Research Office
Legislative Council Secretariat

Information Note

Decarbonization strategy in Shenzhen and Singapore

IN03/2022

1. Introduction

1.1 Adverse impacts of global warming caused by emissions of greenhouse gas ("GHG")[1] are increasingly felt in Hong Kong, as manifested in three record-breaking figures in 2021, namely an annual mean temperature of 24.6°C, 54 very hot days and 61 hot nights.[2] Most recently in April 2022, the Government identified as many as 26 coastal low-lying and windy residential areas in the territory (including Heng Fa Chuen, South Horizons, Kennedy Town and Tsuen Kwan O South) vulnerable to flooding risks upon a rise in sea level under extreme weather by 2050.[3]

1.2 In parallel with decades-long global efforts to combat global warming, the Government released "Hong Kong's Climate Action Plan 2050" in October 2021, pledging to achieve carbon neutrality before 2050, after hitting the earlier milestone of carbon peak in 2014.[4] The decarbonization measures valued at HK$240 billion in the next 15-20 years will straddle across many economic sectors, especially so for electricity generation and transport, which together account for a lion's share (80%) of carbon emissions in Hong Kong. That said, local environmental groups generally consider the Government's decarbonization strategy as "too conservative" and does not have enough implementation details, while other critics are concerned about the feasibility and cost affordability of these carbon pledges for the society at large.[5]

1.3 At the request of Ir Hon CHAN Siu-hung, the Research Office has studied decarbonization strategies (including targets and measures) in selected places, with a specific focus on the aforementioned two largest sectors for local reference. Shenzhen and Singapore are chosen for in-depth study because (a) electricity generation and transport are also their leading sectoral emitters; (b) they are acclaimed low-carbon

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1 Three quarters (76%) of global GHG emissions are carbon dioxide, and the rest are methane (16%), nitrous oxide (6%) and fluorinated gases (2%). See University of Oxford (2020) and Intergovernmental Panel on Climate Change (2021, 2022a).

2 "Very hot days" refer to those days with maximum temperature of at least 33°C, whereas "hot nights" are nights with average temperature of at least 28°C. See GovHK (2022a).

3 Civil Engineering and Development Department (2022).

4 Carbon neutrality refers to net-zero carbon emissions, with additional emissions mitigated or offset by efforts to absorb existing carbon in the atmosphere (e.g. forestation). See Environment Bureau (2021a).

5 香港地球之友 (2021), 信報 (2021) and 東網 (2021).

cities; and (c) they have introduced a number of innovative measures to reduce carbon footprints. This ***Information Note*** begins with an overview of global climate governance, followed by a review of decarbonization targets and policies in Hong Kong. It will then switch to the respective decarbonization strategies in Shenzhen and Singapore, along with a concise table for easy reference (**Appendix 1**).

2. Recent developments in global climate governance

2.1 Excessive carbon emissions have contributed to global warming, with the average temperature figure in 2019 being some 1.07°C higher than the level during 1850 to 1900. Not only does warmer climate contribute to more extreme weather (e.g. intense hurricanes, heatwaves and floods) in past two decades, it also leads to a 0.2 metre rise in global sea level between 1901 and 2018 (due to melting glaciers and sea ice).[6] The **Paris Agreement**, a major global treaty on combating climate change agreed in 2015 and taking effect in 2016, therefore laid down global benchmarks for carbon neutrality with a view to limiting the rise of average global temperature by 2100 to 1.5°C-2°C, as compared to the pre-industrial level in 1850. Most advanced places pledged to achieve carbon neutrality by 2050, but a few affluent countries committed to doing so in earlier years (e.g. Finland in 2035, Israel in 2040 and Sweden in 2045) (**Figure 1**).[7] A chronology of the progress of global decarbonization is presented in **Appendix 2**.

Figure 1 – Major decarbonization targets in selected places

	Hong Kong	World	Mainland	Shenzhen	Singapore
1. Carbon peak year	2014	2025	2030	2025	2030
2. Carbon neutrality year	2050	2050	2060	-	Mid-21st century
3. Annual emissions	↓ 50% (2005-2035)	↓ 45% (2010-2030)	-	-	↓ 50% (2030-2050)
4. Per capita emissions (tCO_2-e)	3.0 (2035)	2.9 (2030)	-	-	-
5. Carbon intensity(1)	↓ 65%-70% (2005-2030)	↓ 40%-75% (2019-2030)	↓ 65% (2005-2030)	↓ 18% (2020-2025)	↓ 36% (2005-2030)

Notes: (1) Carbon intensity refers to carbon emissions produced per dollar of Gross Domestic Product ("GDP").
(-) Information not available.

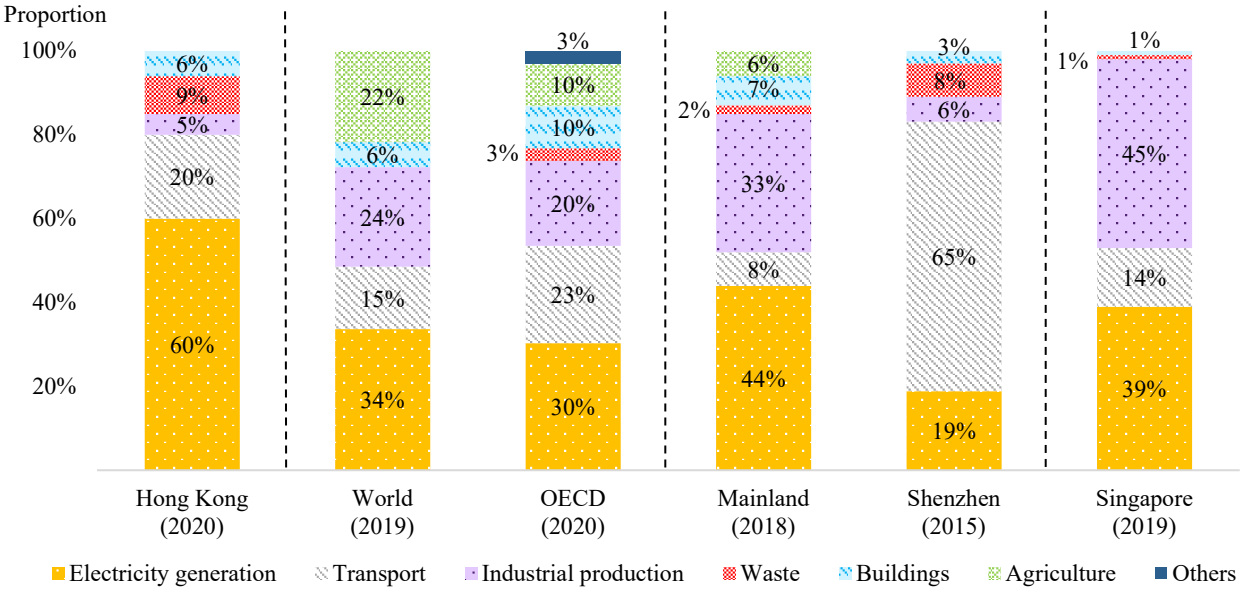
Sources: Environment Bureau, Intergovernmental Panel on Climate Change, International Energy Agency, C40 Cities, National Climate Change Secretariat, Organisation for Economic Co-operation and Development and 深圳市生態環境局.

[6] For example, Hurricane Katrina sweeping across the United States in 2005 brought the largest economic loss on record globally at US$164 billion (HK$1.3 trillion). See Intergovernmental Panel on Climate Change (2021) and World Meteorological Organization (2021, 2022).

[7] Organisation for Economic Co-operation and Development (2021) and Intergovernmental Panel on Climate Change (2022a).

2.2 Globally, electricity generation is the largest GHG emitter, accounting for 34% of annual GHG emissions (**Figure 2**). This is followed by industrial production (24%), agriculture (22%) and transport (15%). However, sectoral distribution of GHG emissions can vary widely from one place to another, depending on the fuel mix of power supply and structure of the economy.

Figure 2 – Annual GHG emissions by sector in selected places



Note: If indirect emissions of electricity imports are included, the shares of electricity generation and transport for Shenzhen in 2015 were 41% and 42% respectively. The proportions may not add up to 100% due to rounding.

Sources: Environment Bureau, Intergovernmental Panel on Climate Change, Organisation for Economic Co-operation and Development, University of Oxford, Jiang et al. and National Climate Change Secretariat.

2.3 As regards decarbonization policies, here is the global common practice in the areas of electricity generation and transport:

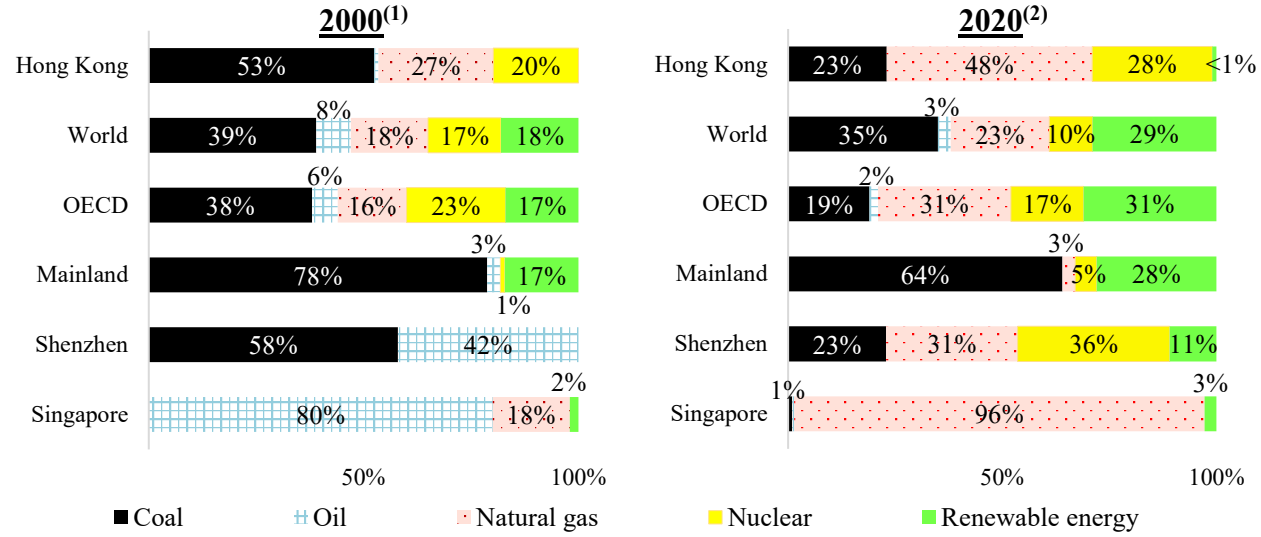
(a) **Phasing out usage of fossil fuels:** As burning fossil fuels (e.g. coal, oil and natural gas) for electricity generation, transport and home heating is responsible for emitting 64% of global GHG emissions in 2019, studies suggest that global usage of coal needs to plunge by 95% during 2019 to 2050, together with 60% and 45% drops in oil and natural gas usage respectively, in order to meet the targets set out in the Paris Agreement;[8]

(b) **Promoting renewable energy, especially in electricity generation:** As affluent places plan to phase out all coal power plants by 2030 specifically and move away from fossil fuels in general, they are

[8] United Nations (2021) and Intergovernmental Panel on Climate Change (2022a).

developing renewable energy (e.g. hydro, solar and wind power) and nuclear power as replacement fuel. Feed-in tariffs and subsidies are adopted to promote mainly solar and wind power.[9] The share of renewables in global energy mix for electricity generation had thus increased from 18% to 29% during 2000 to 2020 (**Figure 3**). According to the International Energy Agency ("IEA"), the share of wind and solar power needs to further increase substantially by as much as seven-fold to 70% by 2050 for carbon neutrality;[10]

Figure 3 – Energy mix for electricity generation in 2000 and 2020



Notes: (1) The figure for Hong Kong is from 1998, while oil accounted for less than 1% of energy used for its electricity generation. Worldwide renewable energy in the 2000s was mostly hydro power and waste-to-energy ("WTE"). The proportions may not add up to 100% due to rounding.

(2) Solar and wind power had been substantially developed in the 2010s, with their combined share in worldwide energy mix soaring from almost none in 2000 to 9% in 2020. For Singapore, oil accounted for less than 1% of energy used for electricity generation. The proportions may not add up to 100% due to rounding.

Sources: Environment Bureau, International Energy Agency, Energy Market Authority and 深圳市生態環境局.

(c) **Cleaner options for transport fuel:** Road vehicles take up 69% of global transport emissions. After rapid advances in battery technology, the production cost of electric vehicles ("EV") had tumbled by 90% over the past decade and became broadly on par with fuel-propelled vehicles.[11] In spite of a 100-fold upsurge of EV fleet over the past decade, EV accounted for just 1% of global vehicle fleet in 2021. Major

[9] Natural gas is a relatively cleaner fossil fuel because its carbon emission is just 56% of coal and 71% of oil. Thus, it is widely adopted to replace dirtier fossil fuels globally, before more mature technologies of renewable energy are developed and have become more cost effective.

[10] United Nations (2021), International Energy Agency (2021b, 2021c) and Intergovernmental Panel on Climate Change (2022a).

[11] Intergovernmental Panel on Climate Change (2022a) and United Nations (2021).

affluent places (e.g. the European Union and the United States) have pledged to phase out sales of new fuel-propelled vehicles before 2035. For the maritime and aviation sectors which are deemed as harder to decarbonize, cleaner fuel options (e.g. biofuels) are not commercially viable yet. Some governments turn their attention to improve energy efficiency in airports and ports instead;[12] and

(d) **Emission quota and carbon trading (so called "cap-and-trade" system):** Some governments impose emission quotas on major polluters (e.g. power generators and industrial plants) and allow them to trade these carbon quotas in emissions trading systems ("ETS") for achieving decarbonization in more cost-effective manners. Alternatively, carbon tax is imposed to internalize the "negative externality" of GHG emissions into the product prices so as to discourage both consumption and production of the relevant products and services. In 2021, while carbon taxes were seen in 35 places, the number of ETS soared from only one in 2005 to 30 in 2021. ETS now covers 16% of global GHG emissions, tripling that of 5% in 2005.[13]

2.4 **That said, current measures are considered inadequate for achieving carbon neutrality and to keep the Paris Agreement's targets in reach due to a number of outstanding challenges**.[14] *First and foremost*, many low carbon and renewable energy technologies are not yet mature for large-scale commercialization. For instance, IEA expects that the share of solar and wind power in the global energy mix needs to increase seven-fold to 70% in the next 30 years. It would represent a radical pick up in the future compared with the past three decades, when it had only risen from none to 9%. *Secondly*, decarbonization entails considerable costs in society. For example, the retirement of a large stock of carbon-intensive power plants and their replacement with renewables is bound to have substantial implications on electricity tariffs.[15] *Thirdly*, some governments may wish to retain a certain proportion of fossil fuels partly for energy security purpose, as manifested particularly in increased investment in fossil fuels amongst some affluent countries (e.g. the United States, France and Germany) after the recent concerns over energy crunch triggered by the war in Ukraine that started in February 2022.[16]

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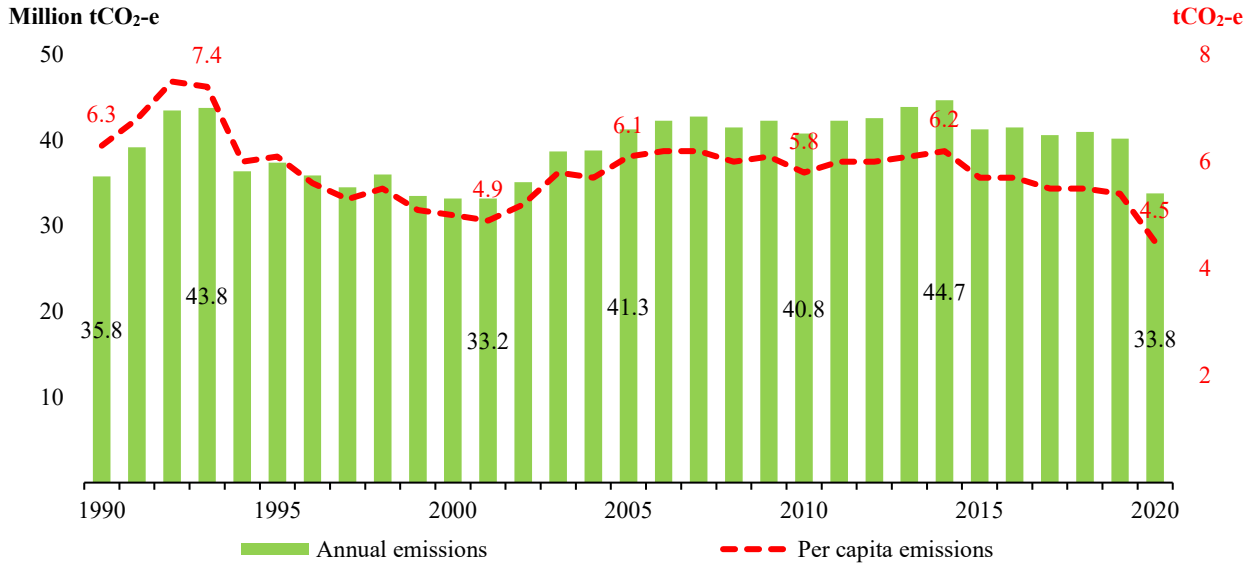
12 International Energy Agency (2021c).
13 World Bank (2022).
14 Intergovernmental Panel on Climate Change (2022b) and United Nations (2021).
15 Early retirement of power plants typically with a lifespan of 30-50 years for the adoption of low-carbon technologies would be very costly. See International Energy Agency (2020) and European Environment Agency (2021).
16 BBC (2022) and The Economist (2022).

3. Decarbonization strategy in Hong Kong

3.1 **Overall carbon emissions in Hong Kong peaked at 44.7 million tCO_2-e in 2014, after a rebound in emissions in the 2000s and early 2010s, thanks to adoption of less carbon-intensive fuel for electricity generation** (**Figure 4**). While the drop in emissions in the 1990s can mostly be attributable to the import of electricity from Daya Bay Nuclear Power Plant, the proactive commissioning of a number of gas-fired power plants[17] over the past few years contributed to the sharp drop of per capita carbon emission from 6.2 tCO_2-e in 2014 to the lowest level of 4.5 tCO_2-e in 2020 (which represented a further lowering from the previous trough of 4.9 tCO_2-e in 2001).[18]

Figure 4 – Overall and per capita GHG emissions in Hong Kong, 1990-2020



Source: Environment Bureau.

3.2 The Government published its first decarbonization blueprint in 2017, followed by an update entitled the "Hong Kong's Climate Action Plan 2050" ("the Action Plan") in October 2021. **It sets out three updated decarbonization targets**, viz. (a) halving annual carbon emissions from 2005 level to 20 million tCO_2-e by 2035; (b) reducing per capita emissions by at least half to no more than 3 tCO_2-e before 2035 versus 6.1 tCO_2-e in 2005; and (c) attaining carbon neutrality before 2050.[19]

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17 The first gas-fired power plant in Hong Kong was commissioned in 1996.

18 Environment Bureau (2022c).

19 Hong Kong is the third Asian metropolises achieving carbon peak, after Tokyo (2012) and Osaka (2013). See Environmental Protection Department (2010) and Environment Bureau (2017, 2021a).

3.3 As regards **policy measures on decarbonization**, the updated Action Plan budgets a total of HK$240 billion in the next 15-20 years (i.e. equivalent to 8% of the annual GDP in 2021).[20] Here are the major policy measures on the two focussed sectors of electricity generation and transport:

(a) **Further increase in gas usage for electricity generation:** To minimize the emissions, the Government required all new electricity generation units proposed from 1997 onwards to be powered by natural gas. There are now 12 gas-fired units in Hong Kong, with three more to be put into operation between 2022 and 2023.[21] The Government expects a further increase in the share of natural gas in local energy mix from 48% in 2020 to 57% by 2024. Meanwhile, net-zero nuclear energy imported from Daya Bay since 1994 now accounts for a noticeable share of 28% in fuel mix for electricity generation in Hong Kong. By contrast, the share of coal in electricity fuel mix has fallen from 98% in 1990 to 24% in 2020, and is expected to drop further in the future;

(b) **Promoting renewable energy for electricity generation:** In spite of measures to expedite local development of solar and wind power in recent years, renewable energy as a whole accounts for only 0.3% of local electricity fuel so far.[22] The Government attributes this slow development to a lack of "favourable conditions" for large-scale commercialization.[23] Yet it expects the share of renewables will jump to 7.5%-10% by 2035[24], and further to 15% before 2050. To this end, the Government is exploring the potential of (i) offshore wind farms; (ii) renewable energy imports; [25] and (iii) more advanced WTE

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[20] Over the past decade, the Government spent at least HK$47 billion on EV popularization, WTE facilities and renewable energy, while the two power companies were required to invest HK$39 billion for cleaner fuel mix. See GovHK (2021).

[21] The Government has ceased construction of any new coal-fired power plant in Hong Kong since 1997. See Environment Bureau (2014, 2021b) and Environmental Protection Department (2021).

[22] Recent measures include (i) installation of solar photovoltaic ("PV") systems in government premises, schools and social welfare organizations; (ii) introducing feed-in tariff to private owners of solar PV systems; and (iii) building WTE and hydro power projects. See Environment Bureau (2021a, 2021b) and GovHK (2022b).

[23] Electrical and Mechanical Services Department (2021) and Environment Bureau (2021a).

[24] More specifically, the target comprises 3.5%-4% from wind power and 3%-4% from WTE, followed by 1%-2% from solar power.

[25] Back in 2014, the Government consulted the public on increasing electricity imports for a more diversified fuel mix. Yet it met with strong opposition concerning, amongst other factors, losing oversight of electricity supply (e.g. control of reliability, cost and fuel mix) when imports are involved. See Environment Bureau (2015, 2021a).

facilities, while incorporating hydrogen into the fuel mix in the future would also be considered;

(c) **Promoting electric vehicles:** As the Government had offered various incentives to encourage EV, including exemption of First Registration Tax and lowering their licence fees, the size of local EV fleet surged from just 162 in end-2010 to 31 393 in April 2022 (or 3% of total registered vehicles). In the Action Plan, new fuel-propelled and hybrid private cars will be banned by 2035.[26] More EV-chargers will also be installed in both the private and public sectors;[27]

(d) **Electrifying public transport:** At present, most public transport vehicles are diesel vehicles, except taxis and public light buses using liquefied petroleum gas. For public buses, there were 42 electric buses only as of April 2022 (i.e. a mere 0.3% of the bus fleet). While a small-scale trial of electric taxis has begun in early 2022, the pilot schemes for electric public light buses and electric ferries will commence in 2023. Moreover, franchised bus companies are subsidized to purchase double-deck electric buses for operation before 2023. A more concrete timetable for developing electric and new energy (e.g. hydrogen fuel cell) public transport will be released in around 2025;[28] and

(e) **Decarbonizing maritime and aviation sectors:** Maritime accounts for just 8% of local energy use in the transport sector against that of 88% for road vehicles. A few measures have been put in place for maritime sector so far to contribute to decarbonization, including requiring ocean going vessels to use cleaner fuels (e.g. liquefied natural gas "LNG") in Hong Kong waters as from 2019. As for aviation industry, the Airport Authority Hong Kong unveiled the "Net Zero Carbon by 2050" strategy in December 2021, aiming to achieve carbon neutrality by 2050. Measures such as electrifying airside vehicles and piloting renewable fuels will be stepped up.[29]

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[26] In addition, "congestion charges" would be further studied to control roadside emissions. See Environment Bureau (2021a, 2022d).

[27] As at end-2021, there were some 4 700 public EV-chargers and over 115 000 private EV-chargers. See Environment Bureau (2021a, 2022a, 2022d).

[28] Environment Bureau (2022b, 2022d).

[29] Comparing with traditional jet fuels, renewable fuels (e.g. biofuels blended with wasted cooking oil) can reduce carbon emissions by up to 80% but two to five times more expensive at present. See Airport Authority Hong Kong (2021) and Legislative Council Secretariat (2022).

3.4 **Notwithstanding the above measures, there are a few public concerns on the local decarbonization strategy.** *First and foremost*, some local environmental groups consider that the updated Action Plan is still "too conservative," given the per capita carbon emission target at 3 tCO_2-e by 2035 would be a few years behind the reduction to 2.9 tCO_2-e by 2030 pledged by major cities globally.[30] *Secondly*, the updated Action Plan is short of implementation details, without concrete timeframes for achieving carbon neutrality in carbon-intensive sectors and phasing out fossil fuels in electricity generation and transport sectors.[31] *Thirdly*, it is deemed very challenging to raise the share of renewables in the energy mix from just 0.3% in 2020 to at least 7.5% by 2035 based on existing initiatives, especially after a drop in the feed-in tariff rates for solar power in April 2022.[32] *Fourthly*, some segments of the public seem to be unaware of the substantial costs (e.g. higher tariffs) involved in decarbonization initiatives, resulting in possible push back when the cumulative effects on their living costs become more visible.

4. Decarbonization strategy in Shenzhen

4.1 Partly due to its position as the global powerhouse for manufacturing, the Mainland is now the world's largest GHG emitting region, taking up three-tenths of the global total (**Figure 5**). Electricity generation is the largest emitter (44%), followed by industrial production (33%) and transport (8%). In September 2020, the Central Government pledged a **"dual carbon target" (i.e. carbon peak before 2030 and carbon neutrality before 2060)** for enhanced commitments. In fact, authorities have stepped up measures for decarbonizing electricity generation and transport since the 2010s spanning across (a) replacing dirtier fossil fuels with low carbon and renewable energy;[33] (b) implementing the cap-and-trade systems at eight piloted cities since 2013 and a national carbon market in July 2021;[34] (c) popularizing EV; and (d) decarbonizing water and air transport activities.[35] Most recently in

[30] C40 Cities (2021) and 東網 (2021).

[31] 東網 (2021) and 香港經濟日報 (2021).

[32] In April 2022, the feed-in tariff rates were adjusted downwards from HK$3-HK$5/kWh (which were set in 2018) to HK$2.5-HK$4/kWh due to significant cost reduction of renewable energy. See GovHK (2022b).

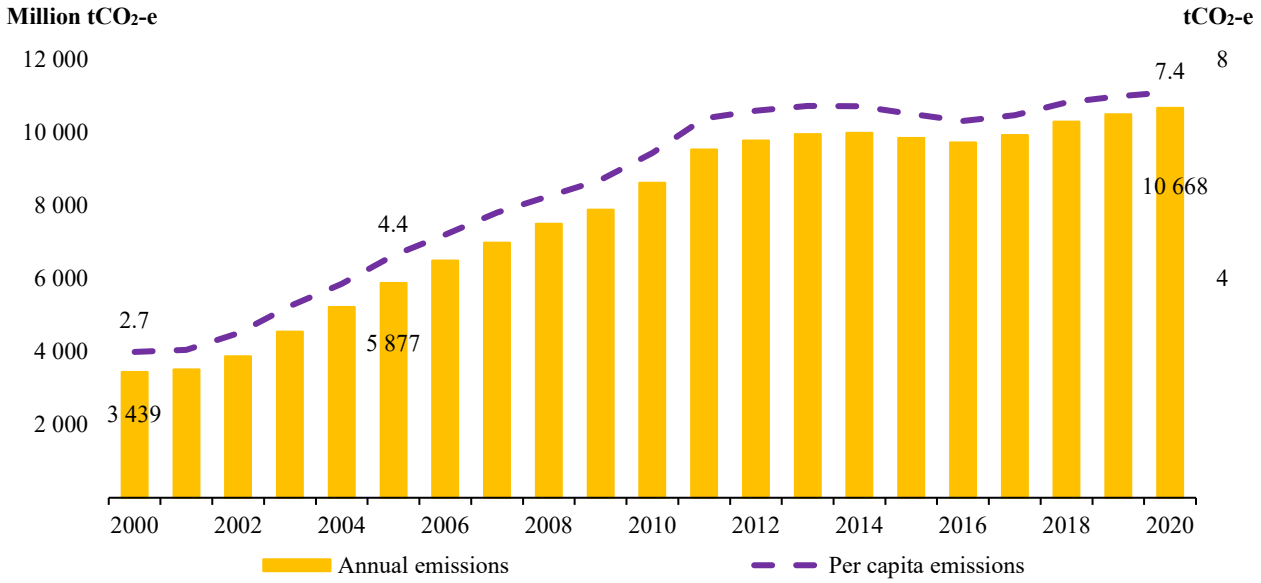
[33] Measures include (a) decreasing annual coal consumption cap from 5 billion tonnes in 2020 to 4.1 billion tonnes by 2025; (b) phasing down coal-fired power plants as from 2026; and (c) investing RMB900 billion (HK$1.1 trillion) on renewables. See International Energy Agency (2021a).

[34] The national carbon market regulates all power companies only.

[35] The EV fleet in the Mainland skyrocketed from fewer than 1 000 in 2011 to 6.4 million in 2021, representing three-fifths of global total. See International Energy Agency (2021a) and 國務院 (2021).

June 2022, the Central Government targeted to raise the share of energy consumption of non-fossil fuels in society from 16% in 2020 to 25% by 2030, and 90% by 2060.[36]

Figure 5 – Overall and per capita GHG emissions in the Mainland, 2000-2020



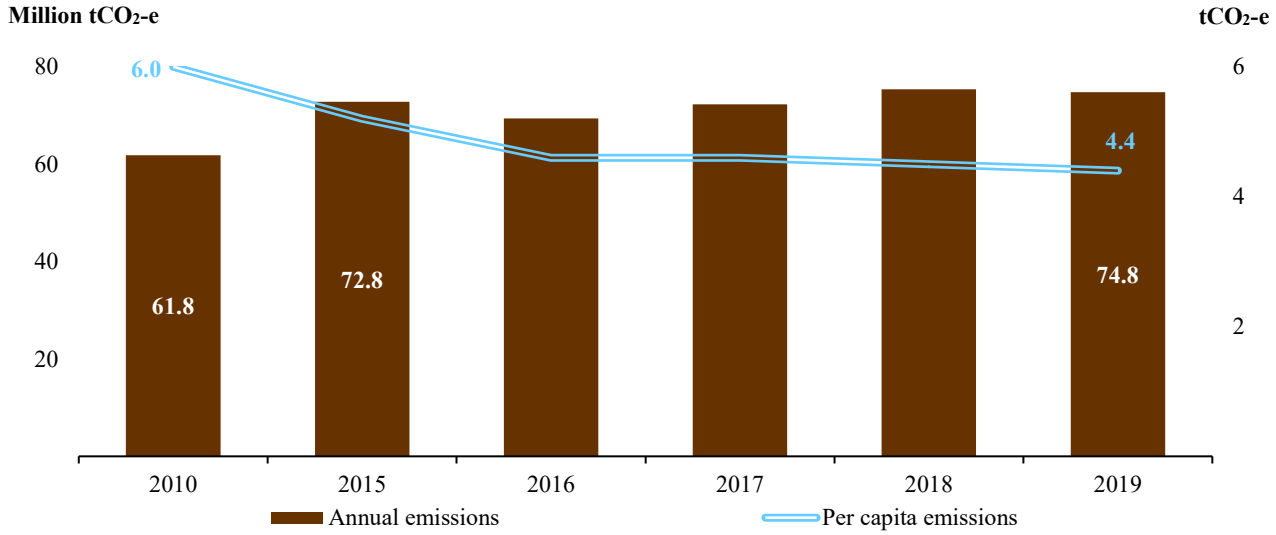
Note: Figures are computed from academic studies due to scattered official data.
Sources: University of Oxford and CEADs.

4.2 As for Shenzhen, it is one of the first eight piloted cities selected in 2010 for low-carbon development. Based on data from academic studies for the period 2010 to 2019, GHG emissions in Shenzhen grew by a relatively moderate pace of 21%, in spite of a strong population growth of 65% and an economic growth of 168%. Consequently, its per capita emissions fell by 25% to just 4.4 tCO_2-e (**Figure 6**), and the reduction in carbon intensity between 2005 and 2020 was even more impressive at 68% (to 0.192 tCO_2-e per RMB10,000 of GDP, and thus completing the task 10 years earlier than the national target of a 65% reduction by 2030). Transport was the largest GHG emitter (65%) in 2015 (most updated data in the public domain with full sectoral breakdowns). On the other hand, electricity generation represented a share of just 19%, when emission arising from electricity imported from cities in Guangdong and nearby provinces is excluded.[37]

[36] 國家發展和改革委員會(2022).

[37] Local governments seldom release official data of their GHG emissions due to confidentiality. In 2021, the Shenzhen government indicated transport represented 40% of local GHG emissions without figures in other sectors. It is not clear if the proportion excluded the emission from electricity imports. It is further noted that Shenzhen imports about 70% of its electricity from other cities.

Figure 6 – Overall and per capita GHG emissions in Shenzhen, 2010-2019



Note: Figures are computed from academic studies due to scattered official data. Emission from electricity imports are included.

Sources: Jiang et al. and 深圳高質量發展與新結構研究院.

4.3 **To achieve "dual carbon target", Shenzhen is expected to (a) reduce carbon intensity by a further 18% during 2020 to 2025; and (b) attain carbon peak before 2025**.[38] Updated decarbonization measures will be laid out by phases within 2022.[39] Here are the policy directions in the sectors of electricity generation and transport:

(a) **Replacing coal and oil in power plants in Shenzhen:** Use of oil for power generation in Shenzhen has ceased after 2015. To reduce usage of dirtier fossil fuels, Ling'ao Nuclear Power Station was built in 2003 and expanded in 2011, while natural gas-fired power plants have been introduced since 2006. The share of coal in the energy mix more than halved from 58% to 23% between 2000 and 2020;[40]

(b) **Promoting generation and import of electricity from renewable energy:** Initiatives have been taken to increase usage of renewable energy since the 2010s. These include (i) nearly doubling the share of renewables in electricity imports from 44% in 2010 to over 80% in 2020;[41] (ii) tripling solar power capacity in Shenzhen during 2015 to

[38] 深圳市人民政府(2021) and 廣東省人民政府(2022).

[39] Wu et al. (2016) and UN-Habitat (2019).

[40] In Shenzhen, coal-fired power plants are retained and retrofitted with emission reduction technologies, keeping coal as a reserve fuel for energy security. See 深圳市經濟貿易局(2003) and 深圳市發展和改革委員會(2016).

[41] 深圳特區報(2021).

2020 through subsidies and public-led installations;[42] and (iii) building seven WTE facilities and a hydro power plant in Shenzhen. With the initiatives under (ii) and (iii), the share of electricity generated in Shenzhen using renewable energy in the city's overall electricity fuel mix increased from 2% in 2015 to 11% in 2020. The Shenzhen government targets to raise the combined share of natural gas, nuclear and renewable energy to 90% in 2025, up from the current figure of 77%, which is noticeably ahead of the nationwide figure of 52%, by (i) expanding the Ling'ao nuclear plant; (ii) building nine more WTE facilities; (iii) constructing offshore wind farms; and (iv) importing more clean energy;[43]

(c) **Promoting new energy and electric vehicles:** Shenzhen is home to BYD, the fourth largest EV manufacturer globally, and in 2018 became the first city in the world to have completed full electrification of its public transport vehicles.[44] For private EV, financial incentives have been offered to owners since the 2010s.[45] New energy vehicles (mostly EV) had thus surged from 3 000 in 2012 to 480 000 in 2020 in Shenzhen (or 14% of the vehicle fleet). By 2025, Shenzhen aims to double the new energy vehicle fleet to 1 million, with a key focus on boosting the number of commercial EV to a further 180 000. This will be complemented by a concurrent upsurge in availability of EV-chargers from 3 000 in 2014 to 833 000 in 2025;[46]

(d) **Decarbonizing maritime and aviation sectors:** Even though maritime and aviation sectors together represent only 15% of transport-related GHG emissions in Shenzhen, the Shenzhen

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42 Subsidies include funding up to 70% of construction cost and feed-in tariff for private solar PV. See 深圳市人民政府(2009) and 深圳市司法局(2022).

43 深圳商報(2021) and 深圳特區報(2022).

44 All 22 000 taxis were electrified in 2018, and electrification of 16 000 buses was completed earlier in 2017. Started from 2015, financial incentives were provided to transport companies, including (i) purchase subsidies up to 50% plus an annual operational grant capped at RMB80,000 (HK$93,768) for each electric bus; (ii) purchase subsidies up to RMB193,000 (HK$226,215) for an electric taxi plus extra 10-year operating licences offered to taxi companies; and (iii) funding the installation of 5 200 taxi chargers and 510 bus charging stations. See South China Morning Post (2015), 國家應對氣候變化戰略研究和國際合作中心(2020), 深圳市交通運輸委員會(2017, 2021), 南方日報(2019) and 深圳市人民政府(2015).

45 Incentives for EV mainly cover (i) purchase cost; (ii) charging fee; (iii) recycling of old EV batteries; (iv) installation of private EV chargers; and (v) parking fee and toll. See UNHabitat (2019) and 深圳市人民政府(2018).

46 New subsidies for commercial EV can be as high as RMB800,000 (HK$937,680) for each eligible vehicle. See 深圳市發展和改革委員會(2021) and 南方日報(2021a).

government has formulated measures to support their decarbonization since 2016, including (i) building shore power facilities covering 80% of vessel berths;[47] (ii) electrifying handling equipment and vehicles in airports and ports; (iii) using solar power for terminals and major facilities; and (iv) encouraging the use of cleaner fuels. All these measures will be further strengthened in the next five years;[48] and

(e) **Emission caps and permit trading for heavy polluters:** Shenzhen is one of the eight cities to set up pilot cap-and-trade systems in the Mainland in 2013, targeting those enterprises with annual emissions exceeding 3 000 tCO_2-e. In 2020, 687 entities in 32 sectors (e.g. utilities, public transport and manufacturing sector) were covered by ETS, taking up 40% of the annual emissions of the city.[49] Allowance is allocated to regulated entities based on their past records of emissions intensity. For those entities using up their allowances, they have to purchase residual quotas on ETS from others to offset excess emissions.[50] As a result, there has been a 40% drop in carbon intensity of regulated industrial entities since 2013. In the longer term, the pilot ETS may be integrated into the national carbon market.[51]

4.4 With the multi-pronged approach as set out in the paragraphs above, Shenzhen was ranked as the greenest city in terms of progress towards net-zero carbon in the Mainland in 2021.[52] Meanwhile, there are suggestions that the decarbonization targets for transport in Shenzhen could be made even more progressive in the light of its strengths in EV, such as laying down a timeframe to phase out fuel-propelled cars (as seen in Hainan province).[53]

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47 Shore power is a land-based port facility to provide electricity to a vessel at berth so that the latter can shut down its engines, reducing up to 90% of the vessel's emissions at the port.

48 深圳市人民政府(2016, 2022), 國家應對氣候變化戰略研究和國際合作中心(2020), 深圳機場集團(2021) and 南方日報(2021b).

49 The number of regulated enterprises expanded to 750 in 2021, though no sectoral breakdown was disclosed.

50 During 2013 to 2021, the cumulative trading volume amounted to 65 million tCO_2-e at a turnover of RMB1.5 billion (HK$1.8 billion). In 2021, emission quota averaged at RMB11 (HK$13) per tCO_2-e.

51 ICAP (2022) and 國家應對氣候變化戰略研究和國際合作中心(2020).

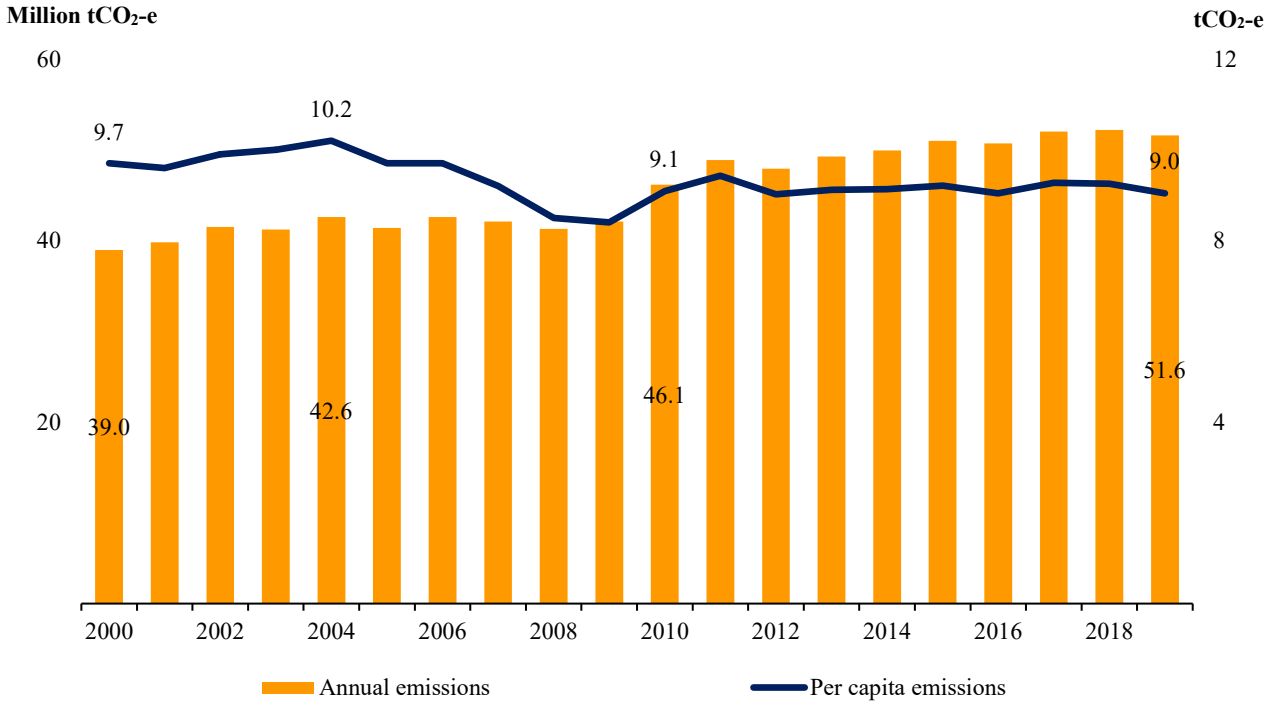
52 深圳市生態環境局(2021a) and 21 世紀經濟報導(2022).

53 深圳市生態環境局(2021b) and 國家應對氣候變化戰略研究和國際合作中心(2020).

5. Decarbonization strategy in Singapore

5.1 Singapore as a low-lying island is prone to the risks of global warming, with 30% of its territory vulnerable to flooding threats. As the manufacturing sector (particularly oil refinery and petrochemicals) takes up 22% of GDP in Singapore, its **annual GHG emissions** had surged by 32% in two decades to 51.6 million tCO_2-e in 2019, though initiatives such as increased usage of natural gas in the fuel mix for electricity generation since 2005 have helped offset some of the upward pressure (**Figure 7**).[54] All in all, **per capita emissions** in Singapore had decreased by 11% to 9 tCO_2-e during 2004 to 2019, while its reduction in **carbon intensity** was more visible at 57% during 2000 to 2019. In terms of sectoral breakdown, industrial production now accounts for 45% of overall emissions in Singapore, followed by electricity generation (39%) and transport (14%).

Figure 7 – Overall and per capita GHG emissions in Singapore, 2000-2019



Source: Singapore Department of Statistics.

[54] Oil refining and petrochemicals sector represented about 15% of GHG emissions in Singapore in 2019.

5.2 **More recently in 2020, the Singaporean government published two strategic plans with updated decarbonization targets** of (a) reaching peak emissions around 2030; (b) halving emissions from its peak by 2050; and (c) achieving carbon neutrality "in the second half of the century". For (c), the completion date was advanced to "by or around mid-century" in February 2022, after the Glasgow Climate Pact in November 2021.[55] **Regarding the decarbonization measures rolled out earlier and proposed in the latest strategic plans**, a summary of major policies for the two sectors of electricity generation and transport is as follows:

(a) **Enhancing efficiency of gas-fired power plants:** Given public opposition to nuclear power, Singapore introduced natural gas in 2005 for electricity generation and it now accounts for 96% of the fuel mix. As an interim measure for further decarbonization, the Singaporean government allocated S$37 million (HK$210 million) in 2018 to improve energy efficiency of existing gas-fired power plants;[56]

(b) **Developing WTE and solar power:** Under natural constraints for certain sources of renewables (e.g. wind, tidal and hydro power), WTE and solar power are now the only viable options available to Singapore for development of renewable energy. As a whole, they account for 3% of electricity production currently.[57] Notwithstanding the difficulties, the Singaporean government has expedited their development to diversify the energy mix since 2015. For instance, it will build two more WTE plants before 2025 and promote solar power through (i) large-scale installations of solar PV in public housing and government sites; (ii) interest-free loans for private solar PV; and (iii) streamlined regulations for selling excess solar power from private owners to the grid and/or corporations.[58] For solar power specifically, Singapore aims to meet 3% of local electricity demand from such facilities by 2030;

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[55] The exact timeframe for carbon neutrality in Singapore will be finalized within 2022. See National Climate Change Secretariat (2016, 2020) and National Environment Agency (2022a).

[56] The second batch of grant will be awarded in mid-2022. See National Climate Change Secretariat (2020, 2022b) and National Environment Agency (2020).

[57] National Climate Change Secretariat (2020) and National Environment Agency (2022b).

[58] Excess solar power sold back to the grid is at prevailing market prices. Alternatively, corporations may purchase Renewable Energy Certificates (i.e. tradable green assets) from larger solar PV owners to offset their annual emissions. See National Environment Agency (2020) and CNA (2020, 2022a).

(c) **Piloting of cleaner energy imports:** As there are "limits" to a compositional change towards net-zero fuel mix in the next two decades, Singapore is now working on three pilot studies of importing cleaner electricity (e.g. solar and hydro power) from Malaysia, Indonesia and Laos, representing 2.5% of its power supply in 2021.[59] Building further on these pilot projects, Singapore plans to have 30% of its electricity supply from the imports in 2035 in a bid to attain carbon neutrality in the power sector by 2050;[60]

(d) **Promoting electric vehicles:** Tax incentives offered for EV purchases in Singapore since 2013 include (i) rebates of up to S$45,000 (HK$255,150) for an electric private car; and (ii) lower road taxes. At the same time, a maximum surcharge of S$25,000 (HK$141,750) is imposed on purchase of "pollutive cars". For this reason, coupled with a zero-growth policy for private cars under the vehicle quota system in 2018, the local EV fleet soared from just 19 in 2013 to over 3 700 (or 0.4% of total vehicles) in 2021.[61] As Singapore targets to decarbonize its land transport by 80% by this mid-century versus the 2016 level, all fossil fuel-propelled vehicles will be phased out by 2040 and EV-chargers will surge to 60 000 in 2030 while financed by issuance of green bonds;[62]

(e) **Electrifying public transport:** Singapore kick-started the electrification of buses and taxis in 2016, backed by measures (i) requiring new buses purchased to be electric only as from 2021; and (ii) offering tax rebates of up to S$57,500 (HK$326,025) for the purchase of an electric taxi and imposing a maximum surcharge of S$37,500 (HK$212,625) for buying a pollutive model. The combined number of electric buses and electric taxis had thus tripled to 429 during

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59 National Climate Change Secretariat (2022b).

60 In March 2022, the Singaporean government released a carbon neutrality report for power sector by 2050. Three future scenarios for net-zero carbon energy mix indicated are (a) electricity imports-dominated; (b) hydrogen-led; and (c) more diversified fuel mix. See National Climate Change Secretariat (2020, 2022b), Energy Market Authority (2022) and The Straits Times (2021).

61 For commercial EV, rebates are capped at S$30,000 (HK$170,100) while surcharge for pollutive models is set at S$10,000 (HK$56,700). See National Climate Change Secretariat (2020, 2022b), Ministry of Transport (2022) and Land Transport Authority (2022).

62 As of January 2022, there were 2 300 EV-chargers in Singapore. While the government has been subsidizing private EV-chargers since July 2021, a proposed piece of legislation for having at least 15% of car parking lots installed with EV chargers in new public housing projects is under consultation, with a view to making all public housing estates EV-charging ready by 2025. See National Climate Change Secretariat (2022b).

2018 to 2021. By 2030, half of the buses and taxis will be electrified, before full electrification in 2040;[63]

(f) **Decarbonizing maritime and aviation sectors:** As a regional maritime and aviation hub, Singapore has implemented decarbonization measures and pledged to achieve carbon neutrality by 2050. Measures to achieve the targets include (i) tax and port fee concessions for using cleaner marine fuels and low-carbon vessels; (ii) LNG bunkering; (iii) electrification of handling equipment and vehicles; (iv) improving energy efficiency of buildings; and (v) piloting of sustainable aviation fuels.[64] Looking ahead, a fully electric-automated Tuas Mega Port to be completed in 2040 will become the only seaport in Singapore. Decarbonization plan for aviation sector will be released by early 2023;[65] and

(g) **Levying carbon tax on major GHG emitters:** Singapore imposed a carbon tax at S$5 (HK$28) per tCO_2-e in 2019 on larger enterprises with annual GHG emissions exceeding 25 000 tCO_2-e locally as a broad-based price mechanism to foster their decarbonization. About 50 facilities in manufacturing, oil refining and utility sectors are now subject to carbon tax, covering 80% of local GHG emissions.[66] In February 2022, the Singaporean government announced to gradually raise the carbon tax rate per tCO_2-e to S$25 (HK$142) in 2024, S$45 (HK$255) in 2026, and S$50-S$80 (HK$284-HK$454) by 2030 upon enhanced commitments globally. Additional tax revenues will fund decarbonization measures and cushion the impact on society.[67] As a relief to those carbon tax liable enterprises with difficulty of emission abatement in the nearer term, they will be allowed to use international carbon credits to offset up to 5% of their emissions in Singapore as from 2024. This can also help Singapore to become a regional carbon

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63 National Climate Change Secretariat (2022b) and The Straits Times (2020).

64 Under a pilot scheme, which is amongst the world's largest of such projects most recently, all flights of the state-owned Singapore Airlines will use sustainable fuels for one year starting from the third quarter of 2022. See Singapore Airlines (2022).

65 National Climate Change Secretariat (2022b), Changi Airport Group (2022), Singapore Airlines (2022) and Maritime and Port Authority of Singapore (2022).

66 Total tax revenue of at least S$1 billion (HK$5.7 billion) is expected in the period of 2019 to 2023, and the proceeds will be spent to improve technologies for energy and carbon efficiency amongst enterprises. See National Climate Change Secretariat (2020, 2022a).

67 Reportedly, oil refiners in Singapore will be difficult to upgrade older plants in the short term due to huge capital costs, except for a few oil giants committing over US$15 billion (HK$118 billion) for low carbon solutions (e.g. carbon capture, hydrogen and biofuels) in the next decade. See S&P Global (2022).

market, coupled with the launch of the Climate Impact X (a public-private exchange of carbon trading) in November 2021.[68]

5.3 After adopting natural gas for its electricity generation, Singapore is now actively considering promoting the use of even cleaner energy through both developing onshore facilities as well as imports from other countries with a view to achieving carbon neutrality in the power sector by 2050. For the transport sector, the maritime sector and the Changi Airport also adopted a carbon neutrality target of year 2050, while the full electrification of public transport could be seen earlier by 2040. At the same time, given the carbon-intensive oil refining and petrochemicals industry is still playing a crucial role in the Singaporean economy (accounting for 3% of GDP and 14% of merchandise exports), this could be a challenge in the city's further decarbonization. Observers would closely follow whether anticipated hikes in the carbon tax could incentivize the industry to switch towards less carbon-intensive modus operandi.

6. Observations

6.1 In **Hong Kong**, after achieving carbon peak in 2014, the Government has budgeted HK$240 billion to attain carbon neutrality before 2050, along with initiatives to develop as a regional carbon market. However, there are noticeable public concerns over the lack of implementation details in the decarbonization strategy, including how to substantially boost the development of renewable energy and how to decarbonize public transport.

6.2 In **Shenzhen**, a basket of measures including importing 70% of its electricity (with over 80% being renewables) and achieving full electrification of public transport has solidified the city's position as one of decarbonization leaders in the Mainland. Moreover, it has been almost a decade since Shenzhen piloted ETS in 2013, and thus heavy polluters outside the power and transport sectors are also required to shoulder their duties in the city's decarbonization efforts.

6.3 In **Singapore**, its carbon emissions is noticeably higher than in Hong Kong because of a strong oil refinery and petrochemical industry there. While the city's decarbonization measures in road transport (e.g. electrification) are similar to that in Hong Kong, Singapore has provided a clearer timeframe for phasing out fossil fuel-propelled vehicles and a comprehensive decarbonization blueprint for the maritime sector. Given the constraints of replacing natural gas with renewables, Singapore is experimenting with imports of electricity generated from cleaner energy, setting a target of enlarging the share of

[68] National Climate Change Secretariat (2022a) and CNA (2022b).

imports to 30% by 2035. Moreover, mandatory carbon tax imposed in 2019 now covers 80% of carbon emissions in Singapore, hence acting as a financial incentive for carbon-intensive enterprises to engage in decarbonization.

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Appendix 1

Decarbonization targets and measures in selected places

		Hong Kong	Mainland	Shenzhen	Singapore
1. Key indicators on GHG emissions in 2020[1]					
(a) Annual emissions (million tCO_2-e)		33.8	10 668	74.8	51.6
(b) Per capita emissions (tCO_2-e)		4.5	7.4	4.4	9.0
(c) Carbon intensity (tCO_2-e/HK$10,000 of GDP)		0.13	0.93	0.24	0.18
(d) Combined share of electricity generation and transport in total emissions		80%	52%	84%	53%
2. Decarbonization targets and measures					
(a) Year of carbon peak		2014	2030	2025	2030
(b) Year of carbon neutrality		2050	2060	-	Mid-21st century
(c) Year of phasing out pollutive power plants	Coal	2035	-	-	2050
	Oil	×	-	2015	2014
(d) Current share of selected cleaner fuels in energy mix for electricity generation	Natural gas	48%	3%	31%[2]	96%
	Renewables	<1%	28%	11%[2]	3%
(e) Target share of non-fossil fuel in energy mix (Hong Kong) / energy consumption (Mainland)		60%-70% (2035)	25% (2030)	-	-
(f) Share of power imports in energy mix (2020)		28%	-	70%	0%
(g) Year of phasing out fuel-propelled vehicles		2035[3]	-	-	2040
(h) Current share of EV to total vehicle fleet		3%	2%	14%	0.4%
(i) Year of full electrification of public transport		-	2035	2018	2040
(j) Targeted number of EV-chargers		-	-	833 000 (2025)	60 000 (2030)
(k) Year of implementing carbon pricing	Cap-and-trade system	×	2013	2013	2021
	Carbon tax		×	×	2019

Notes: (1) Figures for Shenzhen and Singapore are from 2019, except in item 1(d), where that for the Mainland is from 2018 and that for Shenzhen is from 2015.
(2) The Shenzhen government has not indicated if such figures included electricity imports.
(3) Cessation of new registrations of fuel-propelled private cars only.
(-) Information not available/not specified.

Sources: Environment Bureau, International Energy Agency, National Climate Change Secretariat, Singapore Department of Statistics, 深圳市人民政府 and 深圳高質量發展與新結構研究院.

Appendix 2

Major targets and progress of global decarbonization

	Global decarbonization targets
Kyoto Protocol (December 1997)	• GHG emissions reduction from 1990 levels: 5% in the period of 2008-2012; furthering to 18% for the period of 2013-2020
Paris Agreement (December 2015)	• Global warming target: limit the rise in temperature to 1.5°C-2°C by 2100 from pre-industrial levels • Requiring countries to submit decarbonization plans including carbon neutrality targets and measures by 2020 under a five-year review cycle • Reaching carbon peak "as soon as possible" • Achieving climate neutrality by the mid-21st century
Glasgow Climate Pact (November 2021)	• Global warming target: keeping alive the hope of limiting temperature increase to 1.5°C by 2100 • Formulating more stringent emission targets and measures for all sectors to be revisited in the Egypt climate conference in late 2022
IPCC's Sixth Assessment Report (April 2022)	• GHG emission reduction from 2019 levels: 43% by 2030 • Achieving carbon peak before 2025 at the latest • Reaching carbon neutrality by the early 2050s
	Current progress
Global temperature	• Expected global warming of 2.8°C by 2100 under current pledges, lagging behind the target of 1.5°C-2°C stipulated in the Paris Agreement
National decarbonization pledges	• Most carbon neutrality targets set by 2050 or afterwards amongst 131 countries • Ambiguously defined decarbonization targets without detailed timeframes for specific sectors observed in many places

Sources: Intergovernmental Panel on Climate Change, United Nations and Organisation for Economic Co-operation and Development.

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