CHAPTER 15

Singapore Country Report

Zhong Sheng

March 2021

This chapter should be cited as:
Sheng, Z. (2021), 'Singapore Country Report', in Han, P. and S. Kimura (eds.), *Energy Outlook and Energy Saving Potential in East Asia 2020*, Jakarta: ERIA, pp.249-269.

CHAPTER 15

Singapore Country Report

Zhong Sheng

1. Background

Singapore is a small island-state in Southeast Asia, located along the Straits of Malacca between Malaysia and Indonesia. It is the most urbanised and industrialised country in the Association of Southeast Asian Nations (ASEAN), with a per capita gross domestic product (GDP) of US$58,829.60 (in constant 2010 US dollars) in 2019. Under the Copenhagen Accord, Singapore also has a voluntary target of reducing CO2 emissions by 7% to 11% below business-as-usual (BAU) levels in 2020 (NCCS, 2012), which will be increased to 16% if there is a global agreement on climate change. Singapore has signed off on the Paris Agreement as of 22 April 2016 (Ministry of Foreign Affairs, Singapore, 2016) and submitted its Enhanced Nationally Determined Contribution (NDC) and Long-Term Low-Emissions Development Strategy to the United Nations Framework Convention on Climate Change Secretariat on the 31 March 2020 (NCCS, 2020c). Singapore's Enhanced NDC now states an absolute emissions target of 65 million tonnes of carbon dioxide equivalent (MtCO2e) around 2030. In addition, the Enhanced NDC will expand the scope of the country's pledge to include a seventh greenhouse gas, nitrogen trifluoride, within this peak emissions ceiling. The Long-Term Low-Emissions Development Strategy will reduce Singapore's emissions from its peak to 33 MtCO2e by 2050, with a view to achieving net zero emissions as soon as viable in the second half of the century.

2. Singapore's Policy Initiatives

The Inter-Ministerial Committee on Climate Change was created in 2007 to facilitate a Whole-of-Government approach to addressing climate change-related issues. Chaired by Mr. Teo Chee Hean, Senior Minister and Co-ordinating Minister for National Security, the Committee is attended by the Ministers for the Environment and Water Resources, Finance, Foreign Affairs, National Development, Trade and Industry, as well as Transport, to provide overarching strategic planning for Singapore's mitigation efforts.

Switching to cleaner fuels, energy efficiency improvements and the promotion of alternative sources of energy were highlighted as the main tenets of Singapore's mitigation policies. These policies were developed as part of the country's national policy framework to support its multi-pronged objectives of achieving economic competitiveness, energy security and environmental sustainability all at the same time (Ministry of Trade and Industry of Singapore, 2007).

Fuel Switch

Singapore started switching from oil to natural gas as a source for power generation since the early 2000s. Today, natural gas remains a key component of Singapore's power generation mix. Imports into Singapore increased by 0.9% in 2018, and in 2019, natural gas represented 95.3% of the fuel mix for electricity generation in Singapore. Petroleum products, coal and others accounted for the remaining 0.7%, 1.2% and 2.9%, respectively (EMA, 2020c). According to the Third Biennial Update Report published by the National Climate Change Secretariat in 2018 (NCCS, 2018), there are limits to how much more emissions can be reduced by switching fuels, as natural gas already constitutes more than 95% of Singapore's fuel mix for electricity generation.

To expand the country's import capability and sourcing options for liquefied natural gas (LNG), the Singapore LNG terminal began operations in May 2013, with two storage tanks and an initial throughput capacity of 3.5 million tonnes per annum (Mtpa). A third tank and additional regasification facilities were completed in January 2014, increasing the throughput capacity of the terminal to 6 Mtpa, and a secondary jetty was added to the operations in March 2014. Subsequently, in 2018, a fourth LNG storage tank and additional regasification facilities were completed. This further increased the terminal's send-out capacity to around 11 Mtpa (EMA, 2020b).

Promoting Solar Energy

Singapore has been very active in promoting solar energy as the only renewable source of energy to meet its needs. Although there are no subsidies for solar technology, there is policy support for removal of non-market barriers, as well as for facilitating system integration of the intermittency of solar energy without compromising grid stability and for research, development and demonstration efforts aimed at cost reduction and efficiency improvement of solar modules.

As part of the policy objective of accelerating the scale of solar deployment in Singapore, the Housing and Development Board (HDB), together with the Economic Development Board launched the SolarNova programme in 2014, which is a Whole-Of-Government effort promoting solar deployment through aggregating demand across the public sector. This programme is estimated to generate about 420 GWh of solar energy annually, which is approximately 5% of Singapore's total energy consumption, or equivalent to powering 88,000 four-room flats. According to the HDB, SolarNova Phase 1 and Phase 2 tenders have been successfully launched in 2015 and 2016, respectively, which have added another 94 MWp of solar panels to be installed across an estimated 1,500 HDB blocks (HBD, 2020). New SolarNova tenders will be launched until 2020, which is estimated to reach an overall solar target of 350 MWp.

Other approaches to further promote the deployment of solar include floating panels. The Public Utilities Board (PUB), Singapore's National Water Agency launched a floating solar testbed at Tengeh Reservoir in Singapore in October 2016. Further, PUB has plans that implement more floating solar projects in reservoirs in Singapore, such as Bedok, Lower Seletar, Tengeh and Upper Peirce. In particular, the current floating solar project in Tengeh Reservoir offers a large scale solar of 50 MWp. The total amount of energy generated from the four reservoirs can potentially power 15,000 four-room HDB homes (NCCS, 2018).

Energy Efficiency Improvements

Energy efficiency is another integral part of Singapore's mitigation efforts. The Energy Efficiency Programme Office (E2PO), led by the National Environment Agency and the Energy Market Authority, was established in May 2007. The E2PO is a multi-agency committee that jointly promotes and facilitates energy efficiency in Singapore (Energy Efficiency Programme Office, 2020a). Across the nation, energy efficiency improvements are promoted through a plethora of standards and regulations, public awareness and messaging, as well as the adoption of more efficient appliance stock.

Households

The household sector accounts for about 16% of the total electricity consumption in Singapore and thus is a key sector for energy efficiency policies. The Mandatory Energy Labelling Scheme (MELS) and Minimum Energy Performance Standards (MEPS) are two pillars of residential energy efficiency policies. The MELS, introduced in 2008, imposes compulsory display of energy labels on relevant household appliances. This requirement is imposed on all registrable air conditioners and refrigerators, as well as smaller appliances such as television sets, clothes dryers and lighting more recently. The MELS informs consumers and helps them identify, and thereby purchase, more energy-efficient appliances. In September 2014, the tick ratings on energy labels were improved to help consumers better differentiate the energy efficiency of various models.

The MEPS is a supply-side policy that complements the MELS by prohibiting sale of appliance models that do not meet the minimum specified energy efficiency levels. MEPS for air conditioners and refrigerators were raised in 2016 and 2017, respectively. MEPS were also extended to clothes dryers on 1 April 2014 and lamps on 1 July 2015 (NCCS, 2018). They help consumers avoid being locked into using inefficient appliances with high operating costs and encourage suppliers to import more energy-efficient appliances as innovation progresses over time. Both the MELS and MEPS are constantly evaluated and revised to ensure policy efficacy and efficiency.

In addition to the MELS and MEPS, various public messaging campaigns targeting behavioural change in households were also introduced. These initiatives target both the initial purchasing decision, as well as behaviour at the consumption stage. For example, the Life Cycle Calculator and the Saving Energy at Home initiatives, which improves consumer awareness and provides information related to energy efficiency at home. In 2017, the Singapore Government organised "The Energy-Saving Challenge" to encourage households to be more energy efficient and practise energy-saving habits. The Challenge received close to 7,000 entries and participants saved a total of 330,000 kWh.

Transport

According to the E2PO, energy efficiency in the transport sector is governed by three complementary policy objectives: (1) reducing private transport (2) promoting public transport ridership and (3) promoting non-motorised transport. The mitigation measures in the transport sector are projected to achieve 1.64–1.68 MtCO2e abatement by 2020, with an estimated 0.9 MtCO2e abatement in 2016.

The Vehicle Quota System (VQS) regulates the growth of the vehicle population in Singapore. Under the VQS, anyone who wishes to register or buy a new vehicle in Singapore must first obtain a Certificate of Entitlement, which represents a right to vehicle ownership for 10 years. In view of the land constraints on road expansion, the annual vehicle population growth rate has been reduced to 0% effectively from February 2018 onward. The Fuel Economy Labelling Scheme and the Carbon Emissions-based Vehicle Scheme were introduced in 2013 (NCCS, 2018). The Fuel Economy Labelling Scheme provides information on the fuel economy for more informed decisions on high-emissions cars. The Carbon Emissions-based Vehicle Scheme was replaced by the Vehicular Emissions Scheme with a new label in January 2018.

Public transport is the most energy-efficient mode of travel. Under the Land Transport Masterplan, Singapore targets a 70% public transport modal share during peak hours by 2020, and 75% by 2030, up from 59% in 2008 and 67% in 2017. In a nutshell, the promotion of public transport ridership is achieved by ensuring the efficiency and reliability of public transport services. In particular, 1,000 new buses and 80 new bus services were added to the bus network between 2012 and 2017.

In addition to constantly upgrading and expanding the current fleet of public transport vehicles, actions were also taken to expand the existing metro lines and outreach. The length of the rail networks will increase from 230 km to about 360 km by 2030. This will enable eight in 10 households to be within a 10-minute walk of a train station, and 85% of public transport journeys of less than 20 km to be completed within 60 minutes.

To improve the overall experience of commuters, especially in the first and last mile of their journeys, the Government will also be building more than 200 km of sheltered walkways island-wide. The aim is to provide a cycling path network in every public housing town, and an island-wide off-road cycling path network of more than 750 km by 2025, rising from 440 km today (LTA, 2020). More integrated transport hubs will also be built to enable commuters to switch between different types of transport easily, with convenient access to retail, dining and other lifestyle services. Cycling and walking are also encouraged through public messaging campaigns. In addition, various trials are underway to promote the use of the electric vehicles in Singapore. In December 2017, Singapore rolled out an electric car-sharing programme, which aimed to introduce 1,000 shared electric cars and 2,000 charging kiosks island-wide by 2020. In the first quarter of 2019 and mid-2020, 50 hybrid buses and 60 electric buses are planned to be in use, respectively (NCCS, 2018).

Buildings

At the design stage, energy efficiency in building is governed by the Building and Construction Authority of Singapore's Green Mark Scheme. Launched in January 2005, the Green Mark Scheme targets environment-friendly design in buildings, with a focus on energy efficiency, water efficiency, environmental protection, indoor environmental quality and other green features allowing landlords to 'go green' (Energy Efficiency Programme Office, 2020b). As of 2008, all new buildings are required by law, under the Building Control (Environmental Sustainability) Regulations, to meet standards that are equivalent to the Green Mark Certified rating. The Green Mark Scheme promotes green building technologies and reduces the use of electricity in the commercial sector via efficiency improvements and conservation. There are also incentives and financing schemes, such as the SGD50 million Green Mark Incentive Scheme for Existing Buildings and Premises and Building Retrofit Energy Efficiency Financing scheme, for developers to achieve higher-tier Green Mark ratings. The aim is to achieve Green Buildings standards for at least 80% of the total gross floor area in Singapore by 2030, compared to more than 34% as of 1 January 2018.

Since 2006, the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative have placed the public sector at the front of building energy efficiency. Under the PSTLES, public sector agencies have been encouraged to put in place environmental sustainability measures that encompass energy efficiency, water efficiency and recycling. In 2014, the PSTLES initiative was enhanced by, for example, requiring each Ministry to appoint a Sustainability Manager, set sustainability targets for FY2020 and develop a resource management plan. Moreover, the Guaranteed Energy Savings Performance (GESP) Contracts initiative was introduced to ensure reaping the expected energy savings. Under the GESP Contract structure, a public sector agency is expected to engage an accredited Energy Services Company to carry out an energy audit, implement the relevant energy efficiency measures and guarantee annual energy savings over the contract term (typically 5 years) (Energy Efficiency Programme Office, 2020c). As of March 2017, 28 large building owners have called GESP contracts for their building retrofit works, which, on average, help building owners save 16% of their total electricity use, enabling the public sector to save a total of SGD8.5 million annually.

Industry

According to Singapore's third biennial update report, industry consumes the most energy in Singapore; thus, improving industrial energy efficiency is key to reducing emissions. The Singapore Government has implemented various grants, private sector financing schemes and tax incentives to encourage energy-efficient technologies. Mandatory energy management requirements for energy-intensive companies in the industry sector were later introduced in April 2013 under the Energy Conservation Act (ECA). The ECA has been further enhanced. For example, since 2018, companies under the ECA are required to adopt specified methodologies for greenhouse gas measurement and reporting. From 2021, companies under the ECA will be required to put in place a structured energy management and assessment system at existing industrial facilities. In particular, minimum energy performance standards were introduced in late 2018 to phase out the least-efficient industrial electrical motors.

The financing schemes include the Grant for Energy Efficiency Technologies, which is designed to offset part of the initial capital investments in energy-efficient technologies. Similarly, the Energy Efficiency Improvement Assistance Scheme provides co-funding for companies to conduct energy assessments. In 2017, the Energy Efficiency Improvement Assistance Scheme and other existing incentive schemes were consolidated to form the New Energy Efficiency Fund. In addition, Singapore has plans for national schemes for building energy efficiency capabilities within the workforce. Overall, these mitigation measures are estimated to achieve 1.43 MtCO2e abatement by 2020, with an estimated 1.27 MtCO2e abatement in 2016.

3. Modelling Assumptions

The model is calculated under the Business as Usual (BAU) scenario and several Alternative Policy Scenarios (APS). APS1 – 3 allow for larger changes in power generation or sectoral electricity demand, as compared to the BAU scenario. APS5 is the scenario combining changes applied in all other APS scenarios.

3.1 Power Generation Sector

For a BAU scenario, the generation efficiency of combined-cycle gas turbine plants are assumed to improve from 56.48% in 2017 to 58% in 2050. Single-cycle thermal plants are expected to improve marginally as well, from 24.3% in 2017 to 45% in 2050. With respect to the use of solar generation capacity, it is assumed to grow from 0.32% in 2017 to around 6% of total electricity generated in 2050, as part of public efforts towards promoting renewable energies. In addition, the share of municipal solid waste is assumed to increase from 1.16% in 2017 to 1.32% in 2050.

With respect to APS2, which takes into account greater potential for efficiency in the power generation sector, combined-cycle gas turbine plants will reach 65% efficiency by 2050, while single-cycle thermal plants could reach an efficiency of 48% by 2050. APS3 allows for the share of solar to reach 25% of Singapore total electricity needs in 2050.

3.2 Transport Sector

Demand for petrol, natural gas and diesel for Singapore's road vehicles is assumed to be dependent primarily on vehicle growth. Consistent with quota targets set by the Land Transport Authority, vehicle growth will stay at 0% from 2017 to 2050 for the BAU scenario. Electricity demand for the Mass Rapid Transit system is mainly driven by the expected expansion of railway length, which will increase from 203 km in 2017 to 380 km by 2050, an annual average growth rate of 1.91% per year. All APS remain similar to BAU here, as no further vehicle growth reductions or railway efficiency improvements have been assumed.

3.3 Residential Sector

In the BAU scenario, residential electricity demand is assumed to be reduced by 2.5% by 2020 due to the MEPS as compared to the projected values. From 2021 to 2050, the demand is the same with the projected values. The projected residential electricity demand until 2050 is assumed to be affected by GDP per capita and previous year's demand. The projections were conducted by the ordinary least squares estimator with robust standard errors. Electricity demand can be further reduced by 10% by 2030 due to the MEPS as compared to the projected values in the APS1 and APS5 scenarios. Demand for natural gas and oil products increase at the same rate with the growth of population in all scenarios.

3.4 Commercial Sector

In the BAU scenario, the electricity demand is assumed to decrease by 5% by 2020 due to the BCA Green Mark Scheme as compared to the projected values. From 2021 to 2050, the electricity demand changes at the projection rates. The ordinary least squares estimator with standard errors is applied to the projections, which are associated with the commercial sector's GDP and the previous year's demand. The APS1 and APS5 scenarios will lead to a further reduction of 10% by 2030 as compared to the projected values. No reduction is expected in natural gas and oil consumption.

3.5 Industry Sector

For industry, The BAU scenario assumes that industrial electricity demand is reduced by 5% by 2020 due to the ECA as compared to the econometric projected values. From 2021 to 2050, the demand is the same with the projected values. The electricity demand is assumed to be associated with the GDP and previous year's value. In the APS1 scenario, the demand is further reduced by 10% by 2030 as compared to the projections. The industrial natural gas is assumed to grow at the annual rate of 0.024, whereas residual fuel oil is assumed to grow at the same rate with the industrial GDP. Other fuels, such as gasworks gas, diesel, kerosene, petroleum coke, refinery gas, LPG and coal, are assumed to be unchanged over years.

4. Outlook Results

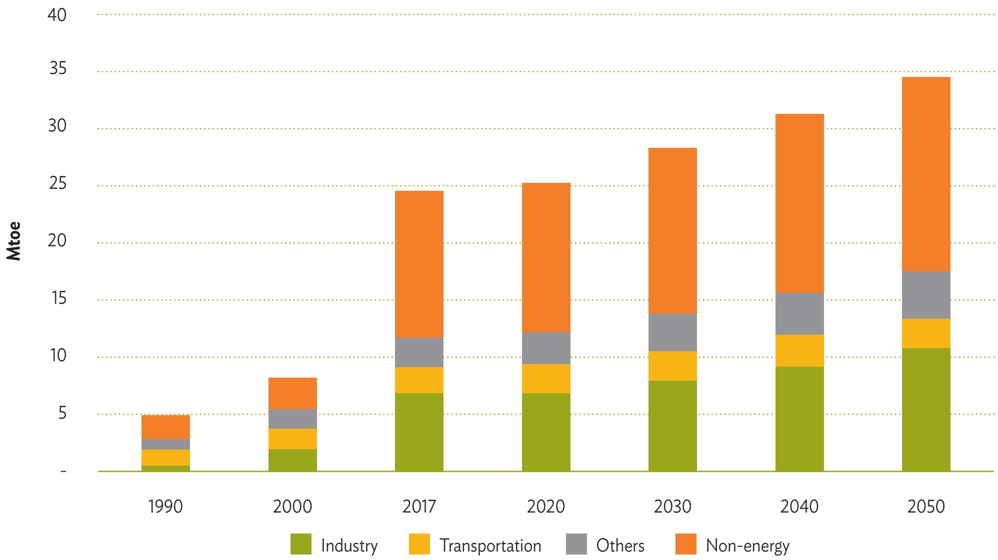
4.1. Final energy consumption

Singapore's final energy consumption grew at an annual rate of 6.1% from 5.01 million tonnes of oil equivalent (Mtoe) in 1990 to 24.56 Mtoe in 2017. During the same period, oil was the dominant energy source, with 3.81 Mtoe and 18.83 Mtoe consumed in 1990 and 2017, respectively. Approximately 51.8% of the country's final energy is consumed for non-energy uses in 2017, particularly as feedstock for petrochemical production. In 1990, 27.1% of the final energy consumption was used in the transport sector, although its share in the total final energy consumption declined to around 9.98% only in 2017.

Under the BAU, final energy consumption is projected to grow by 1% annually between 2017 and 2050. Non-energy sector demand is projected to grow by 0.9%, while industry demand will increase by 1.4% per year. The transport sector is projected to grow by 0.2% per year. The "others" (i.e., residential and commercial) sector is projected to grow by 1.6% per year.

Under the BAU, industry consumption will become the highest share in the total final energy consumption, followed by the non-energy sector. By end of 2050, non-energy use will decline

Figure 15.1. Final Energy Consumption by Sector, BAU



BAU = business as usual.

Source: Author's calculation.

from 51.8% in 2017 to 48.8% of the total energy mix. The industrial sector's share will increase from 27.8% in 2017 to around 31.2% in 2050.

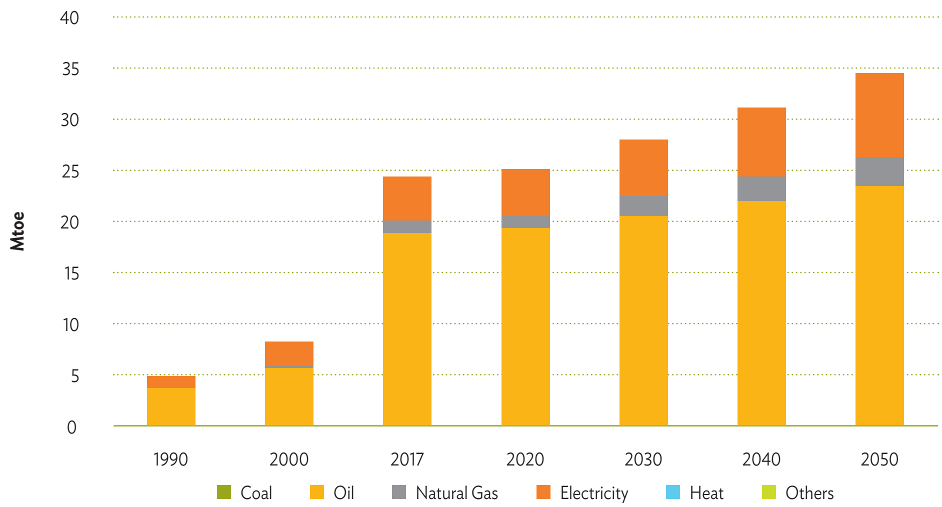
The transport sector's share in the final energy consumption for the period 2017 to 2050 is expected to decrease to 7.7% from its 27.1% height in 1990. This decrease stems from the national policies advocating for more efficient automobile technology and the promotion of public transport. In addition, the Certificate of Entitlement quotas are also expected to remain effective in curbing vehicle growth.

By fuel type, natural gas experienced the fastest growth from 1990 to 2017, at an average rate of 12% per year. The growth of natural gas was due to increasing demand mainly in the rapidly expanding industry sector. Also from 1990 to 2017, demand for electricity grew at an average annual growth of 5.1%.

Under the BAU, the demand for natural gas is expected to continue expanding but at a slower average growth of 2.4% per year till 2050. Meanwhile, electricity demand will only be growing at an average of of about 2% per year.

Oil is still expected to play a major role in the country's final energy consumption. For the past 2 decades, that is, from 1990 to 2017, the share of oil increased from 76% to around 76.6%. Under the BAU, oil's share to the final energy consumption will fall to 76% in 2020 before falling further to 67.9% in 2050. This decline is mainly due to high growth in natural gas usage, which will increase from its share of 5.3% in 2017 to 8.3% in 2050. Meanwhile, the share of electricity in the final energy consumption will increase to around 17.7% starting 2020 and before rising further to 23.3% until 2050. Figure 15-2 shows the final energy consumption by fuel.

Figure 15.2. Final Energy Consumption by Fuel, BAU



BAU = business as usual.

Source: Author's calculation.

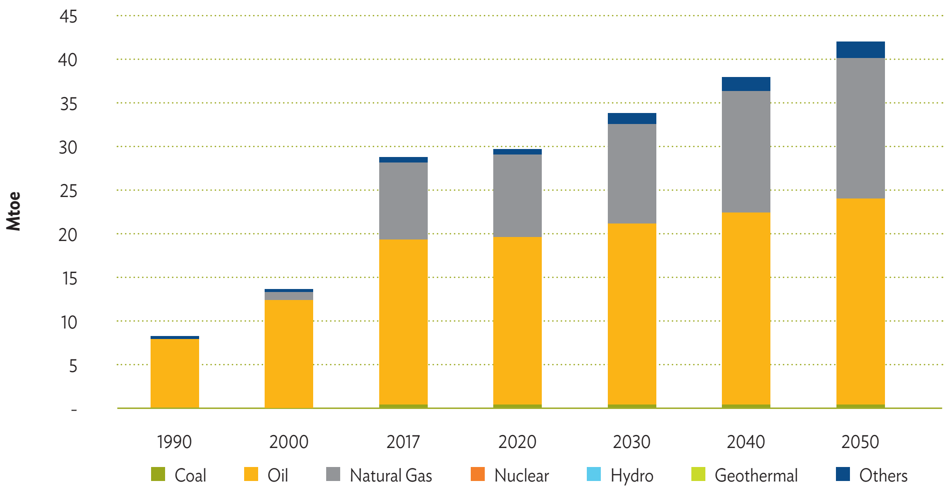
4.1.2 Primary energy supply

Primary energy supply grew by 4.7% per year, from 8.38 Mtoe in 1990 to 29.06 Mtoe in 2017. Singapore's dominant source of energy in 1990 was oil (98.2%), consumption of which increased by 3.1% yearly from 8.23 Mtoe in 1990 to 18.96 Mtoe in 2017. Following the construction of pipelines for gas-fired power plants, the first of which sourced gas from Malaysia in 1991, and two more recent pipelines from Indonesia, the share of natural gas consequently increased. Natural gas consumption increased rapidly from 0.06 Mtoe in 1990 to 8.9 Mtoe in 2017.

Primary energy supply in the BAU is projected to grow by 1.2% per year between 2017 and 2050 (Figure 15-3). Amongst the energy sources, solar energy is expected to grow the fastest at 3.3% a year, followed by biomass and natural gas at 2% and 1.8% per year, respectively. Natural gas demand is expected to grow in line with the expansion of gas-fired power plants.

Oil is expected to remain the primary energy source, accounting for 55.5% of primary energy

Figure 15.3. Primary Energy Supply, BAU



BAU = business as usual.

Source: Author's calculation.

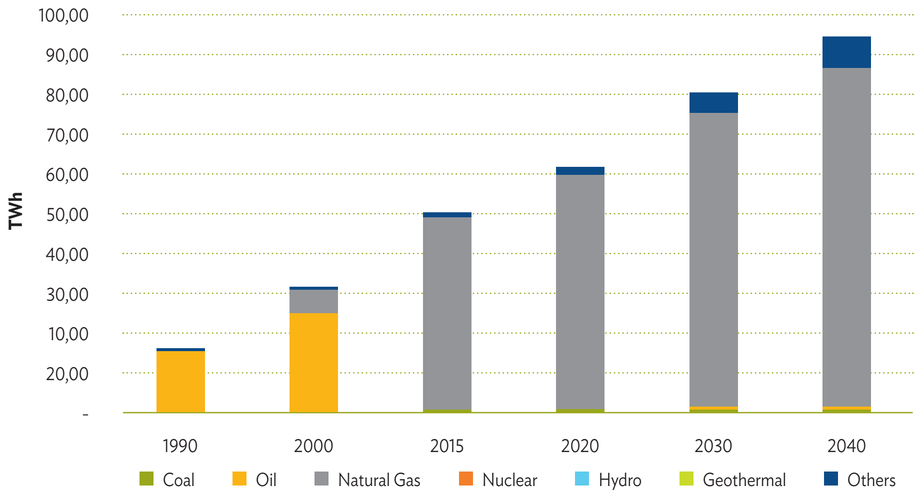
demand in 2050 followed by natural gas at 38%. Between 1990 and 2017, the annual growth of coal consumption was about 12.4%. From 2017 to 2050, the annual growth of coal consumption is projected to be about 1.4%, with its share in total primary energy supply rising from 1.6% in 2017 to about 1.7% in 2050.

4.1.3 Power generation

Electricity generation grew by 4.6% per year from 15.71 TWh to 52.66 TWh over the period 1990 to 2017. The electricity generation mix has changed significantly over the past decade. Natural gas, which accounted for 18.5% of electricity generation in Singapore in 2000, grew rapidly to supply 94.9% of Singapore's electricity in 2017. Fuel oil use for thermal power generation is around 0.37 TWh in 2017. In the same period, biomass and solar takes up a small proportion of the mix, totaling around 3.1%. Coal started to be used in 2013 as a substitute for supply of hydrogen and carbon monoxide as feedstock for the energy and petrochemical sector. It is projected to grow only marginally at 2% per annum.

In the BAU scenario, power generation is projected to increase at 2% per year from 2017 to 2050, reaching 99.64 TWh in 2050. By type of fuel, generation from "Others", which comprises biomass and solar power, will have the fastest growth at an average rate of almost 5.3% per year. "Others" power generation is expected to increase its share from a minimal share of 3.1% in 2017 to 9.1% in 2050.

Figure 15.4. **Electricity Generation, BAU**



BAU = business as usual.

Source: Author's calculation.

Starting in 2017 and extending into the future, at least 89.5% of the country's power generation mix will come from natural gas under the BAU. Its share of generation mix gradually declines over time from 94.9% in 2017 to 89.5% in 2050 as more solar power is used. On the other hand, the share of oil will decline from 0.7% in 2017 to 0.1% over the same period.

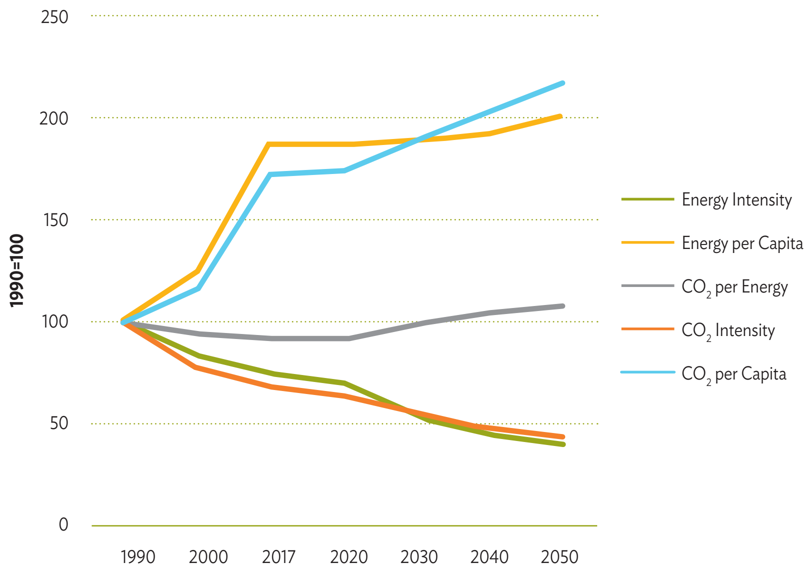
The average thermal efficiency of Singapore's fossil-fueled power plants was around 30.2% in 1990 and improved to 54.6% in 2017 as more natural gas-fired power plants were in operation. In the BAU scenario, thermal efficiency of fossil plants is expected to improve further to around 56.4% in 2050.

By fuel, natural gas plants' thermal efficiency will be 58% in 2050, while oil will be at 45%.

4.1.4. Energy indicators

Primary energy intensity, which is computed as the ratio of primary energy supply over GDP, is expected to decrease. Energy intensity continues to decrease as total primary energy supply will grow at a slower rate compared to population growth. CO2 intensity, defined as emissions per unit of GDP, is projected to have similar declining trends compared to energy intensity. Energy and CO2 per capita increases as population growth is expected to remain lower than fossil fuel demand growth.

Figure 15.5. **Energy Indicators, BAU**



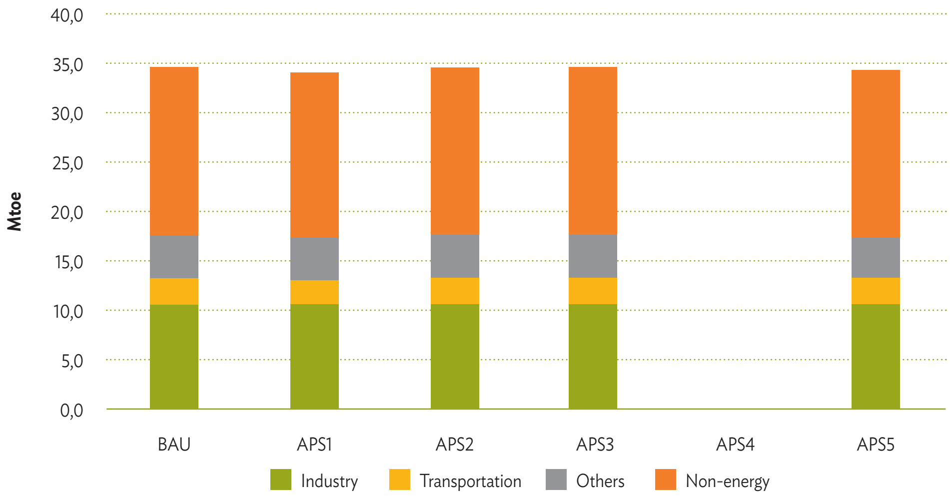
BAU = business as usual.
Source: Author's calculation.

4.2. Energy Savings and CO2 Reduction Potential

4.2.1. Final energy consumption

Final energy consumption under APS1 is projected to increase by 1% annually from 2017 to 2050. Similar to the BAU case, the non-energy sector grows at 0.9% per year. The other (residential and commercial) sector grows at 1.4%, which is followed by the industry sector at 1.3% and transportation at 0.2%. APS2 and APS3 include the same reduction targets due to energy conservation policies for end demand with the BAU scenario, but have different power generation efficiency or renewable energy shares. APS5 has the highest reduction targets, renewable targets and renewable share. In particular, under BAU, the total final energy consumption in 2050 is projected to be 34.65 Mtoe, which is also the projected value for APS2 and APS3. Amongst all APS scenarios, APS1 has the lowest final energy consumption of 34.23 Mtoe, followed by APS5 with 34.43 Mtoe.

Figure 15.6. Final Energy Consumption by Sector in 2050, BAU and APS1-5



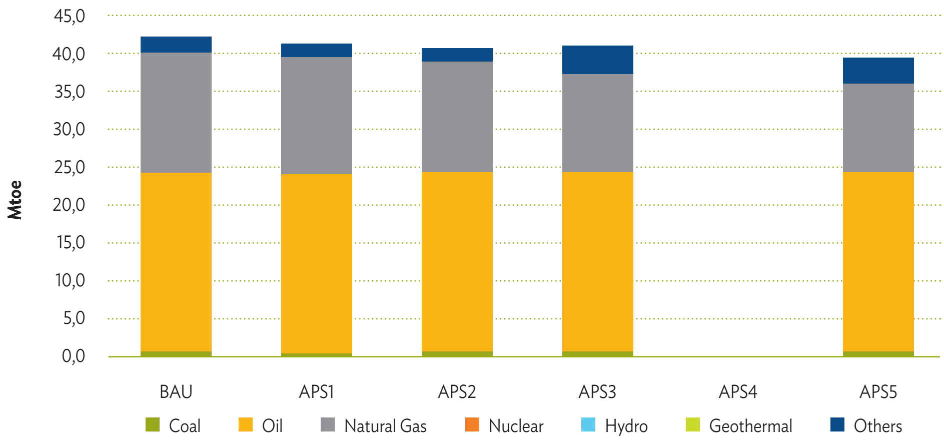
APS = alternative policy scenario, BAU = business as usual.

Source: Author's calculation.

4.2.2. Primary energy supply

Results from APS2 show that primary energy supply for 2017–2050 will increase at an average annual rate of 1%, a 1.4 Mtoe decrease from BAU (Figure 15-7) in 2050. This translates to a percentage reduction of 3.3% from BAU in 2050. APS1 and APS3 will help to lower primary energy supply by 0.8 Mtoe and 1.2 Mtoe respectively in 2050. This illustrates that policies targeting end-user energy efficiency policies and renewables currently still play only a secondary role to power generation efficiency policies in reducing primary energy demand.

Figure 15.7. Total Primary Energy Supply by Fuel in 2050, BAU and APS1-5

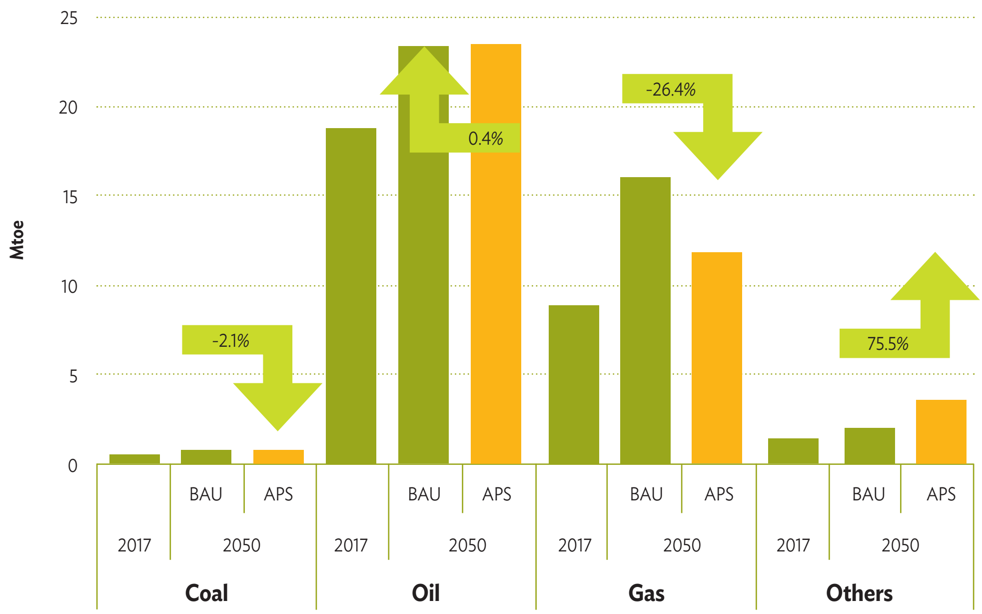


APS = alternative policy scenario, BAU = business as usual.

Source: Author's calculation.

Most of the reduction in primary energy supply will come from natural gas at 4.2 Mtoe, which is a drop of 26.4% from BAU (Figure 15-8). Oil only slightly increases by 0.4% as it is limited by the already declining BAU consumption for power generation, as well as the large consumption in the petrochemical non-energy use. Biomass' consumption will remain relatively constant, while solar power progresses significantly, but is still small in magnitude. Hence, this leads to an increase in consumption of "others" by 75.5%.

Figure 15.8. Primary Energy Supply by Fuel, BAU and APS5



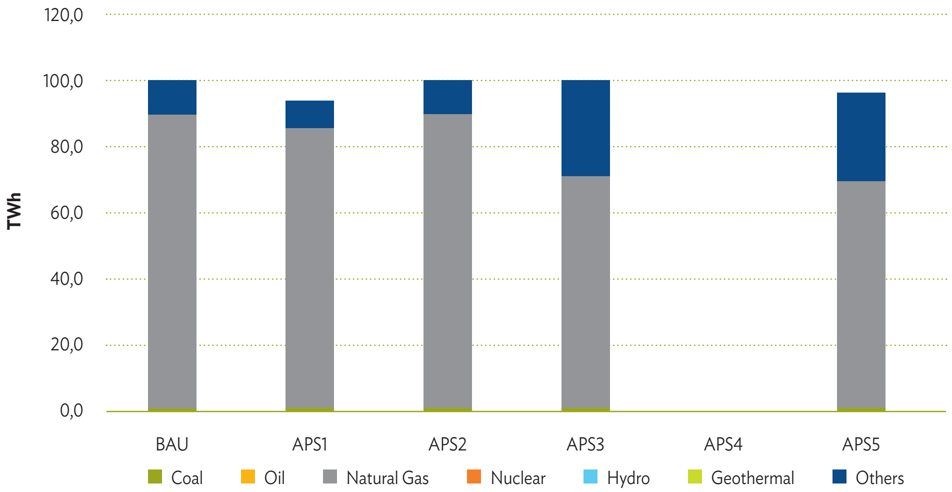
APS = alternative policy scenario, BAU = business as usual, Mtoe = million tons of oil equivalent.

Source: Authors.

4.2.3. Power generation

Result from APS1 and APS5 shows a decrease in electricity generation, registering a drop of 5.17 TWh and 2.71 TWh from BAU, respectively. APS2 and APS3 assume the same generation as BAU since final energy consumption does not fall for these two scenarios (i.e., 99.64 TWh).

Figure 15.9. **Electricity Generation in 2050, TWh**



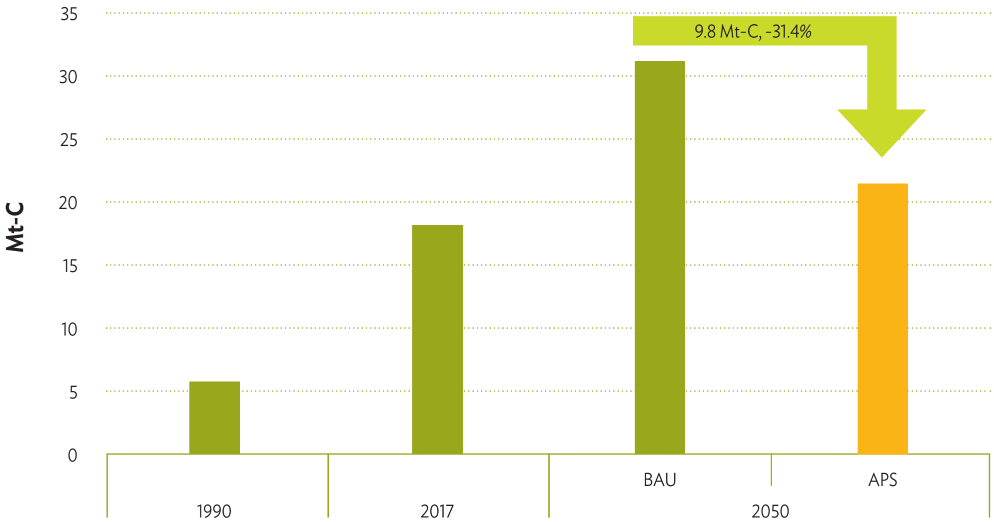
APS = alternative policy scenario, BAU = business as usual.

Source: Author's calculation.

4.2.4. CO2 reduction potential

Under BAU, CO2 emissions from energy demand are projected to increase at an average annual rate of 1.6%, from 18.2 million tonnes of carbon (Mt-C) in 2017 to around 31.1 Mt-C in 2050 (Figure 15-10).

Figure 15.10. **CO_2 Emissions from Energy Consumption, BAU and APS**



APS = alternative policy scenario, BAU = business as usual.

Source: Author's calculation.

CO_2 emissions reduction potential comes mainly from improvements in thermal efficiency for power generation (APS2), with savings of 3.35 Mt-C in 2050, equivalent to a 10.8% decrease from BAU. Educational policies and incentives that target behavioural changes in end-consumers of energy are also very beneficial, with APS1 registering emissions reduction of 1.62 Mt-C in the same time period (5.21% reduction from BAU). Increased utilisation of solar power (APS3) offers large emissions reduction of 6.53 Mt-C (20.1% reduction from BAU). Overall, APS5 will contribute to emissions reduction of 9.8 Mt-C, which is a 31.4% reduction from the BAU scenario. Under this scenario, carbon emissions will increase at an annual average growth rate of 0.5% from 2017 to 2050, compared to 1.6% under BAU.

5. Implications and Policy Recommendations

The Singapore government has been progressively implementing diversified sectoral measures to help incentivise the adoption of clean energy technologies and emissions reduction (NCCS, 2020a). These include, in the power sector, switching fuel mix and encouraging solar test-bedding and research, sludge incineration in waste water management, MEPS in the residential sector, the Green Mark system in buildings, promoting public transport and the Vehicular Emissions Scheme in the transport sector, and the Grant for Energy Efficient Technologies and the Energy Efficiency Fund in the industry sector.

In particular, ongoing innovation has focused on electric vehicles, including electric taxis (starting in February 2017), electric buses (starting in 2018) and an electric car-sharing programme (a 10-year programme, starting on 30 June 2017) (LTA, 2020b). The fleet of electric taxis is expected to be increased to 800 by July 2022. The electric car-sharing programme will deploy 1,000 electric vehicles and build a total of 2,000 charging points by 2020. These programmes will further explore mitigation potentials from the transport sector.

Singapore has also taken measures to ensure that its energy needs are diversified across more countries for energy imports rather than depending on gas pipeline flows from Malaysia and Indonesia as it shifts toward using more natural gas to power its electricity needs. Currently, Singapore has plans to increase LNG import storage facilities, and regulates each stage of gas value chains via a gas license system (e.g., transport, shipping, retail, import of gas, operation of the LNG terminal and onshore receiving facilities for piped natural gas) (EMA, 2020c).

As shown in the forecast results for BAU with 2017 as the base year, Singapore's CO_2

emissions will grow to 31.1 $MtCO_2e$ in 2050, with an average annual growth rate of 1.6%, where estimations show the potential to go as low as 21.08 $MtCO_2e$, if much greater efforts are taken to reduce emissions.

While Singapore is actively supporting research on clean energy innovation and transition, there is limited access to alternative or renewable energy. Singapore has committed to maintain a balance between development and protecting the environment (NCCS, 2020b). In addition to climate/energy policies, public awareness and behaviour change will be essential.

Remarks

All results in this document are for academic research purposes. The views and conclusions contained in this document are those of the author and should not be interpreted as representing the official opinions, either expressed or implied, of National University of Singapore, the Singapore Government or any other governmental organisations.

REFERENCES

Energy Efficiency Programme Office (EEPO) (2020a), *About E2PO*, https://www.e2singapore.gov.sg/who-we-are/about-us (accessed 18 July 2020).

Energy Efficiency Programme Office (EEPO) (2020b), *Buildings*, https://www.e2singapore.gov.sg/overview/buildings (accessed 18 July 2020).

Energy Efficiency Programme Office (EEPO) (2020c), *Programmes and Grants*, https://www.e2singapore.gov.sg/programmes-and-grants/programmes/public-sector-taking-the-lead-in-environmental-sustainability (accessed 18 July 2020).

Energy Market Authority (EMA) (2020a), *Singapore Energy Statistics 2019*, https://www.ema.gov.sg/Singapore_Energy_Statistics.aspx (accessed 18 July 2020).

Energy Market Authority (EMA) (2020b), *Overview of Gas Market*, https://www.ema.gov.sg/Gas_Market_Overview.aspx (accessed 18 July 2020).

Energy Market Authority (EMA) (2020c), Gas Licences, https://www.ema.gov.sg/Licensees_Gas_Licences.aspx (accessed 18 July 2020).

Housing and Development Board (HDB) (2020), *SolarNova Programme*, https://www.hdb.gov.sg/cs/infoweb/about-us/our-role/smart-and-sustainable-living/solarnova-page (accessed 18 July 2020).

Land Transport Authority (LTA) (2020a), *Cycling Friendly City*, https://www.lta.gov.sg/content/ltagov/en/getting_around/active_mobility/walking_cycling_infrastructure/cycling.html (accessed 18 July 2020).

Land Transport Authority (LTA) (2020b), *Electric Vehicles*, https://www.lta.gov.sg/content/ltagov/en/industry_innovations/technologies/electric_vehicles.html (accessed 18 July 2020).

Ministry of Trade and Industry of Singapore (2007), *National Energy Policy Report - Energy for Growth*, http://app.mti.gov.sg/data/pages/2546/doc/NEPR.pdf (accessed 18 July 2020).

Ministry of Foreign Affairs, Singapore (2016), *MFA Press Release: National Statement of Singapore delivered by Minister for Foreign Affairs Dr Vivian Balakrishnan at the Signature Ceremony of the Paris Agreement in New York, 22 April 2016*, https://www.mfa.gov.sg/content/mfa/media_centre/press_room/pr/2016/201604/press_20160423.html (accessed 18 July 2020).

National Climate Change Secretariat (NCCS) (2012), *Speech on Climate Change by Mr Teo Chee Hean, Deputy Prime Minister, Coordinating Minister for National Security and Minister for Home Affairs, at the Committee of Supply Debate*, http://app.nccs.gov.sg/news_details.aspx?nid=642&pageid=97 (accessed 18 July 2020).

National Climate Change Secretariat (NCCS) (2018), *Singapore's Fourth National Communication and Third Biennial Update Report*, https://www.nccs.gov.sg/docs/default-source/default-document-library/singapore's-fourth-national-communication-and-third-biennial-update-repo.pdf (accessed 18 July 2020).

National Climate Change Secretariat (NCCS) (2020a), *Mitigation Efforts*, https://www.nccs.gov.sg/singapores-climate-action/mitigation-efforts/ (accessed 18 July 2020).

National Climate Change Secretariat (NCCS) (2020b), *National Circumstances*, https://www.nccs.gov.sg/singapores-climate-action/overview/national-circumstances (accessed 18 July 2020).

National Climate Change Secretariat (NCCS) (2020c), *Submission Of Singapore's Enhanced Nationally Determined Contribution And Long-Term Low-Emissions Development Strategy To The United Nations Framework Convention On Climate Change*, https://www.nccs.gov.sg/media/press-release/submission-of-singapores-enhanced-nationally-determined-contribution-and-long-term-low-emissions-development-strategy (accessed 18 July 2020).