourage energy efficiency and consequently reduce emissions from Data Centres.	Encouraging energy efficiency retrofits in Data Centres through incentives.	**Completed** One Data Centre has been supported under this scheme to improve energy efficiency.	Incentive	Up to 0.04	Abatement calculated based on PUE improvements. PUE is a measure of how efficiently a Data Centre uses its power and is the ratio of a Data Centre's total facility power needs to that of all Information and Communications Technology (ICT) equipment.	CO_2	Power Usage Effectiveness (PUE) of Data Centres.	Estimated abatement achieved in 2020: 0.00028 Mt

Table 3 — Greening Buildings

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal ($MtCO_2$ eq)	Methodologies and Assumptions	Gas Coverage	Progress Indicators	Results Achieved
Regulatory measures and incentives to encourage adoption of the GM scheme. New standards for SLE buildings have also been introduced as part of the GM scheme to drive green buildings in Singapore towards net zero.	To improve energy efficiency and sustainability standards of buildings.	New Buildings Legislating owners of new buildings to achieve minimum environmental sustainability standards, and encouraging them to achieve a GM rating beyond the minimum standard through incentives. Developments in identified key strategic areas are required to achieve a higher GM rating of GoldPlus or Platinum. Existing Buildings Legislating existing building owners to achieve minimum environmental sustainability standards when undergoing major retrofits, or installing or replacing the building cooling system to improve the energy efficiency of their facilities. Also, building owners are incentivised to achieve a GM rating beyond the minimum standard through co-funding and financing schemes.	**Ongoing** New Buildings Since 2008, owners of new buildings have been required by legislation to achieve minimum environmental sustainability standards equivalent to the previous GM Certified standard. The GM ratings for new buildings are: Gold/GoldPlus/Platinum, differentiated by a set of criteria relating to green initiatives and energy savings of the building. Since 2010, stricter GM standards have been imposed on government land sales sites in certain areas, e.g. Marina Bay, and the Jurong Lake District. Incentive schemes have been introduced to encourage greater adoption of energy-efficient technologies in new buildings. As of December 2021, we have greened more than 49% of our buildings by GFA and are on track to meeting our target of 80% by 2030. Existing Buildings Since 2012, owners of existing buildings have been required by legislation to achieve minimum environmental sustainability standards when the buildings undergo major retrofits. These requirements have been enhanced over the years to higher standards and also more coverage of buildings. In addition, existing prescribed buildings are required to submit building energy consumption data annually. Prescribed building types are also required to submit energy audits on building cooling systems every three years. Co-funding and financing schemes have also been introduced to further improve the energy efficiency in existing buildings. For example, the Building Retrofit Energy Efficiency Financing (BREEF) scheme provides financing options to building owners to address the upfront retrofitting costs required.	Legislation, Incentive and new standards	0.87–1.55	The abatement is calculated by the difference between the BAU emission values (i.e. no legislation/ incentives) projected for the new building stock in 2020, and the emission values after legislation and incentives have been implemented.	CO_2	Through electricity consumption and building information data collected through the Building Energy Submission System (BESS).	Estimated abatement achieved in 2020: 0.99 Mt

Table 4 — Shifting Travel Demand to Low-Emission Modes and Reducing Vehicular Emissions

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal ($MtCO_2$ eq)	Methodologies and Assumptions	Gas Coverage	Progress Indicators	Results Achieved
Increasing the public transport modal share.	To increase usage of public transport, the most energy-efficient mode of powered transport.	Expanding the rail and bus networks, building integrated transport hubs, implementing more bus priority measures; and managing travel demand and planning better as detailed in the Land Transport Master Plan 2040.	**Ongoing** Singapore's target is for the public transport modal share during the morning and evening peak hours to reach 70% by 2020 and 75% by 2030. The length of the rail network will increase further from about 245 km today to about 360 km in early 2030s.	Combination of infrastructure, regulations, incentives, technology and education.	0.78	Mitigation effect is calculated as the difference between the total energy consumed for (i) the projected BAU travel demand and the modal split; and (ii) the actual travel made and the modal split.	CO_2	Public transport modal share.	Estimated abatement achieved in 2020: 1.02 Mt
Promoting Off-Peak Cars (OPCs) and non-motorised transport e.g. walking and cycling.	To reduce the use of cars as a means of transport.	Implementing schemes that limit the use of cars to off-peak periods, and rolling out various initiatives that encourage walking and cycling.	**Ongoing** The OPCs schemes will be tweaked as necessary. By 2030, our cycling path network will be extended to more than 1,000 km, from 460 km in 2020. Beyond the 200 km of sheltered walkways from transport nodes to homes and public amenities built as of now, a further 150 km of these sheltered walkways will be added by 2040.	Combination of infrastructure, incentives, and education.	0.16–0.20	Abatement is calculated based on the number of off-peak cars and the difference between the average carbon emissions of a normal car and those of an OPC. This is calculated against BAU projections which do not include the roll-out of such an OPC scheme.	CO_2	OPC Take-up rate.	Estimated abatement achieved in 2020: 0.15 Mt
Car/Taxi fuel efficiency-CEVS	To encourage the take-up of more energy-efficient vehicles.	Implementing the mandatory FELS and the CEVS/VES.	**Ongoing** The CEVS and the FELS were introduced in 2013. The CEVS was replaced by the VES with a new Vehicular Emissions label in January 2018. In addition to CO_2, the VES includes four additional pollutants hydrocarbons, carbon monoxide, nitrogen oxides, and particulate in the assessment of new cars, taxis and newly imported used cars for rebate or surcharge based on the worst-performing pollutant.	Legislation and Incentives	0.60	Mitigation effect is calculated based on the increased quantity of cars/taxis purchased in the CEVS/VES lower carbon bands (i.e. the rebate bands or similar cleaner cars), compared to the historical rates, and the average carbon emission reduction for the CEVS/VES bands. This is calculated against BAU projections, which are the emissions computed considering the quantity of cars/taxis purchased in the absence of CEVS/VES rebates/ surcharges.	CO_2	Increase in registration of cars in lower carbon bands and reduction in registration of cars in the higher carbon bands.	Estimated abatement achieved in 2020: 0.5 Mt

Table 5 — Improving Energy Performance Standards of Household Appliance and Promoting Energy Efficiency to Households

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal ($MtCO_2$ eq)	Methodologies and Assumptions	Gas Coverage	Progress Indicators	Results Achieved
MEPS for household appliances – air conditioners, fridges, lighting, clothes dryers.	To improve the overall energy efficiency of appliances in the market.	Disallowing the supply of inefficient appliances that fall short of specified minimum energy efficiency levels.	**Ongoing** MEPS for air conditioners and fridges were implemented in September 2011 and raised between 2013 and 2017 respectively. MEPS for air conditioners and refrigerators were raised again in 2021. MEPS for clothes dryers were implemented in April 2014 and were raised again in 2021. MEPS for general lighting were implemented in July 2015. The MELS was extended to common CFLni and fluorescent tubes, and their LED direct replacements in November 2019. MEPS were raised to phase out incandescent lamps in November 2019. MEPS were introduced for fluorescent lamp ballasts in November 2019.	Legislation	0.71–0.79	The carbon emissions arise from the energy use of home appliances. The emissions in two scenarios, the BAU and Policy scenarios, are calculated. In both scenarios, the annual hours of usage of home appliances is assumed to remain the same as that of the reference year, 2005. In the BAU scenario, since there are no policies affecting purchasing decisions, it is assumed that there is no change in the purchasing pattern of home appliances by energy efficiency rating over the forecast period 2006–2020. The emissions are calculated based on the predicted stock of appliances (initial stock plus purchases less displaced and retired stock), annual hours of usage and annual energy consumption based on energy efficiency rating.	CO_2	Annual purchase pattern of appliance models by tick-rating.	Estimated abatement achieved in 2020: 0.72 Mt *MEPS commenced in 2011.
Promotion of energy efficiency to households.	To promote energy efficiency to households.	Promoting the purchase of energy-efficient appliances through the MELS for household appliances and outreach efforts. SSUL Programme.	**Ongoing** The MELS for air conditioners and fridges was introduced in 2008 and extended to clothes dryers in 2009, TVs in 2014 and general lighting in 2015. Household energy efficiency awareness programmes (e.g. media publicity, energy-saving contests, energy efficiency roadshows) have been rolled out since 2008. Under the programme, each one- to two-room public housing household received a S$25 voucher to switch to using LED lights, which are more energy efficient.	Promotion	0–0.28	In the Policy scenario, purchasing decisions are modified by mandated standards and energy labelling. The purchasing pattern of home appliances by energy efficiency rating is obtained from market data on purchases of products of different efficiency levels. This, together with estimated lifespans of the appliances, is used to calculate the mix of appliances by energy efficiency rating in the stock. The carbon emissions of the stock are calculated based on energy consumption. The emissions abatement is the difference in carbon emissions between the BAU and Policy scenarios.			

Table 6 — Reducing Emissions from Waste and Wastewater Treatment

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal ($MtCO_2$ eq)	Methodologies and Assumptions	Gas Coverage	Progress Indicators	Results Achieved
Wastewater sludge disposal by incineration	To reduce methane gas emissions from wastewater sludge.	Incinerating wastewater sludge, a by-product of water reclamation plants, which would otherwise be disposed of at landfills.	**Ongoing** ECO Special Waste Management (SWM) was contracted to perform sludge incineration in 2008. Subsequently in 2016, both ECO SWM and 800 Super have been awarded new contracts to perform sludge incineration from 2018.	Infrastructure, Development	0.10	Assumptions are referenced from IPCC methodology "tool to determine the methane emissions avoided from disposal of waste at a solid waste disposal site", and abatement is calculated from the total amount of sludge incinerated (based on actual weight of sludge disposed of at landfill site, and by ECO Special Waste Management and 800 Super).	CH_4	Amount of sludge incinerated	Estimated abatement achieved in 2020: 0.14 $MtCO_2$ eq
Increase overall recycling rate	To increase the overall recycling rate to 65% by 2020. The overall recycling rate in 2020 was 52%.	Mandatory waste reporting and submission of waste reduction plan for large commercial and industrial premises, starting with large hotels and shopping malls in 2014, and extended to large factories, warehouses and convention/ exhibition centres in 2020.	**Ongoing** Affected premises have submitted their waste report.	Legislation	0.05	Emissions and abatement will be calculated using the amount of waste incinerated and waste recycling rates, compared against BAU projections.	CO_2, CH_4, N_2O	Recycling rate	Estimated abatement achieved in 2020: 0 $MtCO_2$ eq
		Right waste disposal pricing	Currently under evaluation	Market-based instrument					

Table 7 — Cross-Sectoral Measures

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal ($MtCO_2$ eq)	Methodologies and Assumptions	Gas Coverage	Progress Indicators	Results Achieved
Carbon Tax	To complement and support our mitigation package	The carbon tax provides an economy-wide price signal to encourage GHG emission reduction, while giving companies the flexibility to take action where it makes the most economic sense.	**Ongoing** The carbon tax came into force on 1 January 2019 at S$5 or US$3.70/tCO_2 eq. It will be raised to S$25 (or US$18.40/tCO_2 eq) in 2024 and 2025, and S$45 or (US$33.20/tCO_2 eq) in 2026 and 2027, with a view to reaching $50–80 (or US$36.90–59.00/tCO_2 eq) by 2030.	Market-based instrument	Not applicable as the carbon tax is a cross-sectoral measure to complement other policies and measures for meeting Singapore's NDC.	The carbon tax covers around 80% of our national emissions, and applies to large direct industrial emitters from the manufacturing, power generation, water and waste management sectors. It is applied uniformly and without exemptions. Taxable facilities are required to submit a Monitoring Plan, as well as annual Emissions Reports. The Emissions Reports must be verified by an accredited external auditor.	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	Carbon intensity and energy efficiency of the Singapore economy.	Not applicable as the carbon tax is not a standalone measure. The results from having a carbon tax are demonstrated through the abatement from sector-specific policies and measures.

ANNEX

2018 Greenhouse Gas Inventory Worksheets

Greenhouse Gas Summary Tables for 2016, 2014, 2012, 2010, 2000 and 1994

SentoSights was launched in 2021 as a new series of sustainability-themed and heritage-themed tours, where guests will better understand the importance of sustainability and conservation through an immersion into the unique heritage, biodiversity and nature in Sentosa as well as neighbouring islands.

2018
GREENHOUSE GAS SUMMARY TABLE

Greenhouse Gas Source and Sink Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
	(Gg)			CO_2 equivalents (Gg)			
Total National Emissions and Removals	**50,260.88**	**4.05**	**1.83**	**507.29**	**1,437.92**	**127.06**	**381.25**
1 — ENERGY	**49,553.34**	**3.27**	**0.84**				
1A - Fuel Combustion Activities	48,307.43	1.95	0.83				
1A1 Energy Industries	20,220.81	0.32	0.24				
1A2 Manufacturing Industries and Construction	20,056.92	0.42	0.06				
1A3 Transport	7,383.34	1.15	0.53				
1A4 Other Sectors	646.36	0.06	0.00				
1A4a Commercial/Institutional	430.55	0.04	0.00				
14Ab Residential	215.81	0.02	0.00				
1A5 Non-Specified	NO	NO	NO				
1B - Fugitive Emissions from Fuels	1,245.91	1.32	0.01				
1B1 Solid Fuels	NO	NO	NO				
1B2 Oil and Natural Gas	1,245.91	1.32	0.01				
1B3 Other Emissions from Energy Production	NO	NO	NO				
1C - Carbon Dioxide Transport and Storage	NO						
1C1 Transport of CO_2	NO						
1C2 Injection and Storage	NO						
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**380.81**	**0.01**	**0.67**	**507.29**	**1,437.92**	**127.06**	**381.25**
2A - Mineral Industry	NO	NO	NO				
2B - Chemical Industry	325.44	NO	NO	NO	NO	NO	NO
2C - Metal Industry	C	NO	NO	NO	NO	NO	NO
2D - Non-Energy Products from Fuels and Solvent Use	1.43	NO	NO				
2E - Electronics Industry	0.24	0.00	0.67	131.65	1,437.92	112.39	381.25
2F - Product Uses as Substitutes for Ozone Depleting Substances	NO	NO	NO	375.63	NO		NO
2G - Other Product Manufacture and Use	NO	NO	NO	NO	NO	14.67	NO
2H - Other	53.71	0.00	NO				
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE	**106.45**	**0.08**	**0.04**				
3A - Livestock		0.08	0.01				
3B - Land	104.71	NO	0.02				
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land	0.09	NO	0.01				
3D - Other	1.66	NO	NO				
4 — WASTE	**220.27**	**0.69**	**0.27**				
4A - Solid Waste Disposal		0.69					
4B - Biological Treatment of Solid Waste		NO	NO				
4C - Incineration and Open Burning of Waste	220.27	0.00	0.01				
4D - Wastewater Treatment and Discharge		NE	0.26				
4E - Other (please specify)	NO	NO	NO				
5 — OTHER	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
5A - Indirect N_2O emissions from the Atmospheric Deposition of Nitrogen in NO_x and NH_3			NO				
5B - Other (please specify)	NO	NO	NO	NO	NO	NO	NO
INFORMATION ITEMS							
CO_2 from Biomass Combustion for Energy Production	1,660.95						

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. As some figures are considerably small, they may be presented as "0.00" due to rounding.
3. Notation keys: C = confidential information, NE = not estimated and NO = not occurring.
4. Due to confidentiality reasons, CO_2 emissions from 2C Metal Industry is included under 2H Others.
5. Figures may not add up to the totals due to rounding.

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. As some figures are considerably small, they may be presented as "0.00" due to rounding.
3. Notation keys: C = confidential information, NE = not estimated and NO = not occurring.
4. Due to confidentiality reasons, CO_2 emissions from 2C Metal Industry is included under 2H Others.
5. Figures may not add up to the totals due to rounding.

2018
GREENHOUSE GAS BREAKDOWN OF HFCs, PFCs, SF_6 AND NF_3

Greenhouse Gas Source and Sink Categories	HFCs (kg)								
	HFC-23	HFC-32	HFC-41	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea	HFC-43-10mee
Total National Emissions and Removals	**10,584.99**	**3,657.02**	**C**	**4,907.58**	**42,702.88**	**1,838.20**		**845.18**	**176,261.86**
2 — INDUSTRIAL PROCESSES AND PRODUCT USE									
2A - Mineral Industry									
2A1 Cement Production									
2A2 Lime Production									
2A3 Glass Production									
2A4 Other Process Uses of Carbonates									
2A5 Other (please specify)									
2B - Chemical Industry									
2B1 Ammonia Production									
2B2 Nitric Acid Production									
2B3 Adipic Acid Production									
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production									
2B5 Carbide Production									
2B6 Titanium Dioxide Production									
2B7 Soda Ash Production									
2B8 Petrochemical and Carbon Black Production									
2B9 Fluorochemical Production									
2B10 Other (please specify)									
2C - Metal Industry									
2C1 Iron and Steel Production									
2C2 Ferroalloys Production									
2C3 Aluminium Production									
2C4 Magnesium Production									
2C5 Lead Production									
2C6 Zinc Production									
2C7 Other (please specify)									

1. Notation key: C = confidential information.
2. Due to confidentiality reasons,
   - Emissions from 2E2 TFT Flat Panel Display are included under 2E1 Integrated Circuit or Semiconductor;
   - Emissions from HFC-41 is included under HFC-32 of the Electronics Industry (2E).
   - Emissions from HFC-43-10mee under 2F4 Aerosols and 2F5 Solvents are aggregated together and reported under 2F-Product Uses as Substitutes for Ozone Depleting Substances.

Greenhouse Gas Source and Sink Categories	HFCs (kg)								
	HFC-23	HFC-32	HFC-41	HFC-125	HFC-134a	HFC-143a	HFC-152a	HFC-227ea	HFC-43-10mee
Total National Emissions and Removals	**10,584.99**	**3,657.02**	**C**	**4,907.58**	**42,702.88**	**1,838.20**		**845.18**	**176,261.86**
2D - Non-Energy Products from Fuels and Solvent Use									
2D1 Lubricant Use									
2D2 Paraffin Wax Use									
2D3 Solvent Use									
2D4 Other (please specify)									
2E - Electronics Industry	**10,584.99**	**590.72**	**C**						
2E1 Integrated Circuit or Semiconductor	10,584.99	590.72	C						
2E2 TFT Flat Panel Display									
2E3 Photovoltaics									
2E4 Heat Transfer Fluid									
2E5 Other (please specify)									
2F - Product Uses as Substitutes for Ozone Depleting Substances		**3,066.30**		**4,907.58**	**42,702.88**	**1,838.20**		**845.18**	**176,261.86**
2F1 Refrigeration and Air Conditioning		3,066.30		4,907.58	42,702.88	1,838.20			
2F2 Foam Blowing Agents									
2F3 Fire Protection								845.18	
2F4 Aerosols									C
2F5 Solvents									C
2F6 Other Applications									
2G - Other Product Manufacture and Use									
2G1 Electrical Equipment									
2G2 SF_6 and PFCs from Other Product Uses									
2G3 N_2O from Product Uses									
2G4 Other (please specify)									
2H - Other									
2H1 Pulp and Paper Industry									
2H2 Food and Beverages Industry									
2H3 Other (please specify)									

1. Notation key: C = confidential information.
2. Due to confidentiality reasons,
   - Emissions from 2E2 TFT Flat Panel Display are included under 2E1 Integrated Circuit or Semiconductor;
   - Emissions from HFC-41 is included under HFC-32 of the Electronics Industry (2E).
   - Emissions from HFC-43-10mee under 2F4 Aerosols and 2F5 Solvents are aggregated together and reported under 2F-Product Uses as Substitutes for Ozone Depleting Substances.

Greenhouse Gas Source and Sink Categories	PFCs (kg)				SF_6 (kg)	NF_3 (kg)
	PFC-14	PFC-116	PFC-218	PFC-318		
Total National Emissions and Removals	**134,475.52**	**41,986.63**	**2,984.92**	**5,632.04**	**5,406.95**	**23,680.37**
2 — INDUSTRIAL PROCESSES AND PRODUCT USE						
2A - Mineral Industry						
2A1 Cement Production						
2A2 Lime Production						
2A3 Glass Production						
2A4 Other Process Uses of Carbonates						
2A5 Other (please specify)						
2B - Chemical Industry						
2B1 Ammonia Production						
2B2 Nitric Acid Production						
2B3 Adipic Acid Production						
2B4 Caprolactam, Glyoxal and Glyoxylic Acid Production						
2B5 Carbide Production						
2B6 Titanium Dioxide Production						
2B7 Soda Ash Production						
2B8 Petrochemical and Carbon Black Production						
2B9 Fluorochemical Production						
2B10 Other (please specify)						
2C - Metal Industry						
2C1 Iron and Steel Production						
2C2 Ferroalloys Production						
2C3 Aluminium Production						
2C4 Magnesium Production						
2C5 Lead Production						
2C6 Zinc Production						
2C7 Other (please specify)						

1. Notation key: C = confidential information.
2. Due to confidentiality reasons,
   - Emissions from 2E2 TFT Flat Panel Display are included under 2E1 Integrated Circuit or Semiconductor;
   - Emissions from HFC-41 is included under HFC-32 of the Electronics Industry (2E).
   - Emissions from HFC-43-10mee under 2F4 Aerosols and 2F5 Solvents are aggregated together and reported under 2F-Product Uses as Substitutes for Ozone Depleting Substances.

Greenhouse Gas Source and Sink Categories	PFCs (kg)				SF_6 (kg)	NF_3 (kg)
	PFC-14	PFC-116	PFC-218	PFC-318		
Total National Emissions and Removals	**134,475.52**	**41,986.63**	**2,984.92**	**5,632.04**	**5,406.95**	**23,680.37**
2D - Non-Energy Products from Fuels and Solvent Use						
2D1 Lubricant Use						
2D2 Paraffin Wax Use						
2D3 Solvent Use						
2D4 Other (please specify)						
2E - Electronics Industry	**134,475.52**	**41,986.63**	**2,984.92**	**5,632.04**	**4,782.73**	**23,680.37**
2E1 Integrated Circuit or Semiconductor	134,475.52	41,986.63	2,984.92	5,632.04	4,782.73	23,680.37
2E2 TFT Flat Panel Display	C				C	C
2E3 Photovoltaics						
2E4 Heat Transfer Fluid						
2E5 Other (please specify)						
2F - Product Uses as Substitutes for Ozone Depleting Substances						
2F1 Refrigeration and Air Conditioning						
2F2 Foam Blowing Agents						
2F3 Fire Protection						
2F4 Aerosols						
2F5 Solvents						
2F6 Other Applications						
2G - Other Product Manufacture and Use					**624.22**	
2G1 Electrical Equipment					624.22	
2G2 SF_6 and PFCs from Other Product Uses						
2G3 N_2O from Product Uses						
2G4 Other (please specify)						
2H - Other						
2H1 Pulp and Paper Industry						
2H2 Food and Beverages Industry						
2H3 Other (please specify)						

1. Notation key: C = confidential information.
2. Due to confidentiality reasons,
   - Emissions from 2E2 TFT Flat Panel Display are included under 2E1 Integrated Circuit or Semiconductor;
   - Emissions from HFC-41 is included under HFC-32 of the Electronics Industry (2E).
   - Emissions from HFC-43-10mee under 2F4 Aerosols and 2F5 Solvents are aggregated together and reported under 2F-Product Uses as Substitutes for Ozone Depleting Substances.

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A1 — Energy Industries
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
LIQUID FUELS						
Crude Oil						
Orimulsion						
Natural Gas Liquids						
Motor Gasoline						
Aviation Gasoline						
Jet Gasoline						
Jet Kerosene						
Other Kerosene						
Shale Oil						
Gas/Diesel Oil	kt	9.09	43.00	390.85	74,066.67	28.95
Residual Fuel Oil	kt	0.77	40.40	31.20	77,366.67	2.41
LPG						
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Feedstocks						
Refinery Gas						
Paraffin Waxes						
Other Petroleum Products						
SOLID FUELS						
Anthracite						
Coking Coal						
Other Bituminous Coal	kt	478.58	25.80	12,347.29	94,600.00	1,168.05
Sub-Bituminous Coal						
Lignite						
Oil Shale and Tar Sands						

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A1 — Energy Industries
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
LIQUID FUELS					
Crude Oil					
Orimulsion					
Natural Gas Liquids					
Motor Gasoline					
Aviation Gasoline					
Jet Gasoline					
Jet Kerosene					
Other Kerosene					
Shale Oil					
Gas/Diesel Oil	kt	3.00	0.00117	0.60	0.00023
Residual Fuel Oil	kt	3.00	0.00009	0.60	0.00002
LPG					
Ethane					
Naphtha					
Lubricants					
Petroleum Coke					
Refinery Feedstocks					
Refinery Gas					
Paraffin Waxes					
Other Petroleum Products					
SOLID FUELS					
Anthracite					
Coking Coal					
Other Bituminous Coal	kt	1.00	0.01235	1.50	0.01852
Sub-Bituminous Coal					
Lignite					
Oil Shale and Tar Sands					

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
SOLID FUELS						
Brown Coal Briquettes						
Patent Fuel						
Coke Oven Coke /Lignite Coke						
Gas Coke						
Coal Tar						
Gas Work Gas						
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)	ktoe	7,318.94	41.87	306,429.19	56,100.00	17,190.68
OTHER FOSSIL FUELS						
Municipal Wastes (Non-Biomass Fraction)						
Industrial Wastes						
Waste Oils						
PEAT						
Peat						
BIOMASS					**INFORMATION ITEMS**	
Wood/Wood Waste						
Sulphite Lyes						
Other Primary Solid Biomass						
Charcoal						
Biogasoline						
Biodiesels						
Other Liquid Biofuels						
Landfill Gas						
Sludge Gas						
Other Biogas						
Municipal Wastes (Biomass Fraction)						
					TOTAL	18,390.09

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
SOLID FUELS					
Brown Coal Briquettes					
Patent Fuel					
Coke Oven Coke /Lignite Coke					
Gas Coke					
Coal Tar					
Gas Work Gas					
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)	ktoe	1.00	0.30643	0.10	0.03064
OTHER FOSSIL FUELS					
Municipal Wastes (Non-Biomass Fraction)					
Industrial Wastes					
Waste Oils					
PEAT					
Peat					
BIOMASS					
Wood/Wood Waste					
Sulphite Lyes					
Other Primary Solid Biomass					
Charcoal					
Biogasoline					
Biodiesels					
Other Liquid Biofuels					
Landfill Gas					
Sludge Gas					
Other Biogas					
Municipal Wastes (Biomass Fraction)					
		TOTAL	0.32004	**TOTAL**	0.04942

SECTOR	Waste
CATEGORY	Incineration and Open Burning of Waste
CATEGORY CODE	4C1 — Solid Waste Incineration
SHEET	CO_2, CH_4 and N_2O emissions from Solid Waste Incineration

	A	B	C	D	E	F	G
							G = AxBxCxDxExF
CO_2	**Total Amount of Fossil-based Waste Incinerated (Wet Weight)**	**Dry Matter Content**	**Fraction of Carbon in Dry Matter**	**Fraction of Fossil Carbon in Total Carbon**	**Oxidation Factor**	**Conversion Factor**	**Fossil CO_2 Emissions**
	kt	fraction	fraction	fraction	fraction	44/12	Gg
	1,856.10	C	C	C	1	3.67	1,830.716

	A	B	C	D	E
			C = AxBx10^{-9}		E = CxD
CH_4	**Total Amount of Waste Incinerated (Wet Weight)**	**CH_4 Emission Factor**	**CH_4 Emissions**	**Global Warming Potential of CH_4**	**Emissions in CO_2 eq**
	tonnes	kg CH_4/kt waste	Gg		Gg
	2,936,297.04	0.2	0.001	28	0.016

	A	B	C	D	E
			C = AxBx10^{-9}		E = CxD
N_2O	**Total Amount of Waste Incinerated (Wet Weight)**	**N_2O Emission Factor**	**N_2O Emissions**	**Global Warming Potential of N_2O**	**Emissions in CO_2 eq**
	tonnes	kg N_2O/kt waste	Gg		Gg
	2,936,297.04	47	0.138	265	36.572

1. Default conversion and emission factors from the 2006 IPCC Guidelines are used for estimating emissions from solid waste incineration.
2. According to the 2006 IPCC guidelines, emissions from incineration with energy recovery are reported in the Energy sector. As such, the CO_2, CH_4 and N_2O emissions from solid waste incineration are included under 1A1 Energy Industries.
3. Notation key: C = confidential information.

SECTOR	Waste
CATEGORY	Incineration and Open Burning of Waste
CATEGORY CODE	4C1 — Sludge Incineration
SHEET	CH_4 and N_2O emissions from Sludge Incineration

Emissions from Sludge Incineration

GHG	Emissions in Gg	Global Warming Potential	Emissions in Gg CO_2 eq
CH_4	0.0030	28	0.083
N_2O	0.0538	265	14.248

1. Emissions from the incineration of sludge are computed based on CDM methodologies.
2. The emissions were from the sludge incineration plant operated by ECO-SWM which was registered as a CDM project on 13 Sep 2010. From 2012 onwards, emissions from the incineration of sewage sludge were estimated based on the forward trend extrapolation of available data from 2010 and 2011.
3. According to the 2006 IPCC guidelines, emissions from incineration with energy recovery are reported in the Energy sector. As such, the CH_4 and N_2O emissions from sludge incineration are included under 1A1 Energy Industries.

Opposite page: DBS Newton Green is Singapore's first net zero building by a bank. Leveraging net zero technologies and creative design strategies, DBS reduced the energy consumption of the retrofitted building by 70%, with the balance energy needs met by over 1,000 square metres of solar panels deployed on the roof.

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A2 — Manufacturing Industries and Construction
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
LIQUID FUELS						
Crude Oil						
Orimulsion						
Natural Gas Liquids						
Motor Gasoline						
Aviation Gasoline						
Jet Gasoline						
Jet Kerosene						
Other Kerosene						
Shale Oil						
Gas/Diesel Oil	kt	150.67	43.00	6,478.98	74,066.67	479.88
Residual Fuel Oil	kt	812.79	40.40	32,836.89	77,366.67	2,540.48
LPG	kt	C	C	C	C	C
Ethane						
Naphtha						
Lubricants						
Petroleum Coke	kt	C	C	C	C	616.18
Refinery Feedstocks						
Refinery Gas	kt	3,761.86	49.50	186,212.00	57,566.67	10,719.60
Paraffin Waxes						
Other Petroleum Products						
SOLID FUELS						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Oil Shale and Tar Sands						

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A2 — Manufacturing Industries and Construction
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
LIQUID FUELS					
Crude Oil					
Orimulsion					
Natural Gas Liquids					
Motor Gasoline					
Aviation Gasoline					
Jet Gasoline					
Jet Kerosene					
Other Kerosene					
Shale Oil					
Gas/Diesel Oil	kt	3.00	0.01944	0.60	0.00389
Residual Fuel Oil	kt	3.00	0.09851	0.60	0.01970
LPG	kt	C	C	C	C
Ethane					
Naphtha					
Lubricants					
Petroleum Coke	kt	C	0.01591	C	0.00288
Refinery Feedstocks					
Refinery Gas	kt	1.00	0.18621	0.10	0.01862
Paraffin Waxes					
Other Petroleum Products					
SOLID FUELS					
Anthracite					
Coking Coal					
Other Bituminous Coal					
Sub-Bituminous Coal					
Lignite					
Oil Shale and Tar Sands					

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
SOLID FUELS						
Brown Coal Briquettes						
Patent Fuel						
Coke Oven Coke /Lignite Coke						
Gas Coke						
Coal Tar						
Gas Work Gas	GWh	C	C	C	C	C
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)	ktoe	2,427.11	41.87	101,618.27	56,100.00	5,700.78
OTHER FOSSIL FUELS						
Municipal Wastes (Non-Biomass Fraction)						
Industrial Wastes						
Waste Oils						
PEAT						
Peat						
BIOMASS					**INFORMATION ITEMS**	
Wood/Wood Waste						
Sulphite Lyes						
Other Primary Solid Biomass						
Charcoal						
Biogasoline						
Biodiesels						
Other Liquid Biofuels						
Landfill Gas						
Sludge Gas						
Other Biogas						
Municipal Wastes (Biomass Fraction)						
					TOTAL	**20,056.92**

1. According to the 2006 IPCC guidelines, emissions from autoproduction are allocated to the Manufacturing Industries and Construction (1A2) sector.
2. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Work Gas where a country-specific CO_2 emission factor of 15.2 tC/TJ is used.
3. In the Manufacturing Industries and Construction (1A2) sector,
   - Transformation losses from the production of Gas Work Gas is included under the fuel type "Natural Gas". Gas Work Gas was mainly produced from Natural Gas in Singapore.
   - Emissions from the combustion of Synthesis Gas is included under the fuel type "Refinery Gas".
   - Emissions from the combustion of LPG and Gas Work Gas are included under the fuel type "Petroleum Coke".
4. Notation key: C = confidential information.

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
SOLID FUELS					
Brown Coal Briquettes					
Patent Fuel					
Coke Oven Coke /Lignite Coke					
Gas Coke					
Coal Tar					
Gas Work Gas	GWh	C	C	C	C
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)	ktoe	1.00	0.10114	0.10	0.01011
OTHER FOSSIL FUELS					
Municipal Wastes (Non-Biomass Fraction)					
Industrial Wastes					
Waste Oils					
PEAT					
Peat					
BIOMASS					
Wood/Wood Waste					
Sulphite Lyes					
Other Primary Solid Biomass					
Charcoal					
Biogasoline					
Biodiesels					
Other Liquid Biofuels					
Landfill Gas					
Sludge Gas					
Other Biogas					
Municipal Wastes (Biomass Fraction)					
			TOTAL	**0.42121**	**TOTAL**	**0.05521**

1. According to the 2006 IPCC guidelines, emissions from autoproduction are allocated to the Manufacturing Industries and Construction (1A2) sector.
2. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Work Gas where a country-specific CO_2 emission factor of 15.2 tC/TJ is used.
3. In the Manufacturing Industries and Construction (1A2) sector,
   - Transformation losses from the production of Gas Work Gas is included under the fuel type "Natural Gas". Gas Work Gas was mainly produced from Natural Gas in Singapore.
   - Emissions from the combustion of Synthesis Gas is included under the fuel type "Refinery Gas".
   - Emissions from the combustion of LPG and Gas Work Gas are included under the fuel type "Petroleum Coke".
4. Notation key: C = confidential information.

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A3b — Road Transportation
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
LIQUID FUELS						
Crude Oil						
Orimulsion						
Natural Gas Liquids						
Motor Gasoline	kt	786.19	44.30	34,828.00	69,300.00	2,413.58
Aviation Gasoline						
Jet Gasoline						
Jet Kerosene						
Other Kerosene						
Shale Oil						
Gas/Diesel Oil	kt	1,462.63	43.00	62,893.22	74,066.67	4,658.29
Residual Fuel Oil						
LPG						
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Feedstocks						
Refinery Gas						
Paraffin Waxes						
Other Petroleum Products						
SOLID FUELS						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Oil Shale and Tar Sands						

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A3b — Road Transportation
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
LIQUID FUELS					
Crude Oil					
Orimulsion					
Natural Gas Liquids					
Motor Gasoline	kt	25.00	0.87070	8.00	0.27862
Aviation Gasoline					
Jet Gasoline					
Jet Kerosene					
Other Kerosene					
Shale Oil					
Gas/Diesel Oil	kt	3.90	0.24528	3.90	0.24528
Residual Fuel Oil					
LPG					
Ethane					
Naphtha					
Lubricants					
Petroleum Coke					
Refinery Feedstocks					
Refinery Gas					
Paraffin Waxes					
Other Petroleum Products					
SOLID FUELS					
Anthracite					
Coking Coal					
Other Bituminous Coal					
Sub-Bituminous Coal					
Lignite					
Oil Shale and Tar Sands					

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
SOLID FUELS						
Brown Coal Briquettes						
Patent Fuel						
Coke Oven Coke /Lignite Coke						
Gas Coke						
Coal Tar						
Gas Work Gas						
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)	ktoe	2.58	41.87	108.22	56,100.00	6.07
OTHER FOSSIL FUELS						
Municipal Wastes (Non-Biomass Fraction)						
Industrial Wastes						
Waste Oils						
PEAT						
Peat						
BIOMASS					**INFORMATION ITEMS**	
Wood/Wood Waste						
Sulphite Lyes						
Other Primary Solid Biomass						
Charcoal						
Biogasoline						
Biodiesels						
Other Liquid Biofuels						
Landfill Gas						
Sludge Gas						
Other Biogas						
Municipal Wastes (Biomass Fraction)						
					TOTAL	7,077.94

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
SOLID FUELS					
Brown Coal Briquettes					
Patent Fuel					
Coke Oven Coke /Lignite Coke					
Gas Coke					
Coal Tar					
Gas Work Gas					
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)	ktoe	92.00	0.00996	3.00	0.00032
OTHER FOSSIL FUELS					
Municipal Wastes (Non-Biomass Fraction)					
Industrial Wastes					
Waste Oils					
PEAT					
Peat					
BIOMASS					
Wood/Wood Waste					
Sulphite Lyes					
Other Primary Solid Biomass					
Charcoal					
Biogasoline					
Biodiesels					
Other Liquid Biofuels					
Landfill Gas					
Sludge Gas					
Other Biogas					
Municipal Wastes (Biomass Fraction)					
		TOTAL	1.12594	**TOTAL**	0.52423

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A3dii — Domestic Water-borne Navigation
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
LIQUID FUELS						
Crude Oil						
Orimulsion						
Natural Gas Liquids						
Motor Gasoline						
Aviation Gasoline						
Jet Gasoline						
Jet Kerosene						
Other Kerosene						
Shale Oil						
Gas/Diesel Oil	kt	95.89	43.00	4,123.27	74,066.67	305.40
Residual Fuel Oil						
LPG						
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Feedstocks						
Refinery Gas						
Paraffin Waxes						
Other Petroleum Products						
SOLID FUELS						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Oil Shale and Tar Sands						

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A3dii — Domestic Water-borne Navigation
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
LIQUID FUELS					
Crude Oil					
Orimulsion					
Natural Gas Liquids					
Motor Gasoline					
Aviation Gasoline					
Jet Gasoline					
Jet Kerosene					
Other Kerosene					
Shale Oil					
Gas/Diesel Oil	kt	7.00	0.02886	2.00	0.00825
Residual Fuel Oil					
LPG					
Ethane					
Naphtha					
Lubricants					
Petroleum Coke					
Refinery Feedstocks					
Refinery Gas					
Paraffin Waxes					
Other Petroleum Products					
SOLID FUELS					
Anthracite					
Coking Coal					
Other Bituminous Coal					
Sub-Bituminous Coal					
Lignite					
Oil Shale and Tar Sands					

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
SOLID FUELS						
Brown Coal Briquettes						
Patent Fuel						
Coke Oven Coke /Lignite Coke						
Gas Coke						
Coal Tar						
Gas Work Gas						
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)						
OTHER FOSSIL FUELS						
Municipal Wastes (Non-Biomass Fraction)						
Industrial Wastes						
Waste Oils						
PEAT						
Peat						
BIOMASS					**INFORMATION ITEMS**	
Wood/Wood Waste						
Sulphite Lyes						
Other Primary Solid Biomass						
Charcoal						
Biogasoline						
Biodiesels						
Other Liquid Biofuels						
Landfill Gas						
Sludge Gas						
Other Biogas						
Municipal Wastes (Biomass Fraction)						
					TOTAL	305.40

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
SOLID FUELS					
Brown Coal Briquettes					
Patent Fuel					
Coke Oven Coke /Lignite Coke					
Gas Coke					
Coal Tar					
Gas Work Gas					
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)					
OTHER FOSSIL FUELS					
Municipal Wastes (Non-Biomass Fraction)					
Industrial Wastes					
Waste Oils					
PEAT					
Peat					
BIOMASS					
Wood/Wood Waste					
Sulphite Lyes					
Other Primary Solid Biomass					
Charcoal					
Biogasoline					
Biodiesels					
Other Liquid Biofuels					
Landfill Gas					
Sludge Gas					
Other Biogas					
Municipal Wastes (Biomass Fraction)					
		TOTAL	0.02886	**TOTAL**	0.00825

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A4a — Commercial/Institutional
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
LIQUID FUELS						
Crude Oil						
Orimulsion						
Natural Gas Liquids						
Motor Gasoline						
Aviation Gasoline						
Jet Gasoline						
Jet Kerosene						
Other Kerosene						
Shale Oil						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG	kt	67.52	47.30	3,193.68	63,066.67	201.41
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Feedstocks						
Refinery Gas						
Paraffin Waxes						
Other Petroleum Products						
SOLID FUELS						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Oil Shale and Tar Sands						

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A4a — Commercial/Institutional
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
LIQUID FUELS					
Crude Oil					
Orimulsion					
Natural Gas Liquids					
Motor Gasoline					
Aviation Gasoline					
Jet Gasoline					
Jet Kerosene					
Other Kerosene					
Shale Oil					
Gas/Diesel Oil					
Residual Fuel Oil					
LPG	kt	5.00	0.01597	0.10	0.00032
Ethane					
Naphtha					
Lubricants					
Petroleum Coke					
Refinery Feedstocks					
Refinery Gas					
Paraffin Waxes					
Other Petroleum Products					
SOLID FUELS					
Anthracite					
Coking Coal					
Other Bituminous Coal					
Sub-Bituminous Coal					
Lignite					
Oil Shale and Tar Sands					

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
SOLID FUELS						
Brown Coal Briquettes						
Patent Fuel						
Coke Oven Coke /Lignite Coke						
Gas Coke						
Coal Tar						
Gas Work Gas	GWh	907.30	3.60	3,266.29	55,733.33	182.04
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)	ktoe	20.05	41.87	839.45	56,100.00	47.09
OTHER FOSSIL FUELS						
Municipal Wastes (Non-Biomass Fraction)						
Industrial Wastes						
Waste Oils						
PEAT						
Peat						
BIOMASS					**INFORMATION ITEMS**	
Wood/Wood Waste						
Sulphite Lyes						
Other Primary Solid Biomass						
Charcoal						
Biogasoline						
Biodiesels						
Other Liquid Biofuels						
Landfill Gas						
Sludge Gas						
Other Biogas						
Municipal Wastes (Biomass Fraction)						
					TOTAL	430.55

1. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Work Gas where a country-specific CO_2 emission factor of 15.2 tC/TJ is used.

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
SOLID FUELS					
Brown Coal Briquettes					
Patent Fuel					
Coke Oven Coke /Lignite Coke					
Gas Coke					
Coal Tar					
Gas Work Gas	GWh	5.00	0.01633	0.10	0.00033
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)	ktoe	5.00	0.00420	0.10	0.00008
OTHER FOSSIL FUELS					
Municipal Wastes (Non-Biomass Fraction)					
Industrial Wastes					
Waste Oils					
PEAT					
Peat					
BIOMASS					
Wood/Wood Waste					
Sulphite Lyes					
Other Primary Solid Biomass					
Charcoal					
Biogasoline					
Biodiesels					
Other Liquid Biofuels					
Landfill Gas					
Sludge Gas					
Other Biogas					
Municipal Wastes (Biomass Fraction)					
		TOTAL	0.03650	**TOTAL**	0.00073

1. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Work Gas where a country-specific CO_2 emission factor of 15.2 tC/TJ is used.

Standing on Henderson Waves, 36 metres above Henderson Road, the highest pedestrian bridge in Singapore along the Southern Ridges. Steeped in history and one of the best spots in Singapore to enjoy panoramic views of the city, harbour and the southern Islands, the Southern Ridges is a home to a wide variety of flora and fauna.

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A4b — Residential
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
LIQUID FUELS						
Crude Oil						
Orimulsion						
Natural Gas Liquids						
Motor Gasoline						
Aviation Gasoline						
Jet Gasoline						
Jet Kerosene						
Other Kerosene						
Shale Oil						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG	kt	22.51	47.30	1,064.56	63,066.67	67.14
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Feedstocks						
Refinery Gas						
Paraffin Waxes						
Other Petroleum Products						
SOLID FUELS						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Oil Shale and Tar Sands						

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A4b — Residential
SHEET	CO_2, CH_4 and N_2O from fuel combustion by source categories – Tier 1

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
LIQUID FUELS					
Crude Oil					
Orimulsion					
Natural Gas Liquids					
Motor Gasoline					
Aviation Gasoline					
Jet Gasoline					
Jet Kerosene					
Other Kerosene					
Shale Oil					
Gas/Diesel Oil					
Residual Fuel Oil					
LPG	kt	5.00	0.00532	0.10	0.00011
Ethane					
Naphtha					
Lubricants					
Petroleum Coke					
Refinery Feedstocks					
Refinery Gas					
Paraffin Waxes					
Other Petroleum Products					
SOLID FUELS					
Anthracite					
Coking Coal					
Other Bituminous Coal					
Sub-Bituminous Coal					
Lignite					
Oil Shale and Tar Sands					

	Units	Energy consumption			CO_2	
		A	B	C	D	E
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)
				C = A*B		E = C*D/10^6
SOLID FUELS						
Brown Coal Briquettes						
Patent Fuel						
Coke Oven Coke /Lignite Coke						
Gas Coke						
Coal Tar						
Gas Work Gas	GWh	740.99	3.60	2,667.56	55,733.33	148.67
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)						
OTHER FOSSIL FUELS						
Municipal Wastes (Non-Biomass Fraction)						
Industrial Wastes						
Waste Oils						
PEAT						
Peat						
BIOMASS					**INFORMATION ITEMS**	
Wood/Wood Waste						
Sulphite Lyes						
Other Primary Solid Biomass						
Charcoal						
Biogasoline						
Biodiesels						
Other Liquid Biofuels						
Landfill Gas						
Sludge Gas						
Other Biogas						
Municipal Wastes (Biomass Fraction)						
					TOTAL	215.81

1. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Work Gas where a country-specific CO_2 emission factor of 15.2 tC/TJ is used.

	Units	CH_4		N_2O	
		F	G	H	I
	Mass, Volume or Energy unit	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
		(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
			G = C*F/10^6		I = C*H/10^6
SOLID FUELS					
Brown Coal Briquettes					
Patent Fuel					
Coke Oven Coke /Lignite Coke					
Gas Coke					
Coal Tar					
Gas Work Gas	GWh	5.00	0.01334	0.10	0.00027
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)					
OTHER FOSSIL FUELS					
Municipal Wastes (Non-Biomass Fraction)					
Industrial Wastes					
Waste Oils					
PEAT					
Peat					
BIOMASS					
Wood/Wood Waste					
Sulphite Lyes					
Other Primary Solid Biomass					
Charcoal					
Biogasoline					
Biodiesels					
Other Liquid Biofuels					
Landfill Gas					
Sludge Gas					
Other Biogas					
Municipal Wastes (Biomass Fraction)					
		TOTAL	0.01866	**TOTAL**	0.00037

1. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Work Gas where a country-specific CO_2 emission factor of 15.2 tC/TJ is used.

SECTOR	**Energy**
CATEGORY	**Fugitive Emissions from Fuels**
CATEGORY CODE	**1B2 — Oil and Natural Gas**

Fugitive Emissions from Oil and Natural Gas

GHG	Emissions in Gg	Global Warming Potential	Emissions in Gg CO_2 eq
CO_2	1,245.910	1	1,245.910
CH_4	1.319	28	36.919
N_2O	0.011	265	2.800

1. Fugitive emissions from oil and natural gas are compiled based on company-level data.
2. Plant-specific methodologies and factors are used where available, otherwise IPCC default methodologies and factors are used.

SECTOR	**Industrial Processes and Product Use**
CATEGORY	**Electronics Industry**
CATEGORY CODE	**2E**

		A	B	C	D	E
				C = AxB		E = CxDx10^{-6}
Greenhouse Gas (GHG)	**Chemical Formula**	**Mass of F-Gases Used in Process**	**Fraction of F-Gas Used in Process with Emission Control Technology**	**Total emissions for each GHG (1)**	**Global Warming Potential**	**Emissions in CO_2 equivalent**
		kg		**kg**		**Gg CO_2eq**
Carbon Dioxide	CO_2	C	C	237,973.28	1	0.24
Methane	CH_4	C	C	4,092.17	28	0.11
Nitrous Oxide	N_2O	C	C	673,953.12	265	178.60
HFC-23	CHF_3	C	C	10,584.99	12,400	131.25
HFC-32	CH_2F_2	C	C	590.72	677	0.40
HFC-41	CH_3F_2	C	C	C	116	C
PFC-14	CF_4	C	C	134,475.52	6,630	891.57
PFC-116	C_2F_6	C	C	41,986.63	11,100	466.05
PFC-218	C_3F_8	C	C	2,984.92	8,900	26.57
PFC-c318	c-C_4F_8	C	C	5,632.04	9,540	53.73
Sulphur hexafluoride	SF_6	C	C	4,782.73	23,500	112.39
Nitrogen trifluoride	NF_3	C	C	23,680.37	16,100	381.25

1. The total figure includes direct and by-product emissions for each GHG.
2. Notation key: C = confidential information.
3. Due to confidentiality reasons, emissions from HFC-41 are included under HFC-32.

Opposite page: Solar panels affixed on the roof of Marina Barrage. Marina Barrage won the Green Mark Platinum Infrastructure Award in 2009. Its Solar Park has 405 panels that generate electricity to light the barrage's gallery and offices during the day.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	—
CATEGORY CODE	3
SHEET	1 of 2 AFOLU Sectoral Table

Categories	Net CO_2 emissions /removals	Emissions				
	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)					
3 — AFOLU	106.45	0.08	0.04			
3A — Livestock		0.08	0.01			
3A1 - Enteric Fermentation		0.01				
3A1a Cattle		0.01				
3A1ai Dairy Cows		0.00				
3A1aii Other Cattle		0.01				
3A1b Buffalo		NO				
3A1c Sheep		NO				
3A1d Goats		0.00				
3A1e Camels		NO				
3A1f Horses		NO				
3A1g Mules and Asses		NO				
3A1h Swine		NO				
3A1j Other (please specify)		NO				
3A2 - Manure Management		0.07	0.01			
3A2a Cattle		0.00	^NO			
3A2ai Dairy Cows		0.00	^NO			
3A2aii Other Cattle		0.00	^NO			
3A2b Buffalo		NO	NO			
3A2c Sheep		NO	NO			
3A2d Goats		0.00	0.00			
3A2e Camels		NO	NO			
3A2f Horses		NO	NO			
3A2g Mules and Asses		NO	NO			
3A2h Swine		NO	NO			
3A2i Poultry		0.07	0.01			
3A2j Other (please specify)						
3A2ji Quail		0.00	0.00			

1. Cells to report emissions of NO_x, CO, and NMVOC have not been shaded although the physical potential for emissions is lacking for some categories.
2. Notation key: NO = not occurring.
3. ^ Based on anaerobic digestion.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	—
CATEGORY CODE	3
SHEET	1 of 2 AFOLU Sectoral Table

Categories	Net CO_2 emissions /removals	Emissions				
	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)					
3 — AFOLU	106.45	0.08	0.04			
3B — Land	104.71	NO	0.02			
3B1 - Forest Land	-48.13	NO	0.00			
3B1a Forest Land Remaining Forest Land	-22.04	NO	0.00			
3B1b Land Converted to Forest Land	-26.09	NO	0.00			
3B1bi Cropland Converted to Forest Land	-0.03	NO	0.00			
3B1bii Grassland Converted to Forest Land	NO	NO	NO			
3B1biii Wetlands Converted to Forest Land	-1.87	NO	NO			
3B1biv Settlements Converted to Forest Land	-15.80	NO	0.00			
3B1bv Other Land Converted to Forest Land	NO	NO	NO			
3B1bvi Other (Sea) Converted to Forest Land	-8.39	NO	0.00			
3B2 - Cropland	0.76	NO	0.00			
3B2a Cropland Remaining Cropland	0.55	NO	0.00			
3B2b Land Converted to Cropland	0.21	NO	0.00			
3B2bi Forest Land Converted to Cropland	0.29	NO	0.00			
3B2bii Grassland Converted to Cropland	NO	NO	NO			
3B2biii Wetlands Converted to Cropland	0.00	NO	NO			
3B2biv Settlements Converted to Cropland	-0.08	NO	0.00			
3B2bv Other Land Converted to Cropland	NO	NO	NO			
3B2bvi Other (Sea) Converted to Cropland	0.00	NO	0.00			
3B3 - Grassland	NO	NO	NO			
3B3a Grassland Remaining Grassland	NO	NO	NO			
3B3b Land Converted to Grassland	NO	NO	NO			
3B3bi Forest Land Converted to Grassland	NO	NO	NO			
3B3bii Cropland Converted to Grassland	NO	NO	NO			
3B3biii Wetlands Converted to Grassland	NO	NO	NO			
3B3biv Settlements Converted to Grassland	NO	NO	NO			
3B3bv Other Land Converted to Grassland	NO	NO	NO			
3B3bvi Other (Sea) Converted to Grassland	NO	NO	NO			

1. Cells to report emissions of NO_x, CO, and NMVOC have not been shaded although the physical potential for emissions is lacking for some categories.
2. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	—
CATEGORY CODE	3
SHEET	2 of 2 AFOLU Sectoral Table

Categories	Net CO_2 emissions /removals	Emissions				
	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)					
3B4 - Wetlands	1.88	NO	NO			
3B4a Wetlands Remaining Wetlands	NO	NO	NO			
3B4ai Peatlands Remaining Peatlands	NO	NO	NO			
3B4aii Flooded Land Remaining Flooded Land	NO	NO	NO			
3B4aiii Other Wetlands Remaining Other Wetlands	NO	NO	NO			
3B4b Land Converted to Wetlands	1.88	NO	NO			
3B4bi Land Converted for Peat Extraction	NO	NO	NO			
3B4bii Land Converted to Flooded Land	1.88	NO	NO			
3B4biii Land Converted to Other Wetlands	NO	NO	NO			
3B5 - Settlements	150.19	NO	0.02			
3B5a Settlements Remaining Settlements	83.11	NO	0.01			
3B5b Land Converted to Settlements	67.08	NO	0.01			
3B5bi Forest Land Converted to Settlements	93.82	NO	0.01			
3B5bii Cropland Converted to Settlements	1.49	NO	0.00			
3B5biii Grassland Converted to Settlements	NO	NO	NO			
3B5biv Wetlands Converted to Settlements	-2.00	NO	NO			
3B5bv Other Land Converted to Settlements	NO	NO	NO			
3B5bvi Other (Sea) Converted to Settlements	-26.23	NO	NO			
3B6 - Other Land	NO	NO	NO			
3B6a Other Land Remaining Other Land	NO	NO	NO			
3B6b Land Converted to Other Land	NO	NO	NO			
3B6bi Forest Land Converted to Other Land	NO	NO	NO			
3B6bii Cropland Converted to Other Land	NO	NO	NO			
3B6biii Grassland Converted to Other Land	NO	NO	NO			

1. Cells to report emissions of NO_x, CO, and NMVOC have not been shaded although the physical potential for emissions is lacking for some categories.
2. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	—
CATEGORY CODE	3
SHEET	2 of 2 AFOLU Sectoral Table

Categories	Net CO_2 emissions /removals	Emissions				
	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
	(Gg)					
3B6 - Other Land	NO	NO	NO			
3B6biv Wetlands Converted to Other Land	NO	NO	NO			
3B6bv Settlements Converted to Other Land	NO	NO	NO			
3B6bvi Other (Sea) Converted to Other Land	NO	NO	NO			
3C — Aggregate Sources and Non-CO_2 Emissions Sources on Land	0.09	NO	0.01			
3C1 - Burning	NO	NO	NO			
3C1a Burning in Forest Land	NO	NO	NO			
3C1b Burning in Cropland	NO	NO	NO			
3C1c Burnings in Grassland	NO	NO	NO			
3C1d Burnings in All Other Land	NO	NO	NO			
3C2 - Liming	0.09					
3C3 - Urea Fertilization	0.00					
3C4 - Direct N_2O Emissions from Managed Soils			0.01			
3C5 - Indirect N_2O Emissions from Managed Soils			0.00			
3C6 - Indirect N_2O Emissions from Manure Management			^^ NO			
3C7 - Rice Cultivations		NO	NO			
3C8 - Other (please specify)	NO	NO	NO			
3D — Other	1.66	NO	NO			
3D1 - Harvested Wood Products	NO		NO			
3D2 - Other (Sea)	1.66	NO	NO			

1. Cells to report emissions of NO_x, CO, and NMVOC have not been shaded although the physical potential for emissions is lacking for some categories.
2. Notation key: NO = not occurring.
3. ^^ Based on anaerobic digestion and composting.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Agriculture/Livestock
CATEGORY CODE	3A
SHEET	AFOLU Background Table: Agriculture/Livestock

Categories	Activity Data	Emissions	
		CH_4	N_2O
	(number of animals)	(Gg)	
3A — Livestock		**0.07922**	
3A1 - Enteric Fermentation		**0.01160**	
3A1a Cattle	175	0.00922	
3A1ai Dairy Cows	47	0.00320	
3A1aii Other Cattle	128	0.00602	
3A1b Buffalo	NO	NO	
3A1c Sheep	NO	NO	
3A1d Goats	478	0.00239	
3A1e Camels	NO	NO	
3A1f Horses	NO	NO	
3A1g Mules and Asses	NO	NO	
3A1h Swine	NO	NO	
3A1j Other (please specify)	NO	NO	

1. Figures may not add up to the totals due to rounding.
2. Notation key: NO = not occurring.
3. ^ Based on anaerobic digestion.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Agriculture/Livestock
CATEGORY CODE	3A
SHEET	AFOLU Background Table: Agriculture/Livestock

Categories	Activity Data	Emissions	
		CH_4	N_2O
	(number of animals)	(Gg)	
3A — Livestock		**0.07922**	
3A2 - Manure Management		**0.06762**	**0.01018**
3A2a Cattle	175	0.00159	^NO
3A2ai Dairy Cows	47	0.00146	^NO
3A2aii Other Cattle	128	0.00013	^NO
3A2b Buffalo	NO	NO	NO
3A2c Sheep	NO	NO	NO
3A2d Goats	478	0.00012	0.00007
3A2e Camels	NO	NO	NO
3A2f Horses	NO	NO	NO
3A2g Mules and Asses	NO	NO	NO
3A2h Swine	NO	NO	NO
3A2i Poultry	2,179,078	0.06537	0.01008
3A2j Other (please specify)			
3A2ji Quail	136,870	0.00054	0.00002

1. Figures may not add up to the totals due to rounding.
2. Notation key: NO = not occurring.
3. ^ Based on anaerobic digestion.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	1 of 3 AFOLU Background Table: Carbon Stock Changes in FOLU

Categories	Activity Data		Net carbon stock change and CO_2 emissions/removals			
			Biomass			
	Total Area	Thereof: Area of organic soils	Increase	Decrease	Carbon emitted as CH_4 and CO from fires	Net carbon stock change
	(ha)		(Gg C)			
3B — LAND	72,420.0	863.3	27.0	-49.3	NO	-22.3
3B1 - Forest Land	15,882.8	832.3	13.1	-3.9	NO	9.1
3B1a Forest Land Remaining Forest Land	12,912.9	788.3	9.4	-3.9	NO	5.5
3B1b Land Converted to Forest Land	2,969.9	43.9	3.6	0.0	NO	3.6
3B1bi Cropland Converted to Forest Land	104.4	0.0	0.0	0.0	NO	0.0
3B1bii Grassland Converted to Forest Land	NO	NO	0.0	0.0	NO	0.0
3B1biii Wetlands Converted to Forest Land	136.5	0.0	0.0	0.0	NO	0.0
3B1biv Settlements Converted to Forest Land	2,195.0	1.6	3.3	0.0	NO	3.3
3B1bv Other Land Converted to Forest Land	NO	NO	NO	NO	NO	0.0
3B1bvi Other (Sea) Converted to Forest Land	534.1	42.3	0.3	0.0	NO	0.3
3B2 - Cropland	268.6	0.0	1.8	-2.1	NO	-0.3
3B2a Cropland Remaining Cropland	150.0	0.0	0.9	-1.1	NO	-0.1
3B2b Land Converted to Cropland	118.6	0.0	0.8	-1.0	NO	-0.2
3B2bi Forest Land Converted to Cropland	9.7	0.0	0.1	-0.1	NO	0.0
3B2bii Grassland Converted to Cropland	NO	NO	0.0	0.0	NO	0.0
3B2biii Wetlands Converted to Cropland	0.3	0.0	0.0	0.0	NO	0.0
3B2biv Settlements Converted to Cropland	108.6	0.0	0.8	-0.9	NO	-0.1
3B2bv Other Land Converted to Cropland	NO	NO	NO	NO	NO	0.0
3B2bvi Other (Sea) Converted to Cropland	0.0	0.0	0.0	0.0	NO	0.0

1. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	1 of 3 AFOLU Background Table: Carbon Stock Changes in FOLU

Categories	Net carbon stock change and CO_2 emissions/removals					
	Dead organic matter		Soils			
	Net carbon stock change	Carbon emitted as CH_4 and CO from fires	Net carbon stock change	Net carbon stock change in mineral soils	Net carbon stock change in organic soils	Net CO_2 emissions
	(Gg C)					(Gg CO_2)
3B — LAND	-1.5	NO	-1.5	-5.4	0.3	106.4
3B1 - Forest Land	0.9	NO	0.9	2.4	0.6	-48.1
3B1a Forest Land Remaining Forest Land	0.5	NO	0.5	-0.5	0.5	-22.0
3B1b Land Converted to Forest Land	0.5	NO	0.5	2.9	0.1	-26.1
3B1bi Cropland Converted to Forest Land	0.0	NO	0.0	0.0	0.0	0.0
3B1bii Grassland Converted to Forest Land	0.0	NO	0.0	0.0	0.0	0.0
3B1biii Wetlands Converted to Forest Land	0.0	NO	0.0	0.4	0.0	-1.9
3B1biv Settlements Converted to Forest Land	0.2	NO	0.2	0.8	0.0	-15.8
3B1bv Other Land Converted to Forest Land	NO	NO	0.0	NO	NO	0.0
3B1bvi Other (Sea) Converted to Forest Land	0.2	NO	0.2	1.7	0.1	-8.4
3B2 - Cropland	-0.1	NO	-0.1	0.1	0.0	0.8
3B2a Cropland Remaining Cropland	0.0	NO	0.0	0.0	0.0	0.6
3B2b Land Converted to Cropland	-0.1	NO	-0.1	0.2	0.0	0.2
3B2bi Forest Land Converted to Cropland	0.0	NO	0.0	0.0	0.0	0.3
3B2bii Grassland Converted to Cropland	0.0	NO	0.0	0.0	0.0	0.0
3B2biii Wetlands Converted to Cropland	0.0	NO	0.0	0.0	0.0	0.0
3B2biv Settlements Converted to Cropland	0.0	NO	0.0	0.2	0.0	-0.1
3B2bv Other Land Converted to Cropland	NO	NO	0.0	NO	NO	0.0
3B2bvi Other (Sea) Converted to Cropland	0.0	NO	0.0	0.0	0.0	0.0

1. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	2 of 3 AFOLU Background Table: Carbon Stock Changes in FOLU

Categories	Activity Data		Net carbon stock change and CO_2 emissions/removals			
			Biomass			
	Total Area	Thereof: Area of organic soils	Increase	Decrease	Carbon emitted as CH_4 and CO from fires	Net carbon stock change
	(ha)		(Gg C)			
3B — LAND	72,420.0	863.3	27.0	-49.3	NO	-22.3
3B3 - Grassland	NO	NO	NO	NO	NO	NO
3B3a Grassland Remaining Grassland	NO	NO	NO	NO	NO	NO
3B3b Land Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3bi Forest Land Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3bii Cropland Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3biii Wetlands Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3biv Settlements Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3bv Other Land Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3bvi Other (Sea) Converted to Grassland	NO	NO	NO	NO	NO	NO

1. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	2 of 3 AFOLU Background Table: Carbon Stock Changes in FOLU

Categories	Net carbon stock change and CO_2 emissions/removals					
	Dead organic matter		Soils			
	Net carbon stock change	Carbon emitted as CH_4 and CO from fires	Net carbon stock change	Net carbon stock change in mineral soils	Net carbon stock change in organic soils	Net CO_2 emissions
	(Gg C)					(Gg CO_2)
3B — LAND	-1.5	NO	-1.5	-5.4	0.3	106.4
3B3 - Grassland	NO	NO	NO	NO	NO	NO
3B3a Grassland Remaining Grassland	NO	NO	NO	NO	NO	NO
3B3b Land Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3bi Forest Land Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3bii Cropland Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3biii Wetlands Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3biv Settlements Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3bv Other Land Converted to Grassland	NO	NO	NO	NO	NO	NO
3B3bvi Other (Sea) Converted to Grassland	NO	NO	NO	NO	NO	NO

1. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	3 of 3 AFOLU Background Table: Carbon Stock Changes in FOLU

Categories	Activity Data		Net carbon stock change and CO_2 emissions/removals			
			Biomass			
	Total Area	Thereof: Area of organic soils	Increase	Decrease	Carbon emitted as CH_4 and CO from fires	Net carbon stock change
	(ha)		(Gg C)			
3B4 - Wetlands	3,928.7	12.6	0.0	-0.3	NO	-0.3
3B5 - Settlements	52,340.0	18.5	12.1	-42.9	NO	-30.8
3B5a Settlements Remaining Settlements	40,868.3	0.0	8.8	-29.0	NO	-20.2
3B5b Land Converted to Settlements	11,471.7	18.5	3.3	-13.9	NO	-10.6
3B5bi Forest Land Converted to Settlements	3,938.3	18.5	1.0	-13.9	NO	-12.9
3B5bii Cropland Converted to Settlements	305.0	0.0	0.1	0.0	NO	0.1
3B5biii Grassland Converted to Settlements	NO	NO	0.0	0.0	NO	0.0
3B5biv Wetlands Converted to Settlements	342.0	0.0	0.1	0.0	NO	0.1
3B5bv Other Land Converted to Settlements	NO	NO	NO	NO	NO	0.0
3B5bvi Other (Sea) converted to Settlements	6,886.4	0.0	2.1	0.0	NO	2.1
3B6 - Other Land	NO	NO	NO	NO	NO	NO
3B6a Other Land Remaining Other Land	NO	NO	NO	NO	NO	NO
3B6b Land Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6bi Forest Land Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6bii Cropland Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6biii Grassland Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6biv Wetlands Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6bv Settlements Converted to Other Land	NO	NO	NO	NO	NO	NO

1. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	3 of 3 AFOLU Background Table: Carbon Stock Changes in FOLU

Categories	Net carbon stock change and CO_2 emissions/removals					
	Dead organic matter		Soils			
	Net carbon stock change	Carbon emitted as CH_4 and CO from fires	Net carbon stock change	Net carbon stock change in mineral soils	Net carbon stock change in organic soils	Net CO_2 emissions
	(Gg C)					(Gg CO_2)
3B4 - Wetlands	0.0	NO	0.0	-0.2	0.0	1.9
3B5 - Settlements	-2.3	NO	-2.3	-7.8	-0.1	150.2
3B5a Settlements Remaining Settlements	0.2	NO	0.2	-2.7	0.0	83.1
3B5b Land Converted to Settlements	-2.5	NO	-2.5	-5.1	-0.1	67.1
3B5bi Forest Land Converted to Settlements	-2.6	NO	-2.6	-10.0	-0.1	93.8
3B5bii Cropland Converted to Settlements	0.0	NO	0.0	-0.5	0.0	1.5
3B5biii Grassland Converted to Settlements	0.0	NO	0.0	0.0	0.0	0.0
3B5biv Wetlands Converted to Settlements	0.0	NO	0.0	0.4	0.0	-2.0
3B5bv Other Land Converted to Settlements	NO	NO	0.0	NO	NO	0.0
3B5bvi Other (Sea) converted to Settlements	0.0	NO	0.0	5.1	0.0	-26.2
3B6 - Other Land	NO	NO	NO	NO	NO	NO
3B6a Other Land Remaining Other Land	NO	NO	NO	NO	NO	NO
3B6b Land Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6bi Forest Land Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6bii Cropland Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6biii Grassland Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6biv Wetlands Converted to Other Land	NO	NO	NO	NO	NO	NO
3B6bv Settlements Converted to Other Land	NO	NO	NO	NO	NO	NO

1. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B4
SHEET	Emissions in Wetlands

Categories	Activity Data		Emissions	
	Area	CO_2	CH_4	N_2O
	(ha)		(Gg)	
3B4 - Wetlands	3,928.7	1.9	NO	NO
3B4a Wetlands Remaining Wetlands	3,910.8	0.0	NO	NO
3B4ai Peatlands Remaining Peatlands	NO	NO	NO	NO
3B4aii Flooded Land Remaining Flooded Land	3910.8	0.0	NO	NO
3B4b Land Converted to Wetlands	17.9	1.9	NO	NO
3B4bi Land Converted for Peat Extraction	0.0	0.0	NO	NO
3B4bii Land Converted to Flooded Land	17.9	1.9	NO	NO
3B4biii Land Converted to Other Wetlands	0.0	0.0	NO	NO

1. Notation key: NO = not occurring.

The Sungei Buloh Wetland Reserve is an important refuge for migratory birds through the East Asian-Australasian Flyway.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3C2
SHEET	AFOLU Background Table: CO_2 emissions from Liming

Categories	Activity Data			Emissions
	Limestone $CaCO_3$	Dolomite $CaMg(CO_3)_2$	Total amount of lime applied	CO_2
	(Mg/yr)		(Mg/yr)	(Gg)
3C2 - Liming	0.00	191.95135	191.95135	0.09150
Forest Land	NO	NO	NO	NO
Cropland	0.00	191.95135	191.95135	0.09150
Grassland	NO	NO	NO	NO
Wetland	NO	NO	NO	NO
Other Land	NO	NO	NO	NO
Other	NO	NO	NO	NO

1. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3C3
SHEET	AFOLU Background Table: CO_2 emissions from Urea Fertilisation

Categories	Activity Data	Emissions
	Total amount of urea applied	CO_2
	(Mg/yr)	(Gg)
3C3 - Urea applied	0.12476	0.00009
Forest Land	NO	NO
Cropland	0.12476	0.00009
Grassland	NO	NO
Settlements	NO	NO
Other Land	NO	NO

1. Notation key: NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3C4
SHEET	AFOLU Background Table: Direct N_2O emissions from Managed Soils

Categories	Activity Data	Emissions
	Total amount of nitrogen applied	N_2O
	(Gg N/yr)	(Gg)
3C4 - Direct N_2O Emissions from Managed Soils	0.51148	0.00804
Inorganic N fertiliser application	0.01485	0.00023
Forest Land	NE	NE
Cropland	0.01485	0.00023
Grassland	NO	NO
Settlements	NE	NE
Other Land	NO	NO
Organic N applied as fertiliser (manure and sewage sludge)	0.49663	0.00780
Forest Land	NE	NE
Cropland	0.49663	0.00780
Grassland	NO	NO
Settlements	NE	NE
Other Land	NO	NO
Urine and dung N deposited on pasture, range and paddock by grazing animals	NO	NO
N In crop residues	NO	NO
	Area	
	(ha)	
N mineralisation/immobilisation associated with loss/gain of soil organic matter resulting from change of land use of management of mineral soils	IE	IE
Drainage/management of organic soils (i.e. Histosols)	NO	NO

1. Figures may not add up to the totals due to rounding.
2. Notation keys: IE = included elsewhere, NE = not estimated and NO = not occurring.

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3C5 and 3C6
SHEET	AFOLU Background Table: Indirect N_2O emissions from Managed Soils and Manure Management

Categories	Activity Data	Emissions
	Total amount of nitrogen applied/excreted	N_2O
	(Gg N/yr)	(Gg)
3C5 - Indirect N_2O Emissions from Managed Soils	0.51148	0.00339
From atmospheric deposition of N volatilised from managed soils from agricultural inputs of N (synthetic N fertilisers; organic N applied as fertiliser; urine and dung N deposited on pasture, range and paddock by grazing animals; N in crop residues; and N mineralisation/immobilisation associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils)	0.51148	0.00158
Forest Land	IE	IE
Cropland	0.51148	0.00158
Grassland	NO	NO
Settlements	IE	IE
Other Land	NO	NO
From N leaching/runoff from managed soils (i.e.synthetic N fertilisers; organic N applied as fertilser; urine and dung N deposited on pasture, range and paddock by grazing animals; N in crop residues; and N mineralisation/immobilisation associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils)	0.51148	0.00181
Forest Land	IE	IE
Cropland	0.51148	0.00181
Grassland	NO	NO
Settlements	IE	IE
Other Land	NO	NO
3C6 - Indirect N_2O Emissions from Manure Management	^^ NO	^^ NO

1. Figures may not add up to the totals due to rounding.
2. Notation keys: IE = included elsewhere and NO = not occurring.
3. ^^ Based on anaerobic digestion and composting.

SECTOR	Waste
CATEGORY	—
CATEGORY CODE	4
SHEET	Waste Sectoral Table

Categories	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
				(Gg)			
4 — WASTE	220.27	0.69	0.27	NO	NO	NO	NO
4A - Solid Waste Disposal		0.69	NO	NO	NO	NO	NO
4A1 Managed Waste Disposal Sites		0.69	NO	NO	NO	NO	NO
4A2 Unmanaged Waste Disposal Sites		NO	NO	NO	NO	NO	NO
4A3 Uncategorised Waste Disposal Sites		NO	NO	NO	NO	NO	NO
4B - Biological Treatment of Solid Waste		NO	NO	NO	NO	NO	NO
4C - Incineration and Open Burning of Waste	220.27	0.00	0.01	NO	NO	NO	NO
4C1 Waste Incineration	220.27	0.00	0.01	NO	NO	NO	NO
4C2 Open Burning of Waste	NO	NO	NO	NO	NO	NO	NO
4D - Wastewater Treatment and Discharge		NE	0.26	NO	NO	NO	NO
4D1 Domestic Wastewater Treatment and Discharge		NE	0.26	NO	NO	NO	NO
4D2 Industrial Wastewater Treatment and Discharge		NE	IE	NO	NO	NO	NO
4E - Other (please specify)	NO	NO	NO	NO	NO	NO	NO

1. Cells to report emissions of NO_x, CO, NMVOC and SO_2 have not been shaded although the physical potential for emissions is lacking for some categories.
2. Notation keys: IE = included elsewhere, NE = not estimated and NO = not occurring.

SECTOR	Waste
CATEGORY	Solid Waste Disposal
CATEGORY CODE	4A
SHEET	CH_4 emissions from Solid Waste Disposal

Uncertainty factor	Fraction of methane captured at the SWDS and flared, combusted or used in another manner	Oxidation factor	Fraction of methane in the SWDS gas (volume fraction)	Fraction of degradable organic carbon (DOC) that can decompose
f	f	OX	F	DOC_f
0.9	0	0.1	0.5	0.5

Methane Correction Factor	Total amount of organic waste prevented from disposal in year x (tons)	Degradable Organic Carbon (by weight) – dry sludge	Degradable Organic Carbon (by weight) – dewatered sludge
MCF	Wx (tons/yr)	DOC (%)	DOC (%)
1	As per records	0.294	0.074

Decay constant	CH_4 Emissions	Global Warming Potential of CH_4	Emissions in CO_2 eq
k	Gg		Gg
0.4	0.691	28	19.360

1. CH_4 emissions from solid waste disposal are computed based on CDM methodologies.

SECTOR	Waste
CATEGORY	Incineration and Open Burning of Waste
CATEGORY CODE	4C1 — Clinical Waste Incineration
SHEET	CO_2, CH_4 and N_2O emissions from Clinical Waste Incineration

	A	B	C	D	E	F	G
CO_2							F = AxBxCxDxE
	Total Amount of Clinical Waste Incinerated (Wet Weight)	Fraction of Dry Matter Content in Waste Incinerated (Wet Weight)	Fraction of Carbon in Dry Matter (Total Carbon Content)	Fraction of Fossil Carbon in the Total Carbon	Oxidation Factor	Conversion Factor	CO_2 Emissions
	kt	fraction	fraction	fraction	fraction	44/12	Gg
	4.89	0.65	0.6	0.4	1	3.67	2.80

	A	B	C	D	E
CH_4			$C = AxBx10^{-6}$		E = CxD
	Total Amount of Clinical Waste Incinerated (Wet Weight)	CH_4 Emission Factor	CH_4 Emissions	Global Warming Potential of CH_4	Emissions in CO_2 eq
	kt	kg CH_4/kt waste	Gg		Gg
	4.89	0.2	0.00000	28	0.00003

	A	B	C	D	E
N_2O			$C = AxBx10^{-6}$		E = CxD
	Total Amount of Clinical Waste Incinerated (Wet Weight)	N_2O Emission Factor	N_2O Emissions	Global Warming Potential of N_2O	Emissions in CO_2 eq
	kt	kg N_2O/kt waste	Gg		Gg
	4.89	50	0.00024	265	0.065

1. As some figures are considerably small, they may be presented as "0.00000" due to rounding.

SECTOR	Waste
CATEGORY	Incineration and Open Burning of Waste
CATEGORY CODE	4C1 — Hazardous Waste Incineration
SHEET	CO_2, CH_4 and N_2O emissions from Hazardous Waste Incineration

	A	B	C	D	E	F
CO_2						F = AxBxCxDxE
	Total Amount of Hazardous Waste Incinerated (Wet Weight)	Fraction of Carbon in Dry Matter (Total Carbon Content)	Fraction of Fossil Carbon in the Total Carbon	Oxidation Factor	Conversion Factor	CO_2 Emissions
	kt	fraction	fraction	fraction	44/12	Gg
	131.80	0.5	0.9	1	3.67	217,473.300

	A	B	C	D	E
CH_4			$C = AxBx10^{-6}$		E = CxD
	Total Amount of Hazardous Waste Incinerated (Wet Weight)	CH_4 Emission Factor	CH_4 Emissions	Global Warming Potential of CH_4	Emissions in CO_2 eq
	kt	kg CH_4/kt waste	Gg		Gg
	131.80	0.2	0.02636	28	0.73809

	A	B	C	D	E
N_2O			$C = AxBx10^{-6}$		E = CxD
	Total Amount of Hazardous Waste Incinerated (Wet Weight)	N_2O Emission Factor	N_2O Emissions	Global Warming Potential of N_2O	Emissions in CO_2 eq
	kt	kg N_2O/kt waste	Gg		Gg
	131.80	50	6.59010	265	1,746.377

1. As some figures are considerably small, they may be presented as "0.00000" due to rounding.

SECTOR	Waste
CATEGORY	Wastewater Treatment and Discharge
CATEGORY CODE	4D
SHEET	CH_4 and N_2O emissions from Wastewater Treatment and Discharge

	A	B	C	D	E
N_2O					
	Annual per capita protein intake, *Protein*	**Annual per capita protein intake, *Protein***	**Total Population in Singapore**	**Fraction of Nitrogen in Protein**	**Factor for non-consumed protein added to the wastewater**	**Factor for industrial and commercial co-discharged protein into the sewer system**
	gram/person/day	kg/person/year		kg N/kg protein	fraction	fraction
	74.45	27.174	5,638,676	0.16	1.1	1.25

	F	G	H	I	J
N_2O			$H = [(A \times B \times C \times D \times E) - F] \times G \times (44/28) \times 10^{-6}$		$J = H \times I$
	Nitrogen removed with sludge	**Emission factor**	**N_2O Emissions**	**Global Warming Potential of N_2O**	**Emissions in CO_2 eq**
	kg N	kg N_2O-N/kg N	Gg		Gg
	0	0.005	0.265	265	70.189

Opposite page: Marina Barrage is Singapore's 15th reservoir, and the first in the heart of the city. The barrage creates a freshwater lake to boost Singapore's water supply, acts as a tidal barrier to alleviate flooding in low-lying city areas, and offers a venue for water-based activities in the heart of the city.

1. The annual per capita protein intake is estimated from Southeast Asia's average per capita protein intake (Source: UN Food and Agriculture Organisation (FAO)) as Singapore-specific figures are not available.
2. The total population in Singapore is based on the latest data available from DOS.

2016
GREENHOUSE GAS SUMMARY TABLE
As reported in Singapore's Fourth Biennial Update Report

Greenhouse Gas Source and Sink Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)							
Total (Net) National Emissions	**49,070.05**	**103.77**	**338.37**	**469.13**	**1,235.41**	**93.94**	**220.51**	**51,531.18**
1 — ENERGY	**48,537.33**	**78.71**	**233.35**					**48,849.39**
1A - Fuel Combustion Activities	47,451.58	56.80	231.52					47,739.89
1A1 Energy Industries	20,044.55	9.22	63.94					20,117.71
1A2 Manufacturing Industries and Construction	18,653.10	11.72	15.86					18,680.69
1A3 Transport	8,096.88	34.28	151.42					8,282.58
1A4a Commercial/Institutional	445.29	1.06	0.20					446.54
1A4b Residential	211.77	0.51	0.10					212.37
1B - Fugitive Emissions from Fuels	1,085.75	21.91	1.83					1,109.49
1B2 Oil and Natural Gas	1,085.75	21.91	1.83					
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**249.94**	**0.03**	**23.02**	**469.13**	**1,235.41**	**93.94**	**220.51**	**2,291.98**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE	**27.83**	**2.24**	**10.67**					**40.73**
3A - Livestock		2.24	2.66					4.90
3B - Land	26.37	NO	5.18					31.54
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land	0.09	NO	2.83					2.92
3D - Other	1.36	NO	NO					1.36
4 — WASTE	**254.95**	**22.79**	**71.33**					**349.08**
4A - Solid Waste Disposal		22.79						
4C - Incineration and Open Burning of Waste	254.95	0.00	2.09					257.04
Clinical Waste Incineration	2.53	0.00	0.06					2.59
Hazardous Waste Incineration	252.42	0.00	2.03					254.44
4D - Wastewater Treatment and Discharge		NE	69.25					69.25
Information items								
CO_2 from Biomass Combustion for Energy Production	1,707.00							1,707.00

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

2014
GREENHOUSE GAS SUMMARY TABLE

As reported in Singapore's Fourth National Communication and Third Biennial Update Report

Greenhouse Gas Source and Sink Categories	Net CO_2	CH_4	N_2O	HFCs
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**47,571.92**	**107.94**	**324.33**	**364.65**
1 — ENERGY	**47,002.87**	**68.60**	**208.61**	
1A - Fuel Combustion Activities	46,051.38	53.82	207.33	
1A1 Energy Industries	19,601.93	8.97	61.68	
1A2 Manufacturing Industries and Construction	19,136.08	12.08	16.13	
1A3 Transport	6,675.08	31.26	129.24	
1A4a Commercial/Institutional	429.78	1.02	0.19	
1A4b Residential	208.50	0.50	0.10	
1B - Fugitive Emissions from Fuels	951.49	14.78	1.28	
1B2 Oil and Natural Gas	951.49	14.78	1.28	
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**290.85**	**0.01**	**38.42**	**364.65**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE	**81.68**	**2.15**	**10.10**	
3A - Livestock		2.15	2.41	
3B - Land	81.60	NO	4.83	
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land	0.08	NO	2.86	
3D - Other	0.00	NO	NO	
4 — WASTE	**196.53**	**37.18**	**67.20**	
4A - Solid Waste Disposal		37.18		
4C - Incineration and Open Burning of Waste	196.53	0.00	1.61	
Clinical Waste Incineration	1.91	0.00	0.04	
Hazardous Waste Incineration	194.62	0.00	1.56	
4D - Wastewater Treatment and Discharge		NE	65.59	
Information items				
CO_2 from Biomass Combustion for Energy Production	1,669.35			

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

Greenhouse Gas Source and Sink Categories	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**1,260.91**	**178.91**	**164.58**	**49,973.25**
1 — ENERGY				**47,280.08**
1A - Fuel Combustion Activities				46,312.54
1A1 Energy Industries				19,672.59
1A2 Manufacturing Industries and Construction				19,164.28
1A3 Transport				6,835.58
1A4a Commercial/Institutional				430.99
1A4b Residential				209.10
1B - Fugitive Emissions from Fuels				967.54
1B2 Oil and Natural Gas				
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**1,260.91**	**178.91**	**164.58**	**2,298.34**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE				**93.93**
3A - Livestock				4.55
3B - Land				86.43
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land				2.95
3D - Other				0.00
4 — WASTE				**300.90**
4A - Solid Waste Disposal				
4C - Incineration and Open Burning of Waste				198.13
Clinical Waste Incineration				1.95
Hazardous Waste Incineration				196.18
4D - Wastewater Treatment and Discharge				65.59
Information items				
CO_2 from Biomass Combustion for Energy Production				1,669.35

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

2012
GREENHOUSE GAS SUMMARY TABLE
As reported in Singapore's Second Biennial Update Report

Greenhouse Gas Source and Sink Categories	Net CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)							
Total (Net) National Emissions	**46,071.25**	**128.56**	**308.73**	**45.85**	**1,188.01**	**92.54**	**96.97**	**47,931.91**
1 — ENERGY	**45,812.71**	**65.67**	**210.26**					**46,088.64**
1A - Fuel Combustion Activities	45,587.19	57.31	209.40					45,853.90
1A1 Energy Industries	20,585.83	12.05	62.45					20,660.33
1A2 Manufacturing Industries and Construction	17,672.64	11.80	16.65					17,701.08
1A3 Transport	6,684.15	31.93	130.01					6,846.10
1A4a Commercial/Institutional	434.54	1.02	0.19					435.75
1A4b Residential	210.03	0.51	0.10					210.63
1B - Fugitive Emissions from Fuels	225.52	8.36	0.87					234.74
1B2 Oil and Natural Gas	225.52	8.36	0.87					
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**74.88**	**0.01**	**23.54**	**45.85**	**1,188.01**	**92.54**	**96.97**	**1,521.80**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE	**-1.09**	**2.17**	**9.99**					**11.08**
3A - Livestock		2.17	2.45					4.62
3B - Land	-1.74	NO	4.85					3.11
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land	0.09	NO	2.70					2.79
3D - Other	0.56	NO	NO					0.56
4 — WASTE	**184.75**	**60.71**	**64.93**					**310.40**
4A - Solid Waste Disposal		60.71						
4C - Incineration and Open Burning of Waste	184.75	0.00	1.51					186.26
Clinical Waste Incineration	1.49	0.00	0.03					1.52
Hazardous Waste Incineration	183.27	0.00	1.47					184.74
4D - Wastewater Treatment and Discharge		NE	63.43					63.43
Information items								
CO_2 from Biomass Combustion for Energy Production	1,645.87							1,645.87

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

2010
GREENHOUSE GAS SUMMARY TABLE
As reported in Singapore's Third National Communication and First Biennial Update Report

Greenhouse Gas Source and Sink Categories	Net CO_2	CH_4	N_2O	HFCs
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**44,404.34**	**160.53**	**295.77**	**42.32**
1 — ENERGY	**44,153.34**	**63.65**	**208.08**	
1A - Fuel Combustion Activities	43,997.50	57.88	207.21	
1A1 Energy Industries	20,899.50	13.50	66.02	
1A2 Manufacturing Industries and Construction	16,159.14	11.04	15.84	
1A3 Transport	6,279.63	31.78	125.06	
1A4a Commercial/Institutional	448.67	1.05	0.20	
1A4b Residential	210.56	0.50	0.10	
1B - Fugitive Emissions from Fuels	155.84	5.77	0.87	
1B2 Oil and Natural Gas	155.84	5.77	0.87	
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**51.75**	**0.01**	**17.96**	**42.32**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE	**-7.57**	**1.93**	**9.28**	
3A - Livestock		1.93	1.94	
3B - Land	-8.23	NO	4.89	
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land	0.10	NO	2.46	
3D - Other	0.56	NO	NO	
4 — WASTE	**206.82**	**94.94**	**60.45**	
4A - Solid Waste Disposal		94.94		
4C - Incineration and Open Burning of Waste	206.82	0.00	1.68	
Clinical Waste Incineration	1.36	0.00	0.03	
Hazardous Waste Incineration	205.46	0.00	1.65	
4D - Wastewater Treatment and Discharge		NE	58.77	
Information items				
CO_2 from Biomass Combustion for Energy Production	1,653.47			

Greenhouse Gas Source and Sink Categories	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**1,103.99**	**84.81**	**73.99**	**46,165.75**
1 — ENERGY				**44,425.07**
1A - Fuel Combustion Activities				44,262.59
1A1 Energy Industries				20,979.02
1A2 Manufacturing Industries and Construction				16,186.02
1A3 Transport				6,436.47
1A4a Commercial/Institutional				449.92
1A4b Residential				211.16
1B - Fugitive Emissions from Fuels				162.48
1B2 Oil and Natural Gas				
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**1,103.99**	**84.81**	**73.99**	**1,374.83**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE				**3.65**
3A - Livestock				3.87
3B - Land				-3.34
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land				2.55
3D - Other				0.56
4 — WASTE				**362.21**
4A - Solid Waste Disposal				
4C - Incineration and Open Burning of Waste				208.50
Clinical Waste Incineration				1.39
Hazardous Waste Incineration				207.11
4D - Wastewater Treatment and Discharge				58.77
Information items				
CO_2 from Biomass Combustion for Energy Production				1,653.47

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

2000
GREENHOUSE GAS SUMMARY TABLE
As reported in Singapore's Second National Communication

Greenhouse Gas Source and Sink Categories	Net CO_2	CH_4	N_2O	HFCs
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**37,868.56**	**225.52**	**266.86**	**9.50**
1 — ENERGY	**37,676.06**	**61.53**	**196.21**	
1A - Fuel Combustion Activities	37,543.15	56.61	195.34	
1A1 Energy Industries	20,793.35	20.06	67.02	
1A2 Manufacturing Industries and Construction	10,268.95	8.24	13.36	
1A3 Transport	5,840.44	26.81	114.68	
1A4a Commercial/Institutional	294.54	0.70	0.13	
1A4b Residential	345.86	0.80	0.15	
1B - Fugitive Emissions from Fuels	132.91	4.92	0.87	
1B2 Oil and Natural Gas	132.91	4.92	0.87	
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**44.13**	**0.01**	**16.40**	**9.50**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE	**44.52**	**2.25**	**13.45**	
3A - Livestock		2.25	2.16	
3B - Land	41.92	NO	8.87	
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land	0.11	NO	2.43	
3D - Other	2.50	NO	NO	
4 — WASTE	**103.85**	**161.74**	**40.80**	
4A - Solid Waste Disposal		161.74		
4C - Incineration and Open Burning of Waste	103.85	0.00	0.84	
Clinical Waste Incineration	0.49	0.00	0.01	
Hazardous Waste Incineration	103.36	0.00	0.83	
4D - Wastewater Treatment and Discharge		NE	39.96	
Information items				
CO_2 from Biomass Combustion for Energy Production	1,999.40			

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

Greenhouse Gas Source and Sink Categories	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**519.23**	**29.75**	**67.57**	**38,986.99**
1 — ENERGY				**37,933.79**
1A - Fuel Combustion Activities				37,795.09
1A1 Energy Industries				20,880.42
1A2 Manufacturing Industries and Construction				10,290.55
1A3 Transport				5,981.93
1A4a Commercial/Institutional				295.38
1A4b Residential				346.81
1B - Fugitive Emissions from Fuels				138.70
1B2 Oil and Natural Gas				
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**519.23**	**29.75**	**67.57**	**686.59**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE				**60.23**
3A - Livestock				4.40
3B - Land				50.78
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land				2.54
3D - Other				2.50
4 — WASTE				**306.38**
4A - Solid Waste Disposal				
4C - Incineration and Open Burning of Waste				104.69
Clinical Waste Incineration				0.50
Hazardous Waste Incineration				104.19
4D - Wastewater Treatment and Discharge				39.96
Information items				
CO_2 from Biomass Combustion for Energy Production				1,999.40

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.

1994
GREENHOUSE GAS SUMMARY TABLE
As reported in Singapore's Initial National Communication

Greenhouse Gas Source and Sink Categories	Net CO_2	CH_4	N_2O	HFCs
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**27,692.82**	**128.97**	**196.17**	**5.45**
1 — ENERGY	**27,500.56**	**46.79**	**148.75**	
1A - Fuel Combustion Activities	27,445.62	44.76	147.89	
1A1 Energy Industries	13,721.77	12.31	43.57	
1A2 Manufacturing Industries and Construction	8,765.47	7.69	13.14	
1A3 Transport	4,316.09	23.27	90.90	
1A4a Commercial/Institutional	331.06	0.77	0.15	
1A4b Residential	311.23	0.71	0.14	
1B - Fugitive Emissions from Fuels	54.94	2.04	0.87	
1B2 Oil and Natural Gas	54.94	2.04	0.87	
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**18.24**	**0.01**	**0.13**	**5.45**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE	**97.34**	**NE**	**10.92**	
3A - Livestock		NE	NE	
3B - Land	91.00	NO	10.92	
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land	NE	NO	NE	
3D - Other	6.34	NO	NO	
4 — WASTE	**76.68**	**82.17**	**36.37**	
4A - Solid Waste Disposal		82.17		
4C - Incineration and Open Burning of Waste	76.68	0.00	0.62	
Clinical Waste Incineration	0.27	0.00	0.01	
Hazardous Waste Incineration	76.41	0.00	0.61	
4D - Wastewater Treatment and Discharge		NE	35.75	
Information items				
CO_2 from Biomass Combustion for Energy Production	1,587.40			

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.
4. Estimates for Agriculture GHG emissions (3A – Livestock and 3C – Aggregate Sources and Non-CO_2 Emissions Sources on Land) from year 1990 to 1999 are not available.

Greenhouse Gas Source and Sink Categories	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	**119.13**	**8.87**	**0.54**	**28,151.94**
1 — ENERGY				**27,696.10**
1A - Fuel Combustion Activities				27,638.26
1A1 Energy Industries				13,777.64
1A2 Manufacturing Industries and Construction				8,786.30
1A3 Transport				4,430.26
1A4a Commercial/Institutional				331.98
1A4b Residential				312.08
1B - Fugitive Emissions from Fuels				57.84
1B2 Oil and Natural Gas				
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**119.13**	**8.87**	**0.54**	**152.36**
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE				**108.26**
3A - Livestock				
3B - Land				101.92
3C - Aggregate Sources and Non-CO_2 Emissions Sources on Land				
3D - Other				6.34
4 — WASTE				**195.22**
4A - Solid Waste Disposal				
4C - Incineration and Open Burning of Waste				77.30
Clinical Waste Incineration				0.27
Hazardous Waste Incineration				77.03
4D - Wastewater Treatment and Discharge				35.75
Information items				
CO_2 from Biomass Combustion for Energy Production				1,587.40

1. According to the 2006 IPCC guidelines, information items are not included in the national total emissions.
2. In line with IPCC Good Practice Guidance to continually review the GHG inventory, the figures have been updated where necessary.
3. As some figures are considerably small, they may be presented as "0.00" due to rounding.
4. Estimates for Agriculture GHG emissions (3A – Livestock and 3C – Aggregate Sources and Non-CO_2 Emissions Sources on Land) from year 1990 to 1999 are not available.

Besides Sentosa, other Southern Islands with their rich natural and cultural heritage have also grown into popular destinations for day trips.

GLOSSARY

AAP	AWGCC Action Plan
ABC Waters	Active, Beautiful, Clean Waters
ACRF	ASEAN Comprehensive Recovery Framework
AFOLU	Agriculture, Forestry and Other Land Use
APAEC	ASEAN Plan of Action on Energy Cooperation
AR5	Fifth Assessment Report
AR6	Sixth Assessment Report
ARCDAP	ASEAN Regional Climate Data Analysis and Prediction
ASEAN	Association of Southeast Asian Nations
ASEANCOF	ASEAN Climate Outlook Forum
ASMC	ASEAN Specialised Meteorological Centre
ATM	Air Traffic Management
AWGCC	ASEAN Working Group on Climate Change
BAU	Business-As-Usual
BCA	Building and Construction Authority
BESS	Building Energy Submission System
BREEF	Building Retrofit Energy Efficiency Financing
BTR	Biennial Transparency Report
BUR	Biennial Update Report
C40	C40 Cities Climate Leadership Group
CAAS	Civil Aviation Authority of Singapore
CAGR	Compounded Annual Growth Rate
CAP	Climate Action Package
CCGT	Combined Cycle Gas Turbine
CCRS	Centre for Climate Research Singapore
CCUS	Carbon Capture, Utilisation and Storage
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CERT	Clean Energy Research & Testbedding Programme
CESG	Clean Enviro Summit Singapore
CEVS	Carbon Emissions-Based Vehicle Scheme
CEWG	Comms and Engagement Working Group
CFLni	Compact Fluorescent Lamps with Non-Integrated Ballasts
CFPF	Coastal and Flood Protection Fund
CH_4	Methane
CISR	Climate Impact Science Research
CLC	Centre for Liveable Cities
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2 eq	Carbon Dioxide Equivalent
CO	Carbon Monoxide
COP	Conference of the Parties
CORDEX-SEA	Coordinated Regional Downscaling Experiment for the Southeast Asia Region
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CRD	Climate Resilient Development
CREATE	Campus for Research Excellence and Technological Enterprise
dMRV	Domestic Measurement, Reporting and Verification

DRR	Disaster Risk Reduction
DTSS	Deep Tunnel Sewerage System
E2F	Energy Efficiency Fund
EASe	Energy Efficiency Improvement Assistance Scheme
ECA	Energy Conservation Act
EDB	Economic Development Board
EDMA	Emissions Data Monitoring and Analysis
EEAI	Electric Vehicle Early Adoption Incentive
EEO	Energy Efficiency Opportunities
EETC	Energy Efficiency Technology Centre
EITE	Emissions-Intensive Trade-Exposed
EMA	Energy Market Authority
EPHA	Environmental Public Health Act
EPMA	Environmental Protection and Management Act
ESS	Energy Storage Systems
EU	European Union
EV	Electric Vehicle
Exco	Executive Committee
FAO	Food and Agriculture Organisation
FELS	Fuel Economy Labelling Scheme
FFPN	Future Fuels Port Network
FI	Funding Initiative
GBMP	Green Building Masterplan
GDP	Gross Domestic Product
GEA	Green Economy Agreement
GEF	Global Environment Facility
GEWG	Green Economy Working Group
GFA	Gross Floor Area
Gg	Gigagram
GHG	Greenhouse Gas
GlobalABC	Global Alliance for Buildings and Construction for Climate
GM	Green Mark
Green Plan	Singapore Green Plan 2030
GSP	Global Support Programme
GW	Gigawatt
GWh	Gigawatt-Hour
GWp	Gigawatt-Peak
GWP	Global Warming Potential
Ha	Hectare
HDB	Housing & Development Board
HFCs	Hydrofluorocarbons
HUJ	Hebrew University of Jerusalem
IBFWS	Impact-based Forecast and Warning Services
ICAO	International Civil Aviation Organization
ICE	Internal Combustion Engine
ICT	Information and Communications Technology
ICTU	Information to facilitate clarity, transparency and understanding

IEA	International Energy Agency
IES	Institution of Engineers, Singapore
IMCCC	Inter-Ministerial Committee on Climate Change
IMDA	Info-comm Media Development Authority
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IWMF	Integrated Waste Management Facility
IWSDF	Industrial Water Solutions Demonstration Fund
JAIF	Japan-ASEAN Integration Fund
KCA	Key Category Analysis
Keppel O&M	Keppel Offshore & Marine
kg	Kilogramme
kt	Kilotonne
LAO PDR	Lao People's Democratic Republic
LCER	Low-Carbon Energy Research
LCS	Low-carbon Solutions
LDCs	Least Developed Countries
LEDS	Long-Term Low-Emissions Development Strategy
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LTA	Land Transport Authority
LTMS-PIP	Lao PDR-Thailand-Malaysia-Singapore Power Integration Project
LULUCF	Land Use, Land-Use Change and Forestry
LWG	Long-Term Emissions and Mitigation Working Group
M&R	Measurement and Reporting
MAS	Monetary Authority of Singapore
MELS	Mandatory Energy Labelling Scheme
MEPS	Minimum Energy Performance Standards
MGO/MDO	Marine Gas Oil/Marine Diesel Oil
MND	Ministry of National Development
MOF	Ministry of Finance
MOH	Ministry of Health
MOU	Memoranda of Understanding
MPA	Maritime and Port Authority of Singapore
MRT	Mass Rapid Transit
MRV	Measurement, Reporting and Verification
MSE	Ministry of Sustainability and the Environment
MSGI	Maritime Singapore Green Initiative
MSS	Meteorological Service Singapore
Mt	Million Tonnes
$MtCO_2$ eq	Million Tonnes of Carbon Dioxide Equivalent
MW	Megawatts
MWELS	Mandatory Water Efficiency Labelling Scheme
MWp	Megawatt-Peak
N_2O	Nitrous Oxide
NBS	Nature-based Solutions

NC	National Communication
NCCS	National Climate Change Secretariat
NDC	Nationally Determined Contribution
NEA	National Environment Agency
NF_3	Nitrogen Trifluoride
NMVOCs	Non-Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides
NParks	National Parks Board
NRF	National Research Foundation
NSLP	National Sea Level Programme
NUS	National University of Singapore
OECC	Overseas Environmental Cooperation Centre
OPC	Off-Peak Car
PaSTI	Partnership to Strengthen Transparency for co-Innovation
PFCs	Perfluorocarbons
PMO	Prime Minister's Office
PMO-SG/NCCS	Prime Minister's Office - Strategy Group, National Climate Change Secretariat
Pre-FS	Pre-Feasibility Study
PUB	PUB, Singapore's National Water Agency
PUE	Power Usage Effectiveness
PV	Photovoltaic
QA	Quality Assurance
QC	Quality Control
R&D	Research and Development
RAC	Refrigeration and Air Conditioning
RWG	Resilience Working Group
SCP	Singapore Cooperation Programme
SCS	Solar Capability Scheme
SDGs	Sustainable Development Goals
SEADRIF	Southeast Asia Disaster Risk Insurance Facility
SF_6	Sulphur Hexafluoride
SFA	Singapore Food Agency
SGBC	Singapore Green Building Council
SGBMP	Singapore Green Building Masterplan
SHD	Singapore Height Datum
SIDS	Small Island Developing States
SIEW	Singapore International Energy Week
SIT	Singapore Institute of Technology
SIWW	Singapore International Water Week
SLA	Singapore Land Authority
SLE	Super Low Energy
SMEs	Small and Medium-sized Enterprises
SO_2	Sulphur Dioxide
SSUL	Switch and Save – Use LED
SWG	Sustainability Working Group
TASR	Technical Analysis Summary Report
tCO_2 eq	Tonne of Carbon Dioxide Equivalent

TCTP	Third Country Training Programme
TTE	Team of Technical Experts
TWRP	Tuas Water Reclamation Plant
UHI	Urban Heat Island
UHI WG	Urban Heat Island Mitigation Workgroup
UNDP	United Nations Development Programme
UNDRR	UN Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
URA	Urban Redevelopment Authority
V&A	Vulnerability and Adaptation Analysis
V2	Second National Climate Change Study
VES	Vehicular Emissions Scheme
VRF	Variable Refrigerant Flow
WC	Water Closet
WCR	Walk-Cycle-Ride
WCRP	World Climate Research Programme
WCS	World Cities Summit
WCRP	World Climate Research Programme
WEF	World Economic Forum
WEMP	Water Efficiency Management Plan
WOG	Whole-of-Government
WRPs	Water Reclamation Plants

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