CHAPTER 15

Singapore Country Report

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1. Introduction

In February 2020, Singapore officially released its enhanced Nationally Determined Contribution (NDC) and Long-Term Low-Emissions Development Strategy (LEDS) (NCCS, 2020a). Both development and climate strategies would be submitted to the United Nations Framework Convention on Climate Change (UNFCCC). According to Singapore's new enhanced NDC, the country further aims to peak its national emissions at 65 million tonnes of Carbon Dioxide equivalent ($MtCO_2e$) around 2030, which is projected to be consistent with Singapore's existing 2030 NDC. In addition, Singapore's energy intensity target under its existing NDC, which aims to achieve a 36% reduction in Emissions Intensity (EI) from 2005 level by 2030. To further facilitate climate change mitigation and sustainable development, Singapore has addressed its long-term development strategy in the LEDS for the post-2030 period. Specifically, Singapore aims to halve its national emissions from its peak (i.e. 65 $MtCO_2e$ around 2030 as addressed in the enhanced NDC) to 33 $MtCO_2e$ by 2050, to achieve net zero emissions as soon as viable in the second half of the century. To support Singapore's low-emissions development, rigorous analysis is needed, which will inform policymaking in this field by providing quantitative benchmarking information (Su and Ang, 2020; Su, Ang, and Li, 2017).

The analysis was conducted in partnership with the Economic Research Institute for ASEAN and East Asia (ERIA), which involved contributing to the creation of ERIA's flagship research publication titled "Energy Outlook and Energy Saving Potential in East Asia 2020" (ERIA, 2021). Singapore's energy outlook model and scenario analysis were completed by using the Low Emissions Analysis Platform (LEAP) software. The latest 2020 edition of Singapore's energy outlook was completed prior to the coronavirus disease (COVID-19) pandemic by using 2017 as the base year. However, the COVID-19 pandemic led to lots of economic and social impacts on Singapore. These impacts are closely associated with changes in energy demand and supply. In addition, Singapore's enhanced NDC and LEDS are not covered in the 2020 edition of Singapore's energy outlook.

Therefore, it is crucial to update the business-as-usual (BAU) scenario and the alternative policy scenario (APS) of Singapore's LEAP model in the current edition of the energy outlook to incorporate the new macroeconomic conditions during the COVID-19 pandemic. More importantly, this report seeks to explore the scenario that can generate the climate targets and dynamics of emissions as projected by Singapore's Long-Term Low-Emissions Development Strategy (LEDS). In developing the LEDS scenario, this project will take into account specific technological development. This will include Singapore's recent plan of phasing out coal power plants by 2050 and the application of emerging low carbon technologies, such as carbon capture and storage (CCS) in the power and industrial sectors.

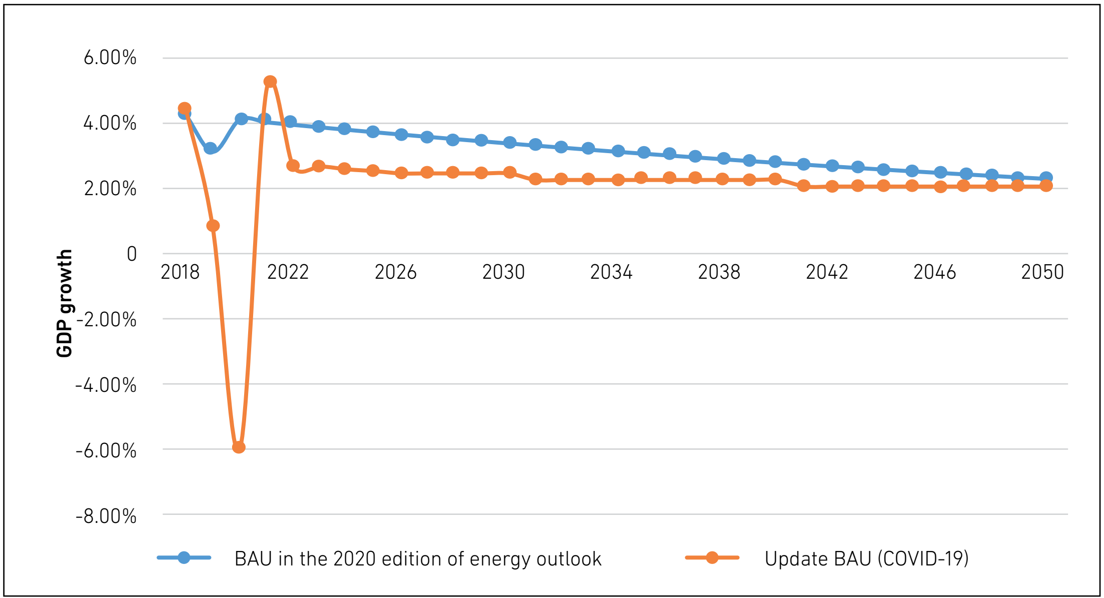
2. Major Model Assumptions

This section introduces the major model assumptions regarding the BAU, APS, and LEDS scenarios used in this project. The LEAP model used in this report draws on Singapore's LEAP model presented in ERIA's Energy Outlook and Energy Saving Potential in East Asia 2020 (ERIA, 2021). However, the model has been updated to meet the specific requirements of this project, as detailed in Sections 2.1–2.3. The rest of the model settings are consistent with the 2020 edition of Singapore's LEAP model.

2.1. Business-as-Usual

As compared to the 2020 edition of Singapore's LEAP model, the key change is the annual GDP growth rate assumption. As shown in Figure 15-1, the BAU GDP growth in this project (i.e. updated BAU) considers the impacts of the COVID-19 pandemic and presents much higher levels of fluctuations during 2018–2023. However, in the long run, the trend of the updated GDP growth converges to the GDP growth in the 2020 edition of Singapore's LEAP model.

Figure 15.1 Comparison of Gross Domestic Product Growth Assumption, 2018–2050
(%)



BAU = business-as-usual, COVID-19 = coronavirus disease, GDP = gross domestic product.

Source: Author's calculations.

Table 15.1 presents a detailed comparison of annual GDP growth rates, highlighting a significant difference since 2019 in the updated BAU, which is 0.7%. The most critical difference is found in 2020, where the impact of the COVID-19 pandemic resulted in a projected decrease of about 6% in Singapore's annual GDP growth, whereas the 2020 edition estimated a 4% growth under the BAU. This project assumes a sharp increase of 5% in GDP growth in 2021. However, due to COVID-19, the expected GDP growth for the upcoming years is lower than the figures projected in the 2020 edition. Specifically, the projected GDP growth for 20222 is 2.6% in 2022 and 2% in the long term (2040–2050), while the 2020 edition predicted 3.9% and 2.5% in the long run.

Table 15.1 Assumptions of Annual Gross Domestic Product Growth Rates

(%)

	2018	2019	2020	2021	2022	2023	2023–2030	2030–2040	2040–2050
Updated BAU (COVID-19)	4.4%	0.7%	-6.0%	5.0%	2.6%	2.6%	2.4%	2.2%	2.0%
BAU in the 2020 edition of energy outlook	4.2%	3.1%	4.0%	4.0%	3.9%	3.8%	3.5%	3.0%	2.5%

BAU = Business-as-usual, COVID-19 = coronavirus disease, GDP = Gross Domestic Product.

Source: Author's estimations.

The other major change in BAU in this project pertains to the forecasted contribution of solar photovoltaic (PV) technology to power generation in the long term. In March 2020, the National Climate Change Secretariat (NCCS) of Singapore released a new solar PV technological roadmap for Singapore (NCCS, 2020b). According the NCCS, under the updated BAU, the share of solar PVs in Singapore's generation mix is projected to be 1.8% in 2030 and 3.4% in 2050.

2.2. Alternative Policy Scenario

In this project, the APS is primarily developed based on the APS in the 2020 edition of Singapore's LEAP model, with several minor changes. In addition, the APS in this project is adapted to the updated annual GDP growth assumptions in the BAU scenario.

According to the solar PV technological roadmap released by NCCS, given the application of more advanced technologies and better policy support, the share of solar PVs in Singapore's generation mix is projected to be 4.5% in 2030 and 7.4% (NCCS, 2020b). Both values are higher than the projections in BAU. The more ambitious shares of solar PVs in the generation mix are used in the APS scenario.

In APS, higher levels of thermal efficiency are assumed for natural gas power plants and conventional thermal power plants. For natural gas power plants, the thermal efficiency is projected to grow from 56.6% in 2019 to 65% in 2050, whereas the efficiency is 58% in 2050 under BAU scenario. For conventional thermal power plants, the efficiency is assumed to increase from 22.0% in 2019 to 48% in 2050, whereas the efficiency is assumed to grow to 45% in 2050 under BAU scenario.

The APS scenario also considers the energy efficiency improvement in industrial, commercial, and residential sectors. The electricity consumption in industrial, commercial, and residential sectors is assumed to drop by 10% by 2030 due to energy efficiency improvement.

2.3. Long-Term Low-Emissions Development Strategy

The LEDS scenario in this project is primarily developed by using the APS scenario, while several major changes have been implemented.

First, in this project, the LEDS scenario considers the phasing out of coal power plants in power generation. In the BAU and APS scenarios, coal power plants account for about 1.19% in generation mix in 2019. However, in the LEDS scenario, the share of coal power plants will gradually decrease to 0 in generation mix by 2050. This is in line with the policy target released by NCCS in November 2021 (NCCS, 2021). In the industrial sector, however, coal will still account for a small share of consumption.

Second, as compared to the BAU and APS scenarios, a critical difference is that Carbon Capture and Storage (CCS) is introduced to the LEDS scenario. This includes the applications of CCS in power generation and the industrial sector. Specifically, a new power generation technology, namely, natural gas power plants with CCS, will be introduced to the power sector over the period 2030–2050. Such new power plants are used to replace the existing natural gas power plants without CCS. By 2050, all natural gas power plants without CCS will be replaced by those with CCS, with a goal to reduce the share of natural gas power plants without CCS to 0 by 2050. This study assumes a 90% CO_2 capture rate for CCS technology, resulting in power plants with CCS having a grid emission factor of 10% compared to those without CCS. However, power plants with CCS will experience a 15% loss in thermal efficiency. This is consistent with the Annual Technology Baseline 2021 developed by the National Renewable Energy Laboratory (NREL) of the US (NREL, 2021). In industrial sector, the application of CCS technology will be extended to natural gas and refinery gas over the period 2030–2050. By 2050, all industrial processes that use these gases will be retrofitted with CCS technology, reducing their emission factors to 10% of those without CCS, based on the assumed 90% CO_2 capture rate. Additionally, the LEDS scenario assumes biomass in the power sector will phase out by 2050.

Third, electricity consumption in industrial sector is projected to increase by 20% by 2050 due to the application of CCS. In the LEDS scenario, the energy efficiency improvements in the commercial and residential sectors are the same as those projected in the APS scenario, with a 10% drop in electricity consumption by 2050.

Finally, electricity is expected to replace the consumption of natural gas and liquefied petroleum gas (LPG) in the residential sector by 2050. In road transport, electric vehicles (EVs) would replace gasoline vehicles by 2040 (LTA, 2023). However, diesel vehicles are not expected to be replaced by EVs.

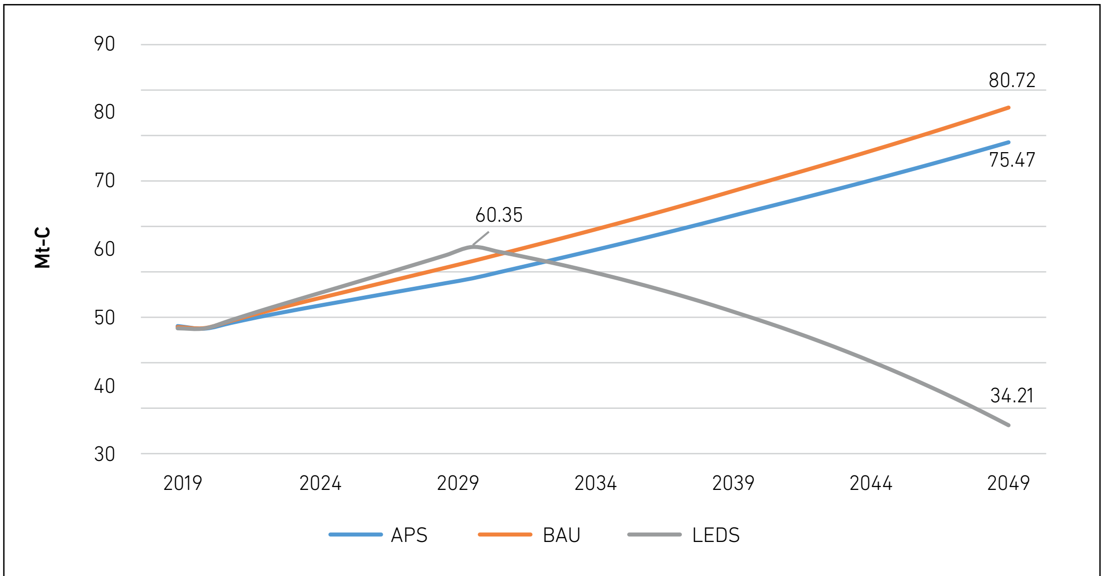
3. Model Results

This section presents the key results of this project, comparing the BAU, APS, and LEDS scenarios. Section 3.1 presents the dynamics of CO_2 emissions at the country level over 2019–2050. Section 3.2 shows the generation mix by scenario. Section 3.3 discusses total primary energy supply, followed by final energy demand in Section 3.4.

3.1. Carbon Dioxide Emissions, 2019–2050

This section reports the country's CO_2 emissions by scenario. Figure 15.2 illustrates that the emissions from BAU and the APS continue to grow over time, increasing from 48.42 $MtCO_2$ in 2019 to 80.72 $MtCO_2$ and 75.47 $MtCO_2$ in 2050, respectively. Across all model years, the emissions peak in 2050 for both BAU and the APS would continue to increase as the energy demand grows after 2050. As expected, CO_2 emissions in the APS are lower than those in the BAU scenario, due to a higher share of solar PV in generation mix, improvement in power plant thermal efficiency, and energy efficiency improvement in industrial, commercial, and residential sectors.

Figure 15.2 Carbon Dioxide Emissions by Scenario, 2019–2050
(Mt-C)



APS = alternate policy scenario, BAU = business-as-usual, LEDS = Long-Term Low-Emissions Development Strategy, Mt-C = million tonnes of carbon dioxide.

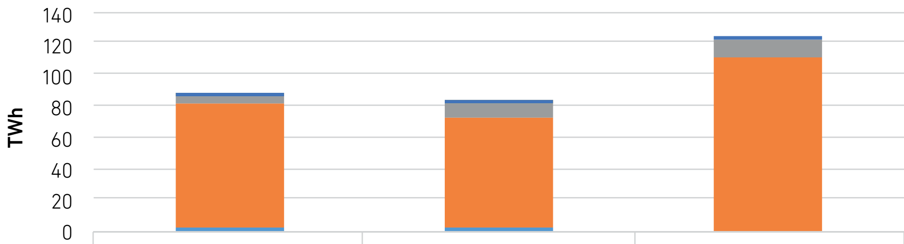
Source: Author's calculations.

The emissions trend for the LEDS scenario significantly differs from the other two scenarios, as it initially increases to a higher level than the other two scenarios and reaches peak emissions at 60.35 $MtCO_2$ in 2030. This aligns with Singapore's enhanced NDC target of peaking at around 65 $MtCO_2$ in 2030. From 2030 and onwards, the CO_2 emissions under the LEDS scenario start to decline to 34.21 $MtCO_2$ in 2050, which is slightly above Singapore's LEDS target of 33 $MtCO_2$ in 2050. This is because, in Singapore's LEDS, more emerging low-carbon technologies have been considered, such as hydrogen and CCS, whereas in the current analysis in this report, hydrogen is not included. In addition, according to Singapore's NDC, the 2005 level of emission intensity was 0.176 kilogram of carbon dioxide/Singapore Dollar ($kgCO_2$/SGD). In the current analysis, the emissions intensity under the LEDS scenario in 2030 is 0.097 $kgCO_2$/SGD. This indicates a reduction of 44.7% in emissions intensity from the 2005 level. This means the LEDS scenario would exceed Singapore's enhanced NDC target of a 36% reduction in emissions intensity from the 2005 level.

3.2. Power Generation Mix

Figure 15.3 below presents the generation mix in the power sector in 2050. The LEDS scenario generates the most electricity, followed by BAU. The APS generates the lowest level of electricity. Regarding the generation mix, a major difference is that coal and biomass power plants phase out in the LEDS scenario, in which renewables generate the most electricity amongst all scenarios at 11.62 TWh. The LEDS scenario also results in a decrease in electricity generated from oil products. Amongst all scenarios, natural gas still contributes the most in power generation mix, i.e. 109.49 TWh in the LEDS scenario, 79.75 TWh in the BAU scenario and 71.6 TWh in APS scenario.

Figure 15.3 Power Generation Mix by Scenario, 2050
(TWh)



	BAU	APS	LEDS
Oil Products	2.03	2.77	0.54
Biomass	0.42	0.40	-
Renewables	5.35	8.46	11.62
Natural gas	79.75	71.60	109.49
Coal	1.06	1.01	-

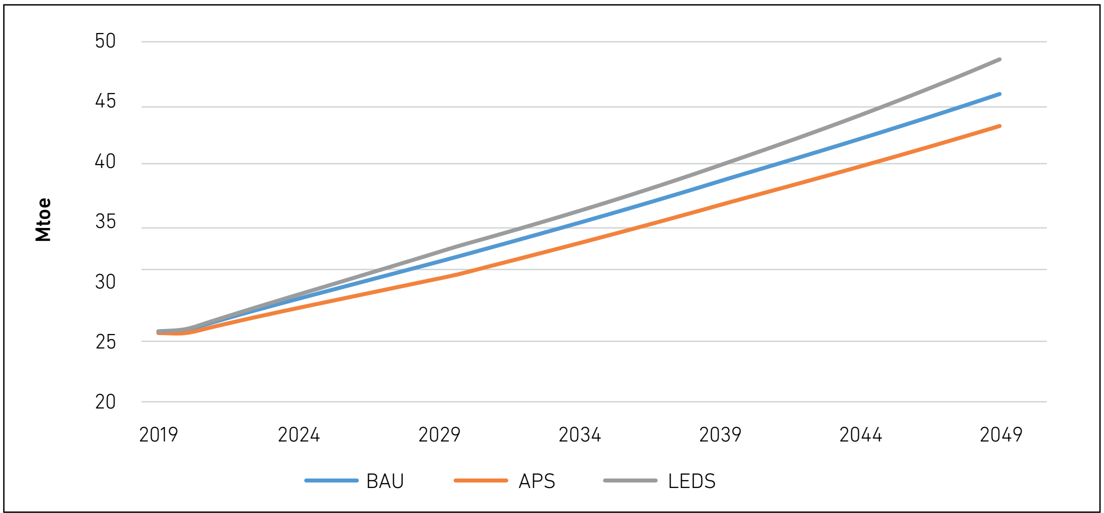
Coal Natural gas Renewable Biomass Oil Products

APS = alternate policy scenario, BAU = business-as-usual, LEDS = Long-Term Low-Emissions Development Strategy, TWh = terawatt-hour.
Source: Author's calculations.

3.3. Total Primary Energy Supply

This section presents the results regarding the total primary energy supply (TPES). Figure 15.4 shows the trends of TPES by scenario over the period 2019–2050. The three curves have similar trends. Amongst all scenarios, the LEDS is the scenario that produces the most TPES, which is followed by the BAU scenario and APS scenario. This is consistent with the results reported in Section 3.2.

Figure 15.4 Total Primary Energy Supply by Scenario, 2019–2050
(Mtoe)

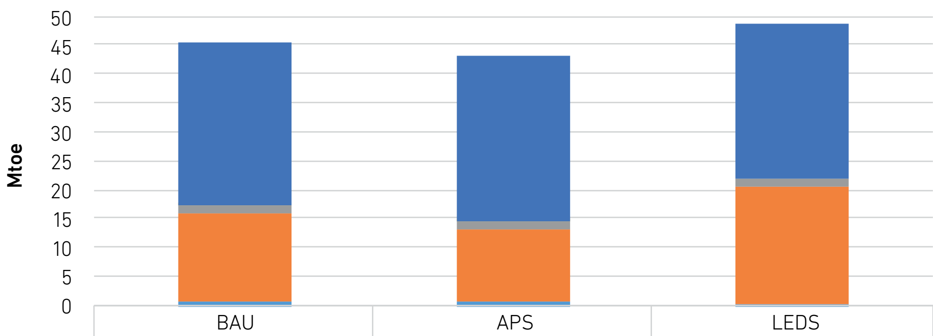


APS = alternate policy scenario, BAU = business-as-usual, LEDS = Long-Term Low-Emissions Development Strategy, Mtoe = million tonnes of oil equivalent.

Source: Author's calculations.

Figure 15.5 illustrates the energy structure in TPES by scenario in 2050. Amongst all energy sources, oil is the largest contributor, followed by natural gas. Notably, the LEDS scenario has a lower level of oil consumption, but a higher level of natural gas, biomass, and renewables compared to the other two scenarios. Further, coal still accounts for a small share in industrial consumption under the LEDS scenario.

Figure 15.5 **Total Primary Energy Supply, Fuel by Scenario, 2050**
(Mtoe)



	BAU	APS	LEDS
Oil	28.20	28.38	26.72
Biomass	0.12	0.11	0.00
Renewables	1.45	1.08	1.42
Natural gas	15.05	12.70	20.21
Coal	0.63	0.61	0.18

Coal Natural gas Renewable Biomass Oil

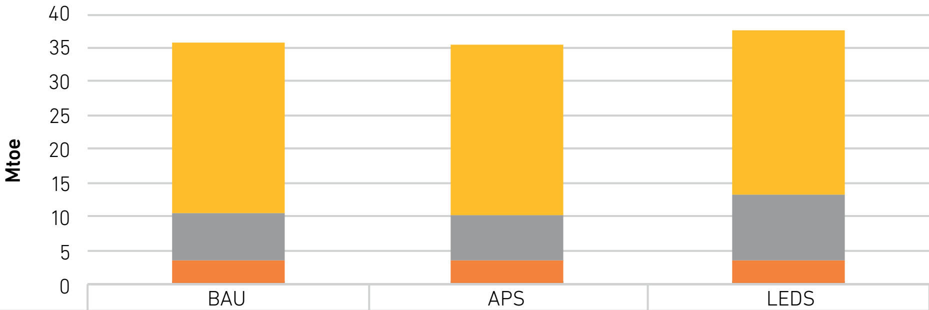
APS = alternate policy scenario, BAU = business-as-usual, LEDS = Long-Term Low-Emissions Development Strategy, Mtoe = million tonnes of oil equivalent.

Source: Author's calculations.

3.4. Final Energy Demand

The following results relate to the final energy demand. Figure 15.6 shows the energy consumption structure by energy source and scenario in 2050. Oil products account for the highest share in final energy demand across all scenarios, followed by electricity. However, the electricity consumption is the highest in the LEDS scenario compared to any of the other two scenarios.

Figure 15.6 **Final Energy Demand, Fuel by Scenario, 2050**
(Mtoe)



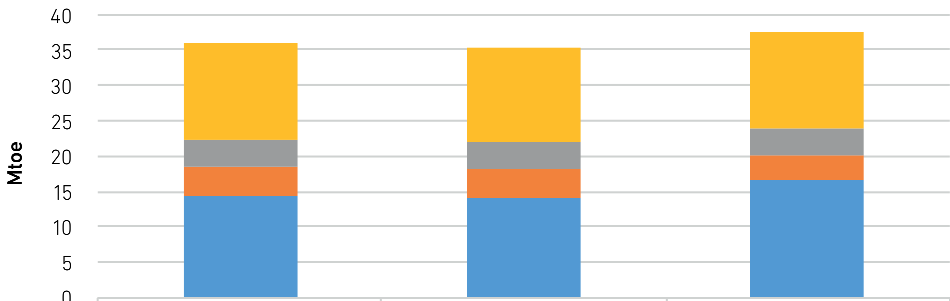
	BAU	APS	LEDS
Oil Products	25.16	25.16	24.21
Electricity	7.18	6.83	9.86
Natural gas	3.23	3.23	3.17
Coal	0.18	0.18	0.18

APS = alternate policy scenario, BAU = business-as-usual, LEDS = Long-Term Low-Emissions Development Strategy, Mtoe = million tonnes of oil equivalent.

Source: Author's calculations.

Figure 15.7 further presents the energy consumption structure by sector and scenario in 2050. Across all sectors, the non-energy sector consumes the most energy, followed by the industrial sector. In particular, the industrial sector under the LEDS scenario consumes more energy than that in any of the other two scenarios.

Figure 15.7 **Final Energy Demand, Sector and Scenario, 2050**
(Mtoe)



	BAU	APS	LEDS
Non Energy	13.50	13.50	13.50
Others	3.90	3.71	3.71
Transport	4.09	4.09	3.60
Industry	14.27	14.10	16.62

APS = alternate policy scenario, BAU = business-as-usual, LEDS = Long-Term Low-Emissions Development Strategy, Mtoe = million tonnes of oil equivalent.

Source: Author's calculations.

4. Conclusions

To achieve sustainable development in the long run, Singapore has set enhanced targets for 2030 and post-2030 periods. The COVID-19 pandemic led to substantial socio-economic changes worldwide, which is perceived to affect energy supply and demand, as well as emissions. The pathways to such targets require rigorous research. Based on the LEAP modelling platform, this project updates Singapore's energy outlook model by incorporating the new macroeconomic circumstances due to COVID-19 and policy changes. This project seeks to explore a scenario that aligns with Singapore's enhanced NDC and LEDS objectives. To do so, an updated BAU, APS, and LEDS scenarios have been developed.

The projected CO_2 emissions for Singapore under BAU and the APS show an increase until the final model year. Under these two scenarios, Singapore's enhanced NDC targets for reducing emissions intensity can be met, but the LEDS targets for peak emissions and emissions in 2050 cannot be achieved. In contrast, the LEDS scenario, which considers a higher share of solar energy and CCS technology, presents a different emissions trajectory. Under LEDS scenario, Singapore's emissions are projected to peak at 60.35 $MtCO_2$ in 2030 and then gradually decline to 34.21 $MtCO_2$ in 2050, achieving both the enhanced NDC and peak emissions targets. The modelled emissions in 2050 are slightly higher than the LEDS policy target of 35 MtCO2. However, in addition to CCS technology, the LEDS policy design considers a wider range of low-carbon emerging technologies, such as hydrogen applications, more diversified energy mix (e.g. energy imports), and policy tools such as carbon tax (Li and Su, 2017; Boey and Su, 2014), which are not considered in the current analysis. With the inclusion of these alternatives, Singapore's emissions target in 2050 would be viable.

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