Chapter 15

Singapore Country Report

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Chapter 15

Singapore Country Report

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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$37,491 (in constant 2005 terms) in 2013. Singapore submitted its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat on 3 July 2015[1] and has signed off to the Paris Agreement as of 22 April 2016.[2] Singapore's INDC highlights its intentions to reduce its emission intensity by 36 percent from 2005 levels by 2030. In addition to emissions intensity targets, Singapore also intends to stabilise emissions with the aim of peaking around 2030. Under the Copenhagen Accord, Singapore also has a voluntary target of reducing carbon dioxide (CO_2) emissions by 7 to 11 percent

[1] National Climate Change Secretariat (NCCS) (2015), 'Singapore's Submission to the United Nations Framework Convention on Climate Change (UNFCCC)', https://www.nccs.gov.sg/news/singapore %E2 %80 %99s-submission-united-nations-framework-convention-climate-change-unfccc

[2] 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

below business-as-usual levels in 2020,[3] which will be increased to 16 percent if there is a global agreement on climate change.

2. Singapore's Policy Initiatives

The Inter-Ministerial Committee on Climate Change (IMCC) was created in 2007 to facilitate a Whole-of-Government approach to addressing climate change related issues. Chaired by Mr Teo Chee Hean, the Deputy Prime Minister and Co-ordinating Minister for National Security and Minister of Home Affairs, 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.

With a national policy framework to maintain a balance among the policy objectives of economic competitiveness, energy security, and environmental sustainability,[4] the switch to cleaner fuels, energy efficiency improvements, and the promotion of alternative sources of energy, in particular solar energy, were highlighted as the main tenets of Singapore's mitigation policies.

Fuel switch

Recognising the value of sustainability and the environment, Singapore switched from fuel oil to the cleaner natural gas in its power generation in the early days, despite the higher costs. Today, natural gas remains a key component of Singapore's power generation mix. In 2015, natural gas represented 95.5 percent of the total licensed generation capacity in Singapore.[5] Petroleum products and 'others' accounted for the remaining 0.7 percent and 3 percent,[6] respectively. In a

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[3] National Climate Change Secretariat (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.
[4]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.
[5] Energy Market Authority (2016), 'Singapore Energy Statistics 2015', https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/SES2015_Final_website_2mb.pdf
[6] ibid.

consultation paper released by the Energy Market Authority (EMA) in 2015,[7] natural gas is expected to remain a dominant energy source in Singapore's power sector into the future.

To expand the country's import capability and sourcing options for liquefied natural gas (LNG), Singapore commenced commercial operations with its newly constructed LNG terminal in May 2013. It currently has a throughput capacity of 6 million tons per year,[8] and 9 million metric tons per annum (Mtpa) from 2017 with a fourth storage tank to be constructed.[9] The current aim is to increase the targeted annual capacity to 11 Mtpa by 2018.[10]

Alternative energy promotion

Despite being renewable-energy disadvantaged due to its dense and urban landscape, Singapore has voiced its intention to capitalise on the only viable renewable option: solar energy. Although there are no subsidies for solar technology, there is policy support for the deployment of solar resources in the form of removal of non-market barriers, system support in terms of facilitating system integration of the intermittency of solar energy without compromising grid stability and continued support for research, development, and demonstration (RD&D) efforts aimed at cost reduction and efficiency improvement of solar modules. In addition to policy support for RD&D, the public sector is also seen to be active in test-bedding projects for innovative solar deployment. As part of the policy objective of accelerating the scale of solar deployment in Singapore, the Housing and Development Board (HDB) recently awarded a public tender for the installation and management of 76MWp of solar photovoltaic (PV) panels under the SolarNova programme.[11] The SolarNova

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[7] Energy Market Authority (2015), 'Preparing for Future Power Generation Investments in Singapore', https://www.ema.gov.sg/cmsmedia/Consultations/Electricity/Consultation 20Paper 20-%20Preparing_for_Future_Power_Generation_Investments_in_Singapore.pdf

[8] Boon, R. (2013), 'Singapore's LNG Terminal Straits Commercial Operations', The Straits Times, 7 May.

[9] ChannelNewsAsia (2014), Singapore Opens First LNG Terminal, Plans for Second Terminal, 25 February.

[10] Otavio Veras (2016), Singapore Aims High as Asia's LNG Trading Hub. The Business Times, 24 February 2016.

[11] Housing and Development Board (2015), 'Singapore's Largest Solar Panel Installation Awarded To Sunseap Leasing Under SolarNova's First Tender', http://www.hdb.gov.sg/cs/infoweb/press-release/singapore-largest-solar-panel-installation-awarded-to-sunseap

programme, which is led by the Economic Development Board (EBD), is a government-led programme to promote solar deployment through aggregating solar demand across the public sector.[12] The EDB and the Public Utilities Board (PUB) have also partnered up to install floating PV platforms in reservoirs.[13]

Beyond these forms of support, Singapore also has a national target to deploy 350 MWp of solar PV by 2020, and extend the share of solar PV to 8 percent of Singapore's peak electricity demand by 2030.[14]

In 2010, Singapore explored the nuclear option with a nuclear energy pre-feasibility study. The results of the study, which were confirmed in a 2012 statement from the Ministry of Trade and Industry, was that nuclear energy was not suitable for deployment given that the high risks associated with the dense urban population of Singapore outweigh the benefits.[15] However, Singapore will continue to monitor technological development and may revisit the option in the future. In the meantime, Singapore will cooperate with international and regional players to actively tackle issues regarding nuclear safety and emergency planning.

Energy efficiency improvements

Energy efficiency is another integral part of Singapore's mitigation efforts. An inter-agency Energy Efficiency Programme Office (EEPO) led by the National Environment Agency and the Energy Market Authority (EMA), was established in May 2007 to help promote and facilitate the adoption of energy efficiency across a variety of sectors in Singapore.[16] Across the nation, energy efficiency improvements are promoted through a mix of standards and regulation, public awareness, and messaging, as well as promotion of technological advancements

[12] Ministry of Trade and Industry (2014), 'SolarNova Factsheet', https://www.mti.gov.sg/MTIInsights/SiteAssets/Pages/Budget-2014/SolarNova.pdf
[13] Channel News Asia (2015), 'PUB Embarks on Study to Tap into Solar Energy via Reservoirs', http://www.channelnewsasia.com/news/singapore/pub-embarks-on-study-to/2285544.html
[14] National Climate Change Secretariat (NCCS) (2016), 'Singapore's Approach to Alternative Energy', https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/singapores-approach-alternative-energy
[15] Ministry of Trade and Industry (2012), 'Factsheet Nuclear Energy Pre-feasibility Study', https://www.mti.gov.sg/NewsRoom/Documents/Pre-FS %20factsheet.pdf
[16] Energy Efficiency Programme Office (2013), 'About E2PO', http://app.e2singapore.gov.sg/About Esup2/supPO/Objective and Members.aspx

Households

Households account for about one-sixth of the electricity consumed in Singapore[17] 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. Initially only levied on all registrable air-conditioners and refrigerators, the requirement has progressively expanded through the years to include television sets, clothes dryers, and lighting. The MELS serves to inform consumers and help them identify, and thereby purchase, more energy efficient appliances. 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. They help consumers avoid being locked into using inefficient appliances with high operating costs and encourage suppliers to bring more energy-efficient appliances to the market as technology improves. 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 that aim to target behavioural change in households were also introduced. These initiatives target both the initial purchasing decision and behaviour at the consumption stage. For example, the Life Cycle Calculator improves consumer awareness at the purchasing stage, while the Home Energy Auditor motivates energy efficiency behavioural change when consuming electricity at home. Recent public messaging campaigns have also begun targeting residential interior design with the *Resource Efficiency Guide for New Home Owners.*

The relevant ministries are currently studying the feasibility and cost–benefit of utilising smart home technologies, such as the Home Energy Management Systems (HEMS), to reduce residential energy consumption. Residents living in the Yuhua estate in the west of Singapore will be the first as a pilot estate to

[17] National Climate Change Secretariat (NCCS) (2016). 'Households', https://www.nccs.gov.sg/climate-change-and-singapore/domestic-actions/reducing-emissions/households

experience such technologies, with progressive implementation of 'Smart Living' features until 2018.[18]

Transport

Energy efficiency in the transport sector is governed by three complementary policy objectives: (i) reducing private transport, (ii) promoting public transport ridership, and (iii) promoting non-motorised transport.

A 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 (COE), which represents a right to vehicle ownership for 10 years.[19] In view of the land constraints on road expansion, the annual vehicle population growth rate was reduced from 3 percent in 1990 to 1.5 percent in 2009, to 1 percent in August 2012, to 0.5 percent in 2013, and has been 0.25 percent since 2015.[20] The Fuel Economy Labelling Scheme has mandated fuel economy labels to be affixed to vehicles at the point of sale since 2012.[21] This is complemented by the Carbon Emissions-based Vehicle Scheme (CEVS), which was introduced in 2013. The CEVS was due to expire in June 2015, but was extended from July 2015. Rebates and surcharges will also be increased for very low and high carbon emission vehicles, respectively, to further encourage vehicle buyers to shift to low-carbon emission models. All new cars and imported used cars with low carbon emissions of less than or equal to 135g carbon emissions per kilometre (CO_2/km) will qualify for vehicle tax rebates of between S$5,000 and S$30,000. Cars with high carbon emissions, of more than 185g CO_2/km, will incur a corresponding registration surcharge of between S$5,000 and S$20,000. Cars with carbon emissions between 136 and 185g CO_2/km receive neither rebate nor surcharge. To encourage taxi companies

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[18] Housing & Development Board (2015), 'Yuhua the First Existing HDB Estate to Go Smart', http://www.hdb.gov.sg/cs/infoweb/press-release/yuhua-the-first-existing-hdb-estate-to-go-smart

[19] Land Transport Authority (2014), 'Overview of Vehicle Quota System', http://www.lta.gov.sg/content/ltaweb/en/roads-and-motoring/owning-a-vehicle/vehicle-quota-system/overview-of-vehicle-quota-system.html

[20] Land Transport Authority (2015), 'Vehicle Quota System', http://www.lta.gov.sg/content/ltaweb/en/roads-and-motoring/owning-a-vehicle/vehicle-quota-system.html

[21] Land Transport Authority (n.d.), 'Fuel Economy Labelling Scheme (FELS)', http://www.onemotoring.com.sg/publish/onemotoring/en/lta_information_guidelines/buy_a_new_vehicle/fuel_economy_.html

to adopt lower emission models for their fleet, the CEVS rebate and registration surcharge for taxis is set 50 percent higher than for cars, between S$7,500 and S$30,000.[22] The treatment of electric vehicles under the CEVS will take into account the power consumption of the vehicle for every kilometre driven and factor in the embedded emissions from the grid emissions factor.[23]

Public transport is the most energy efficient mode of travel. Under the Land Transport Masterplan, Singapore targets to achieve a 75 percent public transport modal share during peak hours by 2030, up from 66 percent in 2014. In a nutshell, the promotion of public transport ridership is achieved by ensuring the efficiency and reliability of public transport services. 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. Mandatory give-way operations also ensure bus priority on the roads. Moreover, a Park & Ride scheme was initiated to ensure a seamless switch between private and public transport.

The government will create more connections through the construction of two new rail lines and three new extensions. By 2030, the rail network will have doubled from the existing 178 kilometres (km) in 2013 to about 360 km, and eight in 10 homes will be located within a 10-minute walk from a train station. Public buses will connect commuters to even more places, with new bus routes added to the bus network. Singapore is adding about 80 new bus services under the Bus Service Enhancement Programme.

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. 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

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[22] Land Transport Authority (2015), 'Revised Carbon Emissions-based Vehicle Scheme (CEVS) from 1 July 2015', *Press Release*, http://www.lta.gov.sg/apps/news/page.aspx?c=2&id=8aa03b88-409f-4852-b2df-09077e101468

[23] Straits Times (2016), 'LTA Relooking Case of Tesla Electric Car Slapped with $15,000 Carbon Surcharge', http://www.straitstimes.com/singapore/transport/lta-relooking-case-of-tesla-electric-car-slapped-with-15000-carbon-surcharge.

encouraged through public messaging campaigns. Specifically, the Intra-town Cycling programme launched by the Land Transport Authority promotes cycling through the designation of specialised road cycling paths. The island-wide cycling path network will eventually be well over 700 km in length. Moreover, an electric vehicle pilot car-sharing programme is currently in progress, which will see the introduction of 1,000 EVs and charging infrastructure to promote their use.[24]

Buildings

At the design stage, energy efficiency in building is governed by the Building and Construction Authority (BCA) of Singapore's Green Mark Scheme. Launched in January 2005 to promote environment sustainability in the construction and real estate sectors, the Green Mark Scheme targets environmentally friendly design in buildings, with a focus on energy efficiency, water efficiency, environmental protection, indoor environmental quality, and other green features focusing on landlords' contributions to 'going green.'25 Since April 2008, all new buildings and existing buildings undergoing major retrofitting works with a gross floor area above 2,000 square meters must meet Green Mark Certified standards. The BCA Green Mark Scheme promotes the adoption of green building technologies and reduces the use of electricity in the commercial sector via efficiency improvements and conservation. Buildings exceeding the minimum requirements are also awarded higher accreditations, such as the Platinum Green Mark, which serves to promote exceptional performance. Technical and financial support mechanisms are also provided to motivate continued energy efficiency upgrades. The Building Energy Efficiency Roadmap, published jointly by the National Climate Change Secretariat and the National Research Foundation in 2014, evaluates existing energy efficiency technologies for building providing technical expertise in the area. A variety of financial support mechanisms, such as Green Mark Incentive Scheme for Existing Buildings and Premises and the Building Retrofit Energy Efficiency Financing scheme are available to provide co-financing for retrofitting and energy efficiency upgrades. The target is for at least 80

[24] Land Transport Authority (2014), 'Joint News Release by the Land transport Authority & EDB on EV Phase 2 – Share an Electric Car', http://www.lta.gov.sg/apps/news/page.aspx?c=2&id=b1f98bcd-e4fc-4902-9f9d-08bc2309c3df

[25] E2 Singapore (2016), 'Buildings', http://www.e2singapore.gov.sg/Buildings.aspx

percent of the buildings in Singapore to achieve BCA Green Mark Certified rating by 2030.26

Since a 2012 survey by Development Authority of Singapore (IDA) revealed that the 10 largest data centre operators in Singapore consumed as much energy as 130,000 households, data centres became a key sector for policymakers. Data centres have been included in the BCA Green Mark Scheme since 2012. A similar technology roadmap has been prepared for data centres, which highlights strong growth prospects for improving energy efficiency in the sector, which was in line with estimates from the 2012 survey that posits that there is an energy efficiency potential of 20 percent. IDA also launched a new Green Data Centre Innovation Programme aimed at promoting innovative technological approaches to improving data centre energy efficiency.

Since 2006, the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative has placed the public sector at the forefront of building energy efficiency. Under the PSTLES, all existing public sector buildings have to meet a minimum Gold Mark rating, as determined by the type of building. Moreover, a Guaranteed Energy Savings Performance (GESP) Contracts initiative was introduced to ensure reaping the expected energy savings. Under the GESP Contract structure, the public sector agency is expected to engage an accredited energy services company who is to carry out an energy audit, implement the relevant energy efficiency measures, and guarantee annual energy savings over a 3 to 5 year contract period.[27] The efficacy of this initiative could be proved by average electricity savings of 15 percent across 14 projects by March 2015[28], contributing to annual monetary savings of S$6 million.

[26] Building Construction Authority (2013), 'R&D Framework', Build Green Magazine, Issue 02/13, https://www.bca.gov.sg/greenmark/others/BGreen2013.pdf

[27] E2 Singapore (n.d.), 'Guaranteed Energy Savings Performance (GESP) Contracting Model in the Public Sector', http://www.e2singapore.gov.sg/DATA/0/docs/GESP%20Contract/e2singapore%20-GESP%20contract%20overview%20(revised).pdf

[28] E2 Singapore (2015), 'Public Sector Taking the Lead in Environmental Sustainability (PSTLES)', http://www.e2singapore.gov.sg/Buildings/BCA_Green_Mark_Scheme/Public_Sector_Taking_the_Lead_in_Environmental_Sustainability.aspx

Industry

The industry-focused Energy Efficiency National Partnership is a voluntary programme that started in 2010 and helps companies put in place energy management systems and implement projects to improve energy efficiency. Mandatory energy management requirements for energy-intensive companies in the industry sector were later introduced in April 2013 under the Energy Conservation Act. Energy-intensive companies consuming more than 15 GWh (electricity) or 54 TJ (fuel or steam) per year are required to appoint an energy manager, monitor and report energy use and greenhouse gas emissions, and submit energy efficiency improvement plans.[29] Besides legislation enforcing mandatory energy management practices, policies were also introduced to incentivise energy efficiency investments. The energy services company Accreditation Scheme supports the Energy Conservation Act by ensuring professionalism in energy related services. To date, there are a total of 29 Qualified Energy Services Specialists from 19 Accredited ECSOs.

Incentives and grants, such as the Design for Efficiency Scheme, Energy Efficiency Improvement Assistance Scheme, and the Grant for Energy Efficiency Technologies (GREET), were also put in place as co-financing schemes to reduce the initial costs of energy efficiency upgrades. The One-Year Accelerated Depreciation Allowance for Energy Efficient Equipment and Technology is another example of a tax incentive to encourage energy efficiency upgrades in industries.[30] Knowledge sharing is also promoted through industry-focused seminars and provision of energy management training and resources.

[29] National Environment Agency, (2014), ' Energy Efficiency National Partnership', http://app.e2singapore.gov.sg/Programmes/Energy_Efficiency_National_Partnership.aspx

[30]E2 Singapore (2015), One-Year Accelerated Depreciation Allowance for Energy Efficient Equipment and Technology (ADAS), http://www.e2singapore.gov.sg/Industry/Designing_a_New_Facility/OneYear_Accelerated_Depreciation_Allowance_for_Energy_Efficient_Equipment_and_Technology.aspx

3. Modelling Assumptions

3.1. Power Generation Sector

In the Business-as-Usual scenario (BAU), the generation efficiency of combined-cycle gas turbine plants is assumed to improve from 49.6 percent in 2013 to 52 percent in 2040, registering an increase of 4.84 percent due to progression towards a competitive electricity market. For single-cycle thermal (ST) plants, efficiency is expected to improve marginally, from 40.14 percent to 42 percent in 2040. With respect to the use of solar generation capacity, it is assumed to grow from less than 0.1 percent to around 5 percent of aggregate demand for electricity in 2040, as part of public efforts towards promoting renewable energies.

With respect to Alternative Policy Scenario (APS)2, which takes into account greater potential for efficiency in the power generation sector, combined-cycle gas turbine plants will achieve 60 percent efficiency by 2040, while ST plants could reach 45 percent. APS3 allows for the share of solar to reach 8 percent of Singapore's total electricity needs in 2040.

3.2. Transport Sector

The demand for petrol, natural gas, and diesel for Singapore's road vehicles are assumed to be dependent primarily on vehicle growth. Consistent with vehicle quota targets set by the Land Transportation Authority, vehicle growth will remain at 0.5 percent from 2012 to 2014, and 0.25 percent from 2015 onwards under the BAU. Electricity demand for the Mass Rapid Transit (MRT) system is mainly driven by the expected expansion of railway length, which will increase from 153.2 km to 328.3 km by 2030, an annual average growth rate (AAGR) of 1.02 percent per year.

For APS1, it is assumed that vehicle growth drops further, to 0.2 percent in 2017 and beyond. No carbon mitigation efforts are imposed for electricity use in the MRT system, hence APS1 remains similar to BAU here.

3.3. Residential Sector

In the BAU, the MEPS, MELS, and continued community outreach efforts to promote energy conservation among households is expected to slow electricity demand growth to an AAGR of 1.5 percent from 2013 to 2040. Electricity demand growth can be further reduced to an AAGR of 1.4 percent in APS1. Demand for natural gas and oil products remain similar to BAU.

3.4. Commercial Sector

In the BAU, electricity demand is assumed to increase at an AAGR of 1.5 percent from 2013 to 2040, which will eventually end up 17 percent below baseline econometric forecasts in 2040. APS1 will lead to a further reduction in AAGR for electricity demand, to 1.36 percent. No reduction is expected from natural gas and oil consumption.

3.5. Industry/Petrochemicals Sector

For industry, The BAU assumes that natural gas, electricity, diesel, kerosene, residual fuel oil, as well as refinery gas demand will grow to reach 5 percent below econometric estimates. This relates to an AAGR of 3.6 percent across all fuels from 2013 to 2040. Demand growth will slow further to 3.4 percent in APS1, which is also 10 percent below econometric estimates in 2040. The BAU and APS1 remain similar for the other fuels in the industry sector.

Production of ethylene is assumed to grow linearly to reach 6 million tons per year by 2020, which translates to 22.2 Mtoe of naphtha produced[31] in the BAU, in line with policy targets. Naphtha is used as an intermediary fuel to produce petrochemicals mainly stockpiled for exports from Singapore to other countries. Hence, statistics for energy and carbon reduction potential, as well as energy intensity, are also reported for the BAU and APS5 with the exclusion of naphtha demand so as not to skew the result of energy intensity and emissions.

[31] Economic Development Board (EDB), (2012).
http://www.sedb.com/content/edb/sg/en_uk/index/news/articles/exxonmobil_s_second.print.html

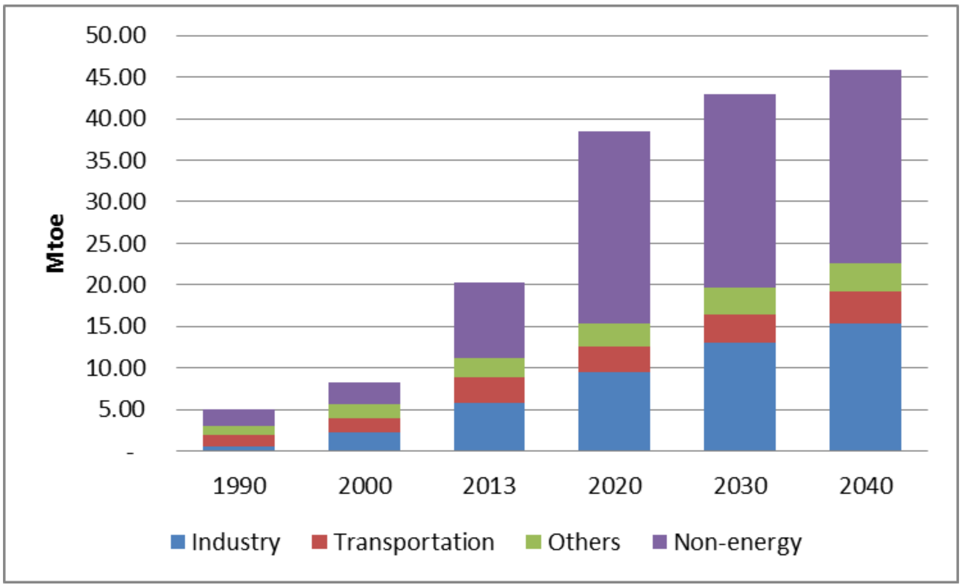
4. Outlook Results

4.1. Business-as-Usual Scenario (BAU)

4.1.1. Final energy consumption

Singapore's final energy consumption grew at an annual average rate of 6.3 percent from 5.01 Mtoe in 1990 to 20.24 Mtoe in 2013. During the same period, oil was the dominant energy source, with 3.8 Mtoe and 14.9 Mtoe consumed in 1990 and 2013, respectively. Approximately 45.0 percent of the country's final energy was consumed for non-energy uses in 2013, particularly as feedstock for petrochemical production. In 1990, 27.1 percent of the final energy consumption was used in the transport sector, although its share of total final energy consumption declined by more than 45 percent, reaching around 14.6 percent only in 2013.

Figure 15-1. Final Energy Consumption by Sector, BAU



BAU = Business-as-Usual scenario; Mtoe = million tons of oil equivalent.
Source: Author's calculation.

Under the BAU, final energy consumption is projected to grow by 3.1 percent a year between 2013 and 2040. The fastest growth is expected to occur in both the petrochemical and industry sector, increasing by 3.6 percent a year (Figure 15-1 above). The transport sector is projected to grow by 1.0 percent per year while the 'others' (residential and commercial) sector is projected to grow by 1.4 percent per year. The exclusion of naphtha demand for Singapore will reduce the AAGR for final energy consumption to only 2.5 percent.

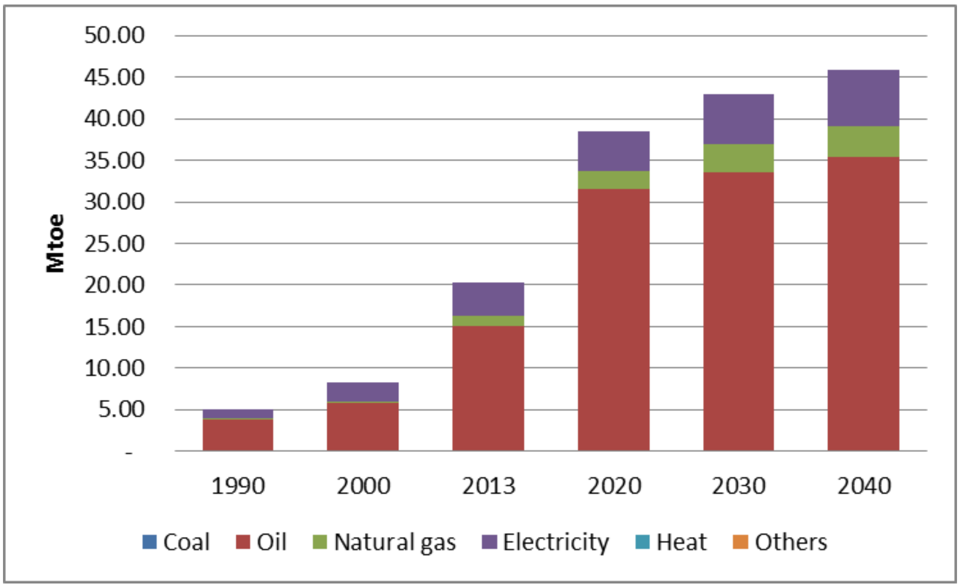
Under the BAU, non-energy consumption will still comprise the highest share in the total final energy consumption followed by the industrial sector. By the end of 2020, non-energy use will exceed 60.0 percent of Singapore's final energy consumption, before declining slightly to 50.7 percent in 2040, assuming that there is no further expansion in petrochemical facilities in Singapore. Excluding naphtha leads to negligible demand in petrochemicals, where they only take up 4.3 percent of the total share of energy use. The industrial sector's share will increase marginally, from a 28.9 percent share in 2013 to around 33.3 percent in 2040.

The transport sector's share in final energy consumption from 2013 to 2040 is expected to decrease to 8.5 percent from its 27.1 percent share in 1990. This decrease stems from the country's national policies advocating more efficient automobile technology and the promotion of public transport as the main means of transportation. In addition, the Certificate of Entitlement quotas are also expected to remain effective in curbing vehicle growth.

By fuel type, natural gas saw the fastest growth from 1990 to 2013, increasing at an average rate of 14.1 percent per year. The growth of natural gas was due to the increasing demand in its use, mainly in the rapidly expanding industry sector. Demand for electricity grew at an average annual rate of 5.6 percent from 1990 to 2013.

Under the BAU, demand for natural gas is expected to continue expanding, but at a slower average growth rate of 4.0 percent per year until 2040, and electricity demand will grow at an average rate of only 2.0 percent per year.

Figure 15-2. Final Energy Consumption by Fuel, BAU



BAU = Business-as-Usual scenario; Mtoe = million tons of oil equivalent.
Source: Author's calculation.

Oil is still expected to play a major role in the country's final energy consumption. From 1990 to 2013, the share of oil fell from 76.1 percent to around 73.5 percent. Under the BAU, oil's share in final energy consumption is projected to rise to 81.4 percent in 2020, before falling to 76.9 percent in 2040. This decline is mainly due to high growth in natural gas usage, which will increase from its share of 6.4 percent in 2013 to 8.1 percent in 2040. The share of electricity in final energy consumption will decrease to around 12.5 percent in 2020 and rise to 14.8 percent in 2040. Figure 15-2 shows the final energy consumption by fuel.

If naphtha is not included, the share of oil will reach 13 Mtoe in 2040, only 55.2 percent of total final energy consumption.

4.1.2. Primary energy supply

Primary energy supply grew by 4.1 percent per year, from 11.53 Mtoe in 1990 to 28.73 Mtoe in 2013. Singapore's dominant source of energy in 1990 was oil, consumption of which increased by 2.3 percent per year from 11.44 Mtoe in 1990 to 19.22 Mtoe in 2013. 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 increased. Natural gas consumption increased rapidly from 0.4 Mtoe in 1992 to 8.9 Mtoe in 2013.

Primary energy supply in the BAU is projected to grow by 2.5 percent per year between 2013 and 2040 (Figure 15-3). Among the energy sources, solar energy is expected to grow the fastest at 22.8 percent a year, followed by oil at 2.7 percent per year. Natural gas demand is expected to grow in line with the expansion of gas-fired power plants.

Singapore's net generation capacity has already increased by more than 2,000 MW or about 20.0 percent of current installed capacity with more efficient combined cycle gas turbines.[32]

Nevertheless, oil is expected to remain the primary energy source, accounting for 69.2 percent of primary energy supply in 2040, followed by natural gas at 28.5 percent.

The exclusion of naphtha from the energy balance will still see oil as the primary energy source at 48.8 percent. In this case, oil demand will grow with an AAGR of 1.6 percent, and total primary energy grows by only 2.0 percent.

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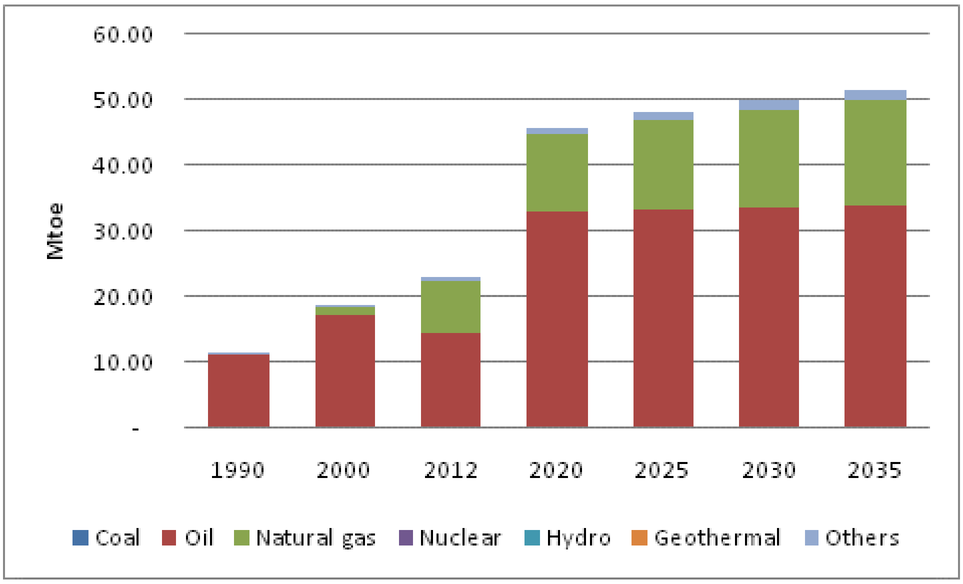
[32] Ministry of Trade and Industry (2013). 'Speech by Mr S. Iswaran' at the *Committee of Supply Debate under Head V,* 11 March. https://www.mti.gov.sg/NewsRoom/Pages/Mr-S-Iswaran,-Second-Minister-For-Trade-and-Industry,-During-The-Committee-Of-Supply-Debate-Under-Head.aspx

Figure 15-3. Total Primary Energy Supply, BAU



BAU = Business-as-Usual scenario; Mtoe = million tons of oil equivalent.
Source: Author's calculation.

4.1.3. Power generation

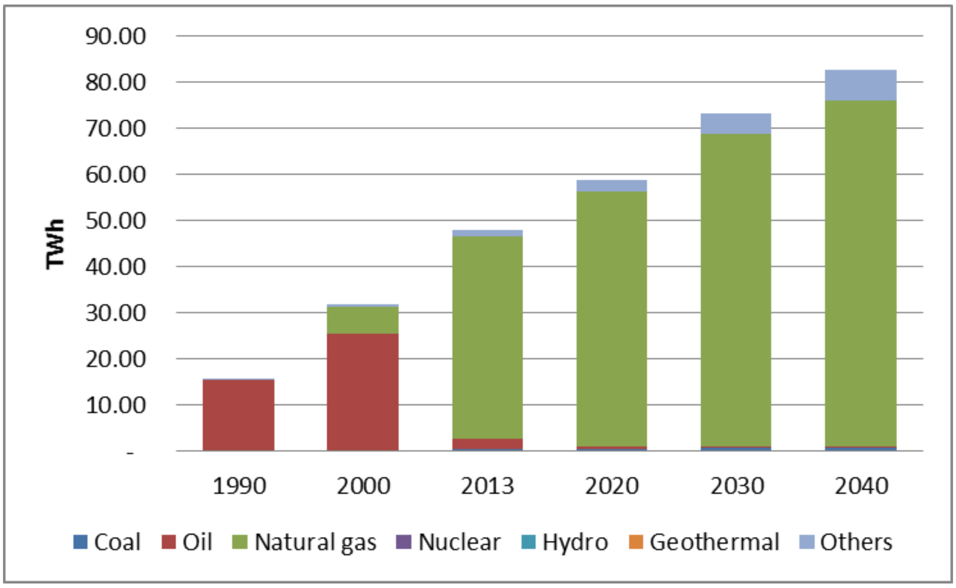
Electricity generation grew by 5.0 percent per year from 15.7 TWh to 48.0 TWh from 1990 to 2013. The electricity generation mix has changed significantly over the past decade. Natural gas, which accounted for 28.0 percent of electricity generation in Singapore in 2001, grew rapidly to supply 91.5 percent of Singapore's electricity in 2013. Fuel oil use for thermal power generation was around 2.33 TWh in 2013. Biomass and solar took up a small proportion of the mix, totalling to around 2.9 percent in 2013. Coal started to be utilised in 2013 as a substitute for the supply of hydrogen and carbon monoxide as feedstock for the energy and petrochemical sector. It is projected to grow only marginally, at 2.0 percent per year.

In the BAU, power generation is projected to increase at a slower rate of 2.0 percent per year, reaching 82.48 TWh in 2040. By type of fuel, generation from 'Others', which comprises of biomass and solar power, will see the fastest growth at an average rate of almost 5.9 percent per year. Others power generation is expected to increase its share from a minimal share of 2.9 percent in 2013 to 7.8 percent in 2040.

From the end of 2013 and in the years thereafter, at least 90.0 percent of the country's power generation mix is estimated to come from natural gas under the BAU. Its share of the generation mix gradually declines from 94.8 percent in 2015 to 91.0 percent in 2040 as more solar power is utilised. The share of oil will decline to 0.4 percent over the same period.

The average thermal efficiency of Singapore's fossil-fuelled power plants was around 30.3 percent in 1990 and improved to 48.6 percent in 2013 as more natural gas-fired power plants came into operation. In the BAU, thermal efficiency of fossil plants is expected to improve further, to around 51.5 percent in 2040. By fuel, natural gas plants' thermal efficiency will be 52.0 percent in 2040, and oil will be at 41.5 percent.

Figure 15-4. Electricity Generation, BAU



BAU = Business-as-Usual scenario; TWh = terawatt-hour.
Source: Author's calculation.

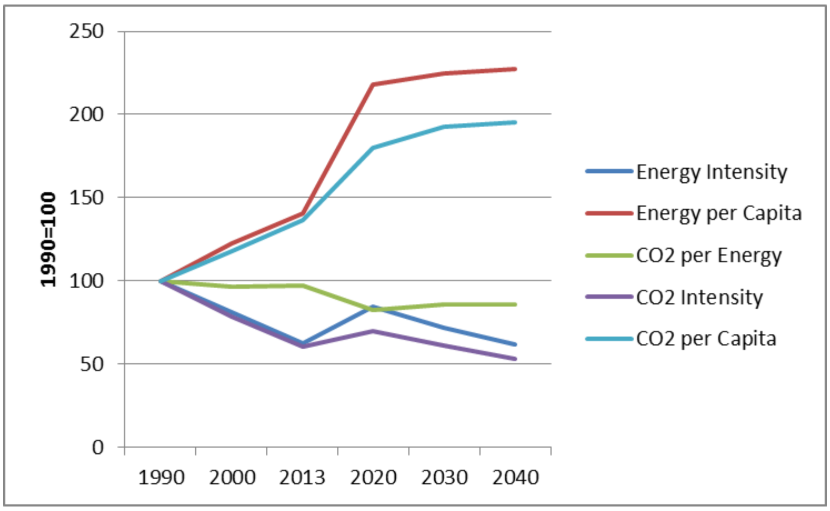
4.1.4. Energy indicators

Primary energy intensity, which is computed as the ratio of primary energy supply over GDP, is expected to increase. Energy intensity continues to increase as Singapore's population will experience slower growth in the future. Energy and

CO_2 per capita increases as population growth is expected to remain lower than fossil fuel demand growth.

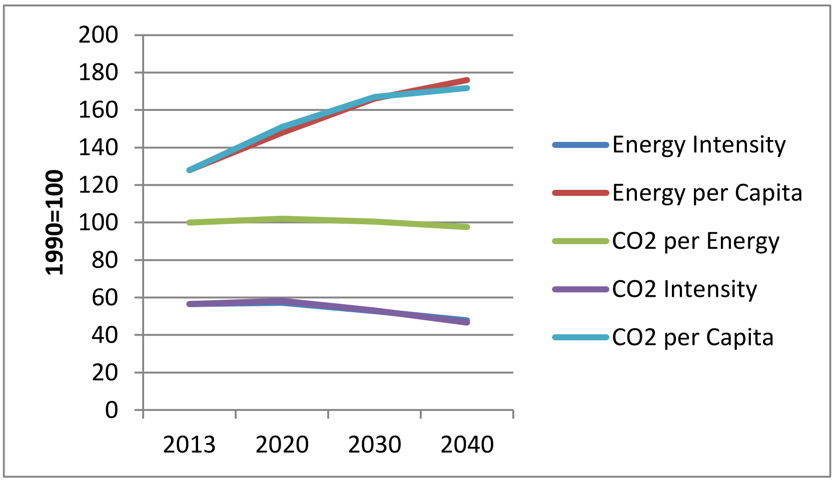
The exclusion of naphtha leads to a slower growth for energy per capita and CO_2 per capita. Energy intensity and CO_2 intensity both decrease as well, compared with forecasts containing naphtha.

Figure 15-5a. Energy Indicators, BAU



BAU = Business-as-Usual scenario; CO_2 = carbon dioxide.
Source: Author's calculation.

Figure 15-5b. Future Energy Indicators, BAU excluding Naphtha



BAU = Business-as-Usual scenario; CO_2 = carbon dioxide.
Source: Author's calculation.

4.2. Energy Saving and CO_2 Reduction Potential

4.2.1. Final energy consumption

Final energy consumption under APS1 is projected to increase by 3.0 percent, from 2013 to 2040. Similar to the BAU case, the non-energy sector leads the growth numbers at 3.6 percent per year, followed by the industry sector at 3.4 percent, and the other (residential and commercial) sector at 1.3 percent. APS2 and APS3 do not include energy conservation policies for end-demand and hence are similar to the BAU. APS5, a combination of all APS, will have the same final energy consumption as that of APS1.

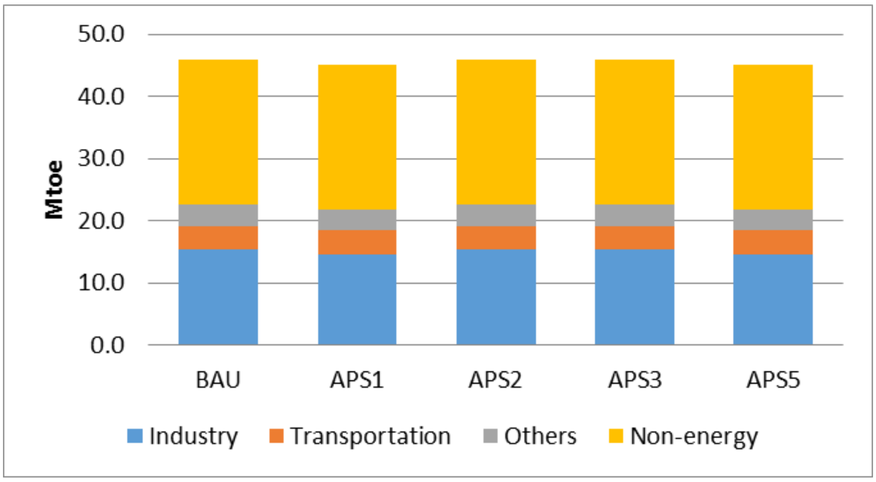
4.2.2. Primary energy supply

Results from APS2 show that primary energy supply from 2013 to 2040 will increase at an average annual rate of 2.5 percent, a 1.65 Mtoe decrease from the BAU (Figure 15-7) in 2040.

This translates to a reduction of 2.9 percent from the BAU in 2040. APS1 and APS3 will help to lower primary energy supply by 1.19 Mtoe and 190 ktoe, respectively, in 2040. This illustrates that policies targeting end-user energy efficiency and renewables currently still play only a secondary role to power generation efficiency policies in reducing primary energy supply.

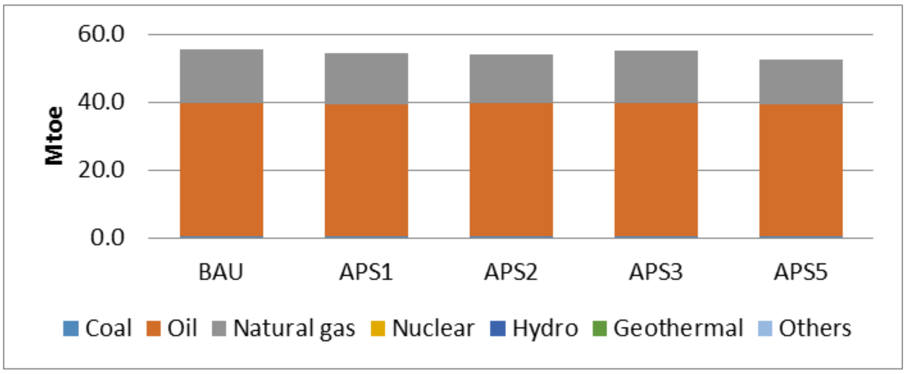
Most of the reduction in primary energy supply will come from natural gas at 2.6 Mtoe, which is a drop of 16.4 percent from the BAU (Figure 15-8A). Oil only falls by 1.1 percent as it is limited by the already declining BAU consumption for power generation, as well as the large consumption in the petrochemical non-energy use.

Figure 15-6. Total Final Energy Consumption by Sector, BAU and APS1–5



BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario; Mtoe = million tons of oil equivalent.
Source: Author's calculation.

Figure 15-7. Total Primary Energy Supply by Fuel, BAU and APS1–5



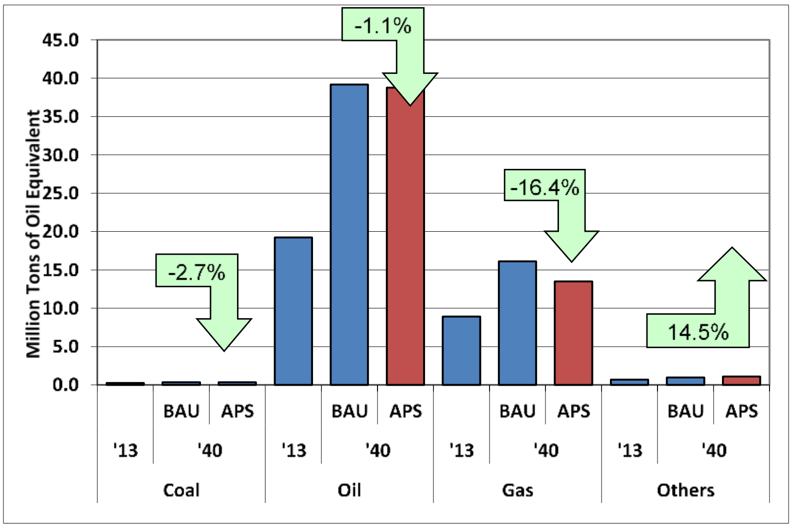
BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario; Mtoe = million tons of oil equivalent.
Source: Author's calculation.

The exclusion of naphtha will lead to a reduction of 2.4 percent from the BAU for oil consumption (Figure 15-8b). Biomass' consumption will remain relatively constant, whereas solar power progresses significantly but remains small in magnitude. Hence, this leads to an increase in consumption of 'others' by 14.5 percent.

4.2.3. Power generation

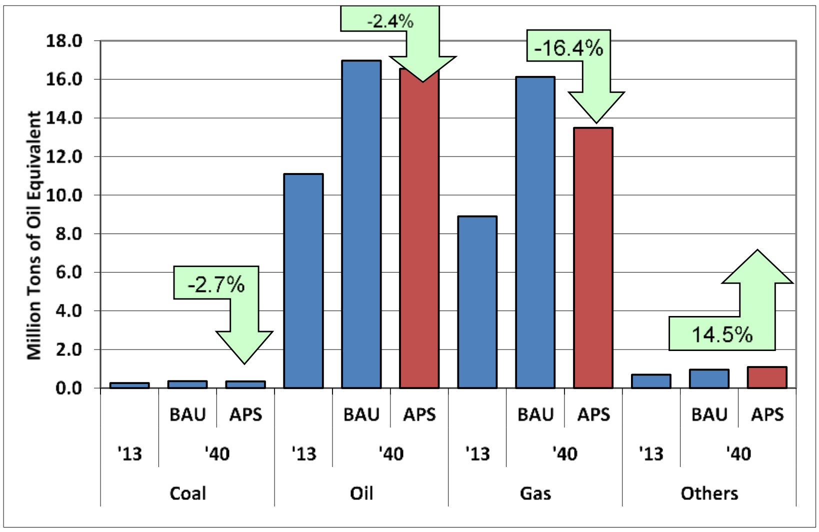
Results from APS1 and APS5 show a decrease in electricity generation, registering a drop of 3.53 TWh or 4.29 percent from the BAU. APS2 and APS3 assume the same generation as the BAU since final energy consumption does not fall under these two scenarios.

Figure 15-8a: Primary Energy Supply by Fuel, BAU and APS5



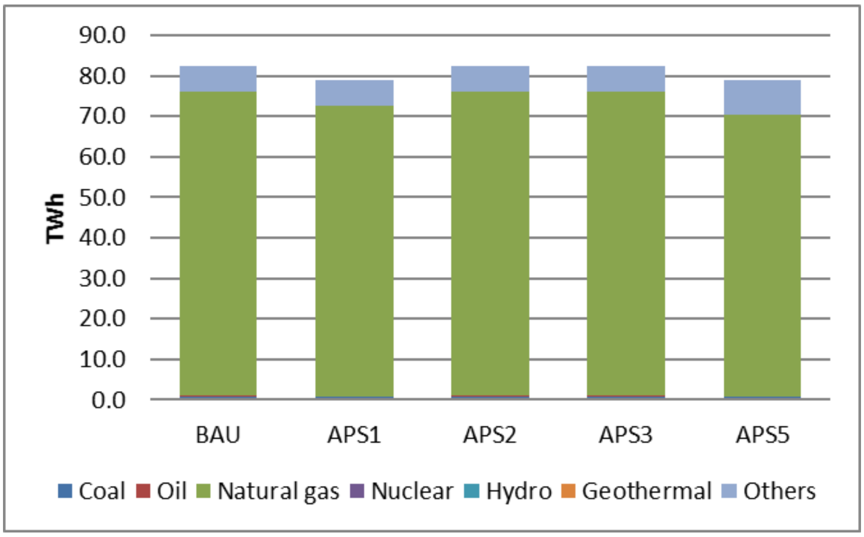
BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario.
Source: Author's calculation.

Figure 15-8b: Primary Energy supply by Fuel, BAU and APS5, excluding Naphtha



BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario.
Source: Author's calculation.

Figure 15-9: Electricity Generation, TWh



BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario; TWh = terawatt-hour.
Source: Author's calculation.

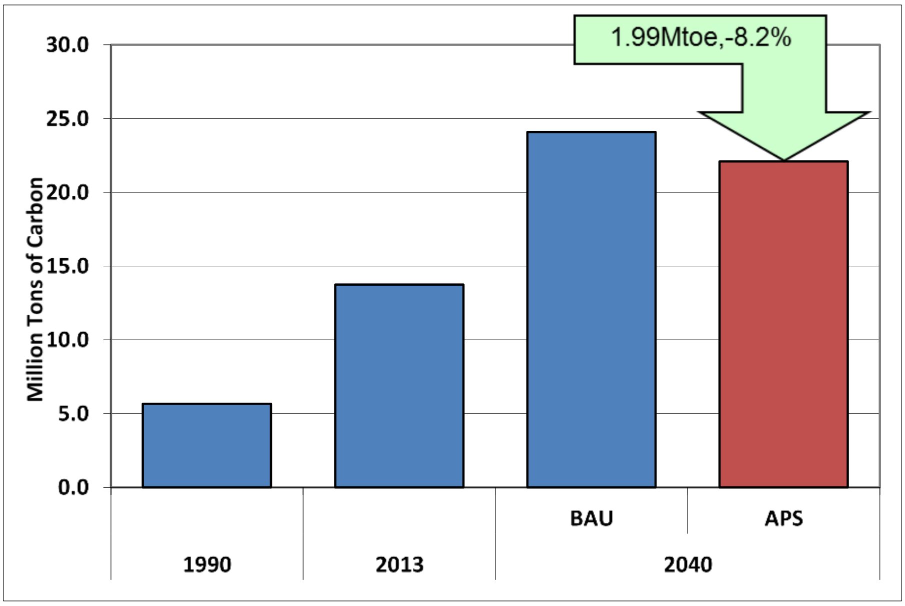
4.2.4. CO_2 reduction potential

Under the BAU, CO_2 emissions from energy demand are projected to increase at an average annual rate of 2.1 percent, from 13.7 Mt-C in 2013 to around 24.1 Mt-C in 2040 (Figure 15-10A).

CO_2 emissions reduction potential comes mainly from improvements in thermal efficiency for power generation (APS2), with savings of 1.1 Mt-C in 2040, equivalent to a 4.6 percent decrease from the BAU. Educational policies and incentives that target behavioural changes in end-consumers of energy are also very beneficial, with APS1 registering emissions reduction of 0.8 Mt-C in the same time period (a 3.3 percent reduction from the BAU). Increased utilisation of solar power results in emissions reduction of 0.26 Mt-C (a 1.1 percent reduction from the BAU). Overall, APS5 will contribute to emissions reduction of 2.71 Mt-C, which is a 4.8 percent reduction from the BAU. Under this scenario, carbon emissions will increase at an annual average rate of 1.8 percent from 2013 to 2040, compared with 2.1 percent under the BAU.

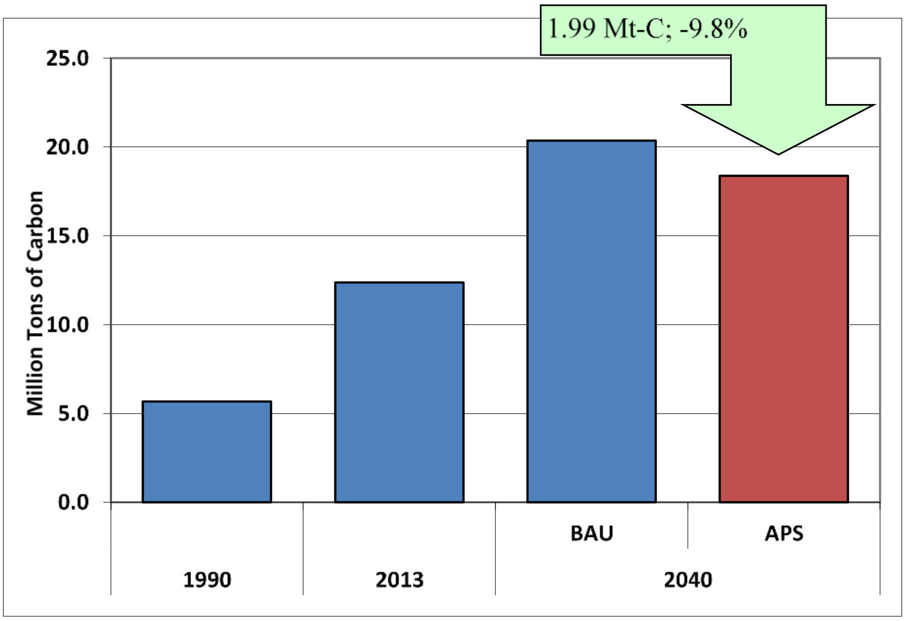
If naphtha is not included, the total reduction in CO_2 emissions remains at 1.99 Mt-C from the BAU to APS5 (Figure 15-10B). The percentage reduction is now 9.8 percent instead of 8.2 percent.

Figure 15-10a. CO_2 Emissions from Energy Consumption, BAU and APS5



CO_2 = carbon dioxide; BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario; Mtoe = million tons of oil equivalent.
Source: Author's calculation.

Figure 15-10b. CO_2 Emissions from Energy Consumption excluding Naphtha, BAU and APS5



CO_2 = carbon dioxide; BAU = Business-as-Usual scenario; APS = Alternative Policy Scenario; Mt-C = million tons of carbon.
Source: Author's calculation.

5. Implications and Policy Recommendations

The Singapore government has been progressively implementing new strategies to help incentivise and advocate the adoption of clean energy technologies and conservation behaviour amongst both industries and households. These programmes include a number of funding schemes, such as the Clean Development Mechanism and the Documentation Grant that help provide companies with financial assistance for the engagement of carbon consultancy services, and the Grant for Energy Efficient Technologies (GREET) to help encourage industry investments in energy efficient equipment or technologies.[33] Zero-Capex (Capital Expenditure) or similar commercial contracts can also be actively promoted to increase the involvement of energy services companies to help conserve energy.

Solar adoption, an electric vehicle car-sharing programme, as well as SMART technologies pave the way for further carbon reduction for both industries and households in the future. There is also an initiative to improve the petrochemical industry's energy efficiency and competitiveness by way of a 'heat-integration' plan.[34]

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 transits towards using more natural gas to power its electricity needs. Currently, Singapore has plans to increase LNG import storage facilities, and it is appointing another one or two companies to import LNG for Singapore in the short term. Coal use for co-generation, as well as the greater adoption of solar are an indication of efforts made towards fuel mix diversification.

As shown in the forecast results for the BAU with 2013 as the base year, Singapore is already on track to meet its projected 2020 targets of hitting 77.2

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[33] Energy Efficiency Programme Office (2013), 'Incentives' available at: http://www.ema.gov.sg/info_directory/id:162/

[34] Lim Ronnie (2013), 'In The Pipeline: Heat Exchange on Jurong Island', *Business Times,* 19 December.

million tons of $CO_{2,}$[35] with estimations showing the potential to go as low as 18.9 Mt-C or about 70 million tons of CO_2 if greater efforts are made to reduce emissions.

Despite the limitations posed by its small size and the paucity of renewable energy sources, Singapore's long-term commitment to building a sustainable city will ensure that the efforts of using energy efficiently and in an environmentally viable manner will continue to receive broad support.

[35] NCCS (2016), 'Singapore's Emissions Profile'. https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/singapores-emissions-profile