SINGAPORE'S FOURTH BIENNIAL UPDATE REPORT

2020

UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

PUBLISHED BY
National Environment Agency
Environment Building
40 Scotts Road
Singapore 228231

IN COLLABORATION WITH
Ministry of Foreign Affairs
Ministry of National Development
Ministry of Sustainability and the Environment
Ministry of Trade and Industry
Ministry of Transport
National Climate Change Secretariat

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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 1st Biennial Update Report (BUR) to the UNFCCC in 2014.[2]

Singapore submitted our 4th NC and 3rd BUR in 2018.

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

This document was prepared in accordance with the UNFCCC Biennial Update Reporting Guidelines (decision 2/CP.17 annex III).

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

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FOREWORD

2020 has been a year of extraordinary circumstances, and a stark reminder of how vulnerable we are to the forces of nature. Even as we continue to tackle the global health crisis, we cannot afford to put the climate agenda on the back burner. Extreme climate and weather events have become more frequent and could become our new reality if global warming is not addressed. The Intergovernmental Panel on Climate Change (IPCC)'s landmark *Special Report on Global Warming of 1.5°C, Special Report on Climate Change and Land* and *Special Report on the Ocean and Cryosphere in a Changing Climate* published in recent years underscore the urgency for a global response to mitigate the impact of climate change.

Therefore, as we rebuild and recover from the pandemic, we must take the opportunity to shift our economies and societies towards a low-carbon and climate-resilient future.

The Paris Agreement represents a clear global commitment to tackle climate change. A concerted response by all countries will be critical towards achieving the long-term temperature goal of the Paris Agreement. Each country must plan for and implement efforts to reduce its carbon footprint and prepare for climate challenges.

Singapore is committed to supporting the global call for enhanced climate action. Although our access to alternative energy sources is greatly limited, we have undertaken early efforts to drive sustainable development and pursue low-carbon growth. We are on track to achieve our 2009 Copenhagen pledge to reduce emissions by 16% below our business-as-usual (BAU) level in 2020. In March this year, Singapore submitted an enhanced Nationally Determined Contribution (NDC) to peak our emissions at 65 million tonnes of carbon dioxide equivalent ($MtCO_2$ eq) around 2030. We have also put forward our long-term low-emissions development strategy (LEDS), which aspires to halve emissions from its peak to 33$MtCO_2$ eq, with a view to achieving net-zero emissions as soon as viable in the second half of the century.

Our transition to a low-carbon future will require a concerted effort across our industry, economy and society. Our actions over the years, such as harnessing solar energy, improving energy efficiency, adopting cleaner vehicles, safeguarding our greenery and implementing a carbon tax, have set the foundation for Singapore's carbon mitigation strategy. We will continue to pursue emissions reductions across all sectors through a comprehensive suite of mitigation measures.

Opposite page: The Farm at One Farrer, Skyrise Greenery Award 2017 winner

The Active, Beautiful, Clean Waters (ABC Waters) Programme has transformed Singapore into a City of Gardens and Water.

At the same time, we are implementing long-term adaptation plans to enhance the nation's climate and resource resilience. For Singapore, climate change is an existential challenge. As a low-lying island city-state, Singapore is fundamentally vulnerable to the threat of rising sea levels and extreme weather conditions.

Singapore's Fourth Biennial Update Report summarises the progress we have made as a nation to address climate change and meet our obligations under the United Nations Framework Convention on Climate Change (UNFCCC). We will continue to press ahead to implement our climate strategies in good faith to advance global climate efforts, in the spirit of collaboration and collective action with all countries. The pandemic reminds us that a global crisis requires a global solution – governments need to work in concert with one another, and in collaboration with the scientific and business communities and civil society.

MR TEO CHEE HEAN

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

Opposite page: Reducing emissions through travel on the MRT

EXECUTIVE SUMMARY

Singapore is a small, low-lying, island city-state vulnerable to the effects of climate change.

Given Singapore's small size and dense urban landscape, there are challenges to using alternative energy sources such as solar, nuclear and wind energy. Such difficulties in switching to alternatives are recognised by the United Nations Framework Convention on Climate Change (UNFCCC).

Singapore's greenhouse gas emissions for 2016 totalled 50,702.71 gigagram CO_2 equivalent. Carbon dioxide (CO_2) accounted for 95.2% 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 4.8% 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.

Singapore is on track to achieve our Copenhagen pledge submitted in 2010 to reduce our emissions by 16% below our business-as-usual (BAU) level in 2020. To build on these efforts, we have submitted an enhanced Nationally Determined Contribution (NDC) committing to peak our emissions at no higher than 65 million tonnes of carbon dioxide equivalent ($MtCO_2eq$) around 2030.

Singapore has also set out a long-term low-emissions development strategy (LEDS), aspiring to halve emissions from its peak to $33MtCO_2eq$ by 2050, with a view to achieving net-zero emissions as soon as viable in the second half of the century. Our enhanced NDC and LEDS build on policies and initiatives we have progressively implemented over the years. They demonstrate our seriousness and commitment to support global climate action and to work towards a low-carbon, climate-resilient future.

A key pillar of Singapore's strategy to mitigate greenhouse gas emissions is to improve energy efficiency across different sectors of the economy. Singapore 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. While Singapore continues to invest actively in research on clean energy technologies to reduce the use of fossil fuels, there are limits to the deployment of alternative or renewable energy sources.

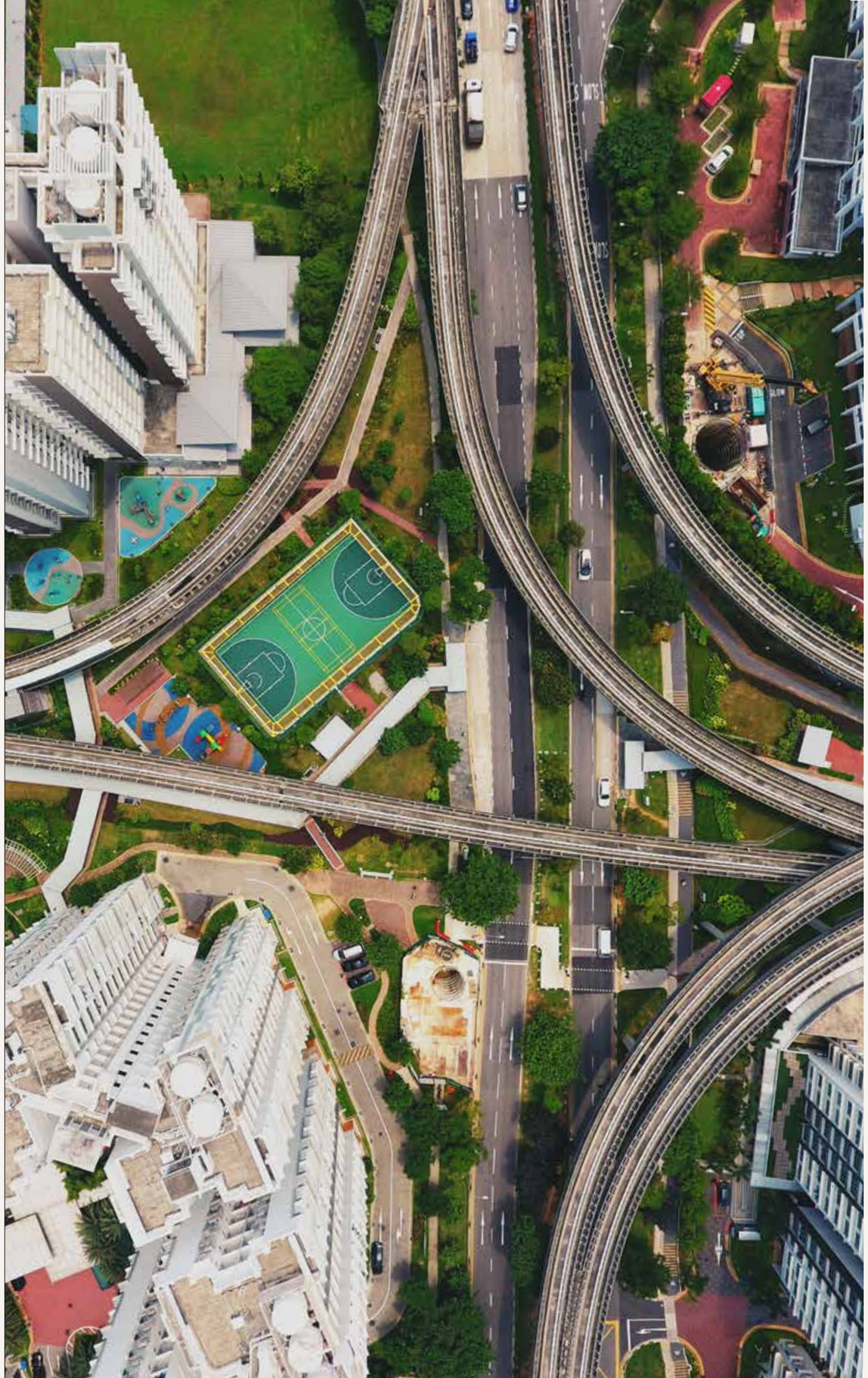
In addition to reducing emissions, Singapore will continue to raise awareness and build capabilities to improve energy efficiency across the sectors through the use of incentives or regulatory measures where appropriate. Singapore has implemented a carbon tax of S$5 or US$3.64 per tonne of CO_2 equivalent (tCO_2eq) of greenhouse gas (GHG) emissions in the first instance, between 2019 and 2023, as a transition period. We intend to increase it to S$10-15 or US$7.27-10.91/tCO_2eq by 2030. The carbon tax will complement our existing mitigation efforts to meet our climate pledge under the Paris Agreement.

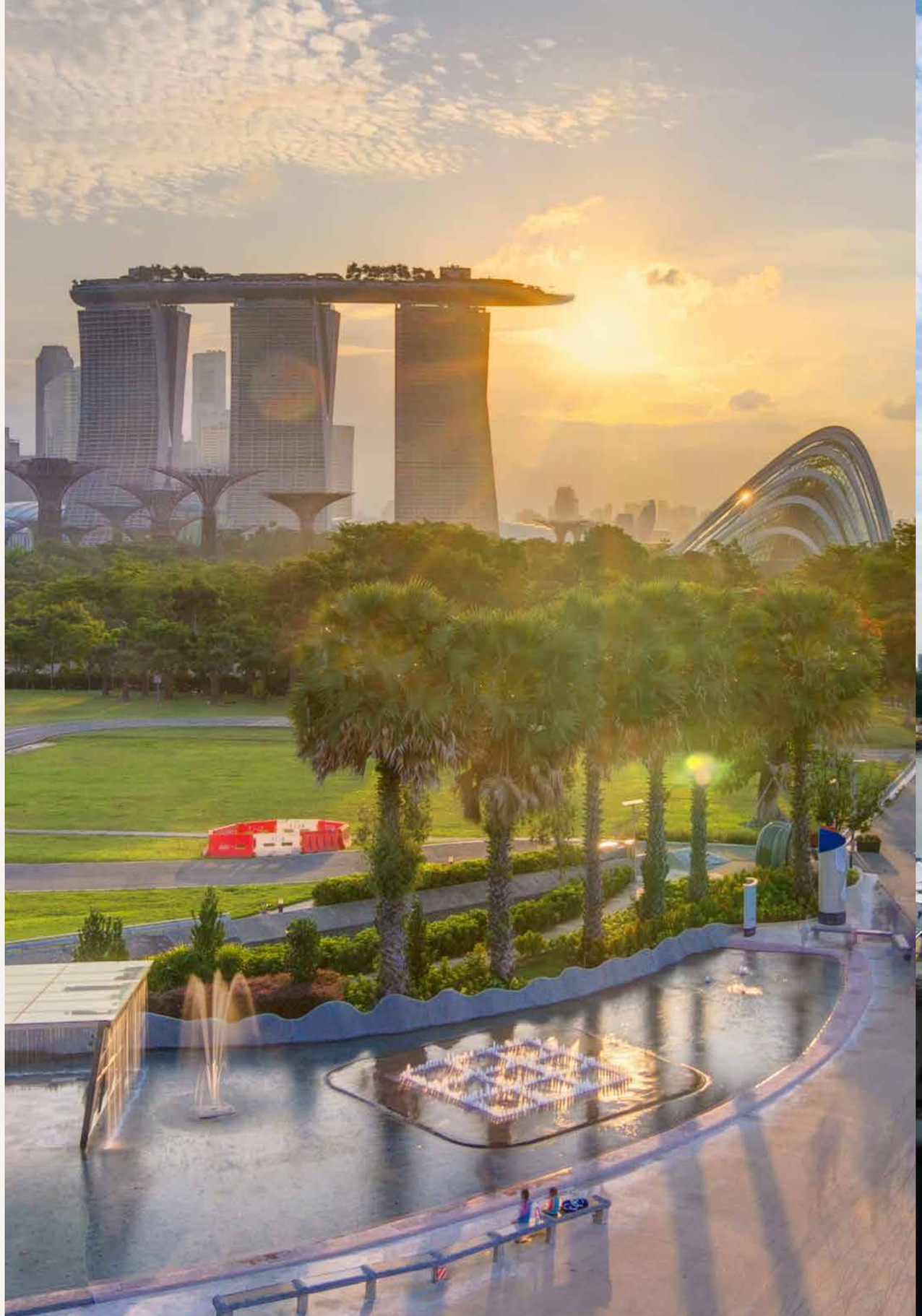
As a relatively low-lying, densely populated island in the tropics, Singapore is naturally vulnerable to the impacts of climate change. Singapore takes a proactive, long-term approach towards climate change adaptation. Climate change resilience goes beyond physical adaptation, and must include building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

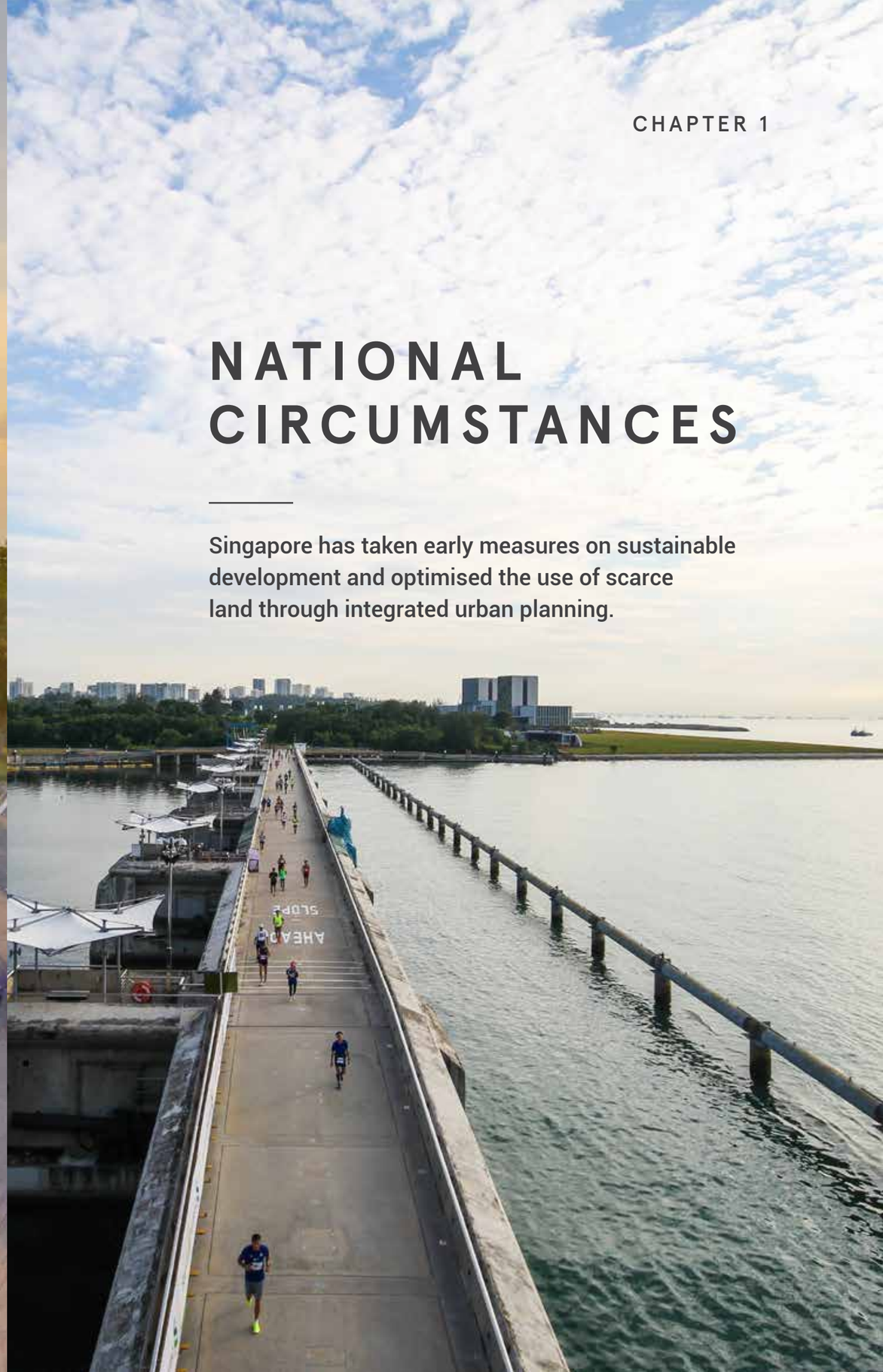
Climate change is an issue with many dimensions that cut across the responsibilities of several ministries. The Inter-Ministerial Committee on Climate Change (IMCCC) continues to play an important role in coordinating Singapore's approach to climate change.

As a responsible member of the global community, Singapore is actively working at the international, regional and bilateral levels to support global efforts to address the challenges of climate change.

Opposite page: Optimising the use of land space







CHAPTER 1

NATIONAL CIRCUMSTANCES

Singapore has taken early measures on sustainable development and optimised the use of scarce land through integrated urban planning.

COUNTRY PROFILE

Singapore is a small 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 137km 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 49km east to west and 28km from north to south, with a coastline of 215km. The total land area (including that of smaller islands) is about 728.0km^2. Among the smaller islands, the larger ones are Pulau Tekong (26.7km^2), Pulau Ubin (10.2km^2) and Sentosa (4.8km^2).

Singapore's surface reaches 163m at our highest point. Much of Singapore is generally flat and less than 15m above sea level, as defined by the Singapore Height Datum (SHD).[3]

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. The 1981-2010 long-term average daily temperature was about 27.5°C, with an average daily maximum of about 31.5°C and an average daily minimum of about 24.7°C. The long-term average annual rainfall is around 2,166mm.

The climate of Singapore is characterised by two monsoon seasons separated by inter-monsoonal periods. The Northeast Monsoon occurs from December to early March, and the comparatively drier Southwest Monsoon from June to September. The early part of the Northeast Monsoon (December to early January) is the wetter period of the year when monsoon surges occur, which sometimes result in prolonged heavy rain. The later part of the Northeast Monsoon (late January to early March) is usually much drier, with February being the driest month during this period. Afternoon thunderstorms are common throughout the year, especially during the inter-monsoonal periods from late March to May and October to November. During the Southwest Monsoon and inter-monsoonal periods, widespread heavy rain and gusty winds associated with Sumatra squalls also occur occasionally.

Recent Trends

Observations by the Meteorological Service Singapore showed that the warm trend experienced in Singapore over the past decades continued in 2019. For 28 consecutive months from February 2018 to May 2020, Singapore's monthly mean temperatures were above the respective monthly average. The annual mean temperature in 2019 was 28.4°C, equalling the record set in 2016. Four of the past five years (2015, 2016, 2018 and 2019) are also among the top 10 warmest years on record with respect to annual mean temperature.

Other than the high temperatures, 2019 was also particularly dry. Rainfall recorded at the climate station was 1,368mm, making 2019 the third driest year behind 1997 (1,119mm) and 2015 (1,267mm) since rainfall records began in 1869.

POPULATION

As of June 2019, Singapore's total population, including foreigners working in Singapore, was estimated at 5.7 million. The resident population, comprising Singapore citizens and permanent residents, was estimated at 4.0 million, or 71% of the total population. Singapore's small land area also means that our population density of about 7,866 people per km^2 is one of the highest in the world.

[3]The SHD is defined as the mean sea level determined at Victoria Dock in Singapore between 1935 and 1937.

ECONOMY

Singapore is an export-oriented economy that is highly dependent on international trade. In 2019, in nominal terms, Singapore's external merchandise trade amounted to S$1,022 billion or US$759 billion, two times its GDP (S$508 billion or US$377 billion). Over several decades, Singapore has built up a strong economy where manufacturing, wholesale trade and retail trade sectors each comprised around 21% and 17% of GDP respectively, in 2019. 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 17% of our total merchandise exports in 2019. Singapore's strategic geographical location has also enabled it to develop into a major air and sea transportation hub. The economic structure in 2019 is as shown.

Economic Structure, 2019

(Nominal Value Added Share, %)	%
Manufacturing	20.9
Construction	3.7
Utilities	1.2
Other Goods Industries	0.0
Wholesale & Retail Trade	17.3
Transportation & Storage	6.7
Accommodation & Food Services	2.1
Information & Communications	4.3
Finance & Insurance	13.9
Business Services	14.8
Other Services Industries	11.3
Ownership of Dwellings	3.8

WATER

Located in the equatorial rain belt, Singapore receives abundant rainfall annually. However, Singapore is considered a water-scarce country due to limited land to collect and store rainwater. To ensure water sustainability, Singapore has developed a diversified and robust supply of water through the Four National Taps, namely local catchment water, imported water, NEWater (high-grade reclaimed water produced from treated used water) 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.

Integral to the large-scale collection of used water for recycling into NEWater is the Deep Tunnel Sewerage System (DTSS). A superhighway for used water management, the DTSS provides a cost-effective and sustainable solution to meet Singapore's long-term needs for used water collection, treatment, reclamation and disposal.

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 the local catchment. PUB, Singapore's National Water Agency, has been investing in research and development (R&D) to improve the energy efficiency of our water production. For instance, biomimetic membrane technology, which mimics and models desalination processes in nature (e.g. in mangrove plants and marine fish), is being engineered and scaled up to reduce the energy needed for membrane-based water purification processes. Another research

The seawater reverse osmosis membrane vessels used in the desalination plant are more energy-intensive compared to treating water from the local catchment.

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 wide-ranging water conservation measures, Singapore's per capita domestic water consumption was reduced from 165 litres per day in 2003 to 141 litres per day in 2019. Through holistic and efficient water demand management strategies, Singapore has a distribution loss of 8.3% in 2019. The number of leaks in Singapore, at 5.3 leaks/100km/year, is low compared to other countries.

SINGAPORE'S NATIONAL CIRCUMSTANCES AND CONSTRAINTS

Singapore currently accounts for around 0.1% of global emissions. 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 emission 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 sector is a large source of our carbon emissions and Singapore has been working to improve energy efficiency in these sectors. This is an ongoing effort.

Singapore has taken early measures on sustainable development such as switching to natural gas for electricity generation instead of more pollutive fuel oil, and imposing a vehicle quota system to cap vehicle growth. In addition, we have optimised the use of our scarce land through integrated urban planning. Given Singapore's unique circumstances as both a city and a nation-state, our small land area has to accommodate not only housing and commercial hubs, but also power plants, reservoirs, air and seaports and industries, all within our boundaries. Singapore has also adopted a greening strategy to extend our natural capital and green cover. Our urban greenery and natural ecosystems help to mitigate the effects of, and build resilience to, climate change by storing and sequestering carbon. As trees grow, they build up biomass and become carbon stock. Our greenery also helps to keep urban areas cooler and improve air quality, thus mitigating the impact of climate change.

CLIMATE VULNERABILITIES

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

Singapore's vulnerability to climate change will require the Government to pursue a comprehensive adaptation programme to protect our coasts, low-lying areas and communities.[4] These adaptation actions will impose significant fiscal costs on the Government.

ALTERNATIVE ENERGY CONSTRAINTS

Singapore has limited land area, relatively flat land, a high urban density, low wind speeds, and lacks geothermal resources. Therefore, harnessing alternative energy sources such as hydroelectric, wind, geothermal or nuclear 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. Such difficulties in transitioning to alternative energy are recognised by the United Nations Framework Convention on Climate Change (UNFCCC), under Articles 4.8 and 4.10.

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. Singapore already converts much of our waste to energy, providing about 2.5% of the total electricity generated in 2018. Nonetheless, we will continue to monitor developments in this area.

The Plant-A-Tree Programme is a platform for organisations and individuals to actively participate in the greening of Singapore by planting trees.

[4] *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 Greenhouse Gas emissions.

CARBON CAPTURE, UTILISATION AND STORAGE (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.

Whilst such solutions have been conceptually proven, their large-scale deployment is currently limited by economic, institutional and technical constraints. We will continue to evaluate such technologies and invest in R&D initiatives to facilitate their cost-effective application.

GEOTHERMAL

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

HYDROELECTRIC POWER

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

Recognition of National Circumstances in the United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) Articles 4.8 and 4.10 calls 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."**

MARINE (TIDAL AND WAVE POWER)

The tidal range (difference between high and low tide) is about 1.7m, well below the 4m tidal range that is typically required for commercial tidal power generation. The availability of wave power is determined by the height and frequency of 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 at the time 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. Newer nuclear power plant designs that are being developed and tested have the potential to be much safer than many of the plants that are in operation today. However, the risks to Singapore, given that we are a small and densely populated city, still outweigh the benefits at this point. Most of these newer technologies are still in the testing phase and have not been operationally proven. As we are planning for the long term and not for our immediate energy needs, we will continue to monitor the progress of these nuclear energy technologies to keep our energy options open for the future. We will also continue to strengthen our capabilities to understand nuclear science and technology.

WIND

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

SOLAR

Despite Singapore's space constraints, the Government is pressing ahead to promote solar photovoltaic (PV) deployment, with solar energy being our most viable renewable energy source. 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 improve the efficiencies and lower the costs of solar PV and related 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, for example, energy storage and solar forecasting.

PURSUIT OF SUSTAINABLE DEVELOPMENT

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

Our pursuit of sustainability and environmental protection is reflected in our approach to urban development and resource management, including how we manage transportation, housing, waste, greenery, energy and water. For instance, since the early 2000s, we have been replacing fuel oil with natural gas – the cleanest form of fossil fuel – as the

primary fuel for electricity generation. In 2019, natural gas accounted for around 95% of our electricity generation, with the remainder mainly from waste-to-energy plants and solar PVs. We have deployed around 400MWp of solar PVs in 2020, including floating PVs, and aim to increase this to at least 2GWp by 2030. We are also developing innovative clean energy solutions in partnership with academia, industry and other countries. 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. 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 safeguard more than 7,800 hectares of green spaces – nature reserves, gardens and parks – across Singapore, and integrate greenery throughout the city.

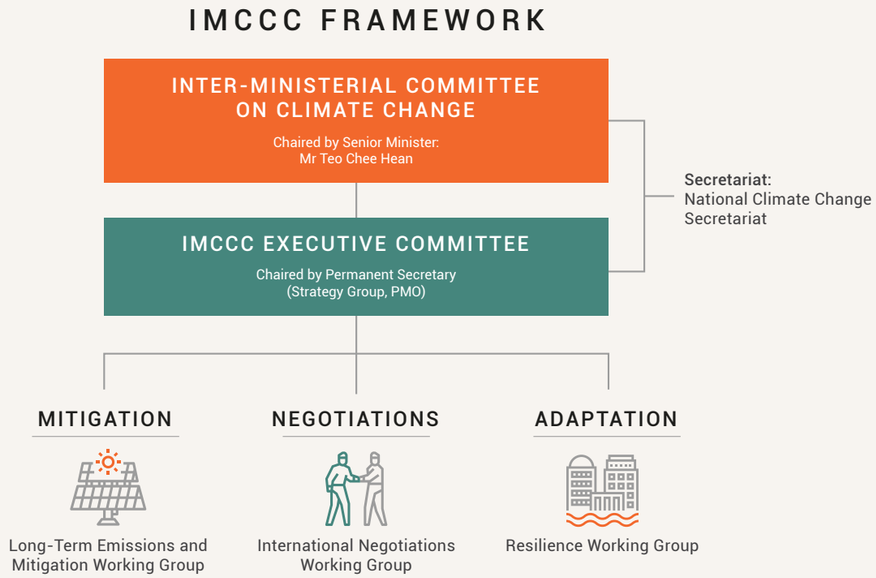
This approach has allowed Singapore's emissions intensity today to be one of the lowest in the world. We ranked among the 20 best-performing out of 141 countries in terms of emissions intensity in 2017.[5] We are recognised as Asia's most sustainable city and the fourth most sustainable city globally according to the 2018 Sustainability Cities Index. The Sustainability Cities Index recognises that Singapore is undertaking several 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 been 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.

Neste, the largest renewable diesel and sustainable aviation fuel producer worldwide, has been operating one of its largest renewable refineries in Singapore since 2010. Its sustainable aviation fuel will be used by international airlines for more environmentally friendly travel.

[5]Source: International Energy Agency, CO_2 Highlights 2019



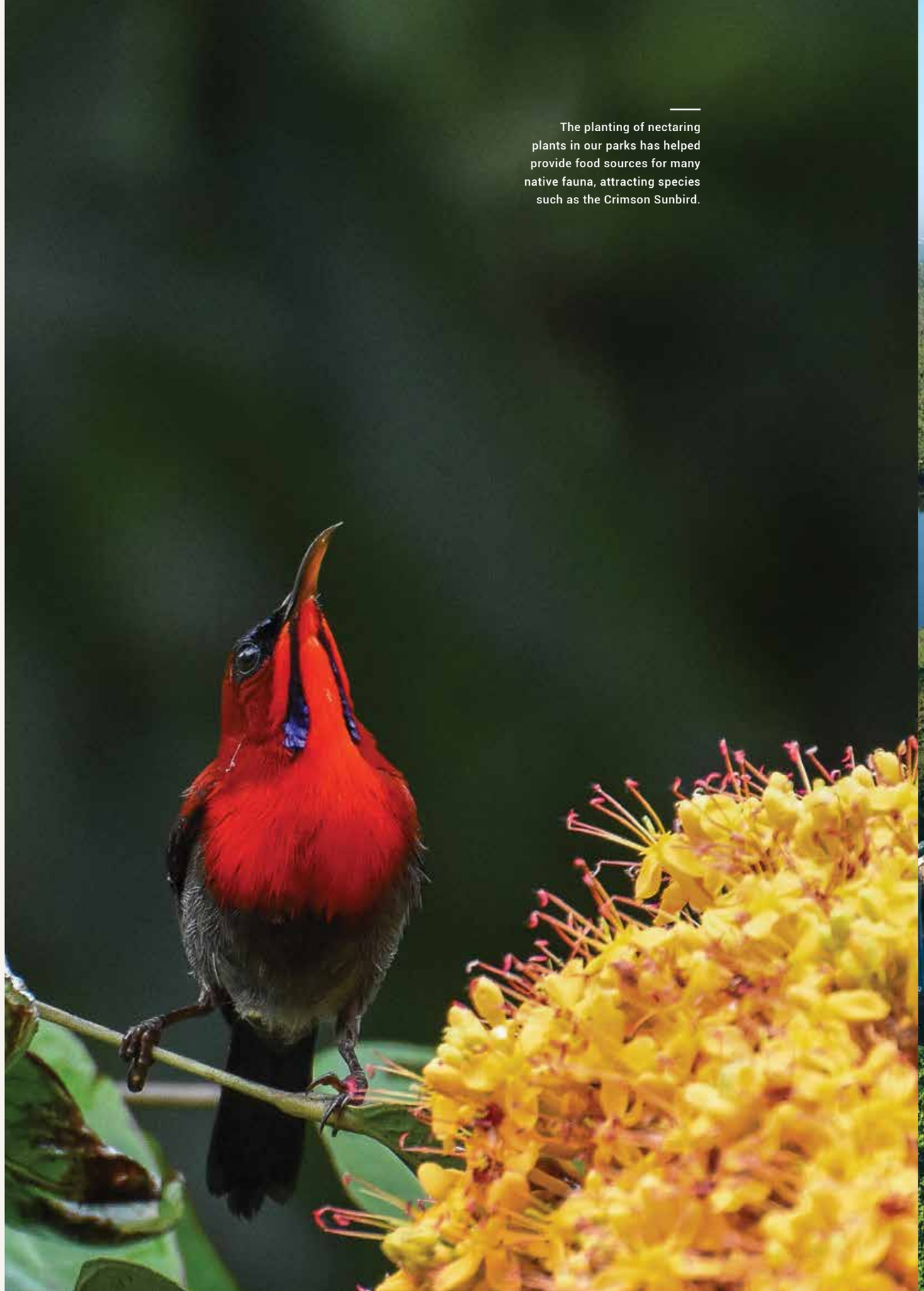
INSTITUTIONAL ARRANGEMENTS

Climate change is an issue with many dimensions that cut across the responsibilities of several ministries. The Inter-Ministerial Committee on Climate Change (IMCCC) was therefore set up in 2007 to oversee the whole-of-government coordination on Singapore's approach to climate change. The IMCCC is chaired by the Senior Minister and Coordinating Minister for National Security, and includes the Minister for Sustainability and the Environment, the Minister for Finance, the Minister for Foreign Affairs, the Minister for National Development, the Minister for Trade and Industry, and the Minister for Transport. The IMCCC is supported by an Executive Committee (Exco) comprising the Permanent Secretaries of the respective Ministries. The IMCCC Exco oversees the work of the International Negotiations Working Group (INWG), Long-Term Emissions and Mitigation Working Group (LWG), and the Resilience Working Group (RWG).

The INWG develops Singapore's international climate change negotiations strategy under the UNFCCC. The LWG examines options for emission reduction and identifies the capabilities, infrastructure and policies needed for long-term mitigation. A Measurement, Reporting and Verification (MRV) Task Force under the LWG is tasked with coordinating inter-agency MRV efforts. This includes the preparation of Singapore's National Communication (NC) and Biennial Update Report (BUR) by an inter-agency working group for approval by the IMCCC, and preparing Singapore to undergo the International Consultations and Analysis (ICA) process. The RWG studies Singapore's vulnerability to the effects of climate change and recommends long-term plans that ensure the nation's adaptation to future environmental changes. Singapore is reviewing our institutional arrangements and will provide an update in the next BUR.

To ensure the effective coordination of Singapore's domestic and international policies, plans and actions on climate change, the National Climate Change Secretariat (NCCS) was established as a dedicated unit in July 2010 under the Prime Minister's Office. 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.

The planting of nectaring plants in our parks has helped provide food sources for many native fauna, attracting species such as the Crimson Sunbird.



CHAPTER 2

ENHANCING CAPACITIES

Even as we build up our Measurement, Reporting and Verification capacities domestically, we continue to share our experiences and best practices with fellow developing countries.

Singapore recognises the importance of enhancing our capacity for Measurement, Reporting and Verification (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. Whilst 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

To enhance the transparency of Singapore's GHG inventory, Singapore has transitioned from using the Revised 1996 IPCC Guidelines for National GHG Inventories for some sectors to using the 2006 IPCC Guidelines for National GHG Inventories for all sectors. In addition, the Global Warming Potentials (GWPs) applied to all GHGs now take reference from the IPCC Fifth Assessment Report (AR5) instead of the IPCC Second Assessment Report (SAR), to take into account the latest science. Singapore has been building its capacity to facilitate the transition by participating in training programmes organised by the UNFCCC Secretariat, IPCC and other expert organisations.

Furthermore, efforts were undertaken to enhance the transparency of GHG inventory reporting in the following areas:

1 — Inclusion of NF_3 gas

In addition to the six GHGs that Singapore has been reporting, Singapore has taken the initiative to include a seventh GHG, NF_3, into the national GHG inventory.

2 — Recalculation of GHG time series

In line with IPCC Good Practice Guidance to continually review the GHG inventory, 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 surrogate method, were applied to ensure time series consistency. More details are provided in Chapter 3.

3 — New and updated reporting tables

As Singapore transitioned to the 2006 IPCC Guidelines, all reporting tables in the GHG inventory chapter were updated to reflect the updated guidance, IPCC sectors, categories and subcategories, where applicable.
For enhanced transparency, a new table is included to reflect the methods and emission factors used for emissions estimation, and GHG emissions estimates provided in the Annex worksheets are now provided in units of mass (e.g. gigagram).

Opposite page: The Supertrees at Gardens by the Bay harvest solar energy for their light-up at night.

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.

LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR

Singapore continues to monitor GHG emissions and removals from the Land Use, Land-Use Change and Forestry (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 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 embarked on our next cycle of field measurements for the national forest inventory, which will provide an update to the emission factors. The revised factors will be used in the preparation of subsequent BURs. We have also taken a closer look at processing our satellite images in order 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 develop our technical capabilities further.

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 2016. The estimate is 6.26MtCO_2 eq.[6]

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 is 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 BURs/biennial transparency 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 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 BURs.

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 Singapore Cooperation Programme (SCP), which is our flagship technical assistance programme. Since its establishment in 1992, more than 131,000 officials from over 170 countries and territories have participated in our training programmes. Our SCP programmes are aimed at strengthening countries' ability to implement the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda and the Paris Agreement, in areas such as Climate Action, Sustainable Cities and Communities, and Affordable and Clean Energy.

Recognising the difficulties faced by many developing countries in countering the growing challenge of climate change, we established the Sustainable Development and Climate Change Programme in 2012 and the Climate Action Package in 2018. Courses under these programmes aim to support all developing countries, in particular the Small Island Developing States and Least Developed Countries, in building climate resilience while achieving their Paris Agreement pledges. They cover topics such as climate adaptation and mitigation strategies, disaster risk reduction, energy efficiency and emission reduction. 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 worked with the UNFCCC Secretariat and the NDC Partnership on a workshop on enhancing NDCs for Southeast Asian countries.

[6]The estimate includes a minute quantity (0.0008MtCO_2 eq) of PFC-116 emissions.

Caribbean participants of the 2019 Singapore-UNDRR Joint Training Programme workshop on disaster resilience at the Earth Observatory of Singapore (EOS)

CHAPTER 3

NATIONAL GREENHOUSE GAS INVENTORY

Carbon dioxide emissions make up about 95% of our total greenhouse gas emissions.

The most significant greenhouse gas (GHG) emitted in Singapore is carbon dioxide (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, the GHG emissions from the Agriculture, Forestry and Other Land Use (AFOLU) sector are negligible in comparison with other economic sectors and the size of carbon stocks.

A natural gas-fired combined cycle plant converted from a conventional oil-fired steam power plant

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 the 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 industrial processes and product use, CH_4 emissions from solid waste disposal and CO_2 emissions from the incineration of solid waste. Emissions from the Land Use, Land-Use Change and Forestry 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 accuracy of the inventory.

The tables on pages 27-31 provide the report for methods and emission factors used for the emissions estimation.

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 **NA** = Not Applicable, **NE** = Not Estimated 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
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:

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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

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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			NE	NE	NE	NE								
3A2 Manure Management			NE	NE	NE	NE								
3B — Land														
3B1 Forest land	T3	CS	NO	NO	T3	D								
3B2 Cropland	T1	D	NO	NO	T1	D								
3B3 Grassland	NO	NO	NO	NO	NO	NO								
3B4 Wetlands	T1	D	NO	NO	T1	D								
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	NE	NE												
3C3 Urea Fertilisation	NE	NE												
3C4 Direct N_2O Emissions from managed soils					T3	CS								
3C5 Indirect N_2O Emissions from managed soils					T3	CS								
3C6 Indirect N_2O Emissions from manure management					NE	NE								
3C7 Rice Cultivations			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, **NE** = Not Estimated 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												
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[7]	T1, T2a	D	T1	D	T1	D								
4D — Wastewater Treatment and Discharge			NE	NE	NA	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 **NA** = Not Applicable, **NE** = Not Estimated and **NO** = Not Occurring

[7]T1 method was used for the emissions estimation from the incineration of clinical waste and hazardous waste, while T2a method was used for the emissions estimation from incineration of solid waste. For the incineration of sludge, it is based on a CDM methodology.

Strict enforcement programmes and air quality monitoring have helped to ensure that air quality remains good.

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 global warming potential (GWP) values from the IPCC Fifth Assessment Report, 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

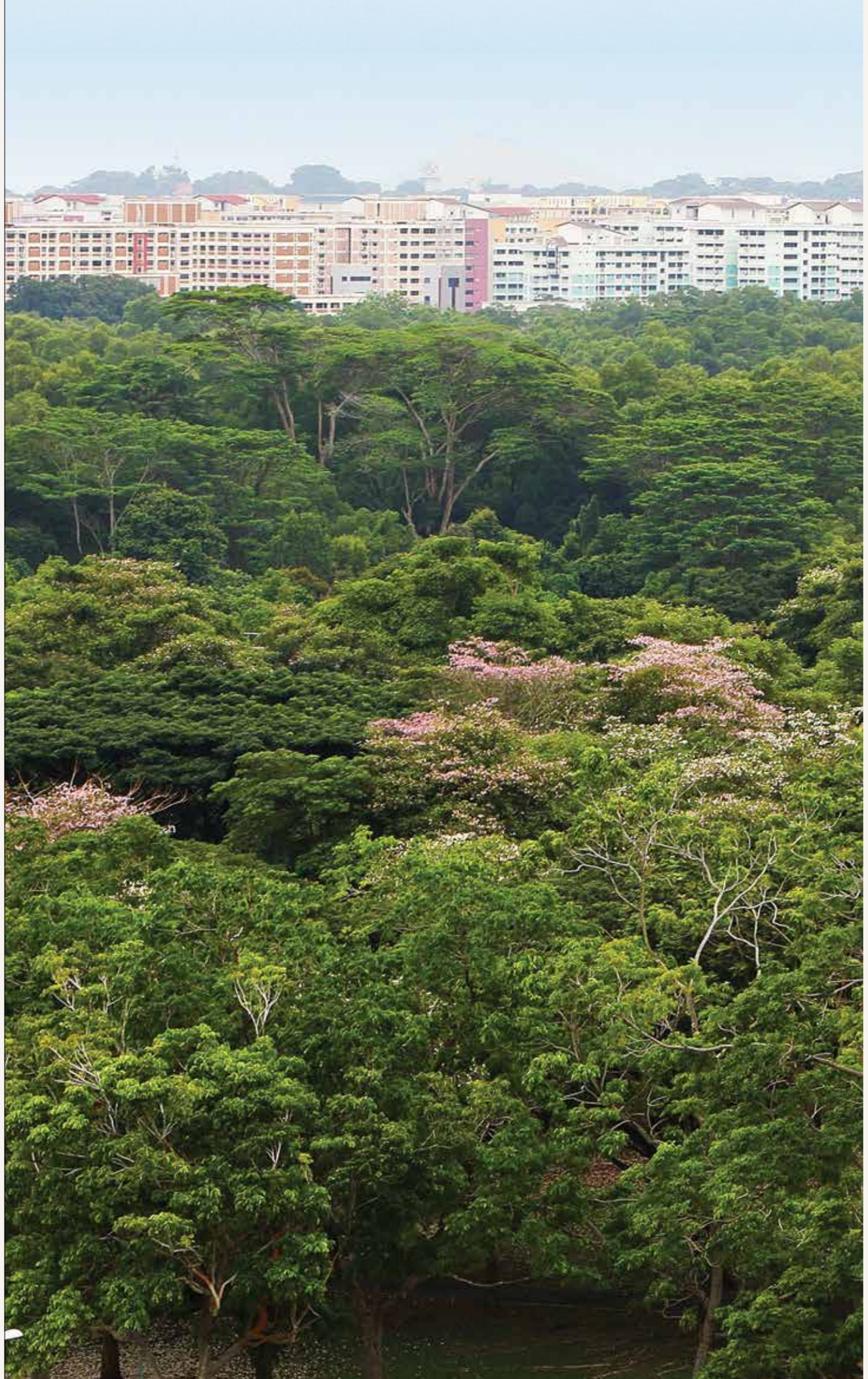
PRECURSORS

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.

SINGAPORE'S EMISSIONS FOR 2016

Singapore's GHG emissions for 2016 totalled 50,702.71 gigagram (Gg) CO_2 eq. This excludes the interim Tier 1b estimate of HFCs emissions from the RAC sector of 6,265.27Gg CO_2 eq in 2016. A breakdown of the total GHG emissions by sources in Gg CO_2 eq[8] is shown in the tables on pages 34-35.[9,10]

[8]Using Global Warming Potentials (GWPs) from the Second Assessment Report (SAR), Singapore's GHG emissions for 2016 totalled 50,570.86Gg CO_2 eq (including NF_3). The GWP for NF_3 was referenced from the Fourth Assessment Report due to unavailability in the SAR.
[9]As some figures are considerably small, they may be presented as "0.00" due to rounding.
[10]Figures may not add up to the totals due to rounding.



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	48,263.33	100.38	320.01	469.13	1,235.41	93.94	220.51	50,702.71
1 — ENERGY	47,746.49	77.55	222.78					48,046.82
1A — Fuel Combustion Activities	46,660.74	55.64	220.95					46,937.33
1A1 Energy Industries	20,044.55	9.22	63.94					20,117.71
1A2 Manufacturing Industries and Construction	18,613.56	11.68	15.78					18,641.02
1A3 Transport	7,345.58	33.17	140.93					7,519.68
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	NE	NE	NE					
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	11.95	NO	5.18					17.12
4 — WASTE	254.95	22.79	69.03					346.78
4A — Solid Waste Disposal		22.79						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	66.95					66.95
INFORMATION ITEMS[11]								
CO_2 from Biomass Combustion for Energy Production	1,707.00							1,707.00

Notation keys:

NE = Not Estimated and **NO** = Not Occurring

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

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

Greenhouse Gas	Emissions (Gg CO_2 eq)	Percentage of Total Emissions
CO_2	48,263.33	95.19%
PFCs	1,235.41	2.44%
HFCs	469.13	0.92%
N_2O	320.01	0.63%
NF_3	220.51	0.43%
CH_4	100.38	0.20%
SF_6	93.94	0.19%

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

WORKSHEETS

The 2016 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 and 2014) in Gg CO_2 eq can also be found in the Annex.[12]

EMISSIONS FROM INTERNATIONAL BUNKERS IN 2016

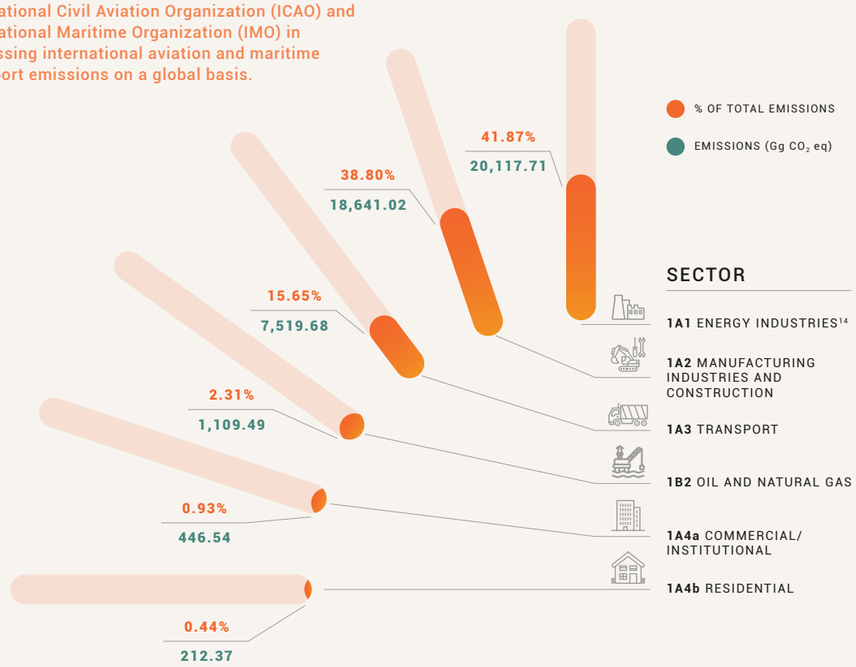
International bunkers	CO_2 emissions (Gg CO_2 eq)[13]
Aviation	15,524.46
Marine	156,418.03

***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 greenhouse gas inventory and national greenhouse gas totals. Singapore actively supports and contributes to the efforts led by the International Civil Aviation Organization (ICAO) and International Maritime Organization (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 2016 was 48,046.82Gg CO_2 eq. The contribution of emissions from fuel combustion activities and fugitive emissions is as shown.



[12]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.
[13]Emission factors from the IPCC Guidelines were applied for the purpose of submission of data on greenhouse gas from international bunkers to the UNFCCC only.
[14]Emissions from the incineration of solid waste and incineration of sludge are included under 1A1 Energy Industries.

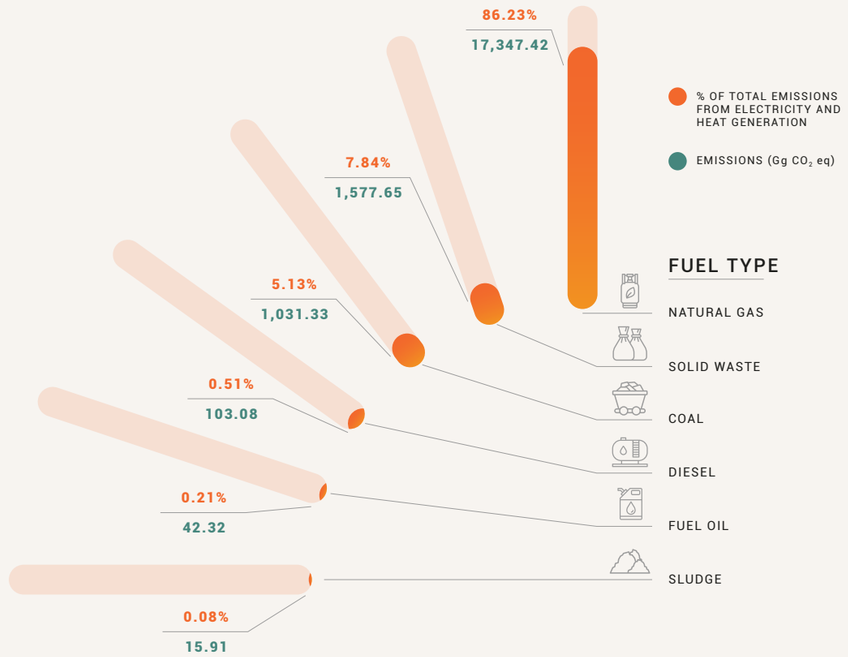
Tuas South Incineration Plant, one of the waste-to-energy (WTE) plants in Singapore

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 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.

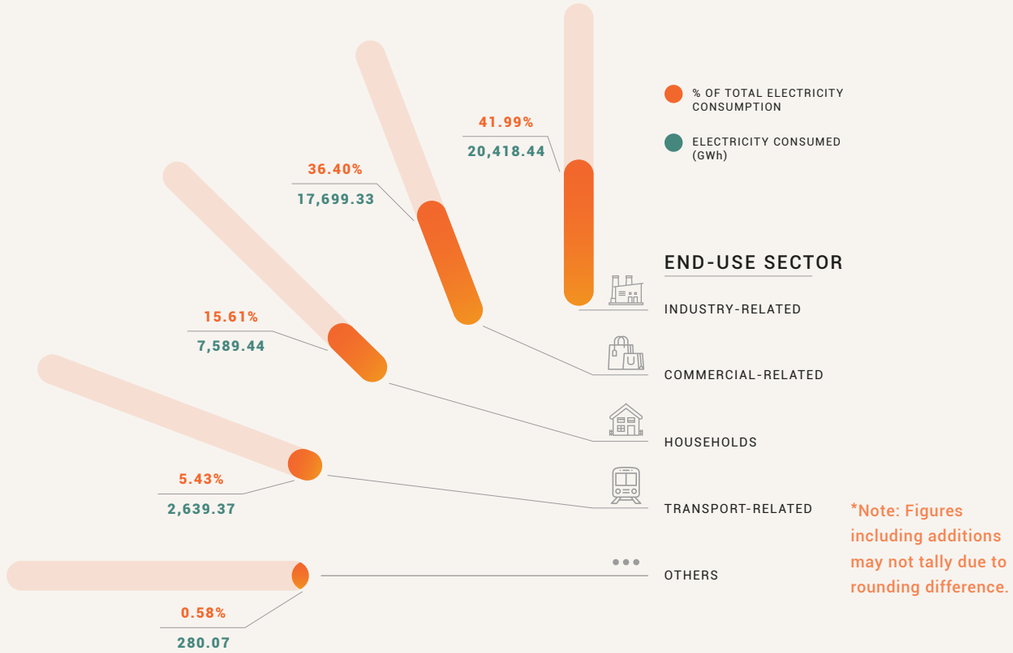
Heat from the incineration of sludge from wastewater processes is also recovered in Singapore, hence CH_4 and N_2O emissions from sludge incineration are reported in the energy sector.[15]

1A1 — Energy Industries

In 2016, emissions from electricity and heat generation totalled 20,117.71Gg CO_2 eq. The breakdown of emissions from different fuel types used for electricity and heat generation is as shown.



[15]More details on the incineration of solid waste and incineration of sludge are presented under 4 Waste section.



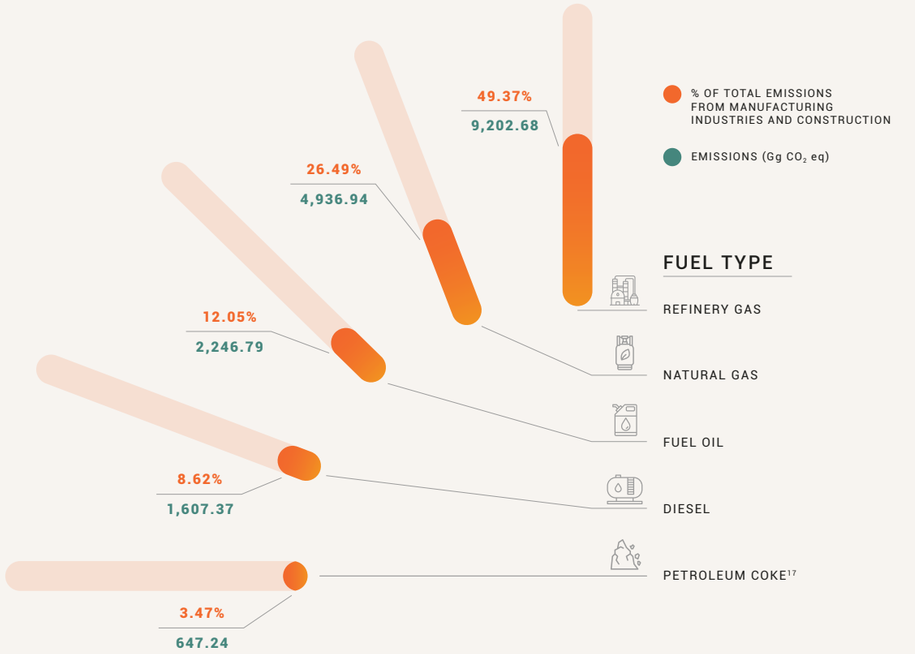
*Note: Figures including additions may not tally due to rounding difference.

Electricity consumed in the same year was 48,626.65 gigawatt-hours (GWh). Consumption of electricity by various sectors is as shown.[16]

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.



[16]Source: EMA, Singapore Energy Statistics 2020, Table 3.2
[17]Due to confidentiality reasons, emissions from the combustion of LPG and Gas Works Gas are included under Petroleum Coke.

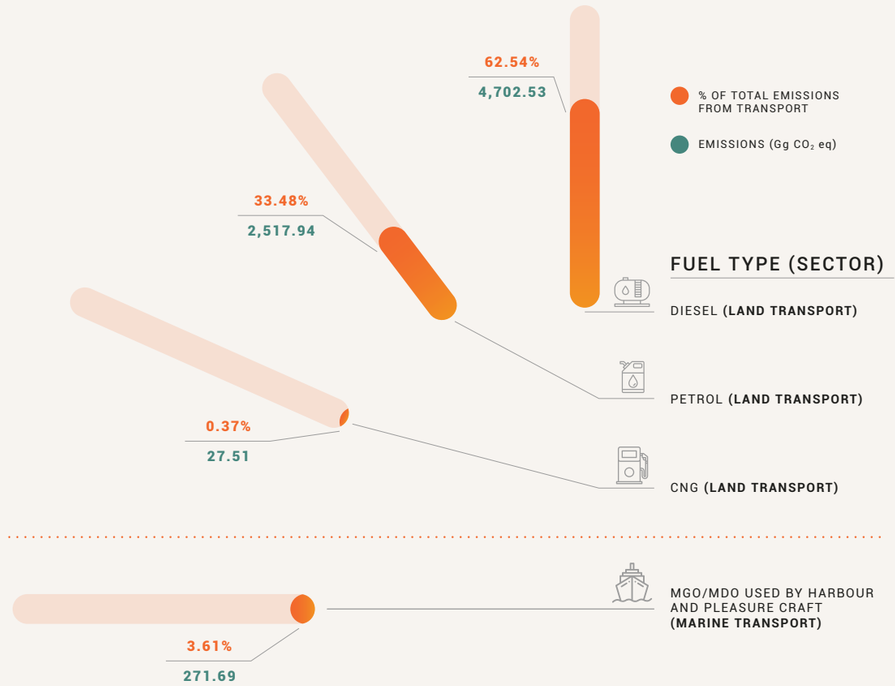
Vehicles passing by old and new buildings.

1A3 — Transport

In 2016, Singapore had a network of 3,512km of paved public roads and a population of 956,430 motor vehicles.[18] These motor vehicles consumed diesel, petrol 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.

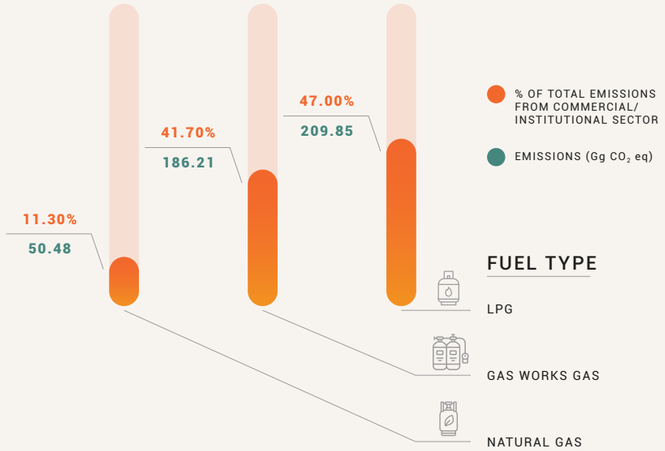
The breakdown of emissions by fuel type in the transport sector is as shown.

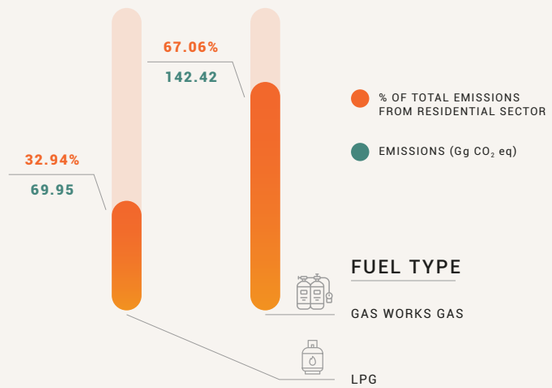


[18]Source: Motor Vehicle Population By Vehicle Type, Annual Vehicle Statistics 2019, Land Transport Authority: https://www.mytransport.sg/content/mytransport/home/dataMall.html

1A4a — Commercial/Institutional & 1A4b — Residential

Emissions from the commercial/institutional and residential sectors were from the use of LPG and Gas Works Gas,[19] mainly for cooking and hot water systems. The breakdown of emissions by fuel type in the commercial and residential sectors is as shown.





1B2 — Fugitive Emissions from Fuel – Oil and Natural Gas

The Energy Conservation Act (ECA), introduced in 2013[20], 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[21] and Industrial Processes and Product Use (IPPU) emissions[22] 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 2.19% of the national 2016 GHG inventory.

[19]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.
[20]From 1 January 2019, measurement and reporting requirements for GHG emissions are imposed under the Carbon Pricing Act.
[21]Prior to 2013, fugitive emissions from oil and natural gas were based on company-level surveys.
[22]More details on IPPU emissions are presented in the next section, 2 Industrial Processes and Product Use.

Solar panels on the rooftops of Housing & Development Board (HDB) blocks in Singapore

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 Industrial Processes and Product Use (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 27-31.

Categories	Total GHG Emissions (Gg CO_2 eq)	% of Total Emissions from IPPU
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	**2,291.98**	**100.00%**
2A Mineral Industry	NO	–
2B Chemical Industry	148.33	6.47%
2C Metal Industry	C	–
2D Non-Energy Products from Fuels and Solvent Use	0.45	0.02%
2E Electronics Industry	1,642.14	71.65%
2F Product Uses as Substitutes for Ozone Depleting Substances	396.97	17.32%
2G Other Product Manufacture and Use	3.04	0.13%
2H Other	101.06	4.41%

Forest Walk at Telok Blangah Hill Park

Founded in 2008, Barramundi Asia Pte Ltd is Singapore's first ocean farm, and draws on world-class sustainable fish farming practices and aquaculture technology to produce premium barramundi. It is certified with Singapore's Good Aquaculture Practices for Fish Farming (GAP-FF) and is the only farm in Singapore that has achieved the internationally recognised Best Aquaculture Practice's (BAP) rating, with the highest score of four stars.

The main source of emissions in the IPPU sector is from the "2E Electronics Industry" category, contributing 71.65% 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 17.32% of the IPPU emissions, mainly due to emissions from the usage of HFCs in the solvents application.

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.

Type of Gas	Emissions (Gg CO_2 eq)	% of Total Emissions from IPPU
PFCs	1,235.41	53.90%
HFCs	469.13	20.47%
CO_2	249.94	10.91%
NF_3	220.51	9.62%
SF_6	93.94	4.10%
N_2O	23.02	1.00%
CH_4	0.03	0.00%

3 — AGRICULTURE, FORESTRY AND OTHER LAND USE

Agriculture

The GHG emissions from agriculture are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors. The small agricultural sector focuses mainly on produce such as eggs, fish and vegetables for local consumption to supplement our imports of these items. Singapore is currently conducting a study on GHG emissions for the agriculture sector using both Tier 1 and Tier 2 methodologies. The data from this study can be used to update the GHG inventory for Singapore's agriculture sector in the next BUR.

Land Use, Land-Use Change and Forestry

Singapore continues the upkeep of a system to capture removals and emissions from the Land Use, Land-Use Change and Forestry (LULUCF) sector. This has been designed to ensure compliance following the approach under the 2006 IPCC Guidelines on LULUCF.

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. The land use and land-use change matrix was 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 on the basis of country-specific data, resulting in out-of-field measurement 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.

Subsequent to the 3rd BUR, we have made further enhancements to our remote sensing methods to increase the accuracy of our estimates. 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 subcategories more than once within a 20-year transition period. This may lead to potential overestimates of greenhouse gas emissions and removals from unrealistic fluctuations in carbon pools. By performing a series of checks, 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.

The total annual net emissions for the reporting year 2016 for the LULUCF sector of Singapore amounted to 17.12Gg CO_2 eq (including N_2O). A summary breakdown of the contributions from each land-use category is represented below.

Land-Use Category	ANNUAL CHANGE IN CARBON STOCKS, Gg CO_2					
	Living Biomass (A)	Dead Organic Matter (B)	Soil (C)	CO_2 removals/ emissions (D=A+B+C)	CH_4 (Gg CO_2 eq)	N_2O (Gg CO_2 eq)
3B1 Forest Land	-40.16	-3.66	-12.09	-55.91	NO	0.00
3B2 Cropland	2.01	0.29	-0.51	1.80	NO	0.00
3B3 Grassland	NO	NO	NO	NO	NO	NO
3B4 Wetlands	0.70	0.10	0.78	1.58	NO	NO
3B5 Settlements	29.53	7.86	25.73	63.12	NO	5.18
3B6 Other Land	NO	NO	NO	NO	NO	NO
3D Other[23]	0.51	0.00	0.85	1.36	NO	NO
TOTAL*	**-7.42**	**4.59**	**14.77**	**11.95**	**NO**	**5.18**

*Note: Figures including additions may not tally due to rounding difference.

Notation key:
NO = Not Occurring

[23] "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.

4 — WASTE

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

Solid Waste Management[24,25]
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 incineration plants. Only non-incinerable waste and ash from the incineration process are disposed of at the offshore Semakau Landfill. Hence, CH_4 emissions from the Semakau Landfill are insignificant.

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

Sludge Incineration[24]
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.[26] The CH_4 emissions from sewage sludge disposal in 2016 were 22.79Gg CO_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 clinical and hazardous waste incineration in Singapore are regulated by the National Environment Agency (NEA) under the Environmental Public Health Act (EPHA). 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 gas from clinical waste incineration is as shown.[27]

Type of Gas	Emissions (Gg CO_2 eq)	% of Total Emissions from Clinical Waste Incineration
CO_2	2.53	97.74%
N_2O	0.06	2.26%
CH_4	0.00	0.00%

The breakdown of emissions by type of gas from hazardous waste incineration is as shown.[26]

Type of Gas	Emissions (Gg CO_2 eq)	% of Total Emissions from Hazardous Waste Incineration
CO_2	252.42	99.20%
N_2O	2.03	0.80%
CH_4	0.00	0.00%

[24] Emissions from the incineration of solid waste and incineration of sludge are included under 1A1 Energy Industries.
[25] 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.
[26] In accordance with the 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas 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 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.
[27] As some figures are considerably small, they may be presented as "0.00" due to rounding.

Semakau Landfill, a unique landfill coexisting with a vibrant marine ecosystem, mangroves, grassland and shoreline habitats

Today, Pulau Semakau is not only a landfill, but also a rich coastal and marine biodiversity haven harbouring flourishing natural ecosystems like mangroves, seagrass meadows and coral reefs. This shows that landfill operations and preservation of the natural environment can be achieved at the same time.

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 together using the activated sludge process. A by-product of this treatment process is waste sludge which is fed into digesters for stabilisation. The biogas produced in the digesters is used as fuel to either generate electricity to power the treatment facilities or to dry dewatered sludge further. 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).[28] The N_2O emissions from wastewater treatment and discharge in 2016 were 66.95Gg CO_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.

The biogas produced in the digesters at Changi Water Reclamation Plant (above) is used as fuel to either generate electricity to power the operation of the treatment facilities or dry dewatered sludge further to become dried sludge.

[28]Singapore's 2016 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.

LEVEL ASSESSMENT

Of the 13 key categories identified, 10 key categories originate from fuel combustion activities which primarily produce CO_2 emissions. The main contributor to Singapore's year 2016 GHG inventory is CO_2 emissions from the combustion of natural gas (34.2%) for electricity and heat generation. The other three key categories identified are PFCs 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** (Gg CO_2 eq)	**Percentage Contribution**	**Cumulative Total of Column E**
1A1	Fuel Combustion Activities - Energy Industries	Natural Gas	CO_2	17,330.58	34.2%	34.2%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Refinery Gas	CO_2	9,193.98	18.1%	52.3%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Natural Gas	CO_2	4,932.17	9.7%	62.0%
1A3b	Fuel Combustion Activities - Transport - Road Transportation	Diesel	CO_2	4,631.09	9.1%	71.2%
1A3b	Fuel Combustion Activities - Transport - Road Transportation	Motor Gasoline	CO_2	2,419.49	4.8%	75.9%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Fuel Oil	CO_2	2,239.75	4.4%	80.4%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Diesel	CO_2	1,602.12	3.2%	83.5%
1A1	Fuel Combustion Activities - Energy Industries	Solid Waste[29]	CO_2	1,542.32	3.0%	86.6%
2E	Industrial Processes and Product Use - Electronics Industry	–	PFCs	1,235.41	2.4%	89.0%
1B2	Fugitive Emissions from Fuels	Oil and Natural Gas	CO_2	1,085.75	2.1%	91.1%
1A1	Fuel Combustion Activities - Energy Industries	Coal	CO_2	1,026.71	2.0%	93.2%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Petroleum Coke[30]	CO_2	645.54	1.3%	94.4%
2F	Industrial Processes and Product Use - Product Uses as Substitutes for Ozone Depleting Substances	–	HFCs	396.97	0.8%	95.2%

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

TREND ASSESSMENT

Ten key categories are identified in the trend assessment, with the highest trend seen in the decrease in fuel oil combustion for electricity and heat generation (41.0%), followed by the increase in natural gas combustion for electricity and heat generation (25.5%). This natural gas and fuel oil trend is also observed in the manufacturing industries and construction sector, where the natural gas combustion increased by 9.2% while the fuel oil combustion decreased by 7.2% respectively.

A	B		C	D	E	F	G	H
IPCC Category Code	**IPCC Category**	**Fuel Type**	**Green-house Gas**	**Year 2000 Emissions** ($Gg\ CO_2\ eq$)	**Year 2016 Emissions** ($Gg\ CO_2\ eq$)	**Trend Assess-ment**	**Percentage Contribution to Trend**	**Cumulative Total of Column G**
1A1	Fuel Combustion Activities - Energy Industries	Fuel Oil	CO_2	16,965.21	42.18	0.57	41.0%	41.0%
1A1	Fuel Combustion Activities - Energy Industries	Natural Gas	CO_2	2,766.79	17,330.58	0.35	25.5%	66.5%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Natural Gas	CO_2	NO	4,932.17	0.13	9.2%	75.7%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Fuel Oil	CO_2	4,650.91	2,239.75	0.10	7.1%	82.8%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Refinery Gas	CO_2	4,781.20	9,193.98	0.08	5.5%	88.3%
1A1	Fuel Combustion Activities - Energy Industries	Coal	CO_2	NO	1,026.71	0.03	1.9%	90.2%
1B2	Fugitive Emissions from Fuels	Oil and Natural Gas	CO_2	132.91	1,085.75	0.02	1.7%	91.9%
1A2	Fuel Combustion Activities - Manufacturing Industries and Construction	Diesel	CO_2	609.93	1,602.12	0.02	1.5%	93.4%
2E	Industrial Processes and Product Use - Electronics Industry	–	PFCs	519.23	1,235.41	0.01	1.0%	94.5%
1A1	Fuel Combustion Activities - Energy Industries	Solid Waste[31]	CO_2	848.81	1,542.32	0.01	0.8%	95.3%

Notation key:
NO = Not Occurring

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

Sembcorp Cogen @ Banyan, a gas-fired cogeneration facility located on Jurong Island's Banyan area, has a gross capacity of 400 megawatts of power and 200 tonnes per hour of process steam.

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 BURs when ready.

Singapore's national GHG inventory was qualitatively assessed based on three levels of confidence, namely 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 under the EMA and the National Environment Agency strengthened the confidence in the data and formed the basis for the high confidence in the greenhouse gas 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 emissions 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.

CONFIDENCE LEVELS OF DATA[32,33]

Greenhouse Gas Source and Sink Categories	Confidence Level	% of Total GHG Emissions
1 — ENERGY		94.8%
1A — Fuel Combustion Activities		
1A1 Energy Industries	H	39.7%
1A2 Manufacturing Industries and Construction	M	36.8%
1A3 Transport	M	14.8%
1A4a Commercial / Institutional	H	0.9%
1A4b Residential	H	0.4%
1B — Fugitive Emissions from Fuels		
1B2 Oil and Natural Gas	H	2.2%
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	H	4.5%
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	M	0.0%
4 — WASTE		0.7%
4A — Solid Waste Disposal	L	0.0%
4C — Incineration and Open Burning of Waste		
Clinical Waste Incineration	H	0.0%
Hazardous Waste Incineration	H	0.5%
4D — Wastewater Treatment and Discharge	L	0.1%

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

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 27-31. Emissions estimates for past inventories were recalculated with updated activity data and emission factors, where applicable. NF_3 has also been included into the national GHG inventory, totalling seven types of GHGs reported in this 4th BUR. 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, the transition to the 2006 IPCC Guidelines, inclusion of NF_3 gas and change in global warming potentials (GWPs) values from SAR to AR5 has resulted in a 1-2% decrease in GHG emissions across the time series for the later years. The increase in GHG emissions in the years 1994 and 2000 was largely due to revision in data or unavailability of data in the earlier years which has now been included through splicing techniques. The table on the next page provides the results and comparison of the recalculated national GHG inventory, for the years reported in previous NCs and BURs.

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

S/N	Net National Emissions	Guidelines Used / Reference for GWPs / Inclusion of NF_3	1994	2000	2010	2012	2014
			($Gg\ CO_2$ eq)				
1	**Net National Emissions reported in 4th NC / 3rd BUR**	**Revised 1996 IPCC Guidelines / SAR**	**26,800.37**	**38,329.57**	**47,062.48**	**48,567.65**	**50,908.13**
2	Net National Emissions *(before splicing techniques were applied)*	2006 IPCC Guidelines / AR5 / NF_3 included	27,482.27	38,338.65	46,065.96	47,801.44	49,943.35
% DIFFERENCE BETWEEN ROWS 1 AND 2:			**2.5%**	**0.0%**	**-2.1%**	**-1.6%**	**-1.9%**
3	**Net National Emissions reported in 4th BUR *(with splicing techniques applied)***	**2006 IPCC Guidelines / AR5 / NF_3 included**	**28,115.53**	**38,952.34**	**46,142.83**	**47,909.83**	**49,943.35**
% DIFFERENCE BETWEEN ROWS 1 AND 3:			**4.9%**	**1.6%**	**-2.0%**	**-1.4%**	**-1.9%**

TIME SERIES OF GREENHOUSE GAS EMISSIONS (2000-2016)

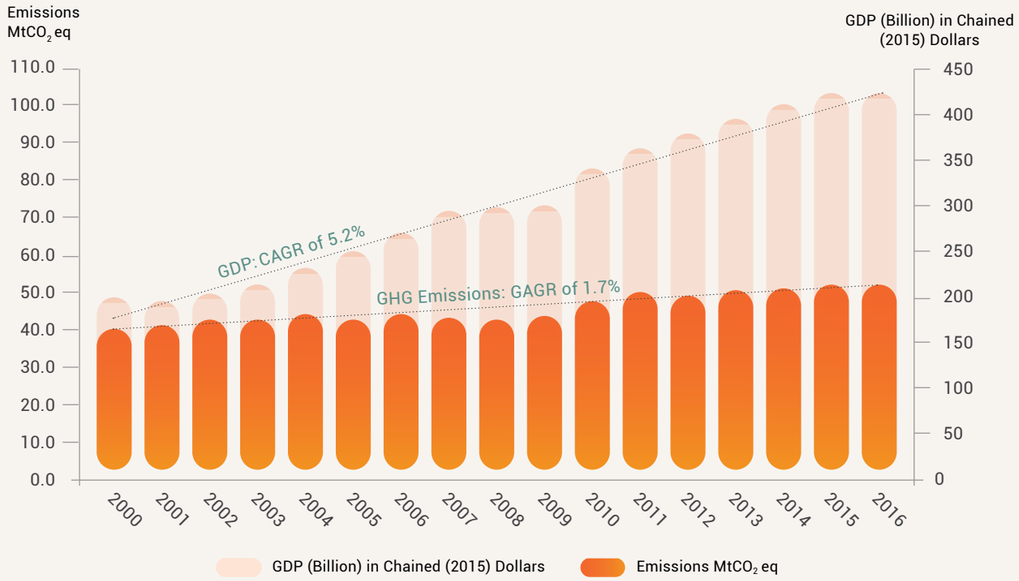
From 2000 to 2016, Singapore's economy grew at a compounded annual growth rate (CAGR) of 5.2%, while real GDP levels (in chained (2015) dollars) increased by 126% from S$193 billion in 2000 to S$437 billion in 2016. In the same period, Singapore's GHG emissions grew at a slower rate with a CAGR of 1.7%, and an increase of 30.2% (11,750Gg CO_2 equivalent) from 2000 to 2016.

As an open trade-oriented economy, Singapore's GDP growth volatility is much higher than that of larger economies.[34] 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.

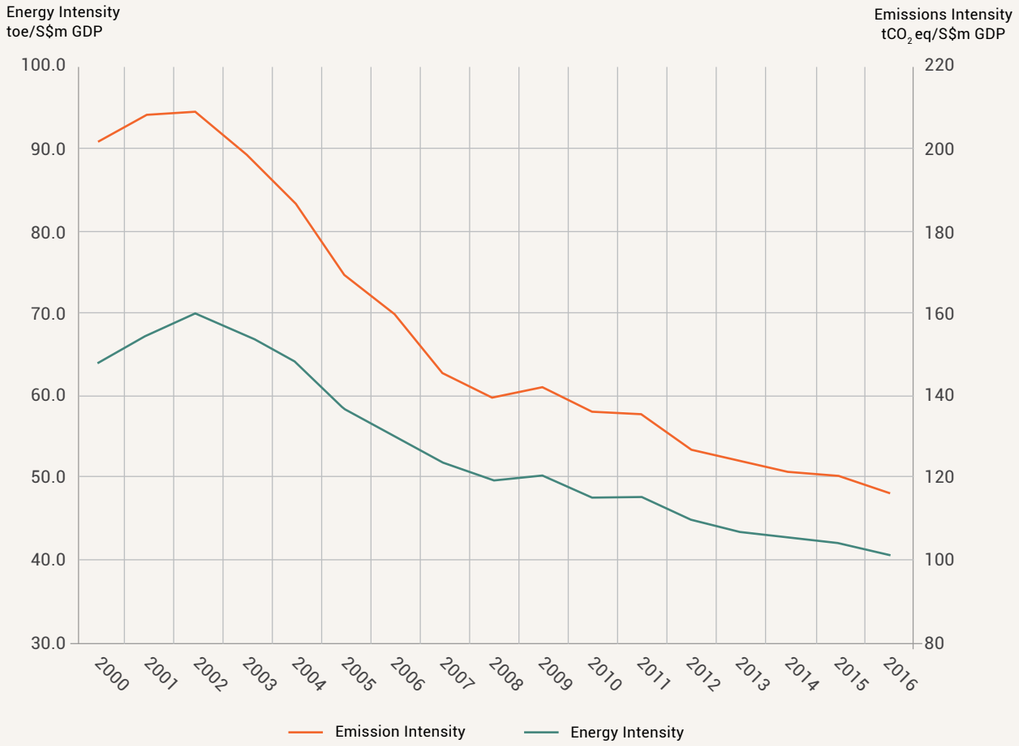
Overall, emissions intensity improved by 42% while energy intensity improved by 37% from 2000 to 2016. Some of the key policy initiatives implemented during this period include a switch in fuel mix from fuel oil to natural gas, which is a cleaner fuel source, as well as various schemes promoting energy efficiency. These 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.

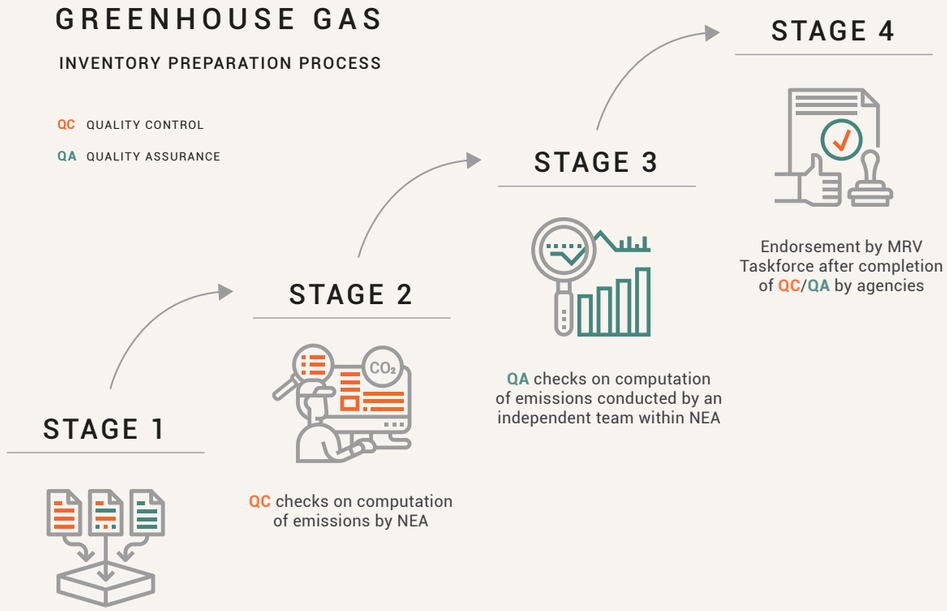
[34]*Is Smoother Always Better? Understanding Singapore's Volatility-Growth Relationship*, Shruthi Jayaram, Titus Lee and Thia Jang Ping, Economic Survey of Singapore 2009

Time Series of GHG Emissions



Time Series of Energy and Emissions Intensity





PREPARATION OF THE GREENHOUSE GAS INVENTORY

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

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 emission 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 greenhouse gas 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.

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

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

SOURCES OF DATA FOR GREENHOUSE GAS INVENTORY

IPCC Sector	Type of GHG	Data Owner
1 — ENERGY		
1A — Fuel Combustion Activities		
1A1 Energy Industries[35]	CO_2, CH_4, N_2O	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 — 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 Organisation of the United Nations (FAO)

[35] CO_2, CH_4 and N_2O emissions from the incineration of solid waste, and CH_4 and N_2O emissions from the incineration of sludge are included under 1A1 Energy Industries.

Opposite page: Sky Greens' vertical vegetable farming system is engineered to produce at least five times more leafy greens than conventional farms, with the ability to support farming on non-arable land. The system features tall aluminium frames that contain planting troughs, which are rotated by a water-pulley system. This technology was the result of a successful R&D collaboration with then-Agri-Food & Veterinary Authority (AVA) of Singapore, a partnership that led to the set-up of Singapore's first commercial vertical farm.

QC for Data

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

	QC Activity	Actions by Data Owner
Units	Check that parameters and units are correctly recorded and that appropriate conversion factors are used	Analysed and verified data trends for potential unit or conversion errors
Database	Check for transcription errors in data input and reference	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 categories	Verified the data mapping tables and files used to ensure that mapping and data consistencies between different categories are maintained. Data mapping tables adopt Singapore classification standards
	Check completeness	Streamlined and aligned data sources used Included new data streams where applicable
	Check time series consistency	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
	Review of internal documentation and archiving	Conducted regular data compilation reviews and documented these processes Archived and stored the data in the EDMA system periodically
Analysis	Trend checks	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 greenhouse gas emissions.

2 — Quality Control for the Computation of Emissions

Greenhouse gas emissions are computed by the greenhouse gas 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 greenhouse gas inventory team within NEA are summarised overleaf.

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.

	QC Activity on Estimation of Emissions	Actions
Units	Check that parameters and emission units are correctly recorded and that appropriate conversion factors are used	Checked the congruence of units and conversion factors throughout the worksheets
Database	Check for transcription errors in data input and reference	Verified data processed in the worksheets against original data files to check for transcription errors Analysed data trends Highlighted deviations and outliers, and verified them for potential data input errors and reference coding errors
	Check for consistency in data between categories	Verified that the emission factors and conversion factors used throughout the inventory are consistent with those in the IPCC Guidelines where applicable Verified that local factors are used consistently where applicable
	Check completeness	Streamlined and aligned data sources used
Calculations	Check that the movement of inventory data among processing steps is correct	Verified that the equations used for the computation are consistent with the IPCC Guidelines Analysed data trends Highlighted deviations and outliers, and verified them for potential data input errors and reference coding errors
	Review of internal documentation and archiving	Checked that the sources, methodologies, assumptions, emission factors and quality control procedures are documented Conducted regular reviews of data sources, methodologies, assumptions and emission factors and documented these processes
Analysis	Trend checks	Analysed time series of totals Highlighted and verified deviations for potential errors

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 the 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 greenhouse gas 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 for to improve future work on the national greenhouse gas inventory. Training is proposed as necessary for new and existing officers involved in the preparation of the national greenhouse gas 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 greenhouse gas inventory.

The Secondary Jetty at the SLNG Terminal has been modified to accommodate small LNG carriers, which help to facilitate the use of LNG for power generation in remote locations in the region, as well as marine fuel for ships.

CHAPTER 4

MITIGATION MEASURES

Singapore is committed to reducing emissions across all sectors to drive sustainable growth.

INTRODUCTION

Under our 2009 Copenhagen pledge, Singapore is committed to reducing emissions by 16% below 2020 business-as-usual (BAU) levels. Having ratified the Paris Agreement on 21 September 2016, Singapore has also formalised our 2030 pledge which builds on our 2020 commitment. As stated in our Nationally Determined Contribution (NDC), Singapore intends to peak emissions at 65MtCO_2eq around 2030. While these are challenging targets given our limited potential for alternative energy sources that could reduce emissions on a significant scale, Singapore is on track to meet our 2020 pledge.

SINGAPORE'S APPROACH TO REDUCING EMISSIONS

Energy is a strategic resource for Singapore as we are almost completely reliant on the import of oil and gas for our energy needs. Recognising that energy is a scarce resource, we price fuel and electricity according to supply and demand. We also do not subsidise energy costs. This policy of pricing energy correctly helps to incentivise firms and households to use energy wisely, minimising energy wastage and overconsumption, thus helping to control emissions.

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 reduce emissions, we will harness the "Four Switches" of Singapore's Energy Story to achieve our vision of a future with clean and efficient energy:

- 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 also one of our key mitigation strategies. This will require our 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

We have switched from fuel oil to natural gas, with the proportion of Singapore's electricity generated by natural gas rising from 26% in 2001 to around 95% in 2019. 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.

Traditionally, Singapore has relied heavily on natural gas piped from Malaysia and Indonesia for power generation. Since May 2013, Singapore has imported liquefied natural gas (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.

Following the success of the floating solar PV test bed at Tengeh Reservoir in 2016 (above), a large-scale solar PV system will be installed by 2021 that will generate sufficient green energy to meet the daily operational needs of the local water treatment plants.

We are also increasing our use of solar energy. Among the renewable energy options, solar energy remains the most promising option for Singapore. While the amount of solar panels installed in Singapore is still small, its deployment has been growing steadily. As of 2020, Singapore has around 400MWp of solar photovoltaics (PV) installed, compared to 15.3MWp in 2013. For solar energy to be adopted at scale, consumers ultimately have to find it cost-competitive vis-à-vis the electricity which they can buy from the grid. We are actively investing in R&D and test-bedding to improve the efficiency and lower the price of solar technologies and systems for adoption on a larger scale.

To facilitate this, the Economic Development Board (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. Four leasing tenders totalling 236MWp have been awarded since 2015, with a fifth tender to be awarded in 2020 for 60MWp of solar energy. The SolarNova programme forms part of Singapore's plan to reach at least 2GWp of installed solar PV capacity by 2030. Singapore has also announced plans to bring forward the deployment of solar energy to achieve 1.5GWp of solar deployment by 2025. In addition, we have adopted other innovative approaches to further push the envelope for solar deployment, such as the use of floating PVs, offshore PVs and building-integrated PVs.

PUB, Singapore's National Water Agency, is actively deploying solar panels on the roofs of water infrastructure and at reservoirs. These are part of PUB's plans to reduce our carbon footprint. In 2016, PUB and EDB launched a 1MWp floating solar PV test bed at Tengeh Reservoir. Propelled by this success, PUB deployed two floating solar PV systems of 1.5MWp each at Bedok and Lower Seletar Reservoirs, which will be commissioned in 2020. PUB will also deploy Singapore's first large-scale floating solar PV system of 60MWp at Tengeh Reservoir, which is one of the world's largest single floating solar PV systems. Upon completion in 2021, the system will generate sufficient green energy to meet the daily needs of Singapore's waterworks. With this system, we can eliminate 32ktCO_2 eq per year. Studies are also ongoing on the feasibility of deploying floating solar PV systems at Upper Peirce and Kranji Reservoirs.

In addition, the 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.[36] This helps to increase public and industry awareness of solar energy in Singapore's context and support deployment. EMA will continue to work with the industry to facilitate greater deployment of solar energy in the power system.

These measures to shift Singapore to cleaner energy sources are projected to achieve 4.18Mt of CO_2 eq abatement by 2020, with an estimated 4.08Mt of CO_2 eq abatement in 2018.

Measure #2 — Improving Industrial Energy Efficiency

As industry is the largest energy-consuming sector in Singapore, improving industrial energy efficiency is key to reducing our emissions. In 2016, our energy intensity was 40.4ktoe/S$ billion or 56.4ktoe/US$ billion.[37] This was achieved through the help of schemes introduced by the Government to overcome market barriers to the adoption of energy-efficient practices, such as limited capital, split incentives, bounded rationality and lack of information.

The Government is committed to encouraging the industry to adopt energy-efficient technologies through a mix of incentives, capability building and regulations.

Since 2005, the Government has been providing grants to help industrial facilities to 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 Resource Efficiency Grant for Energy (REG(E))[38] and the Energy Efficiency Fund (E2F)[39] which offset part of the initial capital investments in energy-efficient technologies. To further support industrial facilities in being more energy-efficient, funding support for the adoption of energy-efficient technologies under REG(E) and E2F was enhanced from the previous cap of up to 30% to up to 50% of qualifying costs from 1 January 2019. In October 2019, the Government launched a new grant under the E2F to encourage companies to implement energy management information systems (EMIS). EMIS can help companies more accurately monitor and analyse their energy usage using real-time data, to identify performance gaps and opportunities for improvement.

[36]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.
[37]Figures cited are calculated from domestic data sources. Conversion from S$ to US$ is based on exchange rates as of July 2020.
[38]Replacing the Grant for Energy Efficiency Technologies (GREET), the predecessor of the Productivity Grant for Energy Efficiency that was introduced in 2016.
[39]Consolidates the previous Energy Efficiency Improvement Assistance Scheme (EASe) and other incentive schemes administered by the NEA to better support a range of energy efficiency efforts, from energy-efficient design of new facilities, energy assessments of existing facilities, to energy-efficient technologies investment.

To develop and build up expertise in energy efficiency, Singapore has also conducted energy efficiency studies and put 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), uncover and implement energy efficiency opportunities, and train a pipeline of industrial energy efficiency engineers to support the future low-carbon economy. The centre is a collaboration between the Government and the Singapore Institute of Technology (SIT).

The Energy Conservation Act (ECA), introduced in 2013[40], mandates energy-intensive companies in the industry sector to appoint a qualified energy manager, monitor and report their energy use and GHG emissions, 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. These companies must also report measured energy performance of key energy-consuming systems in their facilities. From 2021, companies regulated under the ECA will be required to put in place a structured energy management system, and periodically assess energy efficiency opportunities at existing industrial facilities. In addition, minimum energy performance standards have been introduced to phase out inefficient industrial electric motors (2018) and water-cooled chilled water systems at industrial premises (2020). Since the enactment of the ECA in 2013, the industry sector's energy efficiency has improved steadily, with the annual increase in efficiency improving from 0.4% in 2014 to 0.95% in 2018.

Overall, we had expected to achieve 1.43Mt of CO_2 eq abatement from these energy efficiency measures by 2020. In 2018, we achieved an estimated 1.08Mt of CO_2 eq abatement, and will continue to undertake the ongoing measures.

Measure #3 — Greening Buildings

As a highly urbanised island state, the greening of buildings is an important part of Singapore's

NUS School of Design & Environment, winner of the Green Mark Award for Buildings – Zero Energy Building 2019

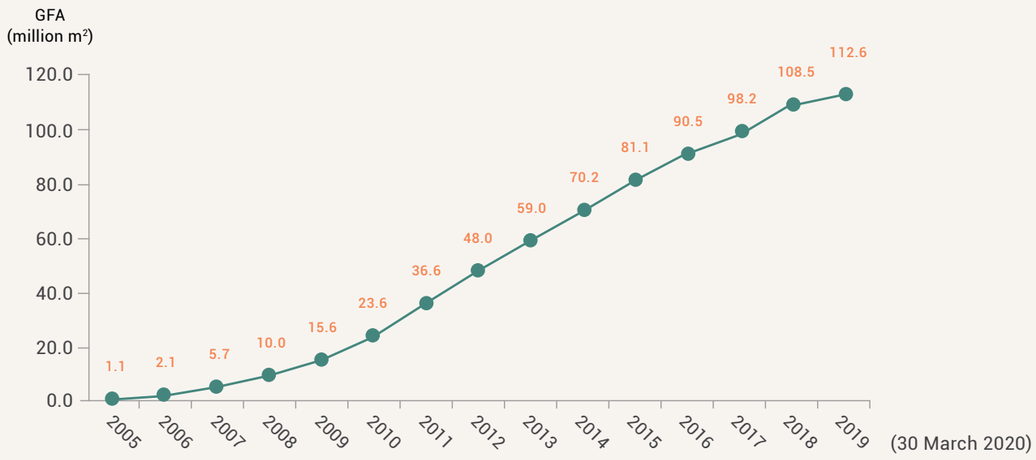
[40]From 1 January 2019, measurement and reporting requirements for GHG emissions are imposed under the Carbon Pricing Act.

mitigation strategy. To address barriers to adopting energy-efficient technologies in buildings[41], 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.

The Government has employed the use of both regulations and incentives 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. New building projects in key strategic areas such as Marina Bay, Downtown Core and Jurong Lake District are required to meet even higher standards. Existing prescribed buildings[42] are required to submit building information and energy consumption data annually. To encourage buildings to consciously adopt measures to improve their energy efficiency, the information from commercial buildings, healthcare facilities and educational institutions are publicly disclosed. In addition, existing office, hotel and retail buildings with gross floor area of more than 15,000 square metres 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. This legislation was further enhanced in 2017 to cover medium-sized buildings of more than 5,000 square metres.

Regulation is complemented with incentives and financing schemes to encourage developers to achieve higher tier Green Mark ratings, and to assist building owners in financing the high upfront retrofitting cost. As of 30 March 2020, we have greened more than 40% of our buildings by gross floor area and are on track to meeting our target of 80% by 2030.

Green Gross Floor Area (GFA) of buildings in Singapore (Cumulative)



[41]These barriers include limited capital and split incentives between building developers and owners.
[42]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.

The mitigation measures in the building sector are projected to achieve 0.87-1.55Mt of CO_2 eq abatement by 2020, with an estimated 0.929Mt of CO_2 eq abatement in 2018.

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 public transport modal share during the morning and evening peak hours to reach 70% by 2020 and 75% by 2030, up from 59% in 2008. We achieved 67% in 2017. 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 of peak period WCR journeys, such as between the home and workplace, will be completed in less than 45 minutes.

To encourage the use of public transport, the length of the rail network will expand from 230km in 2017 to 360km by 2030, with eight in 10 households to 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' 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 choices to make journeys 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 2040, our cycling path network will be extended to more than 1,000km from 440km in 2019. Beyond the 200km of sheltered walkways from transport nodes to homes and public amenities built as of now, a further 150km 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. 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. The FELS provides information on the fuel economy of vehicles for a more informed decision on vehicle purchase, while the CEVS provided rebates for low-emission cars and imposes surcharges on high-emission cars. The CEVS was replaced by the Vehicular Emissions Scheme (VES), with a new Vehicular Emissions label, in January 2018. In addition to CO_2, the 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 the VES, a similar scheme, the Commercial Vehicle Emissions Scheme, will be introduced 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; and from 2020, all new public bus purchases will be cleaner energy buses, including electric or hybrid buses. We are introducing policies and initiatives to encourage the adoption of electric vehicles (EVs). We will launch an

The Government is encouraging the use of cycling and walking for short distance trips. Today, 200km of sheltered walkways from transport nodes to homes and public amenities have been built; a further 150km of these sheltered walkways will be added by 2040.

A wide path for both those on bicycle and on foot to use

As part of the move towards a 100% cleaner energy public bus fleet by 2040, the Land Transport Authority (LTA) has progressively deployed electric buses for passenger service from early 2020 onwards.

Electric Vehicle Early Adoption Incentive (EEAI) for the next three years, from 1 January 2021 to 31 December 2023. The EEAI will lower the upfront cost of an EV through the provision of rebates, narrowing the upfront cost gap between electric and ICE vehicles. We will also expand our public charging infrastructure to support the growth of the EV population.

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.

Overall, the mitigation measures in the transport sector are projected to achieve 1.56Mt of CO_2 eq abatement by 2020, with an estimated 1.24Mt of CO_2 eq abatement in 2018.

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

The household sector accounts for about 14.3% of the total electricity consumption in Singapore. If households reduce their electricity consumption by using energy-efficient appliances, they will help to reduce Singapore's greenhouse gas 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.

Regulations on Minimum Energy Performance Standards (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. Since 2019, 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 refrigerators as well as air conditioners has improved by 47% and 42% respectively. This translates to annual household energy savings of about S$270 million or US$196 million[43].

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 for the Challenge period stood a chance to win prizes from the campaign sponsors. The Challenge received 7,000 entries in 2017 and more than 15,000 in 2018. Participants in the two campaigns saved a total of 800,000kWh.

The mitigation measures in the household sector are projected to achieve about 0.71-1.07Mt of CO_2 eq abatement by 2020, with an estimated 0.73Mt of CO_2 eq abatement achieved in 2018.

Measure #6 — Reducing Emissions from Waste and Wastewater Treatment

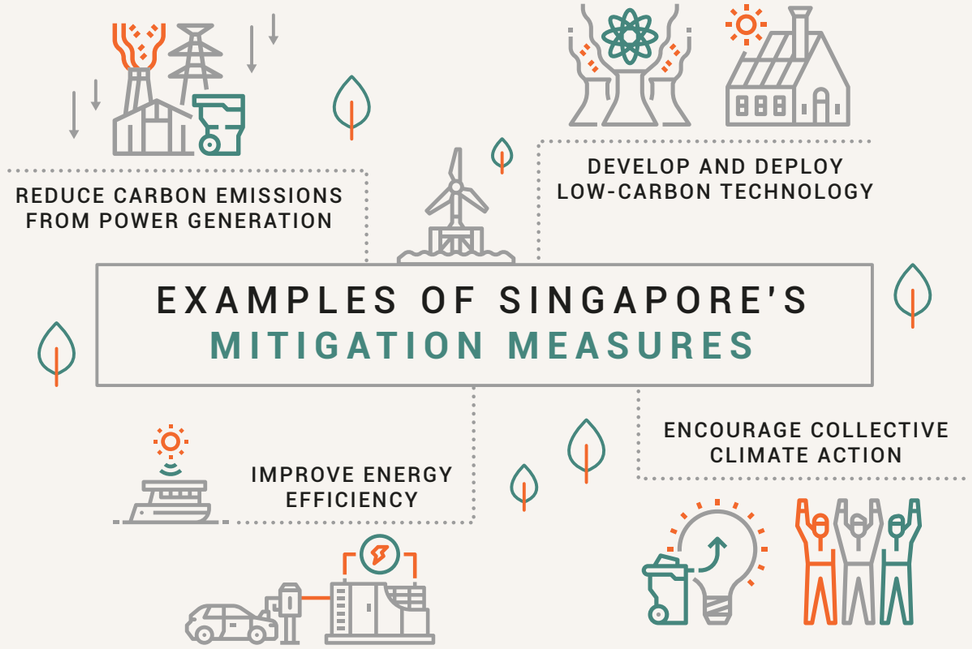
The Government is also looking to reduce emissions from the waste and water sectors. Apart from incinerating our waste and wastewater sludge, which reduces methane emissions from landfills, we also intend to increase our recycling rate to 70% by 2030. Our overall recycling rate was 61% in 2018.

Other measures to reduce emissions are through maximising energy efficiency in operations and increasing energy production and recovery. One key initiative in progress is the co-location of a used water treatment

The "Energy-Saving Challenge" campaign encourages the public to save electricity at home.

[43]Based on the total sales of air conditioners and refrigerators between 2009 and 2018

EXAMPLES OF SINGAPORE'S CLIMATE MITIGATION MEASURES



plant (Tuas Water Reclamation Plant (TWRP)) and an Integrated Waste Management Facility (IWMF) which is expected to be completed by 2025. The integration of these two facilities is collectively known as the Tuas Nexus and provides an opportunity to harness process synergies in treating used water and solid waste, reaping the benefits of a Water-Energy-Waste nexus. The Tuas Nexus will be the first WRP of its kind in Singapore to treat both used water and food waste in the same plant to produce biogas. The co-digestion of used water sludge with food waste can produce 40% more biogas, due to the synergistic effect of co-digestion. The biogas produced will be used to enhance the overall thermal efficiency and electricity production at the Tuas Nexus. In return, the electricity generated will be sufficient for both TWRP and IWMF, with excess electricity exported back to the grid.

We project the mitigation measures in the waste and water sectors to achieve 0.15Mt of CO_2 eq abatement by 2020, with an estimated 0.14Mt of CO_2 eq abatement in 2018.

CARBON TAX

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 25ktCO_2 eq or more greenhouse gas emissions in a year without exemption, and covers around 80% of our national emissions.

The carbon tax provides an economy-wide price signal to encourage GHG emission reduction where it makes the most economic sense. The carbon tax is part of, and complements, Singapore's suite of measures to reduce emissions.

The carbon tax rate is set at S$5 or US$3.64/tCO_2 eq in the first instance from 2019 to 2023. This serves as a transition period for facilities to implement energy efficiency and carbon emission reduction projects. The carbon tax rate will be reviewed by 2023, with the intention to increase it to a rate of between S$10 and S$15/tCO_2 eq (or US$7.27 and US$10.91/tCO_2 eq) by 2030. The Government is prepared to spend more than the expected carbon tax revenue in the initial five years to help companies improve their energy and carbon efficiency by adopting greener and cleaner technologies and practices.

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 2019, Singapore has six registered CDM projects.

Information on the six registered CDM projects was reported earlier in Singapore's 3rd NC and 1st BUR. Singapore will continue to monitor international developments and study how we can leverage robust international market mechanisms to complement our domestic mitigation efforts and position Singapore as a carbon services 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 whole-of-government effort.[44] 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), Intergovernmental Panel on Climate Change (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 Long-Term Emissions and Mitigation Working Group (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.

[44]The agencies involved include the Ministry of Sustainability and the Environment, the Ministry of Trade and Industry, the Ministry of Transport, the National Climate Change Secretariat, the Building and Construction Authority, the Economic Development Board, the Energy Market Authority, the Land Transport Authority, the Maritime and Port Authority of Singapore, the National Environment Agency, the National Parks Board and PUB, Singapore's National Water Agency.

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$MtCO_2$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 case to 95%. 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% in 2016.	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% in 2018. Estimated abatement achieved in 2018: 4.0Mt
Solar installation from existing schemes	To facilitate the adoption of solar photovoltaics (PVs).	Encouraging more R&D, test-bedding and deployment of solar PV.	**Ongoing** Singapore's target is to raise the adoption of solar power in our system to 350 megawatt-peak (MWp) by 2020. The whole-of-government 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 Solar Capability Scheme (SCS), Clean Energy Research & Testbedding (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 Combined Cycle Gas Turbines (CCGTs) that would have resulted from generating the amount of electricity displaced by solar energy.	CO_2	Installed Solar Capacity	Estimated abatement achieved in 2018: 0.078Mt

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.	**Ongoing** Three cogeneration plants have been constructed.	Incentive	0.67-0.73	0.67-0.73Mt 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 2018: 0.59Mt
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 Energy Efficiency Fund (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 2018: 0.42Mt

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 2018: 0.070Mt
Data Centre EE	To encourage energy efficiency and consequently reduce emissions from Data Centres.	Encouraging energy efficiency retrofits in Data Centres through incentives.	**Ongoing** One Data Centre has been supported under this scheme to improve energy efficiency.	Incentive	Up to 0.04	Abatement calculated based on Power Usage Effectiveness (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 of Data Centres.	Estimated abatement achieved in 2018: 0.00028Mt

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 Green Mark scheme	To improve energy efficiency of buildings.	<u>New Buildings</u> Legislating owners of new buildings to achieve minimum environmental sustainability standards, and encouraging them to achieve a Green Mark rating beyond the minimum standard through incentives. Developments in identified key strategic areas are required to achieve a higher Green Mark rating of $Gold^{Plus}$ or Platinum. <u>Existing Buildings</u> 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 Green Mark rating beyond the minimum standard through co-funding and financing schemes.	**Ongoing** <u>New Buildings</u> Since 2008, owners of new buildings have been required by legislation to achieve minimum environmental sustainability standards equivalent to the previous Green Mark Certified standard. The current Green Mark ratings for new buildings are: Gold/ $Gold^{Plus}$/ Platinum, differentiated by a set of criteria relating to green initiatives and energy savings of the building. In addition, stricter Green Mark standards have been imposed in government land sales conditions for certain areas, e.g. Marina Bay, Jurong Lake District. Incentive schemes have been introduced to encourage greater adoption of energy-efficient technologies in new buildings. As of 30 March 2020, we have greened more than 40% of Singapore's buildings by gross floor area and are on track to meeting our target of 80% by 2030. <u>Existing Buildings</u> Since 2012, owners of existing buildings have been required by legislation to achieve minimum environmental sustainability standards when the buildings undergo major retrofits. 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 and Incentives	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 2018: 0.93Mt

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 network, 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, up from 59% in 2008. We achieved 67% in 2017. The length of the rail network will increase further from 230km in 2017 to 360km by 2030.	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 2018: 0.76Mt
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 off-peak car schemes will be tweaked, as necessary. By 2040, our cycling path network will be extended to more than 1,000km, from 440km in 2019. Beyond the 200km of sheltered walkways from transport nodes to homes and public amenities built as of now, a further 150km 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 does not include the roll-out of such an OPC scheme.	CO_2	OPC take-up rate.	Estimated abatement achieved in 2018: 0.11Mt
Car/ Taxi fuel efficiency – CEVS	To encourage the take-up of more energy-efficient vehicles.	Implementing the mandatory Fuel Economy Labelling Scheme (FELS) and the Carbon Emissions-Based Vehicle Scheme (CEVS)/ Vehicular Emissions Scheme (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 matter) 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 2018: 0.37Mt

Table 5 — Improving Energy Performance Standards of Household Appliances 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
Minimum Energy Performance Standards (MEPS) for household appliances – air cons, 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 clothes dryers were implemented in April 2014. 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. 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.	CO_2	Annual purchase pattern of appliance models by tick-rating.	Estimated abatement achieved in 2018: 0.73Mt **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 Mandatory Energy Labelling Scheme (MELS) for household appliances and outreach efforts.	**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.	Promotion	0-0.28				

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** Since 2009, ECO Special Waste Management and Sumitomo Mitsui Bank Corporation have been contracted to perform sludge incineration. 800 Super has also been contracted from 2018 (together with ECO-SWM) to perform sludge incineration.	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 2018: 0.14$MtCO_2$ eq
Increase overall recycling rate	To increase the overall recycling rate to 65% by 2020. The overall recycling rate in 2018 was 61%.	Mandatory waste reporting and submission of waste reduction plan for large commercial premises, starting with large hotels and shopping malls, has been implemented in 2014.	**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 the BAU projections.	CO_2, N_2O, CH_4	Recycling rate	Estimated abatement achieved in 2018: 0Mt
		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$3.64/tCO_2eq. The carbon tax rate will be reviewed by 2023, with the intention to raise the carbon tax rate to between S$10 and S$15/tCO_2eq (or US$7.27 and US$10.91/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, N_2O, CH_4, SF_6, HFCs, PFCs	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 TO FOURTH BIENNIAL UPDATE REPORT

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

Thomson Nature Park: a 50-hectare park which is home to a rich array of biodiversity and serves as one of the buffer parks to the Central Catchment Nature Reserve.

GREENHOUSE GAS SUMMARY TABLE FOR YEAR 2016

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	48,263.21	3.59	1.21	469.13	1,235.41	93.94	220.51
1 — ENERGY	**47,746.49**	**2.77**	**0.84**				
1A — Fuel Combustion Activities	46,660.74	1.99	0.83				
1A1 Energy Industries	20,044.55	0.33	0.24				
1A2 Manufacturing Industries and Construction	18,613.56	0.42	0.06				
1A3 Transport	7,345.58	1.18	0.53				
1A4 Other Sectors	657.05	0.06	0.00				
1A4a Commercial / Institutional	445.29	0.04	0.00				
1A4b Residential	211.77	0.02	0.00				
1A5 Non-Specified	NO	NO	NO				
1B — Fugitive Emissions from Fuels	1,085.75	0.78	0.01				
1B1 Solid Fuels	NO	NO	NO				
1B2 Oil and Natural Gas	1,085.75	0.78	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	**249.82**	**0.01**	**0.09**	**469.13**	**1,235.41**	**93.94**	**220.51**
2A — Mineral Industry	NO	NO	NO				
2B — Chemical Industry	148.33	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	0.45	NO	NO				
2E — Electronics Industry	C	0.01	0.09	72.16	1,235.41	90.90	220.51
2F — Product Uses as Substitutes for Ozone Depleting Substances	NO	NO	NO	396.97	NO		NO
2G — Other Product Manufacture and Use	NO	NO	NO	NO	NO	3.04	NO
2H — Other	101.04	0.00	0.00				
3 — AGRICULTURE, FORESTRY AND OTHER LAND USE	**11.95**	**NE**	**0.02**				
3A — Livestock		NE	NE				
3B — Land	10.58	NO	0.02				
3C — Aggregate Sources and Non-CO_2 Emissions Sources on Land	NE	NO	NE				
3D — Other	1.36	NO	NO				
4 — WASTE	**254.95**	**0.81**	**0.26**				
4A — Solid Waste Disposal		0.81					
4B — Biological Treatment of Solid Waste		NO	NO				
4C — Incineration and Open Burning of Waste	254.95	0.00	0.01				
4D — Wastewater Treatment and Discharge		NE	0.25				
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	1,707.00						

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 Other; and
   – CO_2 emissions is included under CH_4 in the Electronics Industry (2E).

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   – CO_2 emissions is included under CH_4 in the Electronics Industry (2E).

GREENHOUSE GAS BREAKDOWN OF HFCs, PFCs, SF_6 AND NF_3 FOR YEAR 2016

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	5,794.88	2,760.09	C	3,759.57	42,143.53	1,452.30	C	C	194,989.20
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 keys: 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 are included under HFC-32 of the Electronics Industry (2E); and
   – Emissions from HFC-152a and HFC-227ea are included under HFC-43-10mee of the Product Uses as Substitutes for Ozone Depleting Substances (2F) category.

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	5,794.88	2,760.09	C	3,759.57	42,143.53	1,452.30	C	C	194,989.20
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	5,794.88	453.10	C						
2E1 Integrated Circuit or Semiconductor	5,794.88	453.10	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		2,306.99		3,759.57	42,143.53	1,452.30	C	C	194,989.20
2F1 Refrigeration and Air Conditioning		2,306.99		3,759.57	42,143.53	1,452.30	C		
2F2 Foam Blowing Agents									
2F3 Fire Protection								C	
2F4 Aerosols									
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 keys: 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 are included under HFC-32 of the Electronics Industry (2E); and
   – Emissions from HFC-152a and HFC-227ea are included under HFC-43-10mee of the Product Uses as Substitutes for Ozone Depleting Substances (2F) category.

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	108,022.00	41,386.24	4,190.64	2,362.61	3,997.29	13,696.40
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 keys: 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 are included under HFC-32 of the Electronics Industry (2E); and
   – Emissions from HFC-152a and HFC-227ea are included under HFC-43-10mee of the Product Uses as Substitutes for Ozone Depleting Substances (2F) category.

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	108,022.00	41,386.24	4,190.64	2,362.61	3,997.29	13,696.40
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	108,022.00	41,386.24	4,190.64	2,362.61	3,867.90	13,696.40
2E1 Integrated Circuit or Semiconductor	108,022.00	41,386.24	4,190.64	2,362.61	3,867.90	13,696.40
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					129.39	
2G1 Electrical Equipment					129.39	
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 keys: 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 are included under HFC-32 of the Electronics Industry (2E); and
   – Emissions from HFC-152a and HFC-227ea are included under HFC-43-10mee of the Product Uses as Substitutes for Ozone Depleting Substances (2F) category.

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	32.26	43.00	1,387.20	74,066.67	102.75
Residual Fuel Oil	kt	13.50	40.40	545.25	77,366.67	42.18
LPG						
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Feedstocks						
Refinery Gas						
Paraffin Waxes						
Other Petroleum Products						
SOLID FUELS						
Anthracite						
Coking Coal						
Other Bituminous Coal	kt	420.67	25.80	10,853.20	94,600.00	1,026.71
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	0.00416	0.60	0.00083
Residual Fuel Oil	kt	3.00	0.00164	0.60	0.00033
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	0.01085	1.50	0.01628
Sub-Bituminous Coal					
Lignite					
Oil Shale and Tar Sands					

	Units	Energy consumption				CO_2	CH_4		N_2O	
		A	B	C	D	E	F	G	H	I
	Mass, Volume or Energy unit	Consumption	Conversion Factor	Consumption	CO_2 Emission Factor	CO_2 Emissions	CH_4 Emission Factor	CH_4 Emissions	N_2O Emission Factor	N_2O Emissions
			(TJ/unit)	(TJ)	(kg CO_2/TJ)	(Gg CO_2)	(kg CH_4/TJ)	(Gg CH_4)	(kg N_2O/TJ)	(Gg N_2O)
				C=A*B		E=C*D/10^6		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 Works Gas										
Coke Oven Gas										
Blast Furnace Gas										
Oxygen Steel Furnace Gas										
NATURAL GAS										
Natural Gas (Dry)	ktoe	7,378.50	41.87	308,923.08	56,100.00	17,330.58	1.00	0.30892	0.10	0.03089
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 18,502.23			**TOTAL**	0.04833

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A1 — Energy Industries
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
	1,854.00	C	C	C	1	3.67	1,542.320

	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
	2,835,413.26	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
	2,835,413.26	47	0.133	265	35.315

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 keys: C = confidential information.

SECTOR	Energy
CATEGORY	Fuel Combustion Activities
CATEGORY CODE	1A1 — Energy Industries
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	0.0033	28	0.092
N_2O	0.0597	265	15.817

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 September 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: A green roof on a HDB multi-storey car park along Holland Drive

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	503.04	43.00	21,630.75	74,066.67	1,602.12
Residual Fuel Oil	kt	716.58	40.40	28,949.87	77,366.67	2,239.75
LPG	kt	C	C	C	C	C
Ethane						
Naphtha						
Lubricants						
Petroleum Coke	kt	C	C	C	C	645.54
Refinery Feedstocks						
Refinery Gas	kt	3,226.47	49.50	159,710.14	57,566.67	9,193.98
Paraffin Waxes						
Other Petroleum Products						
SOLID FUELS						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Oil Shale and Tar Sands						

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 Works Gas where a country-specific CO_2 emission factor of 15.2tC/TJ is used.
3. In the Manufacturing Industries and Construction (1A2) sector,
   - Transformation losses from the production of Gas Works Gas is included under the fuel type "Natural Gas". Gas Works 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 Works Gas are included under the fuel type "Petroleum Coke".
4. Notation keys: C = confidential information.

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	0.06489	0.60	0.01298
Residual Fuel Oil	kt	3.00	0.08685	0.60	0.01737
LPG	kt	C	C	C	C
Ethane					
Naphtha					
Lubricants					
Petroleum Coke	kt	C	0.01818	C	0.00448
Refinery Feedstocks					
Refinery Gas	kt	1.00	0.15971	0.10	0.01597
Paraffin Waxes					
Other Petroleum Products					
SOLID FUELS					
Anthracite					
Coking Coal					
Other Bituminous Coal					
Sub-Bituminous Coal					
Lignite					
Oil Shale and Tar Sands					

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 Works Gas where a country-specific CO_2 emission factor of 15.2tC/TJ is used.
3. In the Manufacturing Industries and Construction (1A2) sector,
   - Transformation losses from the production of Gas Works Gas is included under the fuel type "Natural Gas". Gas Works 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 Works Gas are included under the fuel type "Petroleum Coke".
4. Notation keys: C = confidential information.

	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 Works Gas	GWh	C	C	C	C	C
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)	ktoe	2,099.87	41.87	87,917.47	56,100.00	4,932.17
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	18,613.56

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 Works Gas where a country-specific CO_2 emission factor of 15.2tC/TJ is used.
3. In the Manufacturing Industries and Construction (1A2) sector,
   - Transformation losses from the production of Gas Works Gas is included under the fuel type “Natural Gas”. Gas Works 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 Works Gas are included under the fuel type “Petroleum Coke”.
4. Notation keys: C = confidential information.

	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 Works Gas	GWh	C	C	C	C
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)	ktoe	1.00	0.08744	0.10	0.00874
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 Frraction)					
		TOTAL	0.41708	**TOTAL**	0.05955

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 Works Gas where a country-specific CO_2 emission factor of 15.2tC/TJ is used.
3. In the Manufacturing Industries and Construction (1A2) sector,
   - Transformation losses from the production of Gas Works Gas is included under the fuel type “Natural Gas”. Gas Works 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 Works Gas are included under the fuel type “Petroleum Coke”.
4. Notation keys: 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	788.11	44.30	34,913.23	69,300.00	2,419.49
Aviation Gasoline						
Jet Gasoline						
Jet Kerosene						
Other Kerosene						
Shale Oil						
Gas / Diesel Oil	kt	1,454.09	43.00	62,525.90	74,066.67	4,631.09
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	0.87283	8.00	0.27931
Aviation Gasoline					
Jet Gasoline					
Jet Kerosene					
Other Kerosene					
Shale Oil					
Gas / Diesel Oil	kt	3.90	0.24385	3.90	0.24385
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 Works Gas						
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)	ktoe	11.05	41.87	462.52	56,100.00	25.95
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	7,076.52

	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 Works Gas					
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)	ktoe	92.00	0.04255	3.00	0.00139
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	1.15923	**TOTAL**	0.52454

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	84.48	43.00	3,632.64	74,066.67	269.06
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	0.02543	2.00	0.00727
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 Works 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	269.06

	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 Works 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	0.02543	**TOTAL**	0.00727

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	70.16	47.30	3,318.73	63,066.67	209.30
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						

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

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	0.01659	0.10	0.00033
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					

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

	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 Works Gas	GWh	925.32	3.60	3,331.14	55,733.33	185.66
Coke Oven Gas						
Blast Furnace Gas						
Oxygen Steel Furnace Gas						
NATURAL GAS						
Natural Gas (Dry)	ktoe	21.43	41.87	897.15	56,100.00	50.33
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	445.29

1. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Works Gas where a country-specific CO_2 emission factor of 15.2tC/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 Works Gas	GWh	5.00	0.01666	0.10	0.00033
Coke Oven Gas					
Blast Furnace Gas					
Oxygen Steel Furnace Gas					
NATURAL GAS					
Natural Gas (Dry)	ktoe	5.00	0.00449	0.10	0.00009
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	0.03774	**TOTAL**	0.00075

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

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	23.39	47.30	1,106.24	63,066.67	69.77
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						

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

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	0.00553	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					

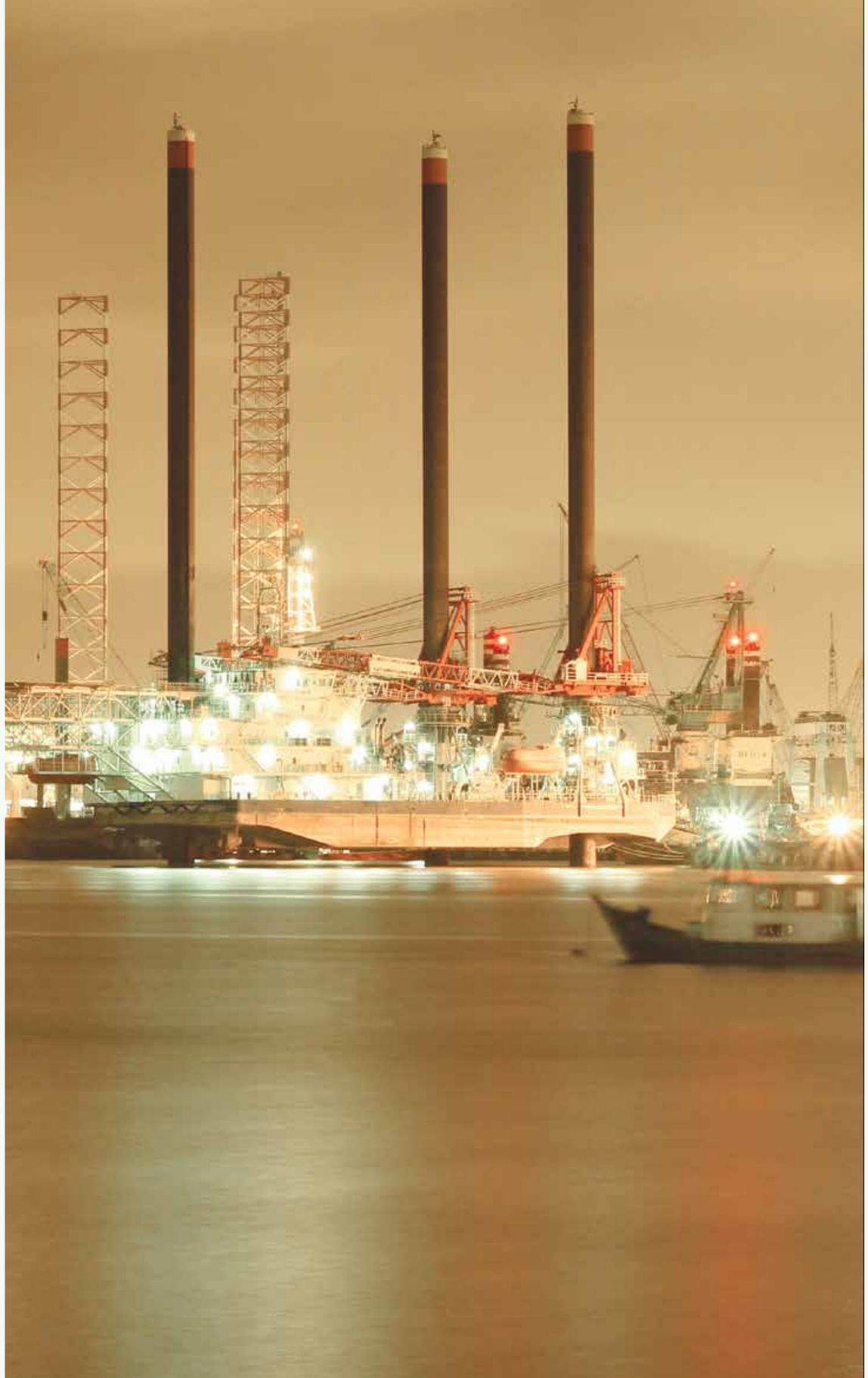
1. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Works Gas where a country-specific CO_2 emission factor of 15.2tC/TJ is used.

	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 Works Gas	GWh	707.73	3.60	2,547.81	55,733.33	142.00
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	211.77

1. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Works Gas where a country-specific CO_2 emission factor of 15.2tC/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 Works Gas	GWh	5.00	0.01274	0.10	0.00025
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	0.01827	**TOTAL**	0.00037

1. IPCC default conversion factors and emission factors are used for emissions computation, except Gas Works Gas where a country-specific CO_2 emission factor of 15.2tC/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	1,085.750	1	1,085.750
CH_4	0.783	28	21.912
N_2O	0.007	265	1.832

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	Global Warming Potential	Emissions in CO_2 equivalent
		kg		kg		Gg CO_2 eq
Carbon Dioxide	CO_2	C	C	C	1	C
Methane	CH_4	C	C	5,181.06	28	0.15
Nitrous Oxide	N_2O	C	C	86,855.77	265	23.02
HFC-23	CHF_3	C	C	5,794.88	12,400	71.86
HFC-32	CH_2F_2	C	C	453.10	677	0.31
HFC-41	CH_3F_2	C	C	C	116	C
PFC-14	CF_4	C	C	108,022.00	6,630	716.19
PFC-116	C_2F_6	C	C	41,386.24	11,100	459.39
PFC-218	C_3F_8	C	C	4,190.64	8,900	37.30
PFC-c318	c-C_4F_8	C	C	2,362.61	9,540	22.54
Sulphur hexafluoride	SF_6	C	C	3,867.90	23,500	90.90
Nitrogen trifluoride	NF_3	C	C	13,696.40	16,100	220.51

1. The total figure includes direct and by-product emissions for each GHG.
2. Notation keys: C = confidential information.
3. Due to confidentiality reasons,
   - CO_2 emissions are included under CH_4
   - Emissions from HFC-41 are included under HFC-32.

Opposite page: An oil refinery at night, as seen from West Coast Park

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	11.95	NE	0.02			
3A — Livestock		NE	NE			
3A1 Enteric Fermentation		NE				
3A1a Cattle		NE				
3A1ai Dairy Cows		NE				
3A1aii Other Cattle		NO				
3A1b Buffalo		NO				
3A1c Sheep		NO				
3A1d Goats		NE				
3A1e Camels		NO				
3A1f Horses		NO				
3A1g Mules and Asses		NO				
3A1h Swine		NO				
3A1j Other (please specify)		NO				
3A2 Manure Management		NE	NE			
3A2a Cattle		NE	NE			
3A2ai Dairy Cows		NE	NE			
3A2aii Other Cattle		NO	NO			
3A2b Buffalo		NO	NO			
3A2c Sheep		NO	NO			
3A2d Goats		NE	NE			
3A2e Camels		NO	NO			
3A2f Horses		NO	NO			
3A2g Mules and Asses		NO	NO			
3A2h Swine		NO	NO			
3A2i Poultry		NE	NE			
3A2j Other (please specify)		NO	NO			

*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.

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)					
3B — Land	10.58		0.02			
3B1 Forest Land	-55.91		0.00			
3B1a Forest Land Remaining Forest Land	-25.85		0.00			
3B1b Land Converted to Forest Land	-30.06		0.00			
3B1bi Cropland Converted to Forest Land	-0.03		0.00			
3B1bii Grassland Converted to Forest Land	NO		NO			
3B1biii Wetlands Converted to Forest Land	-2.04		NO			
3B1biv Settlements Converted to Forest Land	-19.54		0.00			
3B1bv Other Land Converted to Forest Land	NO		NO			
3B1bvi Other (Sea) converted to Forest Land	-8.45		0.00			
3B2 Cropland	1.80		0.00			
3B2a Cropland Remaining Cropland	2.03		0.00			
3B2b Land Converted to Cropland	-0.23		0.00			
3B2bi Forest Land Converted to Cropland	0.16		0.00			
3B2bii Grassland Converted to Cropland	NO		NO			
3B2biii Wetlands Converted to Cropland	0.00		NO			
3B2biv Settlements Converted to Cropland	-0.40		0.00			
3B2bv Other Land Converted to Cropland	NO		NO			
3B2bvi Other (Sea) converted to Cropland	0.00		0.00			
3B3 Grassland	NO		NO			
3B3a Grassland Remaining Grassland	NO		NO			
3B3b Land Converted to Grassland	NO		NO			
3B3bi Forest Land Converted to Grassland	NO		NO			
3B3bii Cropland Converted to Grassland	NO		NO			
3B3biii Wetlands Converted to Grassland	NO		NO			
3B3biv Settlements Converted to Grassland	NO		NO			
3B3bv Other Land Converted to Grassland	NO		NO			
3B3bvi Other (Sea) converted to Grassland	NO		NO			

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	1.58		NO			
3B4a Wetlands Remaining Wetlands	NO		NO			
3B4ai Peatlands Remaining Peatlands	NO		NO			
3B4aii Flooded Land Remaining Flooded Land	NO		NO			
3B4aiii Other Wetlands Remaining Other Wetlands	NO		NO			
3B4b Land Converted to Wetlands	1.58		NO			
3B4bi Land Converted for Peat Extraction	NO		NO			
3B4bii Land Converted to Flooded Land	1.58		NO			
3B4biii Land Converted to Other Wetlands	NO		NO			
3B5 Settlements	63.12		0.02			
3B5a Settlements Remaining Settlements	-1.45		0.01			
3B5b Land Converted to Settlements	64.57		0.01			
3B5bi Forest Land Converted to Settlements	89.92		0.01			
3B5bii Cropland Converted to Settlements	2.26		0.00			
3B5biii Grassland Converted to Settlements	NO		NO			
3B5biv Wetlands Converted to Settlements	-1.94		NO			
3B5bv Other Land Converted to Settlements	NO		0.00			
3B5bvi Other (Sea) converted to Settlements	-25.68		NO			

*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.

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			
3B6a Other Land Remaining Other Land	NO		NO			
3B6b Land Converted to Other Land	NO		NO			
3B6bi Forest Land Converted to Other Land	NO		NO			
3B6bii Cropland Converted to Other Land	NO		NO			
3B6biii Grassland Converted to Other Land	NO		NO			
3B6biv Wetlands Converted to Other Land	NO		NO			
3B6bv Settlements Converted to Other Land	NO		NO			
3B6bvi Other (Sea) converted to Other Land	NO		NO			
3C — Aggregate Sources and Non-CO_2 Emissions Sources on Land	NE	NO	NE			
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	NE					
3C3 Urea Fertilisation	NE					
3C4 Direct N_2O Emissions from Managed Soils			NE			
3C5 Indirect N_2O Emissions from Managed Soils			NE			
3C6 Indirect N_2O Emissions from Manure Management			NE			
3C7 Rice Cultivations		NO				
3C8 Other (please specify)	NO	NO	NO			
3D — Other	1.36	NO	NO			
3D1 Harvested Wood Products	NO					
3D2 Other (Sea)	1.36	NO	NO			

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	1 of 2 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	71,970.0	859.8	29.5	27.3	NO	2.2
3B1 Forest Land	16,354.2	823.9	13.0	2.1	NO	11.0
3B1a Forest Land Remaining Forest Land	13,026.9	778.4	8.5	2.1	NO	6.5
3B1b Land Converted to Forest Land	3,327.4	45.5	4.5	0.0	NO	4.5
3B1bi Cropland Converted to Forest Land	116.0	0.0	0.0	0.0	NO	0.0
3B1bii Grassland Converted to Forest Land	NO	NO	NO	NO	NO	NO
3B1biii Wetlands Converted to Forest Land	147.2	0.0	0.0	0.0	NO	0.0
3B1biv Settlements Converted to Forest Land	2,526.0	1.5	4.1	0.0	NO	4.1
3B1bv Other Land Converted to Forest Land	NO	NO	NO	NO	NO	NO
3B1bvi Other (Sea) converted to Forest Land	538.1	43.9	0.3	0.0	NO	0.3
3B2 Cropland	269.9	0.0	1.7	2.3	NO	-0.5
3B2a Cropland Remaining Cropland	147.0	0.0	0.9	1.4	NO	-0.5
3B2b Land Converted to Cropland	122.8	0.0	0.8	0.9	NO	0.0
3B2bi Forest Land Converted to Cropland	10.4	0.0	0.1	0.1	NO	0.0
3B2bii Grassland Converted to Cropland	NO	NO	NO	NO	NO	NO
3B2biii Wetlands Converted to Cropland	0.3	0.0	0.0	0.0	NO	0.0
3B2biv Settlements Converted to Cropland	112.1	0.0	0.8	0.8	NO	0.0
3B2bv Other Land Converted to Cropland	NO	NO	NO	NO	NO	NO
3B2bvi Other (Sea) converted to Cropland	0.0	0.0	0.0	0.0	NO	0.0
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

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	1 of 2 AFOLU Background Table: Carbon Stock Changes in FOLU

Categories	Net carbon stock change and CO_2 emissions/removals					
	Dead organic matter		Soils			Net CO_2 emissions
	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	
	(Gg C)					(Gg CO_2)
3B — Land	-1.3	NO	-1.3	-4.2	0.4	10.6
3B1 Forest Land	1.0	NO	1.0	2.7	0.6	-55.9
3B1a Forest Land Remaining Forest Land	0.5	NO	0.5	-0.5	0.5	-25.9
3B1b Land Converted to Forest Land	0.5	NO	0.5	3.1	0.1	-30.1
3B1bi Cropland Converted to Forest Land	0.0	NO	0.0	0.0	0.0	0.0
3B1bii Grassland Converted to Forest Land	NO	NO	NO	NO	NO	NO
3B1biii Wetlands Converted to Forest Land	0.0	NO	0.0	0.5	0.0	-2.0
3B1biv Settlements Converted to Forest Land	0.3	NO	0.3	1.0	0.0	-19.5
3B1bv Other Land Converted to Forest Land	NO	NO	NO	NO	NO	NO
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	1.8
3B2a Cropland Remaining Cropland	0.0	NO	0.0	0.0	0.0	2.0
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	0.2
3B2bii Grassland Converted to Cropland	NO	NO	NO	NO	NO	NO
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	-0.4
3B2bv Other Land Converted to Cropland	NO	NO	NO	NO	NO	NO
3B2bvi Other (Sea) converted to Cropland	0.0	NO	0.0	0.0	0.0	0.0
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

ANNEX

SECTOR	Agriculture, Forestry and Other Land Use
CATEGORY	Land
CATEGORY CODE	3B
SHEET	2 of 2 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	3,911.0	14.6	0.0	0.2	NO	-0.2
3B5 Settlements	51,434.9	21.4	14.7	22.8	NO	-8.1
3B5a Settlements Remaining Settlements	40,690.3	0.0	11.3	8.9	NO	2.4
3B5b Land Converted to Settlements	10,744.6	21.4	3.4	13.9	NO	-10.4
3B5bi Forest Land Converted to Settlements	3,684.1	21.4	1.1	13.7	NO	-12.6
3B5bii Cropland Converted to Settlements	330.6	0.0	0.1	0.2	NO	0.0
3B5biii Grassland Converted to Settlements	NO	NO	NO	NO	NO	NO
3B5biv Wetlands Converted to Settlements	311.1	0.0	0.1	0.0	NO	0.1
3B5bv Other Land Converted to Settlements	NO	NO	NO	NO	NO	NO
3B5bvi Other (Sea) converted to Settlements	6,418.8	0.0	2.0	0.0	NO	2.0
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

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

Categories	Net carbon stock change and CO_2 emissions/removals					Net CO_2 emissions
	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	
	(Gg C)					(Gg CO_2)
3B4 Wetlands	0.0	NO	0.0	-0.2	0.0	1.6
3B5 Settlements	-2.1	NO	-2.1	-6.8	-0.2	63.1
3B5a Settlements Remaining Settlements	0.2	NO	0.2	-2.2	0.0	-1.4
3B5b Land Converted to Settlements	-2.3	NO	-2.3	-4.6	-0.2	64.6
3B5bi Forest Land Converted to Settlements	-2.3	NO	-2.3	-9.4	-0.2	89.9
3B5bii Cropland Converted to Settlements	0.0	NO	0.0	-0.6	0.0	2.3
3B5biii Grassland Converted to Settlements	NO	NO	NO	NO	NO	NO
3B5biv Wetlands Converted to Settlements	0.0	NO	0.0	0.4	0.0	-1.9
3B5bv Other Land Converted to Settlements	NO	NO	NO	NO	NO	NO
3B5bvi Other (Sea) converted to Settlements	0.0	NO	0.0	4.9	0.0	-25.7
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

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	0.814	28	22.793

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
							F=AxBxCxDxE
CO_2	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
	4.43	0.65	0.6	0.4	1	3.67	2.53

	A	B	C	D	E
			C=AxBx10^{-6}		E=CxD
CH_4	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
	4.43	0.2	0.00000	28	0.00002

	A	B	C	D	E
			C=AxBx10^{-6}		E=CxD
N_2O	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
	4.43	50	0.00022	265	0.059

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
						F=AxBxCxDxE
CO_2	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
	152.98	0.5	0.9	1	3.67	252.417

	A	B	C	D	E
			C=AxBx10^{-6}		E=CxD
CH_4	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
	152.98	0.2	0.00003	28	0.00086

	A	B	C	D	E
			C=AxBx10^{-6}		E=CxD
N_2O	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
	152.98	50	0.00765	265	2.027

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 the Department of Statistics (DOS).

SECTOR	Waste
CATEGORY	Wastewater Treatment and Discharge
CATEGORY CODE	4D
SHEET	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
	71.41	26.065	5,607,283	0.16	1.1	1.25

	F	G	H	I	J
			H=[(AxBxCxDxE)–F]xGx (44/28)x10^{-6}		J=HxI
N_2O	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	0.253	265	66.949

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	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)							
Total (Net) National Emissions	47,549.73	105.79	318.77	364.65	1,260.91	178.91	164.58	49,943.35
1 — ENERGY	47,002.87	68.60	208.61					47,280.08
1A — Fuel Combustion Activities	46,051.38	53.82	207.33					46,312.54
1A1 Energy Industries	19,601.93	8.97	61.68					19,672.59
1A2 Manufacturing Industries and Construction	19,136.08	12.08	16.13					19,164.28
1A3 Transport	6,675.08	31.26	129.24					6,835.58
1A4a Commercial / Institutional	429.78	1.02	0.19					430.99
1A4b Residential	208.50	0.50	0.10					209.10
1B — Fugitive Emissions from Fuels	951.49	14.78	1.28					967.54
1B2 Oil and Natural Gas	951.49	14.78	1.28					967.54
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	290.85	0.01	38.42	364.65	1,260.91	178.91	164.58	2,298.34
3 — AGRICULTURE	NE	NE	NE					NE
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	59.49	NO	4.83					64.32
4 — WASTE	196.53	37.18	66.91					300.62
4A — Solid Waste Disposal		37.18						37.18
4C — Incineration and Open Burning of Waste	196.53	0.00	1.61					198.13
Clinical Waste Incineration	1.91	0.00	0.04					1.95
Hazardous Waste Incineration	194.62	0.00	1.56					196.18
4D — Wastewater Treatment and Discharge		NE	65.31					65.31
INFORMATION ITEMS								
CO_2 from Biomass Combustion for Energy Production	1,669.35							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.
4. The GHG emissions from the Agriculture, Forestry and Other Land Use sector are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.

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
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	46,056.49	126.39	303.59	45.85
1 — ENERGY	45,812.71	65.67	210.26	
1A — Fuel Combustion Activities	45,587.19	57.31	209.40	
1A1 Energy Industries	20,585.83	12.05	62.45	
1A2 Manufacturing Industries and Construction	17,672.64	11.80	16.65	
1A3 Transport	6,684.15	31.93	130.01	
1A4a Commercial / Institutional	434.54	1.02	0.19	
1A4b Residential	210.03	0.51	0.10	
1B — Fugitive Emissions from Fuels	225.52	8.36	0.87	
1B2 Oil and Natural Gas	225.52	8.36	0.87	
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	75.62	0.01	23.54	45.85
3 — AGRICULTURE	NE	NE	NE	
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	-16.59	NO	4.85	
4 — WASTE	184.75	60.71	64.93	
4A — Solid Waste Disposal		60.71		
4C — Incineration and Open Burning of Waste	184.75	0.00	1.51	
Clinical Waste Incineration	1.49	0.00	0.03	
Hazardous Waste Incineration	183.27	0.00	1.47	
4D — Wastewater Treatment and Discharge		NE	63.43	
INFORMATION ITEMS				
CO_2 from Biomass Combustion for Energy Production	1,645.87			

Greenhouse Gas Source and Sink Categories	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)			
Total (Net) National Emissions	1,188.01	92.54	96.97	47,909.83
1 — ENERGY				46,088.64
1A — Fuel Combustion Activities				45,853.90
1A1 Energy Industries				20,660.33
1A2 Manufacturing Industries and Construction				17,701.08
1A3 Transport				6,846.10
1A4a Commercial / Institutional				435.75
1A4b Residential				210.63
1B — Fugitive Emissions from Fuels				234.74
1B2 Oil and Natural Gas				234.74
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	1,188.01	92.54	96.97	1,522.54
3 — AGRICULTURE				NE
3 — LAND USE, LAND-USE CHANGE AND FORESTRY				-11.74
4 — WASTE				310.40
4A — Solid Waste Disposal				60.71
4C — Incineration and Open Burning of Waste				186.26
Clinical Waste Incineration				1.52
Hazardous Waste Incineration				184.74
4D — Wastewater Treatment and Discharge				63.43
INFORMATION ITEMS				
CO_2 from Biomass Combustion for Energy Production				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
4. The GHG emissions from the Agriculture, Forestry and Other Land Use sector are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.

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	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)							
Total (Net) National Emissions	44,387.75	158.60	291.37	42.32	1,103.99	84.81	73.99	46,142.83
1 — ENERGY	44,153.19	63.65	208.07					44,424.91
1A — Fuel Combustion Activities	43,997.34	57.88	207.21					44,262.43
1A1 Energy Industries	20,899.50	13.50	66.02					20,979.02
1A2 Manufacturing Industries and Construction	16,159.14	11.04	15.84					16,186.02
1A3 Transport	6,279.47	31.78	125.05					6,436.31
1A4a Commercial / Institutional	448.67	1.05	0.20					449.92
1A4b Residential	210.56	0.50	0.10					211.16
1B — Fugitive Emissions from Fuels	155.84	5.77	0.87					162.48
1B2 Oil and Natural Gas	155.84	5.77	0.87					162.48
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	52.26	0.01	17.96	42.32	1,103.99	84.81	73.99	1,375.34
3 — AGRICULTURE	NE	NE	NE					NE
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	-24.52	NO	4.89					-19.63
4 — WASTE	206.82	94.94	60.45					362.21
4A — Solid Waste Disposal		94.94						94.94
4C — Incineration and Open Burning of Waste	206.82	0.00	1.68					208.50
Clinical Waste Incineration	1.36	0.00	0.03					1.39
Hazardous Waste Incineration	205.46	0.00	1.65					207.11
4D — Wastewater Treatment and Discharge		NE	58.77					58.77
INFORMATION ITEMS								
CO_2 from Biomass Combustion for Energy Production	1,653.47							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.
4. The GHG emissions from the Agriculture, Forestry and Other Land Use sector are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.

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	PFCs	SF_6	NF_3	Total (Net) National Emissions
	CO_2 equivalents (Gg)							
Total (Net) National Emissions	37,840.74	223.28	262.27	9.50	519.23	29.75	67.57	38,952.34
1 — ENERGY	37,676.06	61.53	196.21					37,933.79
1A — Fuel Combustion Activities	37,543.15	56.61	195.34					37,795.09
1A1 Energy Industries	20,793.35	20.06	67.02					20,880.42
1A2 Manufacturing Industries and Construction	10,268.95	8.24	13.36					10,290.55
1A3 Transport	5,840.44	26.81	114.68					5,981.93
1A4a Commercial / Institutional	294.54	0.70	0.13					295.38
1A4b Residential	345.86	0.80	0.15					346.81
1B — Fugitive Emissions from Fuels	132.91	4.92	0.87					138.70
1B2 Oil and Natural Gas	132.91	4.92	0.87					138.70
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	44.57	0.01	16.40	9.50	519.23	29.75	67.57	687.02
3 — AGRICULTURE	NE	NE	NE					NE
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	16.28	NO	8.87					25.14
4 — WASTE	103.85	161.74	40.80					306.38
4A — Solid Waste Disposal		161.74						161.74
4C — Incineration and Open Burning of Waste	103.85	0.00	0.84					104.69
Clinical Waste Incineration	0.49	0.00	0.01					0.50
Hazardous Waste Incineration	103.36	0.00	0.83					104.19
4D — Wastewater Treatment and Discharge		NE	39.96					39.96
INFORMATION ITEMS								
CO_2 from Biomass Combustion for Energy Production	1,999.40							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.
4. The GHG emissions from the Agriculture, Forestry and Other Land Use sector are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.

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	27,656.40	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	18.42	0.01	0.13	5.45
3 — AGRICULTURE	NE	NE	NE	
3 — LAND USE, LAND-USE CHANGE AND FORESTRY	60.74	NO	10.92	
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			

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	28,115.53
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				57.84
2 — INDUSTRIAL PROCESSES AND PRODUCT USE	119.13	8.87	0.54	152.54
3 — AGRICULTURE				NE
3 — LAND USE, LAND-USE CHANGE AND FORESTRY				71.67
4 — WASTE				195.22
4A — Solid Waste Disposal				82.17
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. The GHG emissions from the Agriculture, Forestry and Other Land Use sector are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.

GLOSSARY

AFOLU	Agriculture, Forestry and Other Land Use
AR5	Fifth Assessment Report
BAU	Business-As-Usual
BCA	Building and Construction Authority
BESS	Building Energy Submission System
BREEF	Building Retrofit Energy Efficiency Financing
BUR	Biennial Update Report
CAGR	Compounded Annual Growth Rate
CAP	Climate Action Package
CCGT	Combined Cycle Gas Turbine
CCUS	Carbon Capture, Utilisation and Storage
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CERT	Clean Energy Research & Testbedding Programme
CEVS	Carbon Emissions-Based Vehicle Scheme
CFLni	Compact Fluorescent Lamps with Non-Integrated Ballasts
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2 eq	Carbon Dioxide Equivalent
CO	Carbon Monoxide
DC	Data Centre
dMRV	Domestic Measurement, Reporting and Verification
DOC	Degradable Organic Carbon
DOS	Department of Statistics
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
EMA	Energy Market Authority
EMIS	Energy Management Information Systems
EPHA	Environmental Public Health Act
EPMA	Environmental Protection and Management Act
Exco	Executive Committee
FAO	Food and Agriculture Organisation
FELS	Fuel Economy Labelling Scheme

GBMP	Green Building Masterplan
Gg	Gigagram
GHG	Greenhouse Gas
GREET	Grant for Energy Efficient Technologies
GWh	Gigawatt-Hour
GWp	Gigawatt-Peak
GWPs	Global Warming Potentials
HDB	Housing & Development Board
HFCs	Hydrofluorocarbons
ICA	International Consultations and Analysis
ICE	Internal Combustion Engine
ICT	Information and Communications Technology
IEA	International Energy Agency
IES	Institution of Engineers, Singapore
IMCCC	Inter-Ministerial Committee on Climate Change
INWG	International Negotiations Working Group
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IWMF	Integrated Waste Management Facility
KCA	Key Category Analysis
kg	Kilogram
kt	Kilotonne
LDCs	Least Developed Countries
LEDS	Long-Term Low-Emissions Development Strategy
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LTA	Land Transport Authority
LULUCF	Land Use, Land-Use Change and Forestry
LWG	Long-Term Emissions and Mitigation Working Group
MCF	Methane Correction Factor
MELS	Mandatory Energy Labelling Scheme
MEPS	Minimum Energy Performance Standards
MGO/MDO	Marine Gas Oil/Marine Diesel Oil
MRV	Measurement, Reporting and Verification
MSS	Meteorological Service Singapore
Mt	Million Tonnes
$MtCO_2$ eq	Million Tonnes of Carbon Dioxide Equivalent
MWp	Megawatt-Peak
N_2O	Nitrous Oxide
NC	National Communication
NCCS	National Climate Change Secretariat

NDC	Nationally Determined Contribution
NEA	National Environment Agency
NMVOCs	Non-Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides
OPC	Off-Peak Car
PFCs	Perfluorocarbons
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
REG(E)	Resource Efficiency Grant for Energy
RWG	Resilience Working Group
SAR	Second Assessment Report
SCP	Singapore Cooperation Programme
SCS	Solar Capability Scheme
SDCC	Sustainable Development and Climate Change
SDGs	Sustainable Development Goals
SEAS	Sustainable Energy Association of Singapore
SF_6	Sulphur Hexafluoride
SHD	Singapore Height Datum
SIDS	Small Island Developing States
SIT	Singapore Institute of Technology
SMEs	Small and Medium-sized Enterprises
SO_2	Sulphur Dioxide
SWDS	Solid Waste Disposal Site
tCO_2 eq	Tonne of Carbon Dioxide Equivalent
TWRP	Tuas Water Reclamation Plant
UFW	Unaccounted-for-Water
UNFCCC	United Nations Framework Convention on Climate Change
VES	Vehicular Emissions Scheme
WCR	Walk-Cycle-Ride
WEF	World Economic Forum

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