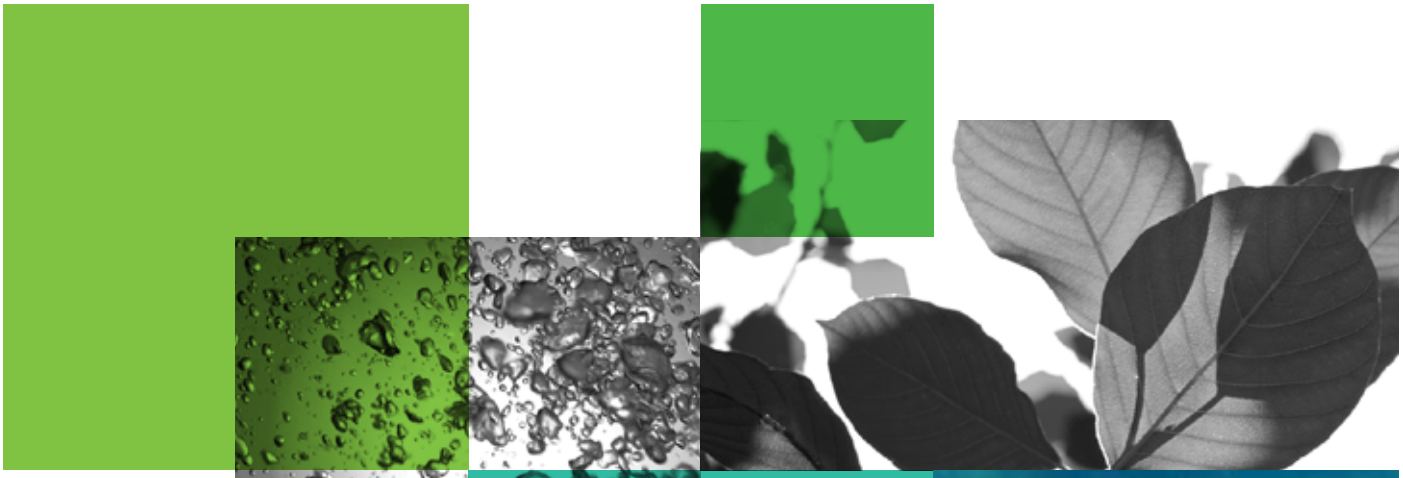
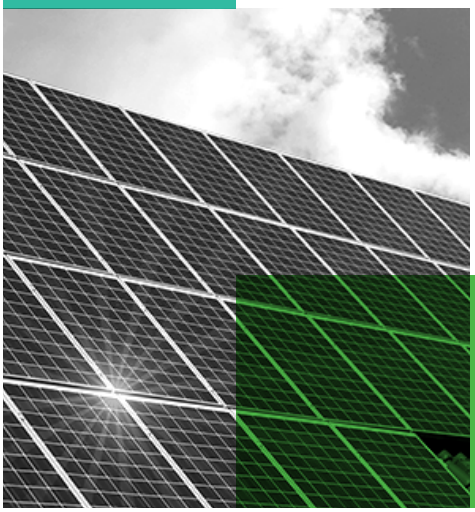


SINGAPORE'S SECOND BIENNIAL UPDATE REPORT 2016

UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE



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Contents

Foreword

On 12 December 2015, the international community took a significant step towards addressing the global challenge of climate change by endorsing the Paris Agreement at the 21st session of the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change. The milestone Paris Agreement will serve as a strong foundation for concerted international action to address this urgent issue. It is now important for all Parties to work in unison towards implementing the Paris Agreement.

As a responsible member of the international community, Singapore is fully committed to play our part. To underscore our commitment, we ratified the Paris Agreement on 21 September 2016 and were among the first 55 Parties to do so.

Singapore accounts for only 0.12% of global emissions. Although our contribution to global emissions is small, we will continue to press on with carbon mitigation measures. This will however be challenging as we are a small island state with limited potential for alternative energy sources. Nevertheless, we have taken early actions to improve energy efficiency in all sectors of the economy, and already have one of the lowest emissions intensities globally[1]. From 2000 to 2012, Singapore's economy grew at a compounded annual growth rate (CAGR) of 5.7%, while our emissions grew at a slower rate with a CAGR of 2.0%. We are working to reduce our emissions by 16% below 2020 business-as-usual (BAU) level in line with our pre-2020 pledge at Copenhagen in 2009. As stated in our Nationally Determined Contribution (NDC), we will work towards further reducing our Emissions Intensity by 36% from 2005 levels by 2030, and to stabilise our emissions with the aim of peaking around 2030.

We aim to achieve these challenging targets through a comprehensive range of mitigation measures. This Biennial Update Report highlights some of the measures we are undertaking to meet our pre-2020 pledge. Our Climate Action Plan, released in July 2016, outlines the measures we will undertake to enhance resilience to climate change and manage our emissions as we work towards achieving our 2030 pledge. Despite our limited potential for renewable energy sources,

[1] *Singapore's emissions intensity ranks favourably at 123rd out of 142 countries. This is amongst the lowest 15% in the world. IEA Key World Energy Statistics 2015 (2013 Data)*

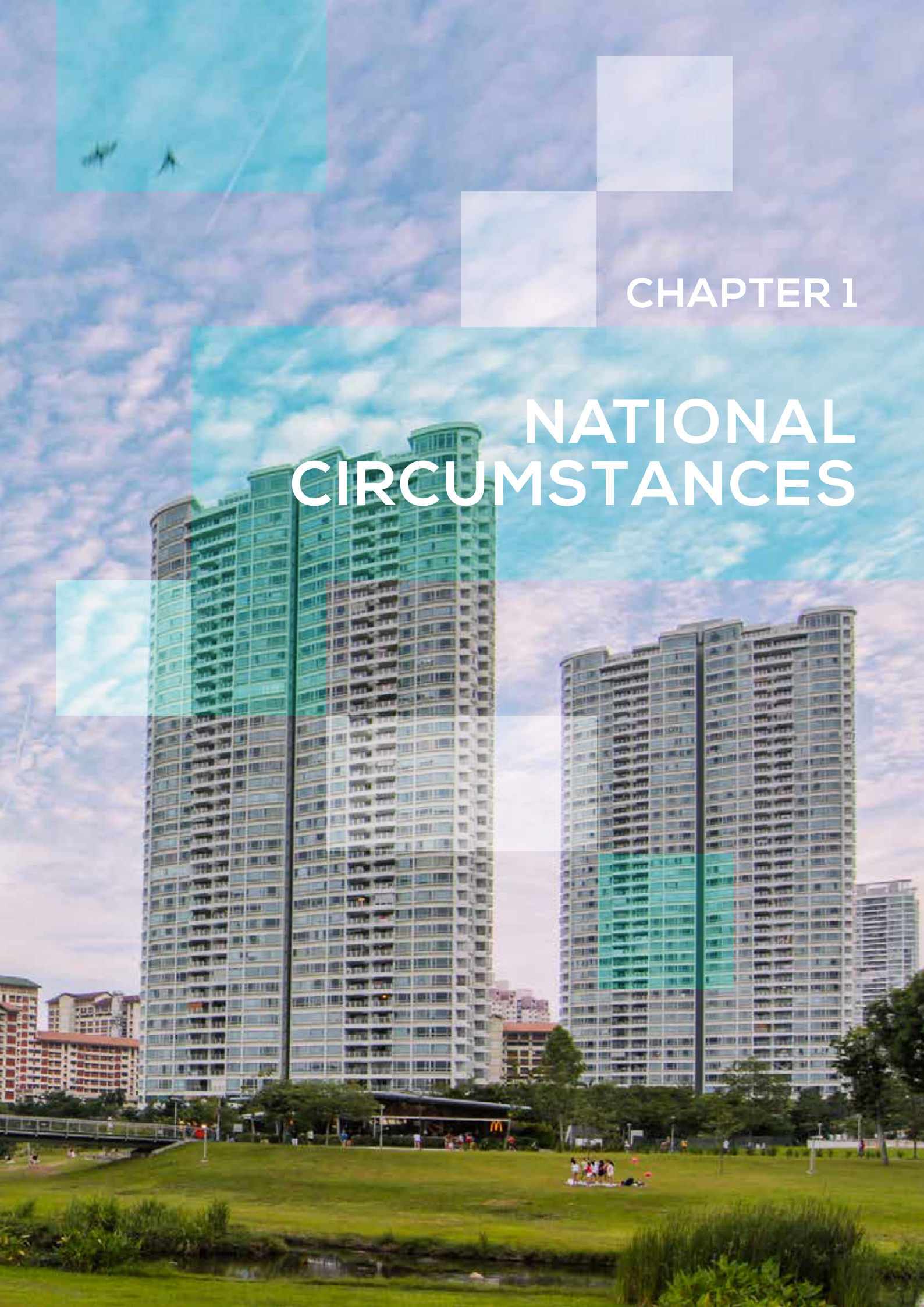
we plan to increase deployment of solar energy from around 100 MWp today to at least 350 MWp by 2020. We will continue to increase our public transport modal share from 66% in 2014 to 75% by 2030. We are also aiming for at least 80% of the buildings in Singapore to achieve Green Mark certification by 2030.

To encourage households to choose energy efficient appliances, we will also expand the Mandatory Energy Labelling Scheme (MELS) and Minimum Energy Performance Standards (MEPS) to more appliances and raise the minimum standards. For example, the MEPS was introduced for air-conditioners in 2011, and minimum performance standards were raised in 2013 and again in 2016. We are also partnering the private sector and academia to use Singapore as a living lab and test-bed to develop new urban solutions. One example is the Building and Construction Authority (BCA)'s Skylab, which is a test facility dedicated to developing innovative technology solutions to enhance energy efficiency for buildings, in partnership with the construction industry. We will also continue to develop technology roadmaps for key areas to guide Research, Development, and Demonstration (RD&D) efforts and realise the long term mitigation potential of key sectors.

Climate change will pose fresh challenges for all countries in the coming decades. Singapore recognises that we must strike difficult policy balances to reduce emissions and build resilience while enhancing our citizens' quality of life and livelihood. This requires judicious, long-term planning, and whole-of-government efforts. This is not new to Singapore. We have achieved growth in a sustainable manner since the early days of our independence. We will work together with businesses, community, and other stakeholders to implement these measures and build a sustainable and climate-resilient Singapore for current and future generations.

Mr Teo Chee Hean
Deputy Prime Minister
Chairman, Inter-Ministerial Committee on Climate Change
Republic of Singapore

Bishan-Ang Mo Kio Park, which is integrated with a naturalised, meandering river, is one of the largest urban parks in central Singapore, covering a full 62 hectares of greenery.



CHAPTER 1

NATIONAL CIRCUMSTANCES

National Circumstances

Singapore's public housing is home to over 80% of Singapore's resident population.

COUNTRY PROFILE

Singapore is a small island state in Southeast Asia and consists of one main island and more than 60 small 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 25km from north to south with a coastline of 195km. The total land area (including that of smaller islands) is about 719km^2. Among the islands, the larger ones are Pulau Tekong (25.5km^2), Pulau Ubin (10.2km^2) and Sentosa (5km^2).

Singapore's surface reaches 163m at our highest point. Much of the island lies within 15m of sea level. The country is generally flat with pockets of low-lying areas.

CLIMATE

Located close to the Equator, Singapore experiences a tropical climate with high and uniform temperatures, high humidity, and abundant annual rainfall of about 2,200mm. The annual average daily temperature is around 27.5°C, with average daily maximum temperature of 31.5°C and average daily minimum temperature of 24.7 °C. December and January are generally the coolest months of the year.

While there is no distinct wet or dry season in Singapore, monthly variations in rainfall do exist. The highest monthly rainfall generally occurs between November and January. The drier months are usually February and June. The relatively wetter Northeast Monsoon is from December to early March, while the drier Southwest Monsoon season is from June to September. Afternoon and early evening showers and thunderstorms are common during the inter-monsoon seasons from late March to May and October to November.

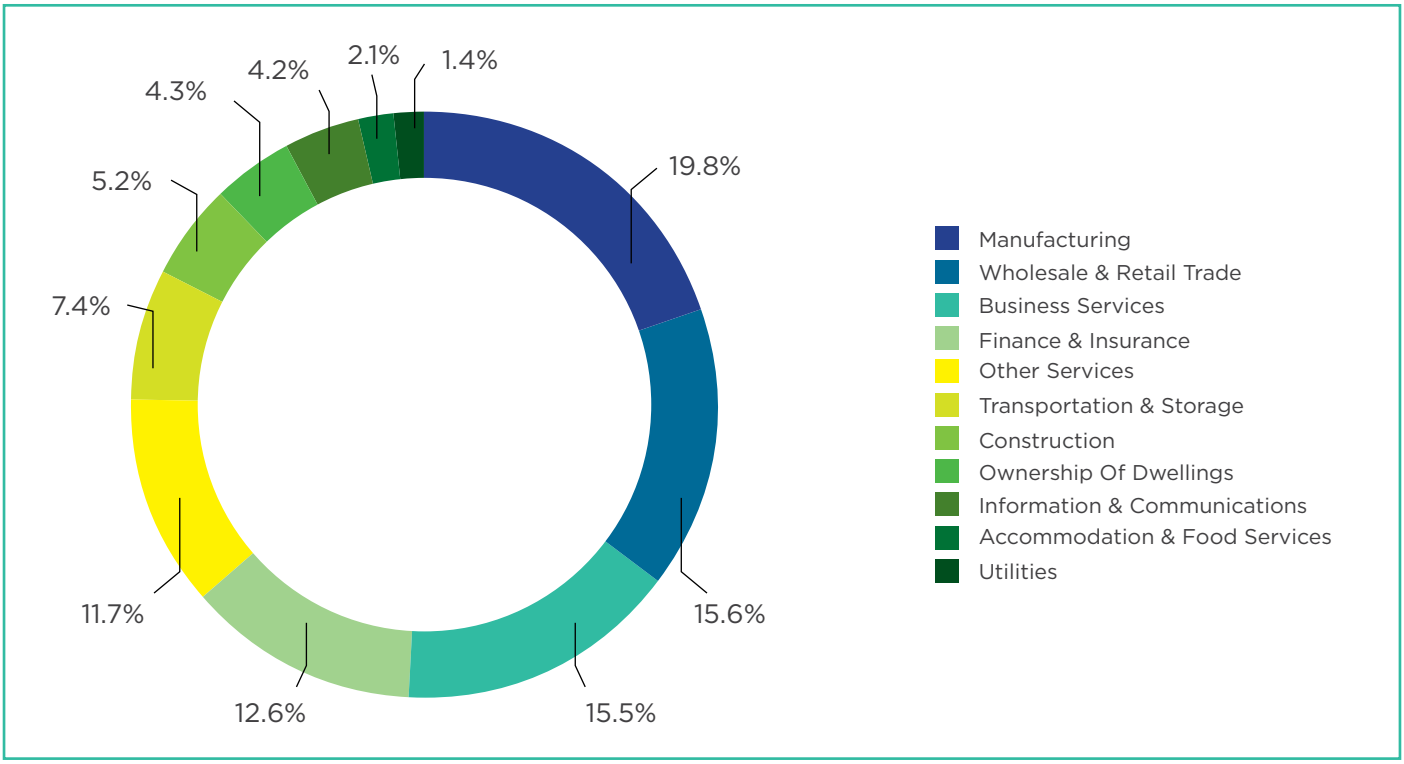
February is usually the sunniest month while December is often the month with the least sunshine.

POPULATION

As of 2015, Singapore's total population, including foreigners working in Singapore, is estimated at 5.5 million. The resident population, comprising Singapore citizens and permanent residents, is estimated at 3.9 million or 71% of the total population. Singapore's small land area also means that our population density of about 7,700 people per km^2 is one of the highest in the world.

ECONOMY

Singapore is an export-oriented economy that is highly dependent on international trade. In 2015, in nominal terms, Singapore's external merchandise trade amounted to S$884 billion, about 2.2 times the GDP of Singapore (S$402 billion). Over several decades, Singapore has built up a strong economy where manufacturing and wholesale & retail trade sectors each comprised around 20% and 16% of GDP respectively in 2015. 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 2015. Singapore's strategic geographical location has also enabled it to develop into a major air and sea transport hub. The economic structure in 2015 is as shown.



WATER

Located in the equatorial rain belt, Singapore receives abundant rainfall annually. However, Singapore is considered to be 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 ultra-clean reclaimed water and desalinated water.

Since 2011, the total water catchment area has been 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. By 2060, Singapore's water use is expected to more than double. To strengthen our water security and drought resilience, we continue to build up the capacities of NEWater and desalinated water, which are weather-resilient sources. Currently, NEWater and desalination capacity is able to meet up to 30% and 25% of our water demand respectively. By 2060, we will expand NEWater and desalination capacities to meet up to 55% and 30% of future water demand respectively.

One implication of using NEWater and desalinated water to augment Singapore's water supply is that the use of reverse osmosis membranes requires more energy as compared to treating water from local catchment. Singapore continues to invest in research and development (R&D) to find ways to improve the energy efficiency of our processes. For instance, in the area of desalination, one project aims to demonstrate the use of electrochemical technology to desalinate seawater using half the energy compared to current membrane-based desalination methods. Another research area is biomimicry (the study of natural desalination processes in mangrove plants and marine fishes), which has the potential to reduce the required energy further. However, these solutions will take time to develop and mature.

Besides ensuring a sustainable water supply, it is also important to manage water demand. Through wide-ranging water conservation measures, Singapore's per capita domestic water consumption has fallen from 165 litres per day in 2003 to 151 litres per day in 2015. The target is to lower it to 140 litres by 2030. Singapore adopts a multi-pronged approach to manage water demand: pricing water to reflect its scarcity value; mandating water efficiency standards; and encouraging water conservation practices. In addition, the use of alternative sources of water, such as ongoing large-scale water recycling to produce NEWater and the use of seawater for industrial cooling, helps to free up potable water for domestic use. Another critical component of demand management is the reduction of unaccounted-for-water (UFW). Singapore has substantially reduced UFW from 11% in the 1980s to about 5% at present. The number of leaks in Singapore, around 5.7 leaks/100km/year, is low when compared to other countries.

More than just an ordinary dam, the Marina Barrage serves three benefits: it creates a freshwater reservoir to boost Singapore's water supply, acts as a tidal barrier to prevent flooding in the low-lying areas in the city and offers a venue for water-based recreation.

Semakau Landfill is located offshore at about 8km south of Singapore.

SINGAPORE'S NATIONAL CIRCUMSTANCES AND CONSTRAINTS

Singapore currently accounts for around 0.12% of global emissions. We will continue to take steps to reduce our carbon emissions in the coming decades. The extent of reductions will depend on our national circumstances, past mitigation efforts, geographical constraints, and the limited potential for alternative energy sources.

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 sectors are a large source of our carbon emissions and Singapore is working to improve energy efficiency in these sectors. This is an ongoing and continuous effort.

Singapore has taken early measures to ensure sustainable development, such as controlling vehicle demand and usage through a vehicular quota and road pricing system to reflect the competing needs for our scarce land. In addition, we have optimised the use of our scarce land through integrated urban planning. As Singapore lacks a hinterland, our small land area has to support the entire spectrum of activities within the country — beyond transport, housing, offices, shops and industries, land is also required for reservoirs and water catchment areas, as well as security.

As Singapore is a small, alternative energy disadvantaged city-state, there will be limits to the extent of emissions reductions that can be undertaken. Given our small size and dense urban landscape, there are challenges to use alternative energy sources such as solar energy on a wide scale. Such difficulties in switching to alternatives are recognised by the United Nations Framework Convention on Climate Change (UNFCCC), as described in Articles 4.8 and 4.10 of the Convention.

Singapore's longstanding focus on sustainable development and environmental quality has helped to significantly moderate our carbon emissions growth. From 2000 to 2005, our emissions grew by 1.1% per year (from 39 million tonnes in 2000 to 41 million tonnes in 2005), much lower than our GDP growth of 4.9% per year over the same period. This was mainly due to the fuel switch from fuel oil to natural gas in the power sector. Previously, our historical rate of emissions growth was about 6.4% per year from 1994 to 2000.

NATIONAL CIRCUMSTANCES IN THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

A Party's national circumstances are recognised by the United Nations Framework Convention on Climate Change (UNFCCC). Convention Articles 4.8 and 4.10 explicitly 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 subclauses 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.**"

SINGAPORE'S LIMITED POTENTIAL FOR ALTERNATIVE ENERGY SOURCES

Given our small size and dense urban landscape, there are challenges to using alternative energy sources such as solar and nuclear. Singapore's geographical features also limit our access to geothermal resources, hydroelectricity, wind, tidal and wave power.

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. Singapore already converts much of our waste to energy, providing about 2% of our electricity needs. However, Singapore's lack of domestic biomass sources and available land may limit the future growth potential of biomass power generation. Nonetheless, Singapore will continue to study and monitor developments in this area.

CARBON CAPTURE, STORAGE AND UTILISATION (CCSU)

A lack of suitable storage sites and low-carbon concentrations in emissions limit the deployment of CCSU as a cost-effective mitigation measure for Singapore. However, research institutions in Singapore are actively carrying out related research to ensure that CCSU remains an option should circumstances become conducive for its deployment.

GEOTHERMAL

Singapore lacks conventional geothermal resources. In addition, unconventional geothermal resources cannot be utilised in a cost-effective manner with current technologies.

HYDROELECTRIC

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. The absence of major river systems means that hydroelectricity is not a viable option in Singapore.

MARINE (TIDAL AND WAVE POWER)

The tidal range (difference between high and low tide) is about 1.7m, well below the 4m tidal range that is typically required for commercial tidal power generation. Wave power from surrounding waters is limited as Singapore is surrounded by land masses resulting in relatively calm waters. In addition, wave, tidal and ocean thermal have limited application as much of our sea space is used for ports, anchorage and international shipping lanes.

NUCLEAR

Nuclear energy could offer increased energy security and is a low-carbon power generation option. However, the risks to Singapore, given that the country is small and densely populated, still outweigh the benefits at this point. A nuclear energy pre-feasibility study concluded in 2012 that nuclear energy technologies presently available are not yet suitable for deployment in Singapore. Nonetheless, Singapore will continue to monitor developments and will focus on research and developing capabilities to keep abreast of progress in nuclear energy technologies so as to keep our options open for the future.

SOLAR

While Singapore's compact and dense urban landscape limits available space for deployment, solar energy remains the most viable source of renewable/alternative energy in Singapore. Singapore has taken proactive steps to facilitate solar deployment, by enhancing the regulatory framework for intermittent generation sources, and streamlining 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 in Singapore. The lead demand generated has also helped and will continue to support the solar industry to develop its capabilities. In addition, we are actively investing in R&D and test-bedding to improve the efficiency and lower the cost of solar technologies.

We are also exploring various solutions to manage the intermittency challenge of solar PV, which if left unaddressed would limit solar deployment. For example, we are studying how energy storage solutions and solar forecasting can be used in Singapore's context to manage intermittency.

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 6m/s, while prime wind sites require annual average wind speeds in excess of 7.5m/s. In addition, there are challenges to harnessing offshore wind due to busy maritime traffic in our waters.

Nestled in the green belt of Southern Ridges, the Interlace condominium is a recipient of the Urban Habitat award 2014 and the BCA Green Mark Gold Award 2010.

ASIA'S GREENEST CITY

According to the 2016 Sustainable Cities Index by Arcadis, Singapore is Asia's most sustainable city and the second most sustainable city in the world. This index studies environmental (Planet), economic (Profit), and social (People) indicators in cities. Singapore tops the Planet and Profit indices in Asia.

Singapore also ranked second in the recently introduced Sustainable Competitiveness Index by the World Economic Forum (WEF), which takes into account countries' environmental policy, resource efficiency and environmental degradation, alongside other economic and social indicators. In the Economist Intelligence Unit (EIU)'s 2012 Global City Competitiveness Index, Singapore ranked third overall and is the highest-placed Asian city. According to the 2011 Siemens/EIU Asian Green City Index, Singapore is Asia's greenest metropolis, and the only city assessed to perform well above average in the overall rankings.

Singapore's focus on environmental sustainability as a key aspect of liveability was emphasised very early on from the 1960s and continues to this day. While Singapore's immutable geographical realities and historical economic development are significant determinants of our emissions profile, we remain committed to stabilising our long term emissions. We have invested significantly in energy-related R&D over the years to help us achieve our goals. For example, the Urban Solutions and Sustainability (USS) R&D thrust aims to overcome resource constraints for the development of a sustainable and liveable city. As part of its integrated approach, USS supports R&D in the areas of energy, water, and land & liveability to provide an integrated response to our urban challenges.

These efforts will take time, given the need for significant improvement in relevant technologies. Singapore serves as a test-bed for innovative clean technology solutions developed specifically for use in cities. Should these efforts bear results, Singapore and other countries with similar circumstances will benefit from these urban solutions.

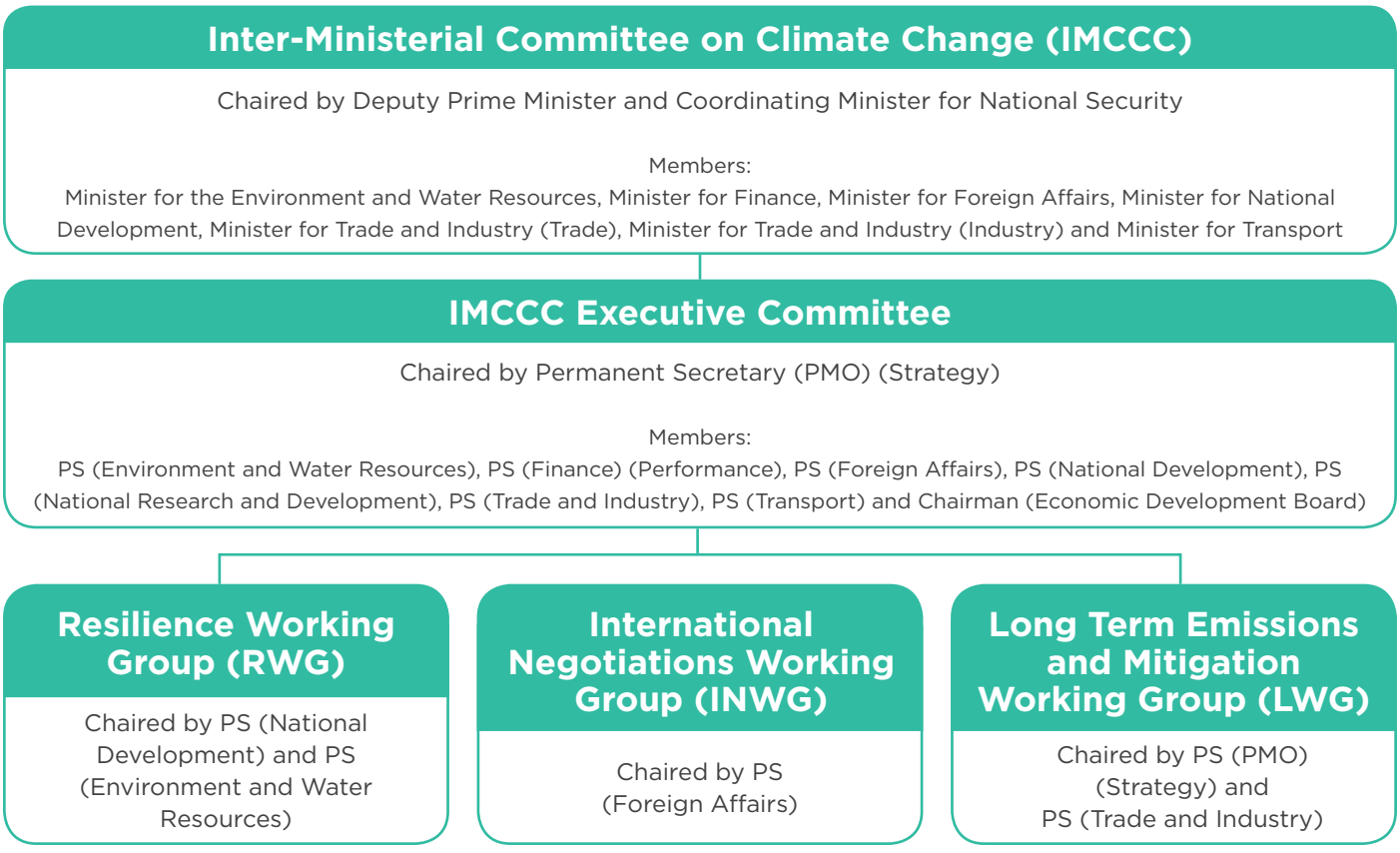
Despite our constraints and unique circumstances as a small island state with limited potential for alternative energy sources, Singapore is putting in a major effort to stabilise our long-term emissions, as described in Chapter 4 on Mitigation Measures.

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 to ensure coordination on Singapore's approach to climate change. The IMCCC is chaired by the Deputy Prime Minister and Coordinating Minister for National Security. It includes the Minister for the Environment and Water Resources, the Minister for Finance, the Minister for Foreign Affairs, the Minister for National Development, the Minister for Trade and Industry (Trade), the Minister for Trade and Industry (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, Long Term Emissions and Mitigation Working Group, and the Resilience Working Group.

The International Negotiations Working Group develops Singapore's international climate change negotiations strategy under the UNFCCC. The Long Term Emissions and Mitigation Working Group (LWG) studies how Singapore can stabilise our long-term emissions. It examines options for emission reduction and identifies the capabilities, infrastructure and policies needed for long-term mitigation. The 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 Communications (NC) and Biennial Update Reports (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 Resilience Working Group studies Singapore's vulnerability to the effects of climate change and recommends long-term plans that ensure the nation can adapt to future environmental changes.

To ensure the effective coordination on 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 (PMO). NCCS is part of the Strategy Group which supports the Prime Minister and his Cabinet to establish priorities and strengthen strategic alignment across Government. The positioning of NCCS underscores the importance that Singapore places on climate change.



Singapore Botanic Gardens was inscribed as a UNESCO World Heritage Site in 2015.

CHAPTER 2

ENHANCING CAPACITIES

Enhancing Capacities

Primary forest trees, in one of the nature reserves in Singapore, continue to store and sequester carbon.

Singapore recognises the importance of improving our MRV processes and identifying opportunities to enhance our climate actions. This is an ongoing national effort. We pursue continual learning to fine-tune our technical expertise on a wide range of issues from reporting processes to enhancing our climate change activities. We also actively collaborate with international partners to identify and promulgate best practices in these areas. We and our partners have learned much from sharing knowledge and experience through different channels, including through working with experts, participating in technical workshops, co-organising technical cooperation programmes, and partnership with tertiary institutes. Tables 1, 2 and 3 show some examples of our collaborative initiatives on these fronts.

ENHANCING CAPACITY TO REPORT ON THE LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR

We are currently working to build Singapore's capacity to more effectively monitor and report on greenhouse gas (GHG) emissions and removals from the Land Use, Land-Use Change and Forestry (LULUCF) sector. In consultation with international experts, the project aims to build up our technical expertise and establish the necessary institutional framework to maintain a detailed GHG inventory of Singapore's LULUCF sector. This self-funded, five-year project, is scheduled to be completed in 2018. However, initial results from this project are presented in this Biennial Update Report (BUR).

A wall-to-wall assessment of the land use and land-use changes in Singapore has been carried out using satellite images covering all land-use classes and the five carbon pools as defined by the Intergovernmental Panel on Climate Change (IPCC). We have established permanent sampling plots across the nation for the tracking of carbon in relevant land-use classes. While vegetation may provide a relatively small carbon source or sink for Singapore, it is important to us to take a comprehensive approach at every stage. We apply the same rigour when it comes to training and capacity building.

Capacity-building session on carbon accounting for land use and vegetation in Singapore, conducted by our external consultants.

PARTICIPATION IN TECHNICAL WORKSHOPS

Singapore has benefited from participation at many international technical workshops, where we learn about and share expertise and experience on the various facets of combating climate change. One such workshop is the Regional Training on Greenhouse Gas Inventory Using 2006 IPCC Guidelines and Software, which was jointly conducted by the Malaysian Ministry of Natural Resources and Environment and the IPCC Task Force for Greenhouse Gas Inventory Technical Support Unit in Kuala Lumpur from 22 to 23 April 2015. The workshop, which was also attended by participants from Brunei and Indonesia, touched on issues regarding the Quality Assurance / Quality Control (QA/QC) processes and the MRV of GHG inventories. It has strengthened our capacity and familiarity in using the 2006 IPCC guidelines and software, with training that comprised both lectures and hands-on practice sessions. It covered energy, industrial processes, agriculture, forestry and other land use, and waste sectors.

CO-ORGANISING OF TECHNICAL COOPERATION PROGRAMMES

Singapore regularly co-organises technical cooperation programmes for fellow developing countries, in collaboration with other Governments, the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat, the United Nations Environment Programme (UNEP) and other agencies. Through exchange of knowledge and experience with the expert trainers and the participants, we also gain new insights on how we can further improve our MRV processes and identify new opportunities to enhance our climate actions.

An example of such technical cooperation programmes is the workshop on BURs, jointly held by Singapore and Australia from 20 to 22 April 2015 in Singapore. The workshop was attended by participants from all ASEAN countries. The trainers included the UNFCCC Secretariat, the UNEP, members of the Consultative Group of Experts on National Communications from Parties not included in Annex I to the Convention (CGE), the Australian Department of Environment and Singapore's National Climate Change Secretariat, amongst others. The workshop considered the BUR guidelines and examined reporting on national circumstances, institutional arrangements, GHG inventories, and mitigation actions and their effects. It also familiarised participants with the support available for reporting. The presentations from trainers and national experts, interactive discussions, and breakout and question-and-answer sessions helped form a facilitative and informative environment. The exercises in the breakout sessions touched on real-life case studies, allowing participants to learn from one another's challenges and propose solutions.

Participants and trainers at the BUR workshop jointly held by Singapore and Australia from 20 to 22 April 2015 in Singapore.

PARTNERSHIP WITH TERTIARY INSTITUTES

Singapore recognises that technological innovation will play a significant role in helping us address our long-term climate change and energy goals. Singapore actively collaborates with international tertiary institutes in research and development to build human capacity in this area. We aim to build an ecosystem of local and international research institutes, to strengthen our capabilities, catalyse breakthroughs, and facilitate partnerships with industry to translate promising research outcomes to deployment.

A prominent example is the Singapore Building and Construction Authority (BCA) SkyLab, which is a test facility pivotal to developing innovative energy efficient building technologies. It is modelled after and designed in collaboration with the Lawrence Berkeley National Laboratory's FLEXLAB in the United States. Our collaboration includes technical capabilities and expertise sharing throughout the development process.

BCA SkyLab

Singapore's Nanyang Technological University (NTU) and Germany's Technische Universität München (TUM) have also collaborated to establish the TUM CREATE (Campus for Research Excellence and Technological Enterprise). The TUM CREATE is a centre under CREATE which houses research centres set up by top international universities. Many of these centres focus on energy-related research, including the Cambridge Centre for Carbon Reduction in Chemical Technology (C4T), Shanghai Jiao Tong University-National University of Singapore (NUS) Research Centre on Energy and Environmental Sustainability Solutions for MegaCities (E2S2), and the TUM-CREATE Centre on Electromobility in Megacities. Recently, an interdisciplinary team of researchers from TUM CREATE created EVA, an electric taxi developed for tropical megacities. EVA features a super-fast charging battery that gives the vehicle a 200km range with just a 15 minute re-charge. The next phase of TUM CREATE will address public transport mobility from a systems perspective, and aims to significantly improve public transport mobility.

Singapore's National Research Foundation (NRF) collaborated with ETH Zurich, the Swiss Federal Institute of Technology Zurich, to establish the Singapore-ETH Centre in Singapore in 2010. The Singapore-ETH Centre aims to strengthen the capacity of Singapore and Switzerland to research, understand and actively respond to the challenges of global environmental sustainability. The first research programme under the Singapore-ETH Centre, the Future Cities Laboratory (FCL), combines science and design to develop new knowledge, technologies, and approaches for a sustainable urban future with an Asian perspective. In addressing the challenges of rapid urbanisation, the FCL research team has developed innovative urban solutions in areas including urban design, mobility and transportation, low-energy cooling systems, and sustainable construction materials, among others.

Pull-Out Test for Bamboo Composite Reinforcement at the Advanced Fibre Composite Laboratory. This work is led by Asst Prof Dirk E Hebel of the Singapore ETH Centre.

EXAMPLES OF COLLABORATIVE INITIATIVES

Table 1 | Courses organised by Singapore for fellow developing countries (in collaboration with third parties)

No.	Course Name	Partnerships	Course Dates/ Duration	No. of participants	Course Description
1	Japan-Singapore Partnership Programme for the 21st Century: Climate Change and Energy Sustainability	Singapore Cooperation Programme (SCP), Japan International Cooperation Agency (JICA) and Singapore Environment Institute (SEI)	11-22 August 2014	16	The course was conducted under the Japan-Singapore Partnership Programme for the 21st Century. Its objective was to enable participants to gain an understanding of Singapore's and Japan's multi-agency engagement in formulating energy solutions to climate change. The participants were from the Pacific Islands.
			5-16 October 2015	18	
2	Singapore-United States Third Country Training Programme: Energy Efficient Buildings Workshop	SCP, BCA Centre for Sustainable Buildings, and US State Department and Department of Energy	2-4 September 2014	20	The workshop provided participants from ASEAN countries with a better understanding of the overall framework for energy efficient buildings applicable to the ASEAN region, in particular the core elements (i.e. policy, finance and technology) and to understand the co-benefits of energy efficient buildings.
3	Capacity Building on 2006 IPCC Guidelines for National Greenhouse Gas Inventories	UNEP and Singapore National Environment Agency	9-11 October 2014	45	The objectives of the workshop were (i) to enhance the capacity of ASEAN member countries in using the IPCC 2006 guidelines and methodology for GHG inventory compilation; and (ii) provide insight on the quality assurance and verification aspects of the inventory. The training comprised both lecture and hands-on training using IPCC software and covered the energy, industrial processes, agriculture, forestry and other land use sectors.
4	Meeting Southeast Asia's Energy Needs: Fuelling the Future	SCP and the Norwegian Embassy in Singapore	28-31 October 2014	26	The seminar examined strategies for accelerating green growth and renewables in the energy mix, balanced by the need for energy security. Experts from the Norwegian and Singaporean Governments, companies and research communities shared ideas and expertise on how to fuel this future in Asia.
			26-30 October 2015	23	
5	Singapore-Cities Development Initiative for Asia (CDIA) Third Country Training Programme: Cities and Climate Change [Note: CDIA was jointly established by the Asian Development Bank (ADB) and the Government of Germany in 2007.]	SCP, Singapore National Environment Agency and CDIA	10-14 November 2014	14	With participants from Asian countries, the course aimed to accelerate cities' efforts on integrating climate change mitigation and adaptation into local policies. The thematic focus of the training course covered municipal solid waste management and wastewater management through structural and non-structural measures.
6	Japan-Singapore Partnership Programme for the 21st Century: Climate Change Adaptation Strategies for Small Island Developing States (SIDS)	SCP, JICA and SEI	24-28 November 2014	23	The course was conducted under the Japan-Singapore Partnership Programme for the 21st Century. It allowed participants from the Pacific Islands to learn about Singapore's and Japan's experience in sustainable development and climate change, with a focus on the adaptation strategies and measures aimed at addressing the challenges and impacts of climate change.
			2-6 November 2015	12	

No.	Course Name	Partnerships	Course Dates/ Duration	No. of participants	Course Description
7	Joint Australia-Singapore Workshop on BURs for ASEAN Countries	SCP, Singapore National Climate Change Secretariat, and Australian Department of Foreign Affairs and Trade (DFAT) and Department of the Environment	20-22 April 2015	16	The course familiarised ASEAN participants with the new reporting obligations and guidelines under the UNFCCC, and provided guidance on the preparation and reporting of relevant information in their BURs. It also provided a safe environment for participants to brainstorm solutions to problems and issues faced in their national experiences and share information on the support available to developing countries in the preparation of their BURs.
8	Assessing Private Sector Financing for Renewable Energy and Energy Efficiency Projects	SCP and German Agency for International Cooperation (GIZ)	27-30 April 2015	23	The course improved participants' understanding of key challenges for public-private climate finance in the region.
9	Singapore-United States Third Country Training Programme (TCTP): Financing Energy Efficient Buildings	SCP, Sustainable Energy Association of Singapore, US State Department and Department of Energy	28-30 September 2015	19	The course followed up on the 2014 Energy Efficiency Building Workshop by concentrating on ways to finance these important energy efficiency projects. Participants from ASEAN countries learned about financial institutions, best practices, financing mechanism, and how governments can attract financing.
10	Disaster Risk Reduction	SCP, UN Office for Disaster Risk Reduction (UNISDR) and NTU Centre for Continuing Education	19-23 October 2015	23	The course shared Singapore's experiences in disaster risk reduction and the Government's approach in formulating adaptation measures and building resilience in the community. Participants also learned from UNISDR about the Sendai Framework for Disaster Risk Reduction 2015-2030 and possible applications to their countries' existing plans. UNISDR provided globally accepted tools to help participants develop draft action plans for integrating disaster risk reduction and climate change adaptation into development policies.
11	Enhancing Climate Action Through Innovative Market-based Mechanisms and Mobilising Private Sector Financing	UNEP, and Singapore National Climate Change Secretariat and National Environment Agency	14-15 October 2015	54	Attended by participants from ASEAN countries, the workshop provided an overview of policy tools and other instruments for reducing barriers to private investments in low carbon and adaptation solutions. More specifically the workshop provided a comparative analysis of the different approaches to carbon pricing, and discussed common rules and standards of a global carbon markets framework in the post-2020 period, as well as the importance of a national enabling environment for mobilizing private financing in climate mitigation and adaptation.

Table 2 | Capacity-building courses participated by Singapore

No.	Course Name	Organiser	Course Dates/ Duration	Participation	Course Description
1	Study Visit on Forest and Carbon Accounting	ASEAN Regional Knowledge Network on Forests and Climate Change	27 January - 5 February 2014	16 participants from ASEAN countries	The visit to Australia (Canberra and Sydney) and New Zealand (Wellington and Rotorua) shared information on government policies and methods for forest and carbon accounting, how these are translated into private sector timber operations, business and economic transition.
2	Training course on LULUCF accounting principles	National Institute for Space Research, Sao Jose dos Campos, Sao Paulo, Brazil	12-14 March 2014	26 international participants	The training course focused on the use of remote sensing, and data capture and manipulation to produce spreadsheets on land use, land use change and forestry information for national accounting purposes.
3	12th Workshop on Greenhouse Gas (GHG) Inventories in Asia (WGIA 12)	Ministry of the Environment of Japan (MOEJ), Japan's Greenhouse Gas Inventory Office (GIO), Thailand's Office of Natural Resources and Environmental Policy and Planning (ONEP), Thailand Greenhouse Gas Management Organization (TGO)	4-6 August 2014	118 participants from Asia	The objective of the workshop was to discuss issues relating to the preparation of national GHG inventories for the reporting in National Communications (NCs) and BURs, including issues on Quality Assurance/Quality Control (QA/QC) processes and Measurement, Reporting and Verification (MRV) of GHG inventories.
4	Regional Training on Greenhouse Gas Inventory Using 2006 IPCC Guidelines and Software	Malaysian Ministry of Natural Resources and Environment and IPCC Task Force for Greenhouse Gas Inventory Technical Support Unit	22-23 April 2015	62 participants from Malaysia, Brunei, Indonesia, and Singapore	The workshop provided capacity building to national greenhouse gas compilers on the usage of the 2006 guidelines and software. The training comprised both lecture and hands-on training using IPCC software and covered the energy, industrial processes, agriculture, forestry and other land use, and waste sectors.
5	European Council for Energy Efficiency Economy (ECEEE) 2015 Summer Study	ECEEE	31 May – 7 June 2015	More than 400 participants from Industry, Energy Suppliers, Governments, Research, Consulting, and NGO's.	Since 1993, ECEEE's biennial Summer Study has explored solutions to our energy-related dilemmas by providing evidence-based knowledge on the full range of energy efficiency topics. In an informal setting conducive to networking and exchange of information, experts work to learn from each other and ensure energy efficiency is fully integrated into energy and climate policies.
6	International Energy Agency (IEA) Energy Efficiency Training Week 2015	IEA	8-12 June 2015	96 participants mostly from emerging economies	The IEA Energy Efficiency Training workshop focused on planning and implementation of energy efficiency practices, and implementation and tracking of outcomes. In particular, it delved into key climate change issues such as implementation details of post-2020 mitigation plans and was structured along sectoral lines with a course specifically focusing on transport.

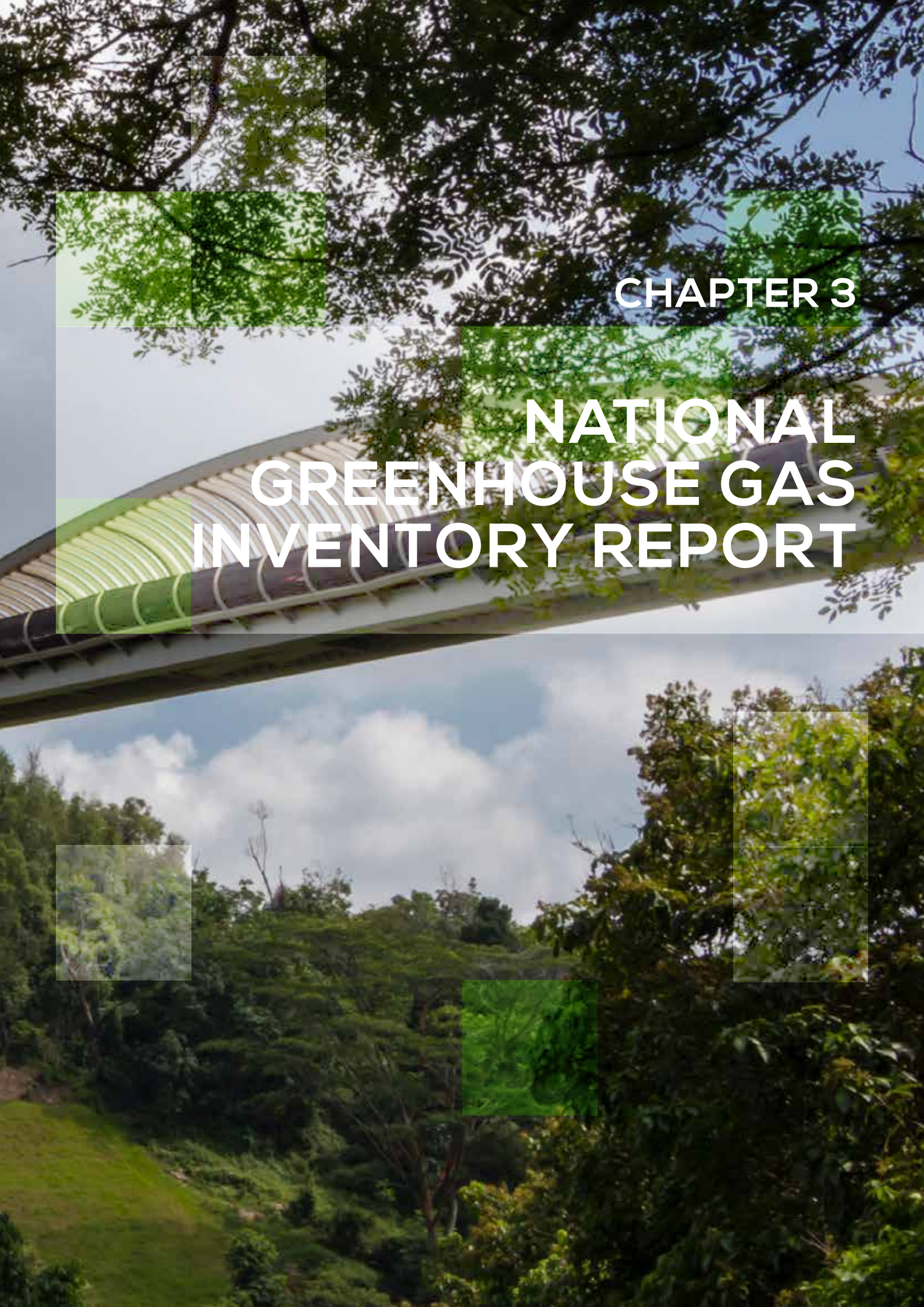
No.	Course Name	Organiser	Course Dates/ Duration	Participation	Course Description
7	Transforming the Global Maritime Transport Industry towards a Low Carbon Future through Improved Energy Efficiency: Project Inception and 1st Global Project Task Force meeting	International Maritime Organization, United Nations Development Programme, Global Environment Facility	30 September-1 October 2015	35 participants from developing countries that are the project's lead pilot countries	The Global Maritime Energy Efficiency Partnerships Project (GloMEEP) is a two-year project to support developing countries' uptake and implementation of energy-efficiency measures for shipping and thereby reduce shipping's greenhouse gas emissions. The project's priority areas include improving the policy and regulatory environments, developing knowledge, building institutional capacity, and promoting the deployment of new technologies and processes for energy-efficient ship operations. Singapore participated at its project inception and its first global project task force meeting.

Table 3 | Collaborative programmes on research and development

No.	Programme Name	Partnerships	Programme Dates/Duration	Programme Description
1	Center for Environmental Sensing and Modeling (CENSAM)	Singapore National Research Foundation (NRF), Massachusetts Institute of Technology (MIT) in the US	Commenced in January 2008	CENSAM seeks to provide pervasive monitoring, modelling and control within the highly developed urban environment of Singapore. MIT and Singapore collaborators work together to develop sensor networks and correlated models. The information derived from these studies is used to address environmental problems in Singapore in three main areas: **Urban:** Urban heat island effect, urban air and water quality, and development of wireless sensor networks to monitor and control urban systems. **Marine:** Sensing and modelling in the near-shore environment, as well as coastal studies of waves, currents and sediment. **Climate:** Predictions of regional climate change and land use.
2	Singapore-ETH Centre Future Cities Laboratory	Singapore NRF and ETH Zurich	Commenced in September 2010	Combining science and design, the Future Cities Laboratory develops new knowledge, technologies, and approaches for a sustainable urban future with an Asian perspective. In addressing the challenges of rapid urbanisation, the FCL research team has developed innovative urban solutions in areas including: mobility and transportation, the design of vibrant urban neighbourhoods, low-energy cooling systems, sustainable construction materials, and robotic fabrication in construction, among others.
3	Technische Universität München Campus for Research Excellence and Technological Enterprise (TUM-CREATE)	Singapore NRF and TUM in Germany	Commenced in April 2011	TUM CREATE aims to improve public transport in Singapore by addressing public transport mobility from a systems perspective.
4	Singapore-Peking University Research Centre (SPURc)	Singapore NRF and Peking University	Commenced in December 2011	SPURc focuses on two main aspects: (a) CO_2 Separation and Capture, and (b) CO_2 Conversion to Useful Chemicals and Fuels.
5	Singapore-Berkeley Building Efficiency and Sustainability in the Tropics (SinBerBEST)	Singapore NRF, University of California (UC) Berkeley in the US	Commenced in January 2012	SinBerBEST is an interdisciplinary group of researchers from UC Berkeley, NTU and NUS who come together to make an impact with broadly applicable research leading to the innovation of energy efficient and sustainable technologies for buildings located in the tropics, as well as for economic development.
6	Singapore-Berkeley Research Initiative for Sustainable Energy (SinBeRISE)	Singapore NRF and UC Berkeley in the US	Commenced in October 2012	The mission of SinBeRISE is to explore novel approaches to harvest solar energy with high conversion efficiencies by advancing material and device technologies readily applicable for low cost manufacturing processes. The foci include conversion of solar energy into electrical energy (photovoltaics) and catalyzing the conversion of CO_2 into liquid fuel (photoelectrochemical cells).
7	Singapore Building and Construction Authority (BCA) BCA SkyLab	Singapore BCA and Lawrence Berkeley National Laboratory in the US	Commenced in November 2012	The BCA SkyLab is a state-of-the-art rotatable test facility pivotal to developing innovative energy efficient building technologies. The facility is modelled after and designed in collaboration with the Lawrence Berkeley National Laboratory's FLEXLAB. There was sharing of capabilities and technical expertise throughout the development process.
8	Singapore Maritime Port Authority (MPA)-DNV GL Cooperation in Maritime Environment and Clean Technologies	Singapore MPA and DNV GL	Commenced in February 2014	A Memorandum of Understanding (MOU) was signed between MPA and DNV GL to jointly promote research and development (R&D) and test-bedding of maritime environment and clean technologies. Under the MOU, the parties would collaborate on R&D areas such as liquefied natural gas (LNG), Green Ports, and Marine Environment & Resources.

No.	Programme Name	Partnerships	Programme Dates/Duration	Programme Description
9	MPA-Nippon Kaiji Kyokai (ClassNK) MOU on Maritime Technologies Research and Development	Singapore MPA and ClassNK	Commenced in February 2015	MPA and Nippon Kaiji Kyokai (ClassNK) signed a MOU to jointly promote and collaborate on maritime technologies R&D and innovation in the areas of ship emissions reduction, ship safety and renewable energy technologies. ClassNK also launched its Global Research and Innovation Centre in Singapore, its first ever R&D facility outside Japan, during the signing event.

At 36 metres above ground, the Henderson Waves bridge is the highest pedestrian bridge in Singapore.



CHAPTER 3

NATIONAL GREENHOUSE GAS INVENTORY REPORT

National Greenhouse Gas Inventory Report

Senoko power plant in Singapore. Singapore has switched from fuel oil to natural gas as our main energy source for electricity generation.

The most significant greenhouse gas (GHG) emitted in Singapore is carbon dioxide, primarily produced by the burning of fossil fuels to generate energy used by the industry, buildings, household and transport sectors. Given Singapore's small land size and highly urbanised landscape, the GHG emissions from agriculture, land-use change and forestry sectors are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.

METHODOLOGY USED

REVISED 1996 IPCC GUIDELINES

Singapore's emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were estimated using the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, in line with the user manual for the guidelines on national communications from non-Annex I Parties. Emission estimates were based on the sectoral approach and were made using the default conversion and emission factors provided in the Revised 1996 IPCC Guidelines. The Tier 1 methodology was used for most emission estimates. The Tier 2 methodology was used for estimating emissions of CH_4 and N_2O from the combustion of petrol and diesel in land transport, in conjunction with vehicle statistics. The figures shown in this chapter refer to sectoral approach figures.

2006 IPCC GUIDELINES

The emissions from waste incineration and hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) from integrated circuit and semiconductor production were estimated using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories as there are no 1996 IPCC factors.

The emissions of HFCs, PFCs and SF_6 were estimated using the Tier 2 methodology and default conversion and emission factors from the 2006 IPCC Guidelines.

Emissions from the Land Use, Land-Use Change and Forestry sector (LULUCF) were estimated using the 2003 IPCC Good Practice Guidance on LULUCF. However, where relevant, emission factors of IPCC (2006) Guidelines and IPCC (2014) Wetland supplement were incorporated if they were not included in or deviated from those of the IPCC (2003) GPG.

IPCC GOOD PRACTICE GUIDANCE

In addition, the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories were applied to improve the transparency, consistency, comparability, completeness and accuracy of the inventory.

GLOBAL WARMING POTENTIALS

The estimated CH_4, N_2O, HFCs, PFCs and SF_6 emissions were converted to CO_2 equivalent (CO_2eq) using 1995 IPCC global warming potential (GWP) values based on the effects of greenhouse gases over a 100-year time horizon in the table below.

Greenhouse Gas	Chemical Formula	GWP
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydrofluorocarbons	HFCs	140 – 11,700
Perfluorocarbons	PFCs	6,500 – 9,200
Sulphur hexafluoride	SF_6	23,900

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 2012

Singapore's GHG emissions for 2012 totalled 48,094.65 gigagram (Gg) CO_2eq. A breakdown of the total GHG emissions by sources for 2012 in Gg CO_2eq is shown in the table below.

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6
Total (Net) National Emissions - (Gg CO_2eq)	**46,538.16**	**86.73**	**411.68**	**37.92**	**930.83**	**89.33**
All Energy	**46,777.39**	**41.20**	**307.04**			
Fuel combustion	**46,551.87**	**41.20**	**307.04**			
Energy and transformation industries	20,366.57	9.02	73.03			
Industry	18,610.71	8.65	14.47			
Transport	6,946.58	23.50	219.54			
Commercial-institutional	419.41	0.03	0.01			
Residential	208.61					
Fugitive fuel emission	**225.52**					
Oil and natural gas system[2]	225.52					
Land Use, Land-Use Change and Forestry	**-239.23**		**0.02**			
Industrial Processes				**37.92**	**930.83**	**89.33**
Waste		**45.53**	**104.62**			
Wastewater Handling		45.53	104.62			

**Blank cell means Not Occurring*

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

Greenhouse Gas	Emissions (Gg CO_2eq)	% of Total GHG Emissions
Carbon dioxide (CO_2)	46,538.16	96.76%
Perfluorocarbons (PFCs)	930.83	1.93%
Nitrous oxide (N_2O)	411.68	0.86%
Sulphur hexafluoride (SF_6)	89.33	0.19%
Methane (CH_4)	86.73	0.18%
Hydrofluorocarbons (HFCs)	37.92	0.08%

WORKSHEETS

The 2012 GHG inventory worksheets are appended in the Annex.

PREVIOUSLY REPORTED GREENHOUSE GAS EMISSIONS

A breakdown of the total GHG emissions by sources reported in previous National Communications and Biennial Update Report (1994, 2000 and 2010) in Gg CO_2eq can also be found in the Annex.

[2] *Fugitive fuel emissions from oil and natural gas systems are based on company-level data.*

BREAKDOWN OF EMISSIONS BY IPCC SECTOR

ALL 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 (fuel combustion) in 2012 was 47,125.64 Gg CO_2eq. The contribution of emissions from fuel combustion in the energy sector and fugitive fuel emissions in 2012 is as shown.

Sector	Emissions (Gg CO_2eq)	% of Total Emissions
Energy & Transformation Industries[3]	20,448.62	43.39%
Industry (Energy Use)	18,633.83	39.54%
Industry (Fugitive Emissions)	225.52	0.48%
Transport	7,189.61	15.26%
Commercial-Institutional	419.45	0.89%
Residential	208.61	0.44%

As heat from the incineration of waste is recovered to produce electricity in Singapore, CO_2 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 fuel based and the biomass fraction is excluded.[4]

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.

Electricity Generation

In 2012, electricity generation emissions totalled 20,448.62 Gg CO_2eq. The breakdown of emissions from different fuel types used for electricity generation in 2012 is as shown.

Fuel Type	Emissions (Gg CO_2eq)	% of Total Emissions from Energy & Transformation Industries
Natural Gas	14,969.54	73.21%
Fuel Oil	3,615.85	17.68%
Waste	1,423.56	6.96%
Diesel	428.62	2.10%
Coal	11.04	0.05%

[3] *Emissions from waste incineration and sludge incineration are included here.*
[4] *More details regarding waste incineration and sludge incineration can be found in the section under Waste.*

Electricity consumed in the same year was 44,200.6 gigawatt-hours (GWh). Consumption of electricity by various sectors is as shown[5].

End-Use Sector	Electricity Consumed (GWh)	% of Total Electricity Consumption
Industry-related	18,572.4	42.02%
Commerce & Service-related	16,366.1	37.02%
Household	6,629.5	15.00%
Transport-related	2,328.6	5.27%
Others	304.0	0.69%

Industry

The majority of the direct emissions from the industrial 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 industrial sector is as shown.

Fuel Type	Emissions (Gg CO_2eq)	% of Total Emissions from Industry
Refinery Gas	10,108.63	54.25%
Fuel Oil	3,611.53	19.38%
Natural Gas	3,102.90	16.65%
Diesel	1,260.39	6.76%
Petroleum Coke	446.42	2.40%
Liquefied Petroleum Gas	81.38	0.44%
Gas Works Gas	22.58	0.12%

Transport

In 2012, Singapore had a network of 3,426km of paved public roads and a population of 958,069 motor vehicles. 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 crafts plying within the waters of Singapore.

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

Sector	Fuel Type	Emissions (Gg CO_2eq)	% of Total Emissions from Transport
Transport (Land)	Diesel	4,193.43	58.33%
	Petrol	2,466.60	34.31%
	CNG	46.76	0.65%
Transport (Marine)	MGO/MDO used in harbour and pleasure craft	482.82	6.71%

[5] *Source: Energy Market Authority, Singapore Energy Statistics 2016, Table 3.2*

Commercial-Institutional and Residential

Emissions from the commercial and residential sectors were from the use of Liquefied Petroleum Gas (LPG) and Gas Works Gas[6], mainly for cooking and hot water systems. The breakdown of emissions by fuel type in the commercial and residential sectors is as shown.

Fuel Type	Emissions (Gg CO_2eq)	% of Total Emissions from Commercial-Institutional Sector
LPG	229.54	54.72%
Gas Works Gas	173.16	41.28%
Natural Gas	16.76	4.00%

Fuel Type	Emissions (Gg CO_2eq)	% of Total Emissions from Residential Sector
Gas Works Gas	132.10	63.32%
LPG	76.51	36.68%

INDUSTRIAL PROCESSES

In the semiconductor industry, although HFCs, PFCs and SF_6 were used in the manufacturing process, emission control technologies were installed in some processes. The breakdown of emissions by type of gas for industrial processes is as shown.

Type of Gas	Emissions (Gg CO_2eq)	% of Total Emissions from Industrial Processes
PFCs	930.83	87.97%
SF_6	89.33	8.44%
HFCs	37.92	3.59%

WASTE

Solid Waste Management

Singapore has adopted waste-to-energy incineration technology to reduce the volume of waste disposed at landfill since the 1970s. As heat from the incineration of waste is recovered to produce electricity, according to the Revised 1996 IPCC Guidelines, CO_2 and N_2O emissions from waste incineration are reported 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 off-shore Semakau Landfill. Hence, CH_4 emissions from the Semakau Landfill are insignificant.

According to the IPCC Guidelines, CH_4 emissions from waste incineration are not likely to be significant because of the combustion conditions in incinerators. N_2O emissions were estimated based on the amount of waste incinerated at the waste-to-energy incineration plants.

[6] *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.*

Sludge incineration

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[7]. As heat from the incineration of sludge is recovered to produce electricity, according to the Revised 1996 IPCC Guidelines, CH_4 and N_2O emissions from incineration of sludge are reported in the energy sector.

Wastewater handling

Used water is conveyed, via sewers, to water reclamation plants for treatment. This includes, among other processes, an activated sludge process. The sludge is further stabilised in digesters. The biogas produced in the digesters is used as fuel to generate electricity to power the operation of the treatment facilities. CO_2 produced from the combustion of biogas is not counted in the national inventory as it is part of the natural carbon cycle of decomposition. Fugitive CH_4 emission is negligible as all unused biogas is flared.

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)[8].

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

Gas	Emissions (Gg CO_2eq)	% of Total Emissions from Waste Sector
N_2O	104.62	69.68%
CH_4	45.53	30.32%

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. Some ornamental plants and fish are also grown and reared for export.

LAND USE, LAND-USE CHANGE AND FORESTRY

A system to capture removals and emissions from the Land Use, Land-Use Change and Forestry sector (LULUCF) has been initiated since 2013. The system is designed to ensure compliance following the approach under IPCC (2003) Good Practice Guidance on LULUCF. Where relevant, the most recent emission factors of the latest IPCC standards of 2006 and 2014 were incorporated if they were not included in or deviated from those of the IPCC (2003) GPG.

Estimation and reporting of the GHG removals and emissions were carried out for all land use and land-use change categories that exist in Singapore and assessment was made for all five carbon pools. The main land-use categories (Forest Land, Cropland and Settlements) were further subdivided for assessment of their respective contributions to the removals and emissions. The category grassland does not exist for Singapore. Any lawns and grassland patches are located in between infrastructure or stocked forests and

[7] *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 Sep 2010 to Dec 2010. The emissions were from the sludge incineration plant operated by ECO-SWM which was registered as a CDM project on 13 Sep 2010. From 2012 onwards, emissions from the incineration of sewage sludge were estimated by PUB based on the forward trend extrapolation of available data from 2010 and 2011.*

[8] *Singapore's 2012 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.*

in city parks and are accounted for under the Forest Land category or under Settlements. For all land-use change categories, the IPCC approach of estimating removals and emissions in all pools for a transition period of 20 years was applied. A complete time series of annual LULUCF emissions and removals for all pools for the time series 1990-2012 was estimated.

Methods employed in the assessment follow higher tier approaches, where required. The land use and land-use change matrix was assessed based on a wall-to-wall mapping using satellite images (IPCC Approach 3). The emission factors of all pools of subcategories which were expected to be significant were estimated with Tier 2 or 3 approaches and on basis of country specific data, resulting out of field measurement of tree biomass and soil inventory and estimated by modelling approaches. Country-specific carbon stocks in mangroves from published literature complemented the data. Biomass and soil carbon stocks of cropland were estimated on the basis of IPCC default values due to the insignificant share of this land-use category in Singapore.

The LULUCF sector represented a net carbon sink in Singapore in each year of the time series 1990 to 2012. The annual net removals in 2012 amounted to -239.21 Gg CO_2eq. A breakdown based on land-use category computed based on consolidation of the respective land-use changes and subcategories is represented below.

Land-Use Category	Annual Change in carbon stocks, Gg CO_2				CH_4 (Gg CO_2eq)	N_2O (Gg CO_2eq)
	Living Biomass	Dead Organic Matter	Soils	CO_2 removals/ emissions		
	A	B	C	D=A+B+C		
Forest Land	-143.34	-5.06	-22.02	-170.42	NO	NO
Cropland	-8.65	0.73	-2.31	-10.23	NO	0.02
Grassland	NO	NO	NO	NO	NO	NO
Wetlands	1.44	0.05	2.49	3.98	NO	NO
Settlements	-92.44	3.34	19.72	-69.38	NO	NO
Other Lands	3.51	0.01	3.30	6.82	NO	NO
TOTAL	**-239.48**	**-0.93**	**1.18**	**-239.23**	**NO**	**0.02**

KEY CATEGORY ANALYSIS

The 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gases Inventories recommends the use of the Key Category Analysis (KCA) to prioritise key categories in the national inventory. Key categories under the guidelines are sectors whose emissions when summed in descending order of magnitude add up to 95% of total GHG emissions.

All of Singapore's key categories originate from energy consumption activities which primarily produce CO_2 except the 10th key category which refers to emissions of PFCs from industrial processes. PFCs are used and emitted by companies which manufacture semiconductors and integrated circuits. The main contributor to GHG emissions (30.79%) is the combustion of natural gas to generate electricity.

Key Category Analysis						
	IPCC Category		Type of Greenhouse Gas	Emissions (kt CO_2eq)	Percentage Contribution	Cumulative
1	Energy and Transformation Industries	Natural Gas	CO_2	14,955.61	30.79%	30.79%
2	Industry	Refinery Gas	CO_2	10,108.63	20.81%	51.60%
3	Land Transport	Diesel	CO_2	4,122.95	8.49%	60.09%
4	Energy and Transformation Industries	Fuel Oil	CO_2	3,604.13	7.42%	67.51%
5	Industry	Fuel Oil	CO_2	3,600.81	7.41%	74.92%
6	Industry	Natural Gas	CO_2	3,095.42	6.37%	81.29%
7	Land Transport	Petrol	CO_2	2,296.85	4.73%	86.02%
8	Energy and Transformation Industries	Municipal Solid Waste[9]	CO_2	1,368.67	2.82%	88.84%
9	Industry	Diesel	CO_2	1,256.48	2.59%	91.43%
10	Industrial Processes	-	PFCs	930.83	1.92%	93.35%
11	Transport (Marine Craft)	Diesel	CO_2	480.91	0.99%	94.34%
12	Industry	Petroleum Coke	CO_2	445.40	0.92%	95.26%

UNCERTAINTY

Singapore's national inventory was assessed based on three levels of confidence as described in the Revised 1996 IPCC Guidelines, namely H for High confidence in estimation, M for Medium confidence in estimation and L for Low confidence in estimation.

99.2% of GHG data has a confidence level of either "medium" or "high". A large proportion of this data are emissions from fuel combustion. The collection of fuel combustion data through legislations under the Energy Market Authority and the National Environment Agency strengthened the confidence in the data and formed the basis for the high confidence in the GHG emissions. Data collected under surveys were assessed to be of medium confidence level. Quality control and quality assurance procedures outlined in the 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories were also applied to minimise human errors during inventory compilation and to ensure that the inventory is complete, accurate and consistent.

[9] *According to the IPCC Guidelines, CO_2 emissions from waste incineration are estimated from the portion of waste that is fossil fuel based.*

The categories that were assessed to be of lower confidence accounted for about 0.8% of total emissions/removals. The conservative level of confidence reflected the uncertainties for these emission estimates. Methodological issues such as the high uncertainties associated with IPCC default emission factors used for the calculation of CH_4 and N_2O emissions from the combustion of fuels and proxy data used to estimate N_2O emissions from wastewater handling[10] resulted in lower levels of confidence for those categories. A higher tier method was used to reduce the uncertainty in the emission estimates for CH_4 and N_2O from the combustion of fuels. 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 highest tier approaches are applied (as in the case of Singapore). The highly dynamic Settlement subcategories and the subcategory land-use change to Forest Land contribute most to the total uncertainty of the LULUCF sector.

Confidence Levels of Data		
Greenhouse Gas Source and Sink Categories	**Confidence Level**	**% of Total GHG Emissions/Removals**
All Energy		97.02%
Fuel Combustion		
Energy and transformation industries	H	42.10%
Industry	M	38.36%
Transport	M	14.80%
Commercial-institutional	H	0.86%
Residential	H	0.43%
Fugitive fuel emission		
Oil and natural gas systems	M	0.47%
Land Use, Land-Use Change and Forestry		0.49%
Land Use, Land-Use Change and Forestry	L	0.49%
Industrial Processes		2.18%
Integrated Circuit or Semiconductor Production	M	2.18%
Waste		0.31%
Wastewater handling	L	0.31%

[10] *Singapore's annual per capita protein intake is estimated using Southeast Asia's average per capita intake published by the Food and Agriculture Organization of the United Nations (FAO).*

Singapore is taking the lead in terms of raising the bar in energy efficiency, emissions management as well as accelerating the development of new, sustainable feedstock and technologies in partnership with industry through the Jurong Island version 2.0 initiative.

TIME SERIES OF GREENHOUSE GAS EMISSIONS (2000-2012)

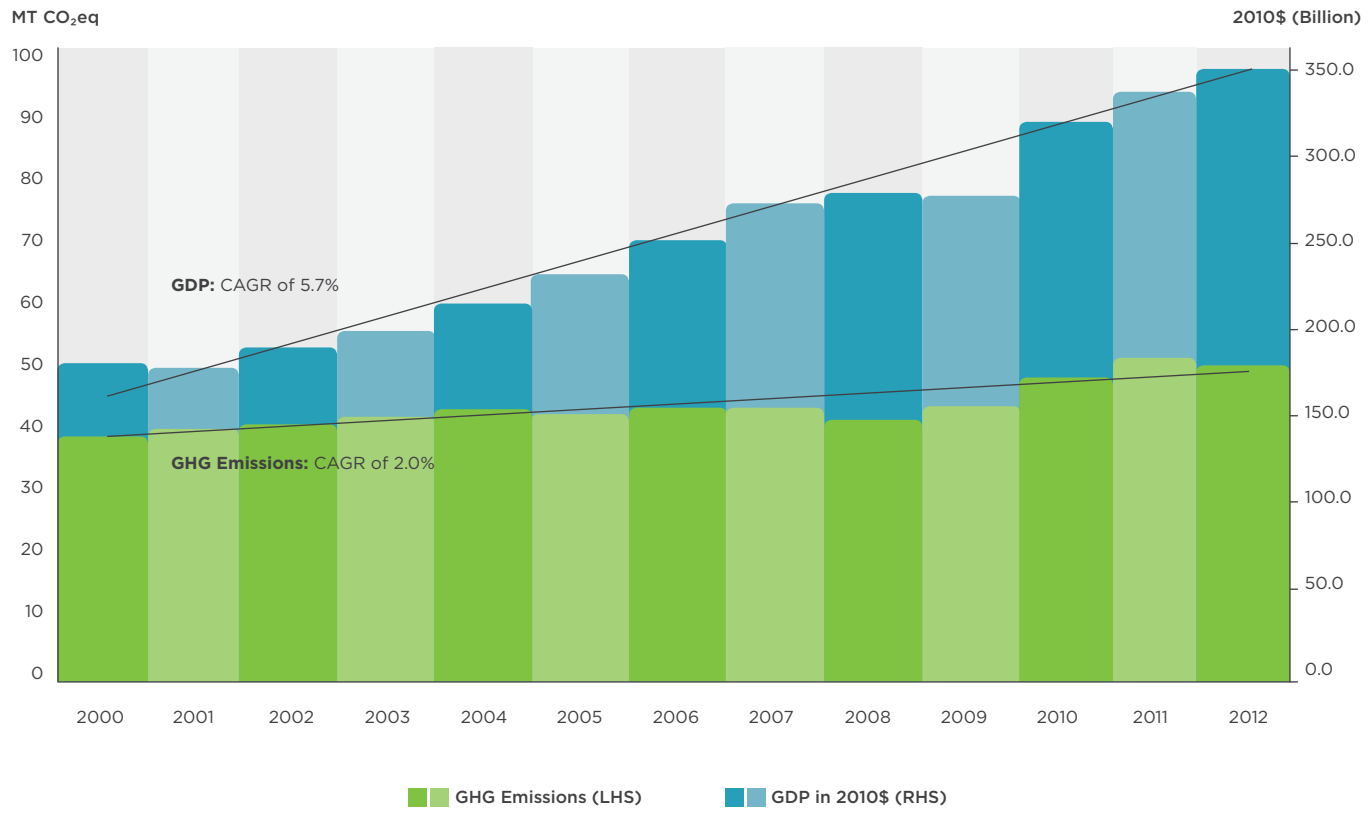
From 2000 to 2012, Singapore's economy grew at a compounded annual growth rate (CAGR) of 5.7%, while real GDP levels (in 2010 dollars) increased by 94% from S$183 billion in 2000 to S$355 billion in 2012. In the same period, Singapore's GHG emissions grew at a slower rate with a CAGR of 2.0%, or an increase of 26% (9,839 Gg CO_2eq) from 2000 to 2012.

As an open trade-oriented economy, Singapore's GDP growth volatility is much higher than that of larger economies[11]. As emissions attributable to economic activity makes up a large proportion of Singapore's emissions, 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 15.2% in 2010 after contracting by 0.6% in 2009.

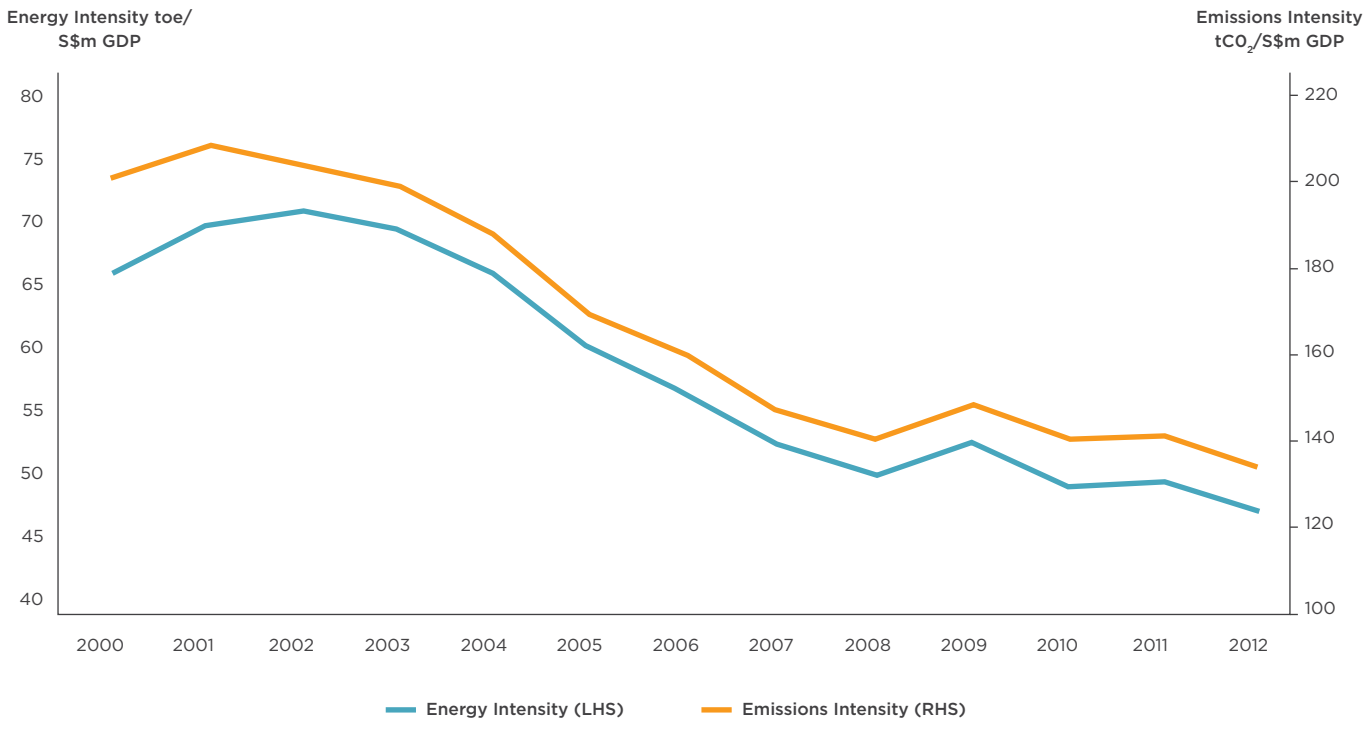
Overall, emissions intensity decreased by 35% from 2000 to 2012 while energy intensity decreased by 29%. Some of the key policy initiatives implemented during this period included a switch in fuel mix for electricity generation from fuel oil to natural gas which is a cleaner fuel source, as well as introducing various schemes promoting energy efficiency, such as the Green Mark Scheme for buildings, and the Grant for Energy Efficient Technologies (GREET) for industry.

[11] *"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 GREENHOUSE GAS EMISSIONS

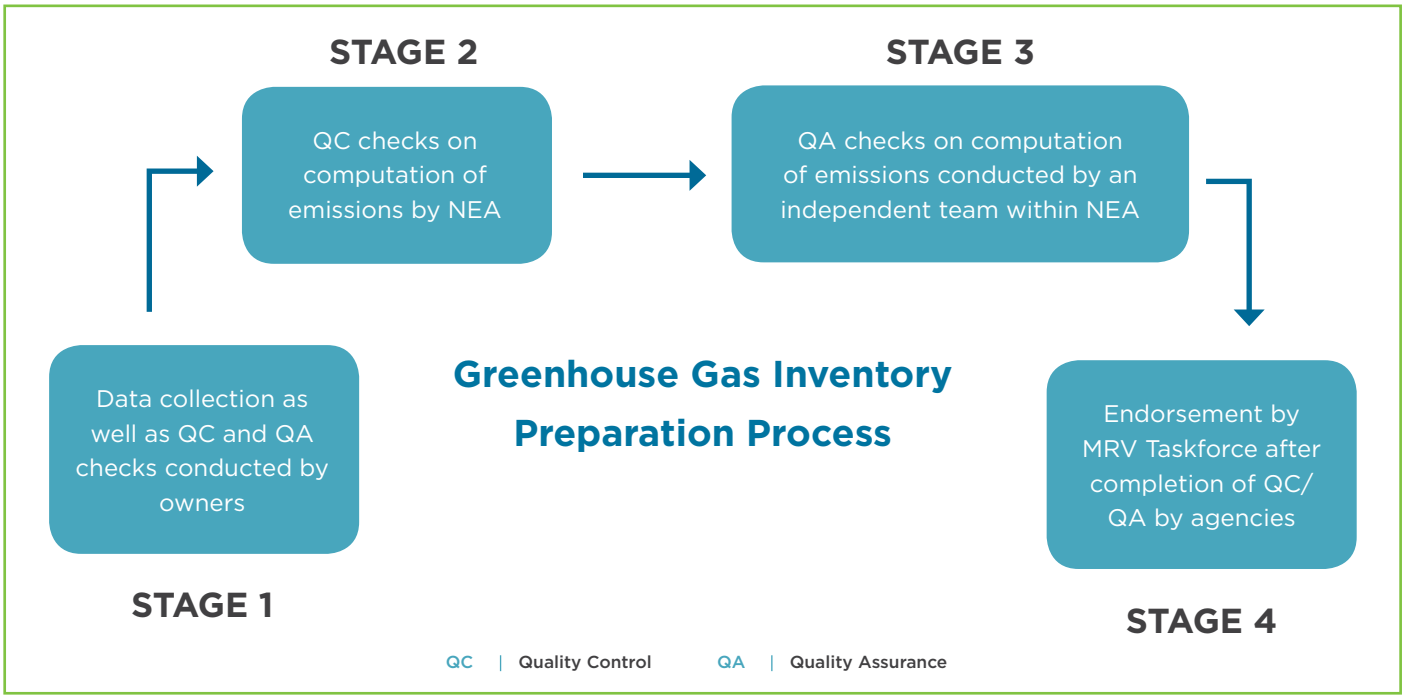


TIME SERIES OF ENERGY AND EMISSIONS INTENSITY



PREPARATION OF THE GREENHOUSE GAS INVENTORY

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



1) QUALITY CONTROL AND QUALITY ASSURANCE FOR THE COLLECTION / COMPILATION OF DATA

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

Sources of Data for Greenhouse Gas Inventory		
IPCC Sector	**Type of Greenhouse Gas**	**Data Owner**
Energy		
Electricity Generation	CO_2 , CH_4 , N_2O	Energy Market Authority
Industries		National Environment Agency Energy Market Authority
Land Transport		National Environment Agency Energy Market Authority Land Transport Authority
Transport (marine craft)		Maritime and Port Authority of Singapore
Commercial		Department of Statistics
Residential		Department of Statistics
Land Use, Land-Use Change and Forestry	CO_2 , N_2O	National Parks Board
Industrial Processes	HFCs , PFCs , SF_6	National Environment Agency
Waste		
Waste Incineration[12]	CO_2 , N_2O	National Environment Agency
Wastewater Handling	CH_4, N_2O	PUB, Singapore's national water agency, Food and Agriculture Organization of the United Nations (FAO)

[12] *According to the IPCC Guidelines, CO_2 and N_2O emissions from waste incineration are reported in the Energy sector.*

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

The system has been designed for efficient electronic data management and archiving of all data used in the estimation of emissions to ensure the continuity and security of the national GHG inventory. The data management functions of the system include archival and storage of past activity data and emissions 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.

QC for Data

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

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

QA for Data

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

2) QUALITY CONTROL FOR THE COMPUTATION OF EMISSIONS

GHG emissions are computed by the GHG inventory team within NEA based on the data provided by agencies, activity data and emission factors. For example, CO_2 emissions were computed from fuel consumption data and emission factors using the Revised 1996 IPCC Guidelines.

Quality control checks for the computation of GHG emissions were developed based on the 2000 IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. The quality control checks on emissions computed from source data are verified by persons who are not involved in the emission computation. These procedures help to minimise human errors during inventory compilation, and ensure the production of complete, accurate and consistent inventories. The quality control procedures that were conducted by the GHG inventory team within NEA are summarised overleaf.

Quality checks were 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 parameter 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 source 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.
	Undertake completeness checks	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.
	Internal documentation	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.
Comparison	Compare estimates to previous estimates	Analysed time series of totals. Highlighted and verified deviations for potential errors.

Key Category Analysis

A key category analysis is conducted for the GHG inventory to identify major sources of GHG emissions, so that the resources available for inventory preparation are prioritised for major sources of emissions (see preceding section). The analysis is performed for emission sources, in terms of CO_2eq emissions. Disaggregation to lower levels was not considered necessary as it splits important aggregated categories into small sub-categories that are no longer key.

3) QUALITY ASSURANCE FOR COMPUTATION OF EMISSIONS

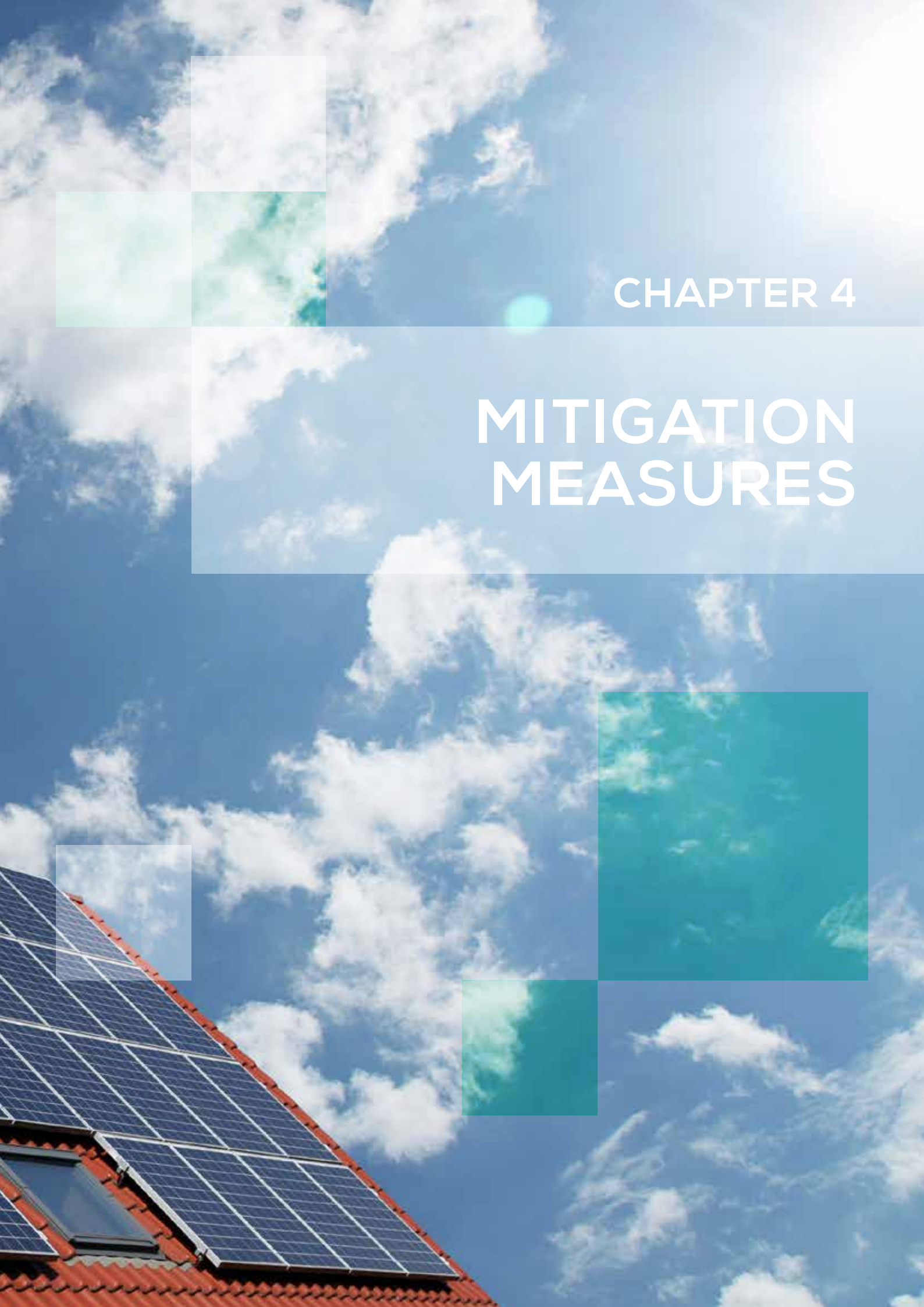
The quality assurance procedures comprise checking of transcription of data between databases, verification of data, emission factors, conversion factors and equations, including checking of the congruence of totals and sub-totals.

The computed emissions are verified by an independent NEA team that is not involved in the computation of the GHG emissions. This quality assurance team conducts a review of the inventory compilation process. The review involves the verifying 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 GHG inventory. Training is proposed as necessary for new and existing officers involved in the preparation of the national GHG inventory.

4) ENDORSEMENT

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

Among the alternative energy options available to Singapore, solar energy offers the most promising opportunity for Singapore.



CHAPTER 4

MITIGATION MEASURES

Mitigation Measures

To accelerate solar deployment in Singapore, the SolarNova programme has been launched to promote and aggregate solar demand across government agencies.

With the global agreement at COP-21 in Paris, Singapore is committed to reduce emissions by 16% below 2020 business-as-usual (BAU) level. 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 aims to reduce its Emissions Intensity by 36% from 2005 levels by 2030, and stabilise its emissions with the aim of peaking around 2030. These are challenging targets, given our limited potential for alternative energy sources that could reduce emissions on a significant scale.

SINGAPORE'S APPROACH TO REDUCING EMISSIONS

As reported in the previous chapter, the majority of Singapore's emissions are from the energy sector. 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 over-consumption, thus helping to control emissions.

Since 2005, 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 currently constitutes about 95% of our fuel mix for electricity generation. Although there are physical limits to the deployment of alternative or renewable energy sources in Singapore, we nonetheless continue to invest actively in the research, development, and demonstration (RD&D) of clean energy technologies, since the most direct way to reduce emissions is to cut down the use of fossil fuels.

Given Singapore's limited potential for alternative energy sources, improving energy efficiency is 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 Singapore 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.

The Energy Labelling Scheme for Appliances was introduced in 2008 to raise consumer awareness of the energy consumption of various household appliances.

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 reductions from registered projects implemented in non-Annex I Party to earn certified emission reductions (CER) credits, which could be used to offset emissions of Annex I Parties.

As of September 2016, Singapore has six registered CDM projects, which are estimated to reduce approximately 473 kt CO_2eq annually.

Information on the six registered CDM projects was reported earlier in Singapore's Third National Communication and First Biennial Update Report.

PARKROYAL on Pickering and the adjoining One Upper Pickering received the BCA Green Mark Platinum rating in 2012 and the Solar Pioneer Award.

DOMESTIC MEASUREMENT, REPORTING AND VERIFICATION

The domestic measurement, reporting and verification (dMRV) of Singapore's mitigation actions is a whole-of-government effort[13]. 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 are 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 annually. The lead agency for the power sector, Energy Market Authority (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 these data to monitor emissions from the electricity generation sector. The aggregated data is also available through EMA's annual statistical publication – the Singapore Energy Statistics.

Information collected by the lead agencies is consolidated by the Long Term Emissions and Mitigation Working Group secretariat annually. The Long Term Emissions and Mitigation Working Group will then assess the effect of the various mitigation measures and track Singapore's progress in meeting our mitigation pledge and objectives.

[13] *The agencies involved include the Ministry of the Environment and Water Resources, the Ministry of Transport, the Ministry of Trade and Industry, 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 (MT)	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** 4MT 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 about 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 about 95% in 2015.	Infrastructure development	4.0	Natural gas is expected to form more than 90% of Singapore's fuel mix for power generation in year 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 about 95% in 2015. Estimated abatement achieved in 2014: 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** Overall, Singapore plans 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 and Test-bedding (CERT) scheme and floating PV project. EDB also launched the SolarNova programme, which aims to accelerate solar deployment in Singapore by promoting and aggregating solar demand across government building and spaces.	Incentive, Technology	0.179	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.	CO_2	Installed Solar Capacity.	Estimated abatement achieved in 2014: 0.0150MT

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 (MT)	Methodologies and Assumptions	Gas coverage	Progress Indicators	Results Achieved
Co-generation plants	To encourage investment in co-generation plants.	Encouraging co-generation 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** One co-generation plant has been constructed with an estimated 157ktpa of abatement, while two co-generation plants are currently under construction with an estimated 331ktpa of abatement. A fourth co-generation plant is expected to be constructed in the period 2016-2020.	Incentive	0.67-0.73	0.67-0.73MT of carbon mitigation by 2020 is assumed to be delivered by 3 to 4 co-generation plants in the petroleum and petrochemical sector. Carbon mitigation achieved per co-generation 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 co-generation plants, total funding given out, abatement achieved calculated through data collection/ audits.	Estimated abatement achieved in 2014: 0.488MT
Manufacturing Energy Efficiency	To encourage Energy Efficiency (EE) and consequently reduce emissions from the manufacturing sector.	Encouraging EE retrofits in the manufacturing sector through incentives, and conducting a pilot on private sector financing of EE projects.	**Ongoing** 472ktpa of carbon abatement has been achieved through the Grant for Energy Efficient Technologies (GREET), tax incentives, and other supporting schemes such as the Energy Efficiency Improvement Assistance (EASe) and Design for Efficiency (DfE) schemes.	Incentive	0.31-0.40	Abatement assumed to be 1% above BAU levels for a period of 3 years for 90% of manufacturing sector. Abatement arising from GREET and tax incentives will be audited by Professional Engineers or Qualified Energy Services Specialists shortly after the commissioning period. All other incentives verified by company voluntary reporting.	CO_2	Total funding given out, abatement achieved calculated through data collection/ audits.	Estimated abatement achieved in 2014: 0.472MT

Mitigation Action	Objectives	Description	Progress of Implementation/ Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal (MT)	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** 70ktpa carbon abatement has been achieved with the investment of two woodchip boilers totalling 60 tons per hour of steam production capacity.	Incentive	0.07	Abatement calculated based on company feedback and announced publicly by company.	CO_2	Abatement achieved calculated through data collection/ audits.	Estimated abatement achieved in 2014: 0.07MT
Data Centre EE	To encourage EE and consequently reduce emissions from data centres.	Encouraging EE retrofits in data centres through incentives.	**Ongoing** Since 2012, investment allowances have been made available to green Data Centres (DCs).	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 2014: 0.000283 MT

Table 3 | Greening Buildings

Mitigation Action	Objectives	Description	Progress of Implementation/Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal (MT)	Methodologies and Assumptions	Gas coverage	Progress Indicators	Results Achieved
Green Mark new buildings	To improve energy efficiency of new buildings.	Legislating new building owners to achieve minimum Green Mark (GM) standard and incentivising building owners to achieve GM rating beyond the minimum standard through the Green Mark Incentive Scheme for New Buildings (fully committed). Developments in identified key strategic areas are required to achieve higher GM rating of Goldplus or Platinum.	**Ongoing** Since 2008, new building owners have been required by legislation to achieve minimum Green Mark (GM) standards. The four GM ratings are: Certified/ Gold/ Goldplus/ Platinum, differentiated by a set of criteria relating to green initiatives and energy savings of the building. In addition, stricter GM standards have been imposed in land sales conditions for certain areas, e.g. Marina Bay, Jurong Lake. The $20mil Green Mark Incentive Scheme (fully committed) and Green Mark Gross Floor Area Incentive Scheme have also been introduced to encourage greater efficiency in new buildings. As of Jan 2016, there were close to 2,600 new and existing buildings that has met BCA Green Mark standard, accounting for more than 30% of total built-up area in Singapore.	Legislation and Incentives	0.47	The target 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 using the Building Energy Submission System (BESS).	Estimated abatement achieved in 2014: 0.364MT
Green Mark existing buildings	To improve energy efficiency of existing buildings.	Legislating existing building owners to improve the energy efficiency of their facilities when undergoing major retrofits to achieve minimum GM standards and incentivising building owners to achieve GM rating beyond the minimum standard through fiscal measures.	**Ongoing** Existing buildings are required by legislation to achieve minimum Green Mark (GM) standard when they undergo major retrofits. In addition, existing office, hotel and retail buildings are required to submit building energy consumption annually. Prescribed building types are also required to submit energy audits on building-cooling systems every 3 years. To incentivise further EE improvements in existing buildings, $100 million has been set aside to co-fund up to 50% (capped at $3mil) of EE investments for existing buildings (upgrading and retrofitting components have been fully committed) and a Building Retrofit Energy Efficiency Financing (BREEF) scheme was also introduced to provide financing options to building owners, to address the high upfront costs required.	Legislation and Incentives	0.40-1.08	The target abatement is calculated by the difference between the BAU emission values (i.e. no legislation) projected for the existing building stock in 2020, and the emission values after legislation has been implemented.	CO_2	As above.	Estimated abatement achieved in 2014: 0.131MT

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 (MT)	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 motorised travel.	Various infrastructural improvements such as expanding the rail and bus network, better planning (e.g. integrated transport hubs), bus priority measures; and managing travel demand as detailed in the Land Transport Master Plan 2013.	**Ongoing** The current rail network comprises 200km of MRT and LRT lines. We will increase this to 360 km by 2030. By then, 8 in 10 households will be within a 10-minute walk of a rail station. The Bus Service Enhancement Programme (BSEP) was introduced in 2012 to increase the bus fleet, and improve capacity and service standards. Together with the buses injected by the public transport operators, as well as the City Direct Services (CDS) and Peak Period Short Services (PPSS) run by private bus operators, this will increase Singapore's total bus fleet available for public bus services by 35% by 2017. With these improvements, we expect the public transport mode share to improve from 66% in 2015 to 75% in 2030. By 2017, we will add another 200 buses and amend or add around 17 bus services to improve connectivity. At the same time, we will continue our early measures to manage ownership and usage of private cars through various fees and taxes to reflect the competing needs for our scarce land. Prospective car owners will continue to bid and pay for limited permits (called "Certificates of Entitlement") whose numbers are controlled in accordance with the sustainable vehicle population growth rate. Electronic Road Pricing where vehicles pay a charge for using congested roads during specific periods will be upgraded to allow for locational and distance-based pricing to improve efficiency and equity.	Combination of infrastructure, regulations, incentives, technology and education	0.78MT of abatement is expected from a public-private transport modal split improvement in 2020 from 55:45 in the BAU case to 70:30.	Mitigation effect of public transport modal split is calculated as the difference between the total energy per GHG for the projected BAU travel demand and the modal split and the actual travel demand and the modal split.	CO_2	Public transport modal share.	Estimated abatement achieved in 2014: 0.38MT

Mitigation Action	Objectives	Description	Progress of Implementation/Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal (MT)	Methodologies and Assumptions	Gas coverage	Progress Indicators	Results Achieved
Promoting Off-Peak Cars and non-motorised transport, e.g. / walking and cycling	To reduce reliance on cars as a means of transport.	Implementing schemes that limit use of cars to off-peak periods, and rolling out various initiatives that encourage walking and cycling.	**Ongoing** The Revised Off-Peak Car (ROPC), Off-Peak Car (OPC) and Weekend Car (WEC) Schemes offer car owners savings on car registration-related fees and road taxes in return for reduced usage. In 2015, the number of off-peak cars was 5.1% of the total car population, which was an increase from the 3.0% in 2005. To encourage more non-motorised transport, 61.9km of cycling paths have been constructed as of August 2016. Cycling path networks have been completed in five towns (Tampines, Sembawang, Pasir Ris, Yishun and Changi - Simei). Moreover, to make Singapore a walkable city, more than 200km of sheltered walkways will be built by 2018 under the Walk2Ride programme. In addition, an Active Mobility Advisory Panel has been set up to propose rules and norms to facilitate the use of footpaths and cycling paths safely and harmoniously. The Government has accepted all the recommendations on the Rules and Code of Conduct for Cycling and the Use of Personal Mobility Devices (PMDs) recommended by the Active Mobility Advisory Panel in April 2016.	Combination of infrastructure, incentives and education	0.16-0.20	Abatement calculated based on the number of off-peak cars and the difference between the average carbon emissions of a normal car compared to those of an OPC.	CO_2	OPC take-up rate.	Estimated abatement achieved in 2014: 0.05MT
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).	**Ongoing** The CEVS was implemented in 2013 and enhanced in 2015 by increasing the maximum rebate/ surcharge and tightening of emissions standards. Taxis are given higher rebates or surcharges for each of the bands because of their higher average annual mileage.	Legislation and Incentive	0.67	Mitigation effect of CEVS is calculated based on the increased quantity of cars purchased in the lower-carbon band, compared to the historical rates, and the average carbon emission reduction between the CEVS bands.	CO_2	Increase in registration of cars in low-carbon bands and reduction in registration of cars in the high-carbon bands.	Estimated abatement achieved in 2014: 0.05MT
Green Technology Programme (GTP)	To encourage local maritime companies to develop and adopt green technologies.	Providing grants to Singapore-registered companies engaging in maritime related businesses like terminal operations, ship owning and/ or operations and harbour craft operations to co-fund the development and adoption of green technological solutions.	**Ongoing** Projects approved by the Green Technology Programme are ongoing. When completed, a review will be conducted to determine whether the green technologies adopted under this programme can be successfully implemented on a larger scale.	Incentive	0.10 (subject to review based on take-up rates of projects)	Abatement will be calculated based on specific information from each project and monitored for take-ups.	CO_2, SO_x, NO_x	Take-up rates of various programmes.	Estimated abatement achieved in 2014: 0.01MT

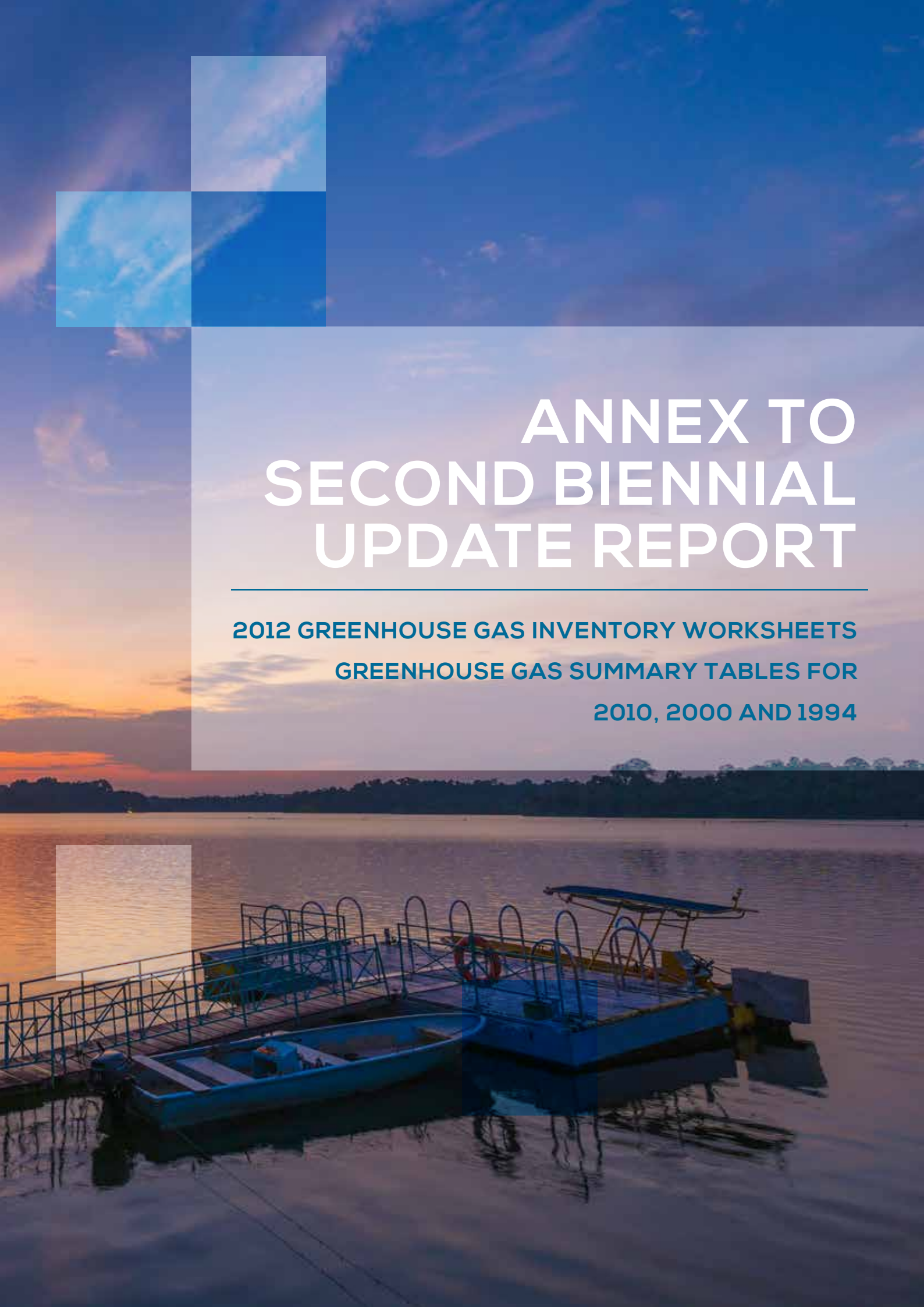
Table 5 | Improving Energy Performance Standards of Household Appliances and Promoting Energy Efficiency to Households

Mitigation Action	Objectives	Description	Progress of Implementation/Steps taken or envisaged to achieve action	Nature of Action	2020 Quantitative Goal (MT)	Methodologies and Assumptions	Gas coverage	Progress Indicators	Results Achieved
Minimum Energy Performance Standards (MEPS) for household appliances – e.g. air-cons, fridges, lighting, clothes dryers	To improve the overall energy efficiency (EE) of appliances in the market.	Disallowing the supply of inefficient appliances that fall short of specified minimum EE levels.	**Ongoing** MEPS for air-conditioners and fridges were implemented in September 2011 and raised in September 2013. MEPS for air-conditioners will be further raised in 2016. MEPS for clothes dryers were implemented in April 2014. MEPS for general lighting were implemented in July 2015.	Legislation	0.71-0.79	The carbon emissions arise from the energy use of home appliances. The emissions in two scenarios are calculated, the BAU and the Policy scenarios. 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 annual energy consumption and 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 2014: 0.44MT* *MEPS commenced in 2011.
Promotion of energy efficiency to households	To promote EE to households.	Promoting the purchase of energy efficient appliances through the Mandatory Energy Labelling Scheme (MELS) for household appliances and outreach efforts.	**Ongoing** MELS for air-conditioners and fridges were introduced in 2008 and extended to clothes dryers in 2009, televisions in 2014 and general lighting in 2015. Household EE awareness programmes (e.g. media publicity, energy-saving contests, EE 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 (MT)	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 off at landfills.	**Ongoing** Since 2009, ECO Special Waste Management and Sumitomo Mitsui Bank Corporation have been contracted 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 at landfill site and ECO-SWM).	CH_4	Amount of sludge incinerated.	Estimated abatement achieved in 2014: 0.08MT
Increase overall recycling rate	To increase the overall recycling rate to 65% by 2020. The overall recycling rate in 2014 was 60%.	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.	CO_2, N_2O	Recycling rate	Estimated abatement achieved in 2014: NIL
		Right waste disposal pricing.	Currently under evaluation.	Market-based instrument					

Upper Seletar Reservoir, one of the 17 reservoirs in Singapore.



ANNEX TO SECOND BIENNIAL UPDATE REPORT

2012 GREENHOUSE GAS INVENTORY WORKSHEETS

GREENHOUSE GAS SUMMARY TABLES FOR 2010, 2000 AND 1994

2012 Greenhouse Gas Inventory

1A1 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

		STEP 1	STEP 2		STEP 3		
		A	B	C	D	E	F
		Consumption	Conversion Factor	Consumption [C=AxB]	Carbon Emission Factor	Carbon Content [E=CxD]	Carbon Content [F=E/1000]
Fuel Types	Unit	Actual	1996 IPCC	Actual	1996 IPCC		
		(quantity)	(TJ/unit)	(TJ)	(tC / TJ)	(t C)	(Gg C)
Energy Industry							
Liquid Fuels							
Crude Oil	Kt						
Ethane	Kt						
Gas/Diesel Oil	Kt	134.45	43.33	5,825.59	20.20	117,676.89	117.68
Gasoline	Kt						
Jet Kerosene	Kt						
Liquefied Petroleum Gases (LPG)	Kt						
Lubricants	Kt						
Naphtha	Kt						
Natural Gas Liquids	Kt						
Orimulsion	Kt						
Other Kerosene	Kt						
Petroleum Coke	Kt						
Refinery Gas	Kt						
Residual Fuel Oil	Kt	1,170.83	40.19	47,055.58	21.10	992,872.68	992.87
Solid Fuels							
Anthracite	Kt						
Blast Furnace Gas	Kt						
Brown Coal Briquettes	Kt						
Coke Oven Coke	Kt						
Coke Oven Gas	Kt						
Coking Coal	Kt						
Gas Coke	Kt						
Gas Works Gas	GWh						
Lignite	Kt						
Other Bituminous Coal	Kt	4.24	28.00	118.61	25.80	3,060.09	3.06
Patent Fuel	Kt						
Peat	Kt						
Sub-Bituminous Coal	Kt						
Natural Gas							
Natural Gas (Dry)	Ktoe	6,399.35	41.86	267,928.04	15.30	4,099,299.08	4,099.30
Other Fossil-Based Fuels							
Industrial Waste	Kt						
Municipal Solid Waste	Kt						
Memo Items							
Gaseous Biomass	Kt						
Liquid Biomass	Kt						

1A1 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

		STEP 4			STEP 5		STEP 6
		G	H	I	J	K	L
		Fraction of Carbon Stored	Carbon Stored [H=FxG]	Net Carbon Emissions [I=F-H]	Fraction of Carbon Oxidised	Actual Carbon Emissions [K=IxJ]	Actual CO_2 Emissions [L=Kx44/12]
Fuel Types	Unit	1996 IPCC			1996 IPCC		Actual
			(Gg C)	(Gg C)		(Gg C)	(Gg CO_2)
Energy Industry							**18,997.90**
Liquid Fuels							
Crude Oil	Kt						
Ethane	Kt						
Gas/Diesel Oil	Kt	0	0	117.68	0.99	116.50	427.17
Gasoline	Kt						
Jet Kerosene	Kt						
Liquefied Petroleum Gases (LPG)	Kt						
Lubricants	Kt						
Naphtha	Kt						
Natural Gas Liquids	Kt						
Orimulsion	Kt						
Other Kerosene	Kt						
Petroleum Coke	Kt						
Refinery Gas	Kt						
Residual Fuel Oil	Kt	0	0	992.87	0.99	982.94	3,604.13
Solid Fuels							
Anthracite	Kt						
Blast Furnace Gas	Kt						
Brown Coal Briquettes	Kt						
Coke Oven Coke	Kt						
Coke Oven Gas	Kt						
Coking Coal	Kt						
Gas Coke	Kt						
Gas Works Gas	GWh						
Lignite	Kt						
Other Bituminous Coal	Kt	0	0	3.06	0.98	2.99	10.99
Patent Fuel	Kt						
Peat	Kt						
Sub-Bituminous Coal	Kt						
Natural Gas							
Natural Gas (Dry)	Ktoe	0	0	4,099.30	1.00	4,078.80	14,955.61
Other Fossil-Based Fuels							
Industrial Waste	Kt						
Municipal Solid Waste	Kt						
Memo Items							
Gaseous Biomass	Kt						
Liquid Biomass	Kt						

1A2 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

		STEP 1	STEP 2		STEP 3		
		A	B	C	D	E	F
		Consumption	Conversion Factor	Consumption [C=AxB]	Carbon Emission Factor	Carbon Content [E=CxD]	Carbon Content [F=E/1000]
Fuel Types	Unit	Actual	1996 IPCC	Actual	1996 IPCC		
		(quantity)	(TJ/unit)	(TJ)	(tC / TJ)	(t C)	(Gg C)
Manufacturing Industries and Construction							
Liquid Fuels							
Crude Oil	Kt						
Ethane	Kt						
Gas/Diesel Oil	Kt	395.47	43.33	17,135.59	20.20	346,138.82	346.14
Gasoline	Kt						
Jet Kerosene	Kt						
Liquefied Petroleum Gases (LPG)	Kt	27.55	47.31	1,303.44	17.20	22,419.13	22.42
Lubricants	Kt						
Naphtha	Kt						
Natural Gas Liquids	Kt						
Orimulsion	Kt						
Other Kerosene	Kt						
Petroleum Coke	Kt	143.93	31.00	4,461.80	27.50	122,699.47	122.70
Refinery Gas	Kt	3,177.74	48.15	153,008.03	18.20	2,784,746.22	2,784.75
Residual Fuel Oil	Kt	1,169.75	40.19	47,012.25	21.10	991,958.53	991.96
Solid Fuels							
Anthracite	Kt						
Blast Furnace Gas	Kt						
Brown Coal Briquettes	Kt						
Coke Oven Coke	Kt						
Coke Oven Gas	Kt						
Coking Coal	Kt						
Gas Coke	Kt						
Gas Works Gas	GWh	113.10	3.6	407.17	15.2	6,189.05	6.19
Lignite	Kt						
Other Bituminous Coal	Kt						
Patent Fuel	Kt						
Peat	Kt						
Sub-Bituminous Coal	Kt						
Natural Gas							
Natural Gas (Dry)	Ktoe	1,324.50	41.86	55,454.17	15.30	848,448.74	848.45
Other Fossil-Based Fuels							
Industrial Waste	Kt						
Municipal Solid Waste	Kt						
Memo Items							
Gaseous Biomass	Kt						
Liquid Biomass	Kt						

1A2 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

		STEP 4			STEP 5		STEP 6
		G	H	I	J	K	L
		Fraction of Carbon Stored	Carbon Stored [H=FxG]	Net Carbon Emissions [I=F-H]	Fraction of Carbon Oxidised	Actual Carbon Emissions [K=IxJ]	Actual CO_2 Emissions [L=Kx44/12]
Fuel Types	Unit	1996 IPCC			1996 IPCC		Actual
			(Gg C)	(Gg C)		(Gg C)	(Gg CO_2)
Manufacturing Industries and Construction							**18,610.71**
Liquid Fuels							
Crude Oil	Kt						
Ethane	Kt						
Gas/Diesel Oil	Kt	0	0	346.14	0.99	342.68	1,256.48
Gasoline	Kt						
Jet Kerosene	Kt						
Liquefied Petroleum Gases (LPG)	Kt	0	0	22.42	0.99	22.19	81.38
Lubricants	Kt						
Naphtha	Kt						
Natural Gas Liquids	Kt						
Orimulsion	Kt						
Other Kerosene	Kt						
Petroleum Coke	Kt	0	0	122.70	0.99	121.47	445.40
Refinery Gas	Kt	0	0	2,784.75	0.99	2,756.90	10,108.63
Residual Fuel Oil	Kt	0	0	991.96	0.99	982.04	3,600.81
Solid Fuels							
Anthracite	Kt						
Blast Furnace Gas	Kt						
Brown Coal Briquettes	Kt						
Coke Oven Coke	Kt						
Coke Oven Gas	Kt						
Coking Coal	Kt						
Gas Coke	Kt						
Gas Works Gas	GWh	0	0	6.19	0.995	6.16	22.58
Lignite	Kt						
Other Bituminous Coal	Kt						
Patent Fuel	Kt						
Peat	Kt						
Sub-Bituminous Coal	Kt						
Natural Gas							
Natural Gas (Dry)	Ktoe	0	0	848.45	0.995	844.21	3,095.42
Other Fossil-Based Fuels							
Industrial Waste	Kt						
Municipal Solid Waste	Kt						
Memo Items							
Gaseous Biomass	Kt						
Liquid Biomass	Kt						

1A3 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

		STEP 1	STEP 2		STEP 3		
		A	B	C	D	E	F
		Consumption	Conversion Factor	Consumption [C=AxB]	Carbon Emission Factor	Carbon Content [E=CxD]	Carbon Content [F=E/1000]
Fuel Types	Unit	Actual	1996 IPCC	Actual	1996 IPCC		
		(quantity)	(TJ/unit)	(TJ)	(tC / TJ)	(t C)	(Gg C)
Transport							
Road Transport							
Gas/Diesel Oil	Kt	1,297.66	43.33	56,227.61	20.20	1,135,797.68	1,135.80
Gasoline	Kt	747.28	44.80	33,478.32	18.90	632,740.31	632.74
Liquefied Petroleum Gases (LPG)	Kt						
Natural Gas (Dry)	Ktoe	19.63	41.868	821.79	15.30	12,573.31	12.57
Rail Transport							
Anthracite	Kt						
Coke Oven Coke	Kt						
Gas/Diesel Oil	Kt						
Other Bituminous Coal	Kt						
Residual Fuel Oil	Kt						
Pipeline Transport							
Natural Gas (Dry)	Ktoe						
National Navigation							
Gas/Diesel Oil	Kt	151.36	43.33	6,558.56	20.20	132,482.89	132.48
Gasoline	Kt						
Lubricants	Kt						
Residual Fuel Oil	Kt						
Sub-Bituminous Coal	Kt						
Domestic Aviation							
Gasoline	Kt						
Jet Kerosene	Kt						
Memo Items							
Liquid Biomass	Kt						

1A3 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

Fuel Types	Unit	STEP 4			STEP 5		STEP 6
		G	H	I	J	K	L
		Fraction of Carbon Stored	Carbon Stored [H=FxG]	Net Carbon Emissions [I=F-H]	Fraction of Carbon Oxidised	Actual Carbon Emissions [K=IxJ]	Actual CO_2 Emissions [L=Kx44/12]
		1996 IPCC			1996 IPCC		Actual
			(Gg C)	(Gg C)		(Gg C)	(Gg CO_2)
Transport							**6,946.58**
Road Transport							
Gas/Diesel Oil	Kt	0	0	1,135.80	0.99	1,124.44	4,122.95
Gasoline	Kt	0	0	632.74	0.99	626.41	2,296.85
Liquefied Petroleum Gases (LPG)	Kt						
Natural Gas (Dry)	Ktoe	0	0	12.57	0.995	12.51	45.87
Rail Transport							
Anthracite	Kt						
Coke Oven Coke	Kt						
Gas/Diesel Oil	Kt						
Other Bituminous Coal	Kt						
Residual Fuel Oil	Kt						
Pipeline Transport							
Natural Gas (Dry)	Ktoe						
National Navigation							
Gas/Diesel Oil	Kt	0	0	132.49	0.99	131.16	480.91
Gasoline	Kt						
Lubricants	Kt						
Residual Fuel Oil	Kt						
Sub-Bituminous Coal	Kt						
Domestic Aviation							
Gasoline	Kt						
Jet Kerosene	Kt						
Memo Items							
Liquid Biomass	Kt						

1A4 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

		STEP 1	STEP 2		STEP 3		
		A	B	C	D	E	F
		Consumption	Conversion Factor	Consumption [C=AxB]	Carbon Emission Factor	Carbon Content [E=CxD]	Carbon Content [F=E/1000]
Fuel Types	Unit	Actual	1996 IPCC	Actual	1996 IPCC		
		(quantity)	(TJ/unit)	(TJ)	(tC / TJ)	(t C)	(Gg C)
Commercial / Institutional Sector							
Liquid Fuels							
Gas/Diesel Oil	Kt						
Gasoline	Kt						
Jet Kerosene	Kt						
Liquefied Petroleum Gases (LPG)	Kt	77.71	47.31	3,676.34	17.20	63,233.08	63.23
Other Kerosene	Kt						
Residual Fuel Oil	Kt						
Solid Fuels							
Anthracite	Kt						
Brown Coal Briquettes	Kt						
Coke Oven Coke	Kt						
Coke Oven Gas	Kt						
Gas Works Gas	GWh	867.35	3.60	3,122.47	15.2	47,461.50	47.46
Lignite	Kt						
Other Bituminous Coal	Kt						
Natural Gas							
Natural Gas (Dry)	Ktoe	7.15	41.87	299.52	15.30	4,582.71	4.58
Memo Items							
Gaseous Biomass	Kt						
Liquid Biomass	Kt						

1A4 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

Fuel Types	Unit	STEP 4 G: Fraction of Carbon Stored (1996 IPCC)	STEP 4 H: Carbon Stored [H=FxG] (Gg C)	STEP 4 I: Net Carbon Emissions [I=F-H] (Gg C)	STEP 5 J: Fraction of Carbon Oxidised (1996 IPCC)	STEP 5 K: Actual Carbon Emissions [K=IxJ] (Gg C)	STEP 6 L: Actual CO_2 Emissions [L=Kx44/12] (Actual) (Gg CO_2)
Commercial / Institutional Sector							**419.41**
Liquid Fuels							
Gas/Diesel Oil	Kt						
Gasoline	Kt						
Jet Kerosene	Kt						
Liquefied Petroleum Gases (LPG)	Kt	0	0	63.23	0.99	62.60	229.54
Other Kerosene	Kt						
Residual Fuel Oil	Kt						
Solid Fuels							
Anthracite	Kt						
Brown Coal Briquettes	Kt						
Coke Oven Coke	Kt						
Coke Oven Gas	Kt						
Gas Works Gas	GWh	0	0	47.46	0.995	47.22	173.16
Lignite	Kt						
Other Bituminous Coal	Kt						
Natural Gas							
Natural Gas (Dry)	Ktoe	0	0	4.58	0.995	4.56	16.72
Memo Items							
Gaseous Biomass	Kt						
Liquid Biomass	Kt						

1A4 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

		STEP 1	STEP 2		STEP 3		
		A	B	C	D	E	F
		Consumption	Conversion Factor	Consumption [C=AxB]	Carbon Emission Factor	Carbon Content [E=CxD]	Carbon Content [F=E/1000]
Fuel Types	Unit	Actual	1996 IPCC	Actual	1996 IPCC		
		(quantity)	(TJ/unit)	(TJ)	(tC / TJ)	(t C)	(Gg C)
Residential Sector							
Liquid Fuels							
Gas/Diesel Oil	Kt						
Gasoline	Kt						
Jet Kerosene	Kt						
Liquefied Petroleum Gases (LPG)	Kt	25.90	47.31	1,225.45	17.20	21,077.69	21.08
Other Kerosene	Kt						
Residual Fuel Oil	Kt						
Solid Fuels							
Anthracite	Kt						
Brown Coal Briquettes	Kt						
Coke Oven Coke	Kt						
Coke Oven Gas	Kt						
Gas Works Gas	GWh	661.70	3.60	2,382.10	15.20	36,207.95	36.21
Lignite	Kt						
Other Bituminous Coal	Kt						
Patent Fuel	Kt						
Peat	Kt						
Sub-Bituminous Coal	Kt						
Natural Gas							
Natural Gas (Dry)	Ktoe						
Memo Items							
Gaseous Biomass	Kt						
Liquid Biomass	Kt						

NOTE

1. *Data on international bunker fuels have been reported in a separate memo to the UNFCCC as emissions from such bunker fuels are to be excluded from the national greenhouse gas totals.*
2. *IPCC default factors are used except for the Emission Factor for Gas Works Gas (15.2) which is a country-specific factor.*
3. *According to the IPCC Guidelines, autoproducers are classified under the Industry Sector.*
4. *Natural Gas data which is obtained from EMA in ktoe is multiplied by 0.9 to correct the gross calorific value (GCV) into the net calorific value (NCV), in line with the Revised 1996 IPCC Guidelines.*
5. *Transformation losses from the production of Gas Works Gas are included under the fuel type "Natural Gas" in the Industry Sector.*
6. *Emissions from the combustion of Synthesis Gas are included under the fuel type "Refinery Gas" in the Industry Sector.*
7. *Gas Works Gas was mainly produced from Natural Gas in Singapore.*

1A4 - CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

Fuel Types	Unit	STEP 4 G: Fraction of Carbon Stored (1996 IPCC)	STEP 4 H: Carbon Stored [H=FxG] (Gg C)	STEP 4 I: Net Carbon Emissions [I=F-H] (Gg C)	STEP 5 J: Fraction of Carbon Oxidised (1996 IPCC)	STEP 5 K: Actual Carbon Emissions [K=IxJ] (Gg C)	STEP 6 L: Actual CO_2 Emissions [L=Kx44/12] (Gg CO_2)
Residential Sector							**208.61**
Liquid Fuels							
Gas/Diesel Oil	Kt						
Gasoline	Kt						
Jet Kerosene	Kt						
Liquefied Petroleum Gases (LPG)	Kt	0	0	21.08	0.99	20.87	76.51
Other Kerosene	Kt						
Residual Fuel Oil	Kt						
Solid Fuels							
Anthracite	Kt						
Brown Coal Briquettes	Kt						
Coke Oven Coke	Kt						
Coke Oven Gas	Kt						
Gas Works Gas	GWh	0	0	36.21	0.995	36.03	132.10
Lignite	Kt						
Other Bituminous Coal	Kt						
Patent Fuel	Kt						
Peat	Kt						
Sub-Bituminous Coal	Kt						
Natural Gas							
Natural Gas (Dry)	Ktoe						
Memo Items							
Gaseous Biomass	Kt						
Liquid Biomass	Kt						

1A - NON-CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

			STEP 1						STEP 2						
			Fuel Consumption (TJ)						Emission Factors (kg/TJ)						
			A1	A2	A3		A4	A5	A6	B1	B2	B3		B4	B5	B6
Activity			Coal	Natural Gas	Oil		Wood / Wood Waste	Charcoal	Other Biomass and Wastes	Coal	Natural Gas	Oil		Wood / Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries			118.61	267,928.04	52,881.17					1	1	3		30	200	30
Manufacturing Industries and Construction				54,980.64	68,609.64					10	5	2		30	200	30
Transport	Domestic Aviation[a]					0.00							0.5			
	Road				Gasoline	Diesel						Gasoline	Diesel			
				821.79							50	20	5			
	Railways				0.00					10		5				
	National Navigation[a]				6,558.56					10		5				
Other Sectors	Commercial/Institutional			299.52						10	5	10		300	200	300
	Residential									300	5	10		300	200	300
	Agriculture / Forestry / Fishing	Stationary								300	5	10		300	200	300
		Mobile									5	5				
Other (not elsewhere specified)																
Total[a]			**118.61**	**324,029.99**	**128,049.36**		**0.00**	**0.00**	**0.00**							

NOTE

1. *The IPCC Tier 2 methodology is used for computing CH_4 and N_2O emissions from petrol and diesel vehicles as the vehicle population statistics are available from the Land Transport Authority.*

1A - NON-CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

			STEP 3						STEP 4	STEP 5	STEP 6
			C								
			Emissions by Fuel (kg)						Total Emissions (Gg)	GWP	Total Emissions in CO_2eq (Gg)
			C=(AxB)								F = D x E
			C1	C2	C3	C4	C5	C6	D= sum	E	F
Activity			Coal	Natural Gas	Oil	Wood / Wood Waste	Charocal	Other Biomass and Wastes	(C1..C6) / 1 000 000		
Energy Industries			118.61	267,928.04	158,643.50				0.427	21	8.96
Manufacturing Industries and Construction				274,903.18	137,219.27				0.412	21	8.66
Transport	Domestic Aviation[a]								0.000	21	
	Road				Gasoline	Diesel			0.000	21	
				41,089.26					0.041	21	0.86
	Railways								0.000	21	0.69
	National Navigation[a]				32,792.79				0.033	21	0.03
Other Sectors	Commercial/Institutional			1,497.62					0.001	21	
	Residential								0.000	21	
	Agriculture / Forestry / Fishing	Stationary							0.000	21	
		Mobile							0.000	21	
Other (not elsewhere specified)									0.000	21	
Total[a]			**118.61**	**585,418.09**	**328,655.56**	**0.00**	**0.00**	**0.00**	**0.914**	**21**	**19.20**

1A - NON-CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

			STEP 1						STEP 2					
			Fuel Consumption (TJ)						Emission Factors (kg/TJ)					
			A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6
Activity			Coal	Natural Gas	Oil	Wood / Wood Waste	Charocal	Other Biomass and Wastes	Coal	Natural Gas	Oil	Wood / Wood Waste	Charocal	Other Biomass and Wastes
Energy Industries			118.61	267,928.04	52,881.17				1.4	0.1	0.6	4	4	4
Manufacturing Industries and Construction				54,980.64	68,609.64				1.4	0.1	0.6	4	4	4
Transport	Domestic Aviation[a]				0.00						2			
	Road				Gasoline / Diesel						Gasoline / Diesel			
				821.79						0.1	20 / 5			
	Railways				0.00				1.4		0.6			
	National Navigation[a]				6,558.56				1.4		0.6			
Other Sectors	Commercial/Institutional			299.52					1.4	0.1	0.6	4	1	4
	Residential								1.4	0.1	0.6	4	1	4
	Agriculture / Forestry / Fishing	Stationary							1.4	0.1	0.6	4	1	4
		Mobile								0.1	0.6			
Other (not elsewhere specified)														
Total[a]			**118.61**	**324,029.99**	**128,049.36**	**0.00**	**0.00**	**0.00**						

NOTE

1. *The IPCC Tier 2 methodology is used for computing CH_4 and N_2O emissions from petrol and diesel vehicles as the vehicle population statistics are available from the Land Transport Authority.*

1A - NON-CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 1)

COUNTRY: SINGAPORE

YEAR: 2012

			STEP 3						STEP 4	STEP 5	STEP 6
			C								
			Emissions by Fuel (kg)						Total Emissions (Gg)	GWP	Total Emissions in CO_2eq (Gg)
			C=(AxB)								F = D x E
			C1	C2	C3	C4	C5	C6	D= sum	E	F
Activity			Coal	Natural Gas	Oil	Wood / Wood Waste	Charocal	Other Biomass and Wastes	(C1..C6) / 1 000 000		
Energy Industries			166.05	26,792.80	31,728.70				0.059	310	18.19
Manufacturing Industries and Construction				5,498.06	41,165.78				0.047	310	14.47
Transport	Domestic Aviation[a]								0.000	310	
	Road				Gasoline	Diesel			0.000	310	
				82.18					0.000	310	0.03
	Railways								0.000	310	
	National Navigation[a]				3,935.14				0.004	310	1.22
Other Sectors	Commercial/Institutional			29.95					0.000	310	0.01
	Residential								0.000	310	
	Agriculture / Forestry / Fishing	Stationary							0.000	310	
		Mobile							0.000	310	
Other (not elsewhere specified)									0.000	310	
Total[a]			**166.05**	**32,403.00**	**76,829.62**	**0.00**	**0.00**	**0.00**	**0.11**	**310**	**33.91**

1A3 - NON-CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 2)

COUNTRY: SINGAPORE

YEAR: 2012

Vehicle Type	Fuel Type	Vehicle Population	Emission Factor (g/ kg fuel)	Weighted-average Emission Factor	IPCC Table
Cars	Petrol	609,792	0.3	0.23892	I-36
Taxis	Petrol	460	0.3	0.00018	I-36
Tax Exempted Cars	Petrol*	2,441	0.3	0.00096	I-36
Motorcycles & Scooters+	Petrol	143,278	5.0	0.93562	I-42
Tax Exempted Motorcycles	Petrol*	824	5.0	0.00538	I-42
Buses+	Petrol	167	0.8	0.00017	I-40
Light Goods Vehicles (LGVs)	Petrol	8,721	0.8	0.00911	I-40
Sub-Total		**765,683**		**1.1903**	
Cars	Diesel	681	0.08	0.00028	I-37
Taxi	Diesel	25,017	0.08	0.01030	I-37
Buses-	Diesel	16,576	0.2	0.01706	I-39
Tax Exempted Buses-	Diesel*	394	0.2	0.00041	I-39
Light Goods Vehicles (LGVs)	Diesel*	89,337	0.06	0.02758	I-38
Heavy Goods Vehicles (HGVs)	Diesel*	46,988	0.2	0.04835	I-39
Tax Exempted Goods Vehicles-	Diesel*	15,371	0.2	0.01582	I-38
Sub-Total		**194,364**		**0.1198**	

Type of Fuel (Sales in Singapore)	2012 Fuel Sales (kg)	Weighted-average Emission Factor (g/ kg fuel)	CH_4 Emissions (tonnes)	CH_4 Emissions (kilotonnes-CO_2eq)
Petrol	747,284,000	1.1903	889.527	18.68
Diesel	1,297,660,000	0.1198	155.440	3.26

NOTE

1. *The IPCC Tier 2 methodology is used for computing CH_4 and N_2O emissions from petrol and diesel vehicles as the vehicle population statistics are available from the Land Transport Authority.*
2. *The average weighted emission factor is calculated based on the following formula: (vehicle population) / sub-total vehicle population by fuel type) * emission factor.*
3. *The weighted average emission factor by fuel type (petrol or diesel) is the sum of the individual weighted average emission factors by vehicle type.*

1A3 - NON-CO_2 FROM FUEL COMBUSTION BY SOURCE (TIER 2)

COUNTRY: SINGAPORE

YEAR: 2012

Vehicle Type	Fuel Type	Vehicle Population	Emission Factor (g/ kg fuel)	Weighted-average Emission Factor	IPCC Table
Cars	Petrol	609,792	0.8	0.63712	I-36
Taxis	Petrol	460	0.8	0.00048	I-36
Tax Exempted Cars	Petrol*	2,441	0.8	0.00255	I-36
Motorcycles & Scooters+	Petrol	143,278	0.06	0.01123	I-42
Tax Exempted Motorcycles	Petrol*	824	0.06	0.00006	I-42
Buses+	Petrol	167	0.06	0.00001	I-40
Light Goods Vehicles (LGVs)	Petrol	8,721	0.06	0.00068	I-40
Sub-Total		**765,683**		**0.6521**	
Cars	Diesel	681	0.2	0.00070	I-37
Taxi	Diesel	25,017	0.2	0.02574	I-37
Buses-	Diesel	16,576	0.1	0.00853	I-39
Tax Exempted Buses-	Diesel*	394	0.1	0.00020	I-39
Light Goods Vehicles (LGVs)	Diesel*	89,337	0.2	0.09193	I-38
Heavy Goods Vehicles (HGVs)	Diesel*	46,988	0.1	0.02418	I-39
Tax Exempted Goods Vehicles-	Diesel*	15,371	0.2	0.01582	I-38
Sub-Total		**194,364**		**0.1671**	

Type of Fuel (Sales in Singapore)	2012 Fuel Sales (kg)	Weighted-average Emission Factor (g/ kg fuel)	N_2O Emissions (tonnes)	N_2O Emissions (kilotonnes-CO_2eq)
Petrol	747,284,000	0.6521	487.335	151.07
Diesel	1,297,660,000	0.1671	216.831	67.22

NOTE

1. *The IPCC Tier 2 methodology is used for computing CH_4 and N_2O emissions from petrol and diesel vehicles as the vehicle populatio statistics are available from the Land Transport Authority.*
2. *The average weighted emission factor is calculated based on the following formula: (vehicle population) / sub-total vehicle population by fuel type) * emission factor.*
3. *The weighted average emission factor by fuel type (petrol or diesel) is the sum of the individual weighted average emission factors by vehicle type.*

2 - EMISSIONS FROM INDUSTRIAL PROCESSES

COUNTRY: SINGAPORE

YEAR: 2012

Direct Emissions		A	B	C	D	#
						C = AxB / 10^6
Greenhouse Gas (GHG)	Chemical Formula	Mass of F-Gases Used in Process	Fraction of F-Gas Used in Process with Emission Control Technology	Total (Direct and by-product) emissions for each GHG	Global Warming Potential	Emissions in CO_2eq
		kg		kg		Gg CO_2eq
HFC-23	CHF_3	C	C	3,237.38	11,700	37.88
HFC-32	CH_2F_2	C	C	67.72	650	0.04
PFC-14	CF_4	C	C	73,518.60	6,500	477.87
PFC-116	C_2F_6	C	C	41,946.42	9,200	385.91
PFC-218	C_3F_8	C	C	9,018.38	7,000	63.13
PFC-c318	c-C_4F_8	C	C	450.63	8,700	3.92
Sulphur hexafluoride	SF_6	C	C	3,737.49	23,900	89.33

2 - EMISSIONS FROM INDUSTRIAL PROCESSES

COUNTRY: SINGAPORE

YEAR: 2012

Industrial Processes (Semiconductor Manufacturing)			
Emissions in CO_2eq	HFCs	Gg CO_2eq	37.92
	PFCs	Gg CO_2eq	930.83
	SF_6	Gg CO_2eq	89.33

NOTE

1. *The IPCC Tier 2 methodology is used for computing of HFCs, PFCs and SF_6 emissions.*
2. *C denotes confidential.*
3. *Country-specific factors are used where they are available.*

6C - EMISSIONS FROM WASTE INCINERATION

COUNTRY: SINGAPORE

YEAR: 2012

CO_2	A	B	C	D	E	F	G
							G=AxBxCxDxExF
	Total Amount of Plastic Waste Incinerated (Dry 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
	497.7	1	0.75	1	1	3.6667	1,368.67

6C - EMISSIONS FROM WASTE INCINERATION

COUNTRY: SINGAPORE

YEAR: 2012

N_2O	Total Amount of Waste Incinerated (Wet Weight)	N_2O Emission Factor	N_2O Emissions	Emissions in CO_2eq
	tonnes	kg N_2O/kt waste	Gg	Gg
	2,735,968.98	47	0.129	39.86

NOTE

1. *The CO_2 emissions are added to the total emissions from fuel combustion (All Energy - Fuel combustion - Energy and Transformation Industries).*
2. *The N_2O emissions are reflected in CO_2eq in the GHG summary table (Waste - Waste incineration).*

6B - EMISSIONS FROM WASTEWATER HANDLING

COUNTRY: SINGAPORE

YEAR: 2012

		A	B	C	D	E	F	G
						E = (A x B x C x D) x (44/28) x 10^{-6}		G = E x F
N_2O	Annual per capita protein intake, Protein	Annual per capita protein intake, Protein	Total Population in Singapore	Fraction of Nitrogen in Protein	Emission Factor	N_2O Emissions	Global Warming Potential of N_2O	Emissions in CO_2eq
	gram /person /day	kg /person /year		kg N/ kg protein	kg N_2O-N/ kg sewage-N produced	Gg		Gg
	69.22	25.27	5,312,400	0.16	0.01	0.337	310	104.62

NOTE

1. *The annual per capita protein intake is the average of the UNFAO data for ASEAN member states.*
2. *The total population in Singapore is based on the latest data available from DOS.*
3. *The N_2O emissions are reflected in CO_2eq in the GHG summary (Waste - Wastewater Handling).*

6B - EMISSIONS FROM WASTEWATER HANDLING

COUNTRY: SINGAPORE

YEAR: 2012

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	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	Decay constant	CH_4 Emissions in CO_2eq
f	f	OX	F	DOCf	MCF	Wx (tons/yr)	DOC (%)	DOC (%)	k	Gg
0.9	0	0.1	0.5	0.5	1	As per records	0.294	0.074	0.4	45.53

NOTE

1. *The CH_4 emissions are reflected in CO_2eq in the GHG summary table (Waste - Wastewater Handling).*
2. *CH_4 emissions from wastewater handling are computed based on CDM methodologies.*

6B - EMISSIONS FROM WASTEWATER HANDLING

COUNTRY: SINGAPORE

YEAR: 2012

	Incineration of sludge		
Emissions in CO_2eq	CH_4	Gg CO_2eq	0.06
	N_2O	Gg CO_2eq	14.98

NOTE

1. *The CH_4 and N_2O emissions in CO_2eq are added to the total emissions from fuel combustion (All Energy - Fuel combustion - Energy and Transformation Industries).*
2. *Emissions from the incineration of sludge are computed based on CDM methodologies.*

EMISSIONS AND REMOVALS OF CO_2 AND NON-CO_2 GASES FROM LULUCF

COUNTRY: SINGAPORE

YEAR: 2012

Land-use Category		IPCC Guidelines[1]	Annual change in carbon stocks[2], Gg CO_2				CH_4 (Gg)	N_2O (Gg)	NO_x[3] (Gg)	CO[3] (Gg)
Initial Land-use	Land-use during reporting Year		Living Biomass	Dead Organic Matter	Soils	CO_2 Emissions/ Removals				
			A	B	C	D = A+B+C				
Forest Land	Forest Land	5A	-18.34	-1.80	0.20	-19.94	NO	NO		
Cropland	Forest Land	5A, 5C, 5D	-0.06	-0.24	0.28	-0.01	NO	NO		
Grassland	Forest Land	5A, 5C, 5D	NO	NO	NO	NO	NO	NO		
Wetlands	Forest Land	5A, 5C, 5D	-0.07	-0.23	-2.83	-3.13	NO	NO		
Settlements	Forest Land	5A, 5C, 5D	-124.30	-1.93	-9.95	-136.17	NO	NO		
Sea	Forest Land	5A, 5C, 5D	-0.57	-0.88	-9.72	-11.17	NO	NO		
	Sub-Total for Forest Land		-143.34	-5.06	-22.02	-170.42	NO	NO		
Cropland	Cropland	5A, 5D	-0.32	0.00	-0.12	-0.44	NO	NO		
Forest Land	Cropland	5B, 5D	-1.64	0.37	-0.20	-1.48	NO	0.00		
Grassland	Cropland	5B, 5D	NO	NO	NO	NO	NO	NO		
Wetlands	Cropland	5D	0.00	0.00	0.00	0.00	NO	NO		
Settlements	Cropland	5D	-6.64	0.36	-1.97	-8.24	NO	0.00		
Sea	Cropland	5D	-0.05	0.00	-0.02	-0.07	NO	NO		
	Sub-Total for Cropland		-8.65	0.73	-2.31	-10.23	NO	0.00		
Grassland	Grassland	5A, 5D	NO	NO	NO	NO	NO	NO		
Forest Land	Grassland	5B, 5D	NO	NO	NO	NO	NO	NO		
Cropland	Grassland	5C, 5D	NO	NO	NO	NO	NO	NO		
Wetlands	Grassland	5C, 5D	NO	NO	NO	NO	NO	NO		
Settlements	Grassland	5C, 5D	NO	NO	NO	NO	NO	NO		
Sea	Grassland	5C, 5D	NO	NO	NO	NO	NO	NO		
	Sub-Total for Grassland		NO	NO	NO	NO	NO	NO		
Wetlands	Wetlands	5A, 5E	0.00	0.00	0.00	0.00	NO	NO		
Forest Land	Wetlands	5B	0.53	0.05	1.62	2.20	NO	NO		
Cropland	Wetlands	5E	0.01	0.00	0.02	0.02	NO	NO		
Grassland	Wetlands	5B	NO	NO	NO	NO	NO	NO		
Settlements	Wetlands	5E	0.90	0.01	0.85	1.76	NO	NO		
Sea	Wetlands	5E	0.00	0.00	0.00	0.00	NO	NO		
	Sub-Total for Wetlands		1.44	0.05	2.49	3.98	NO	NO		

EMISSIONS AND REMOVALS OF CO_2 AND NON-CO_2 GASES FROM LULUCF

COUNTRY: SINGAPORE

YEAR: 2012

Land-use Category		IPCC Guidelines[1]	Annual change in carbon stocks[2], Gg CO_2				CH_4 (Gg)	N_2O (Gg)	NO_x[3] (Gg)	CO[3] (Gg)
Initial Land-use	Land-use during reporting Year		Living Biomass	Dead Organic Matter	Soils	CO_2 Emissions/ Removals				
			A	B	C	D = A+B+C				
Settlements	Settlements	5A	-44.63	-1.58	17.69	-28.52	NO	NO		
Forest Land	Settlements	5B	10.44	5.02	22.84	38.29	NO	NO		
Cropland	Settlements	5E	-3.48	-0.01	3.22	-0.27	NO	NO		
Grassland	Settlements	5B	NO	NO	NO	NO	NO	NO		
Wetlands	Settlements	5E	-3.57	-0.01	-1.47	-5.05	NO	NO		
Sea	Settlements	5E	-51.19	-0.08	-22.56	-73.83	NO	NO		
	Sub-Total for Settlements		-92.44	3.34	19.72	-69.38	NO	NO		
Other Land	Other Land	5A	NO	NO	NO	NO	NO	NO		
Forest Land	Other Land	5B	NO	NO	NO	NO	NO	NO		
Cropland	Other Land	5E	NO	NO	NO	NO	NO	NO		
Grassland	Other Land	5B	NO	NO	NO	NO	NO	NO		
Wetlands	Other Land	5E	NO	NO	NO	NO	NO	NO		
Settlements	Other Land	5E	NO	NO	NO	NO	NO	NO		
	Sub-Total for Other Land		NO	NO	NO	NO	NO	NO		
Land	Sea		3.51	0.01	3.30	6.82	NO	NO		
	Sub-Total for Sea		3.51	0.01	3.30	6.82	NO	NO		
	Total		**-239.48**	**-0.93**	**1.18**	**-239.23**	**NO**	**0.00**		

NOTE

1. *Headings from the IPCC Guidelines Reporting Instructions p.1.14 - 1.16: 5A - Changes in Forest and Other Woody Biomass Stocks; 5B - Forest and Grassland Conversion; 5C - Abandonment of Managed Lands; 5D - Emissions and Removals from Soils, and 5E - Other.*
2. *The values are expressed as (-) for removal or uptake and (+) for emission.*
3. *The IPCC Guidelines provide methodology to estimate NO_x and CO emissions for Land Use, Land-Use Change and Forestry for emissions from fires only.*
4. *The values in this table are rounded to two decimal places.*

GREENHOUSE GAS SUMMARY TABLE FOR 2010

COUNTRY: SINGAPORE

YEAR: 2010

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

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O	HFCs	PCFs	SF_6
Total (Net) National Emissions (Gg CO_2eq per year)	**45,137.92**	**113.87**	**400.73**	**39.94**	**987.91**	**86.25**
All Energy	**45,137.92**	**42.66**	**304.93**			
Fuel Combustion	**44,982.08**	**42.66**	**304.93**			
Energy and transformation industries	20,667.42	10.09	77.17			
Industry	16,951.52	8.07	14.13			
Transport	6,722.69	24.46	213.62			
Commercial-institutional	431.34	0.03	0.01			
Residential	209.10					
Fugitive fuel emission	**155.84**					
Oil and natural gas systems	155.84					
Industrial Processes				**39.94**	**987.91**	**86.25**
Waste		**71.21**	**95.80**			
Wastewater handling		71.21	95.80			

NOTE

1. *The greenhouse gas emissions from agriculture, land-use change and forestry sectors are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.*
2. *In line with IPCC Good Practice Guidance (GPG) to continually review the GHG inventory, the figures have been updated where necessary.*

GREENHOUSE GAS SUMMARY TABLE FOR 2000

COUNTRY: SINGAPORE

YEAR: 2000

As reported in Singapore's Second National Communication.

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O	HFCs	PCFs	SF_6
Total (Net) National Emissions (Gg CO_2eq per year)	**37,755.81**	**111.72**	**334.87**	**7.47**	**496.06**	**84.04**
All Energy	**37,755.81**		**189.26**			
Fuel Combustion	**37,755.81**					
Energy and transformation industries	20,973.74					
Industry	10,526.41					
Transport	5,621.57		189.26			
Commercial-institutional	291.63					
Residential	342.46					
Fugitive fuel emission						
Oil and natural gas systems						
Industrial Processes				**7.47**	**496.06**	**84.04**
Waste		**111.72**	**145.61**			
Wastewater handling		111.72	73.75			
Waste incineration			71.86			

NOTE

1. *The greenhouse gas emissions from agriculture, land-use change and forestry sectors are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.*

GREENHOUSE GAS SUMMARY TABLE FOR 1994

COUNTRY: SINGAPORE

YEAR: 1994

As reported in Singapore's Initial National Communication.

Greenhouse Gas Source and Sink Categories	CO_2	CH_4	N_2O	HFCs	PCFs	SF_6
Total (Net) National Emissions (Gg CO_2eq per year)	**26,800.18**	**0.00**	**0.19**	**0.00**	**0.00**	**0.00**
All Energy	**26,800.18**					
Fuel Combustion	**26,800.18**					
Energy and transformation industries	13,141.90					
Industry	8,922.33					
Transport	4,099.99					
Commercial-institutional	327.79					
Residential	308.17					
Fugitive fuel emission						
Oil and natural gas systems						
Industrial Processes						
Waste			**0.19**			
Wastewater handling			0.19			
Waste incineration						

NOTE

1. *The greenhouse gas emissions from agriculture, land-use change and forestry sectors are negligible in comparison with the size of carbon stocks and in comparison with other economic sectors.*

Glossary

ADB	Asian Development Bank
BAU	Business-As-Usual
BCA	Building and Construction Authority
BESS	Building Energy Submission System
BREEF	Building Retrofit Energy Efficiency Financing
BSEP	Bus Service Enhancement Programme
BUR	Biennial Update Report
CAGR	Compounded Annual Growth Rate
CCGT	Combined Cycle Gas Turbine
CCSU	Carbon Capture, Storage and Utilisation
CDIA	Singapore-Cities Development Initiative for Asia
CDM	Clean Development Mechanism
CDS	City Direct Services
CER	Certified Emission Reduction
CERT	Clean Energy Research Testbedding
CEVS	Carbon Emissions-based Vehicle Scheme
CGE	Consultative Group of Experts
CH_4	Methane
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2eq	Carbon Dioxide Equivalent
CREATE	Campus for Research Excellence and Technological Enterprise
DC	Data Centre
DfE	Design for Efficiency
dMRV	Domestic Measurement, Reporting and Verification
E2S2	Energy and Environmental Sustainability Solutions for MegaCities
EASe	Energy Efficiency Improvement Assistance Scheme
ECO-SWM	ECO-Special Waste Management
EDB	Economic Development Board
EDMA	Emissions Data Monitoring and Analysis
EE	Energy Efficiency
EIU	Economist Intelligence Unit
EMA	Energy Market Authority
EPMA	Environmental Protection and Management Act
Exco	Executive Committee
FAO	Food and Agriculture Organisation
FELS	Fuel Economy Labelling Scheme
FCL	Future Cities Laboratory
Gg	Gigagram
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GM	Green Mark
GREET	Grant for Energy Efficient Technologies
GTP	Green Technology Programme
GWh	Gigawatt-Hour
GWP	Global Warming Potential
HDB	Housing and Development Board
HFCs	Hydrofluorocarbons
ICA	International Consultations and Analysis
ICT	Information and Communications Technology
IEA	International Energy Agency
IMCCC	Inter-Ministerial Committee on Climate Change
IMO	International Maritime Organisation
INWG	International Negotiations Working Group
IPCC	Intergovernmental Panel on Climate Change

KCA	Key Category Analysis
kt	Kilo-Tonnes
ktoe	Kilo-Tonnes of Oil Equivalent
ktpa	Kilo-Tonne Per Annum
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
MELS	Mandatory Energy Labelling Scheme
MEPS	Minimum Energy Performance Standards
MEWR	Ministry of the Environment and Water Resources
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
MND	Ministry of National Development
MOF	Ministry of Finance
MOH	Ministry of Health
MOU	Memorandum of Understanding
MPA	Maritime and Port Authority of Singapore
MRT	Mass Rapid Transit
MRV	Measurement, Reporting and Verification
MT	Million Tonnes
MWp	Mega-Watt 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
NOx	Nitrogen Oxides
NParks	National Parks Board
NRF	National Research Foundation
NTU	Nanyang Technological University
NUS	National University of Singapore
OPC	Off-Peak Car
PFCs	Perfluorocarbons
PMD	Personal Mobility Device
PMO	Prime Minister's Office
PPSS	Peak Period Short Services
PUE	Power Usage Effectiveness
PV	Photovoltaic
QA	Quality Assurance
QC	Quality Control
R&D	Research and Development
RD&D	Research, Development, and Demonstration
ROPC	Revised Off-Peak Car
RWG	Resilience Working Group
SCP	Singapore Cooperation Programme
SCS	Solar Capability Scheme
SEI	Singapore Environment Institute
SF_6	Sulphur Hexafluoride
SIDS	Small Island Developing States
SLA	Singapore Land Authority
SO_2	Sulphur Dioxide
TCTP	Third Country Training Programme
TUM	Technische Universitat Munchen
UFW	Unaccounted-for-Water
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	UN Office for Disaster Risk Reduction
USS	Urban Solutions and Sustainability
WEC	Weekend Car

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