CHAPTER 1

Main Report

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1. Introduction

The Economic Research Institute for ASEAN and East Asia (ERIA) updates the energy outlook and analyses saving potential in the East Asia Summit (EAS)[1] region every 2 years. The last update was in 2019–2020. In 2020–2021, ERIA assessed the impacts of the coronavirus disease (COVID-19) pandemic on energy demand in East Asia using the updated energy outlook models in 2019–2020 and released a special report of the assessment (ERIA, 2022). Whilst highlighting the EAS economies that have been hit hard by the pandemic, the report cites the energy demand growth that is expected to rebound strongly as economies recover after 2022. The report calls the attention of EAS leaders to how energy decisions and policy measures will need to be weighed against potentially higher energy costs and security risks in the post–COVID-19 era. Since the Russian Federation–Ukraine war broke out on 24 February 2022, the fear of rising global oil and gas prices has grown. The Brent crude oil price, recorded at US$95.42 per barrel on 24 February 2022, soared to US$127.98 per barrel on 8 March 2022. The price went down to US$87 per barrel on 18 November 2022 (OilPrice.com, 2022). The gas price, indexed to the global oil price, has temporarily moved up more than the global oil price. In Asia, natural gas demand is being met by imported liquefied natural gas (LNG). On the Japan/Korea Marker (Platts), the price of LNG moved down slightly from US$32.47/million British thermal units (Mbtu) in September 2022 to US$27/Mbtu on 18 November 2022. The oil market sentiment and concerns could last longer if the war continues and no immediate alternative sources of supplies of oil and natural gas are available.

From the United Nations Climate Change Conference (COP 26) in Glasgow to COP 27 in Sharm El-Sheikh, countries have pledged net-zero emission by mid-century. However, the ongoing oil and gas price hikes due to the war could discourage fuel switching from coal to natural gas, which is a low-hanging mitigation opportunity for the fossil fuel–dependent region. Fossil fuels, especially coal, could stay in the energy mix in some Asian countries longer than previously anticipated. Decarbonisation pathways will need to consider various socio-economic and political circumstances that can help countries become carbon neutral. The Working Group for Analysis of Energy Saving Potential in East Asia has added to the report low-carbon energy transition (LCET), a carbon-neutral scenario. By analysing the energy outlook and saving potential in each EAS country, the working group predicts the medium- to long-term growth of energy demand and supply in 2019–2050. The outlook consists of two scenarios: business as usual (BAU), which considers only the existing policies and does not consider any future policy change; and the alternative policy scenario (APS). APS includes aggressive energy efficiency and conservation (EEC) and renewable energy targets until 2050. It assesses how targets can contribute to energy saving and carbon dioxide (CO_2) emission reduction in EAS17 countries. LCET will analyse the impacts of net-zero emission technologies that can help countries achieve carbon neutrality by 2050 or beyond.

[1] The EAS is an annual regional forum of leaders of, initially, 16 countries, comprising the 10 member states of the Association of Southeast Asian Nations (ASEAN) plus Australia, China, India, Japan, Republic of Korea (henceforth, Korea), and New Zealand. EAS membership expanded to 18 countries, including the Russian Federation and the US, at the Sixth EAS in 2011. ASEAN has led the forum since its establishment. EAS meetings are held after the annual ASEAN leaders' meetings. The EAS plays an important role in the regional architecture of Asia-Pacific.

Recalling the Cebu Declaration,[2] the outlook continues to shed light on the policy implications for decision-making to ensure that the region can enjoy economic growth and investment opportunities whilst averting energy security threats and environmental problems. Multiple pathways can be sought for LCET to help countries embark on the journey to carbon neutrality by 2050.

1.1. East Asia Summit

EAS17 countries vary widely in per capita income, standards of living, energy resource endowments, climate, and per capita energy consumption. They include the 10 Association of Southeast Asian Nations (ASEAN) member countries – Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam – and Australia, China, India, Japan, Republic of Korea (henceforth, Korea), New Zealand, and the United States (US).

Whilst some EAS17 countries are mature economies, most are developing. Several had a per capita gross domestic product (GDP) of less than US$1,500 (in 2015 prices)[3] in 2019, whilst some mature economies had per capita GDP of more than US$53,000. Countries with mature economies have higher per capita energy consumption than do developing countries. A large percentage of people in developing countries still meet their energy needs mainly with traditional biomass fuels.

These differences partly explain why EEC goals, action plans, and policies are assigned different priorities across countries. Developed economies may be keen to reduce energy consumption, whilst developing countries tend to emphasise economic growth and improvement of the standard of living. However, as economies grow, per capita energy consumption is expected to grow, as well.

Despite differences, EAS17 leaders agree that the EAS 'could play a significant role in community building', which could be an important cornerstone for the development of regional cooperation in the years to come (Ministry of Foreign Affairs, 2005a).

1.2. Objective and Rationale

The study aims to analyse the potential impacts of proposed additional energy-saving goals, action plans, and policies in EAS17 on energy consumption, by fuel and sector and greenhouse gas (GHG) emissions. The study provides a platform for EAS17 countries to collaborate on energy and to build capacity in energy modelling and policy development.

[2] In 2007, leaders from ASEAN Member States, Australia, China, India, Japan, the Republic of Korea (henceforth, Korea), and New Zealand adopted the Cebu Declaration, which focuses on energy security. The leaders agreed to promote energy efficiency, new renewable energy, and the clean use of coal. Japan proposed to undertake a study on energy savings and the potential of reducing CO_2 emissions. The outlook results have been reported yearly to the EAS Energy Ministers Meeting to support studies on the agreed areas of energy work streams of the East Asia Summit – Energy Cooperation Task Force.

[3] All US dollars in this document are stated at constant year 2015 values unless specified.

The study supports the Cebu Declaration (ASEAN Secretariat, 2007), which highlights several goals, including the following:

(i) improving the efficiency and environmental performance of fossil fuel use;
(ii) reducing dependence on conventional fuels through intensified EEC programmes, increased share of hydropower, expansion of renewable energy systems and biofuel production and utilisation, and, for interested parties, civilian nuclear power; and
(iii) mitigating GHG emissions through effective policies and measures, thus helping abate global climate change.

The Government of Japan asked ERIA to conduct a study on energy saving and CO_2 emission-reduction potential in East Asia. Japan is the coordinating country of the energy efficiency work stream under the Energy Cooperation Task Force. As a result, the working group was convened, representing all EAS17 countries.

2. Data and Methodology

2.1. Scenarios

Like the studies conducted annually since 2007, the study continues to examine a BAU scenario reflecting each country's current goals, action plans, and policies; and an APS, which includes additional goals, action plans, and policies reported annually to the East Asia Energy Ministers Meeting. The assumptions incorporate the latest policies and targets into the model. The APS assumptions are grouped into (i) more efficient final energy consumption (APS1), (ii) more efficient thermal power generation (APS2), (iii) higher consumption of new and renewable energy (NRE) and biofuels (APS3), and (iv) introduction or higher utilisation of nuclear energy (APS4). APS is the total of APS1 to APS4. LCET is to combine APS with additional technological options, including clean fuels such as hydrogen and ammonia and clean technology such as carbon capture and storage.

The energy models can estimate the individual impacts of the assumptions on primary energy supply and CO_2 emissions. The combination of the assumptions constitutes the assumptions of APS and LCET. The main report highlights only BAU, APS, and LCET. However, each country report will analyse all APS scenarios, from APS1 to APS4.

Detailed assumptions for each APS are follows:

(i) The assumptions in APS1 are the reduction targets in sectoral final energy consumption, assuming that more efficient technologies are utilised, and that energy-saving practices are implemented in the industrial, transport, residential, commercial, and even agricultural sectors of some countries. The scenario resulted in less primary energy and CO_2 emission in proportion to the reduction in final energy consumption.
(ii) APS2 assumes the utilisation of more efficient thermal power plant technologies in the power sector. The assumption resulted in lower primary energy supply and CO_2 emission in proportion to the efficiency improvement in generating thermal power. The most efficient coal and natural gas combined-cycle technologies are assumed to be utilised for new power plant construction.

(iii) APS3 assumes higher contributions of NRE for electricity generation and utilisation of liquid biofuels in transport, resulting in lower CO_2 emissions as NRE is considered carbon-neutral or not emitting additional CO_2 into the atmosphere. However, primary energy supply may not decrease as NRE, like biomass and geothermal energy, is assumed to have lower efficiencies than fossil fuel–fired generation when converting electricity generated from NRE sources into their primary energy equivalent.

(iv) APS4 assumes the introduction of nuclear energy or a higher contribution of nuclear energy in countries already using the energy source. The scenario would produce less CO_2 emissions as nuclear energy emits minimal CO_2. However, as the assumption of thermal efficiency when converting nuclear energy output into primary energy is only 33%, primary energy supply is not expected to be lower than in BAU.

Detailed assumptions for LCET are as follows: APS considers further fuel switch from fossil fuels to hydrogen, electricity, and biomass in transport and industry, and application of carbon capture, utilisation, and storage (CCUS) in industry production and power generation.

(i) **Fuel switching**. Coal to highly efficient combined-cycle gas turbine is considered a transitional pathway. Hydrogen will be introduced into industry by replacing coal in iron and steel production and diesel in other activities in 2035–2050 at a 100% utilisation rate. Hydrogen and ammonia, including for co-firing in power generation and boilers in industry, will be applied after 2040. Biomass will replace coal and natural gas in other activities, depending on the country's situation. Some countries will start from 2030 and continue until 2050 at a higher utilisation rate of up to 95%.

(ii) **Electric vehicles**. Electricity will be introduced into public passenger transport by replacing diesel and gasoline. Some countries are expected to introduce electric buses by 2035. Electric vehicles will be introduced into private transport by replacing diesel and gasoline in 2025–2050 at a maximum 70% utilisation rate, depending on the country's situation.

(iii) **Application of CCUS**. CCUS will be applied for cement production and power generation, including coal and natural gas, in 2040–2050, with a 100% utilisation rate.

However, EAS17 countries are diverse in speed, pace, and progress, and are at various levels of implementing EEC goals, action plans, and policies. Some countries are ahead whilst others are just getting started. A few already have significant energy-saving goals, action plans, and policies built into BAU, whilst others have only started to quantify their goals.

2.2. Data

For consistency, the historical energy data used in the analysis were changed to the energy balances of national energy statistics of EAS17 countries from the International Energy Agency (IEA). Of the ASEAN 10 countries, Cambodia, Lao PDR, and Myanmar use their national energy statistics produced by ERIA, and the other 7 use the Asia-Pacific Economic Cooperation energy database, which includes national energy data submitted by the 7 countries. ASEAN+7 countries, including China and India, use IEA energy balance tables (IEA, 2020). Socio-economic data for 17 countries were obtained from the World Bank's World Databank–World Development Indicators and Global Development Finance. Other data, such as those relating to transport, buildings, and industrial production indices, if available, were provided by the working group members from each EAS17 country. Where official data were not available, estimates were obtained from other sources or developed by the Institute of Energy Economics, Japan (IEEJ), especially international energy prices such as crude oil price.

2.3 Methodology

In 2007, the primary model used was IEEJ's world energy outlook model, which was used to prepare Asia/World Energy Outlook. Since 2008, all ASEAN 10 member countries have used their own energy models. The rest have depended on the IEEJ model but provided their own key assumptions on population and GDP growth; electric generation fuel mixes; and EEC goals, action plans, and policies. The next section describes the study's energy models.

ASEAN countries. The energy models of ASEAN countries were developed by applying the econometrics approach to forecast energy balance tables based on final energy consumption and energy input and output in the transformation sector. Final energy consumption is forecast using energy demand equations by energy, sector, and future macroeconomic assumptions. For the study, all 10 member countries used the Long-range Energy Alternative Planning software.

Other countries. IEEJ produced energy outlooks of other countries using its model, which has various explanatory variables based on exogenously specified GDP growth rates. The model projects prices for natural gas and coal based on exogenously specified oil price assumptions. Demand equations are econometrically calculated in another module using historical data, and future parameters are projected using the explanatory variables. An econometric approach means that future demand and supply will be heavily influenced by historical trends. However, the supply of energy and new technologies are treated exogenously. For electricity generation, working group members specified assumptions about the future electricity generation mix in their countries by energy source. The assumptions were used to determine the future electricity generation mix.

3. Assumptions of the Study

Growth in energy consumption and GHG emissions is driven by various socio-economic factors. In EAS17, the factors – including increasing population, sustained economic growth, increasing vehicle ownership, and increasing access to electricity – will tend to increase energy demand. Together, they create a huge growth headwind that works against efforts to limit energy consumption. Understanding the nature and size of the headwind is critical for any analysis of energy demand in the region. However, an increase in consumption of energy services is fundamental to achieve a range of socio-economic development goals.

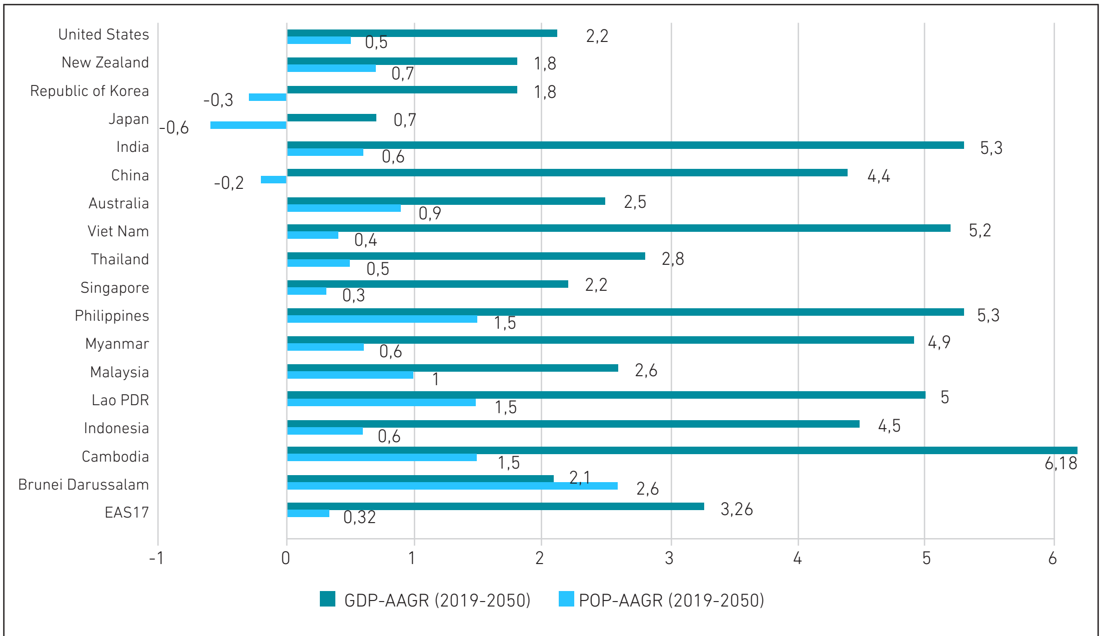
This section discusses the assumptions of key socio-economic indicators and energy policies for EAS17 until 2050.

3.1. Size of Population, Gross Domestic Product, and Their Growth Rates in East Asia Summit 17

The study's modelling assumption assumes that changes in population until 2050 are set exogenously. No difference in population between BAU, APS, and LCET is assumed. The EAS17 countries, except China, submitted assumed changes in population based on United Nations' population projections.

In 2019, the EAS17 total population was about 3.89 billion. It is forecast to increase at an average annual rate of about 0.4%, reaching about 4.37 billion in 2050.

Figure 1.1 Average Annual Growth Rates of Gross Domestic Product and Population in East Asia Summit 17 Countries



GDP-AAGR = gross domestic product average annual growth rate, POP-AAGR = population average annual growth rate, Lao PDR = Lao People's Democratic Republic.

Source: Authors.

Brunei Darussalam, Cambodia, Lao PDR, and the Philippines are generally assumed to have the fastest average annual population growth rate, from 2.6% to 1.5% in 2019–2050 (Figure 1.1). Australia, India, Indonesia, Malaysia, New Zealand, Singapore, Thailand, Viet Nam, and the US are expected to have moderate average annual population growth rate, from 0.3% to 1.0%. Populations of China, Japan, and Korea are assumed to decline slowly throughout the projection period as they continue to age. Their average annual population growth rates are predicted to be –0.2%, –0.3%, and –0.6%, respectively.

Long-term economic growth rates are assumed to be high in the developing countries, and highest in Cambodia, India, the Philippines, Lao PDR, Indonesia, Viet Nam, and Myanmar (Figure 1.1). Economic growth in other developing countries is assumed to be rapid. Brunei Darussalam, Singapore, Malaysia, and Thailand are expected to have moderate average annual GDP annual growth rates of 2.1%–2.8% in 2019–2050. Developed EAS17 countries – the US, Japan, Republic of Korea, New Zealand, and Australia – are expected to have moderate annual GDP growth rate. Due to their large economies, China, India, and Indonesia, together with the US, are likely to see rapid growth, which will be especially significant for energy demand.

In 2019, the total GDP in EAS17 was about US$47.9 trillion in 2015 US dollar constant price and accounted for more than half of global GDP. The region's GDP is assumed to grow at an average annual rate of about 3.26% in 2019–2050, implying that, by 2050, total GDP in the region will reach about US$129.2 trillion in 2015 US dollar constant price. China is projected to have the largest real GDP, about $55 trillion (2015 US dollar constant price), by 2050, followed by the US, with about $38.6 trillion. India and Japan are projected to have the next-largest GDPs, projected at about $13.4 trillion and $5.7 trillion, respectively, in 2015 US dollar constant price, by 2050 (Table 1.1).

Table 1.1 Gross Domestic Product (2015 US$ Constant Prices) and Population in East Asia Summit 17 Countries (2019–2050)

Region	GDP (2015 US$ billion)		Population (millions)		Per Capita GDP	Per Capita GDP
	2019	2050	2019	2050	2019	2050
Brunei Darussalam	14.01	26.55	0.44	0.67	46,700	39,627
Cambodia	20.92	134.14	16.49	26.16	1,269	5,128
Indonesia	1,204	4,710	271	325	4,443	14,492
Lao PDR	18.5	82.8	7.2	11.4	2,569	7,263
Malaysia	364.7	816.6	32.0	43.9	11,397	18,601
Myanmar	74.276	327.01	54.0	65.3	1,375	5,008
Philippines	377	1,847	108.1	171.3	3,488	10,782
Singapore	348.9	683.1	5.8	6.4	60,155	106,734
Thailand	460.8	1,092.5	69.6	82.4	6,621	13,259
Viet Nam	162.19	773.93	96.5	108.9	1,681	7,107

Region	GDP (2015 US$ billion)		Population (millions)		Per Capita GDP	Per Capita GDP
	2019	2050	2019	2050	2019	2050
Australia	1,346	2,871	25.4	33.0	52,992	87,000
China	14,296	55,025	1,397.7	1,320.0	10,228	41,686
India	2,751	13,447	1,366.4	1,639.2	2,013	8,203
Japan	4,591	5,737	126.3	105.	36,350	54,482
Republic of Korea	1,638	2,611	51.7	47.3	31,682	55,200
New Zealand	201	348	5.104	6.3	39,381	55,238
United Sates	19,975	38,670	328.2	378.5	60,862	102,166
EAS17	47,843	129,203	3,961	4,370	21,953	37,175

EAS17 = East Asia Summit 17, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic.

Source: Authors.

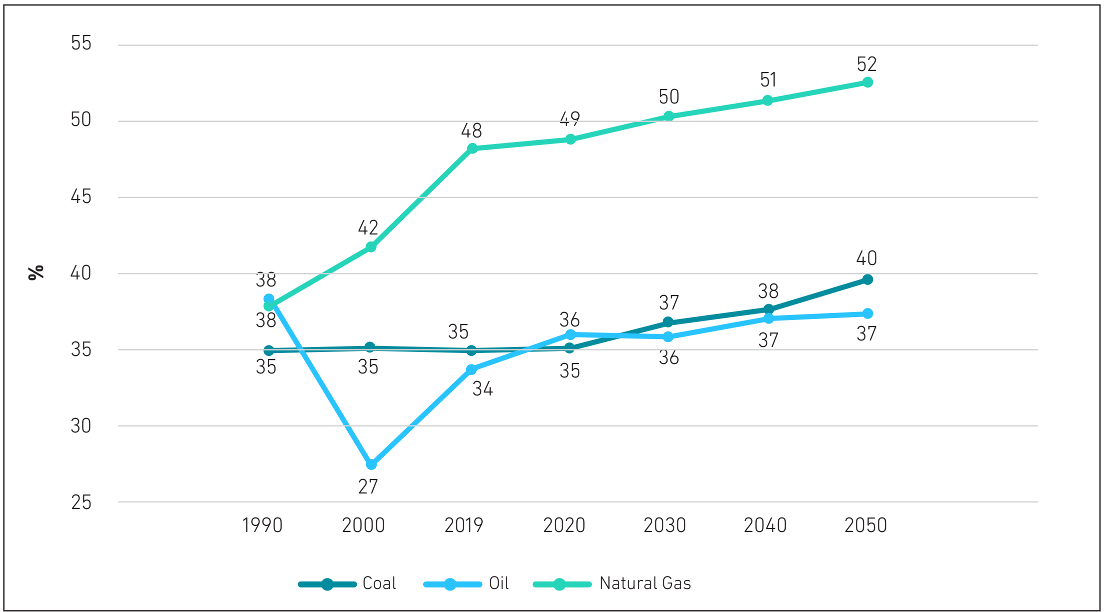
Average real per capita GDP (2015 US dollar constant price) in EAS17 is assumed to increase from about US$21,953 in 2019 to about US$37,175 in 2050. However, there are, and will continue to be, significant differences in per capita GDP amongst EAS17 countries. In 2019, per capita GDP (2015 US dollar constant price) ranged from about US$1,269 in Cambodia to over US$36,350 in Japan, the US, Singapore, and Australia. In 2050, per capita GDP is assumed to range from about US$5,127 in Cambodia to over US$102,166 in the US and Singapore.

3.2. Thermal Efficiency of Power Generation

The thermal efficiency of electricity generation reflects the amount of fuel required to generate a unit of electricity. Thermal efficiency was another exogenous assumption used in the study. Base year 2019 thermal efficiencies by fuel type (coal, gas, and oil) were derived from fossil fuel input and fuel output as electricity production. Thermal efficiencies by fuel type (coal, gas, and oil) were projected by Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam, and growth rates in thermal efficiency were derived from the projections. For the remaining countries, assumptions about the potential changes in thermal efficiency were based on IEEJ's *Asia/World Energy Outlook 2020*. As analyses start to add new fuels (hydrogen and ammonia) for thermal efficiency in LCET, data availability starts from 2020 and is projected towards 2050.

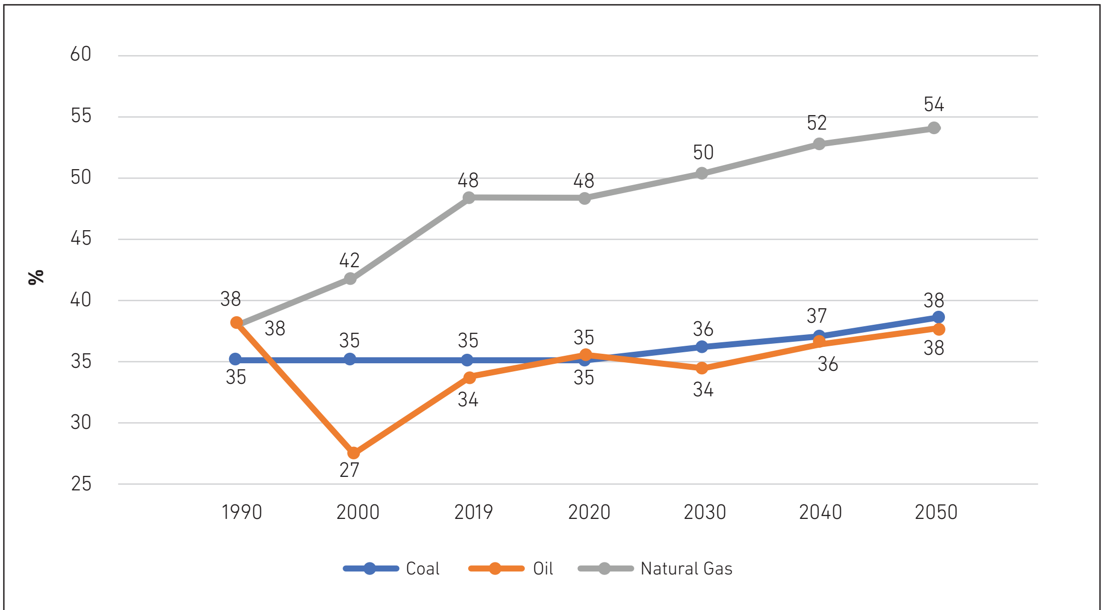
Thermal efficiencies may differ significantly amongst countries due to differences in technological availability, age, cost of technology, temperature, and cost and availability of fuel inputs. Thermal efficiencies in ASEAN and EAS7 countries are expected to improve considerably over time in BAU as more advanced-generation technologies, such as natural gas combined-cycle and supercritical coal-fired power plants, become available. In many countries, additional improvements are assumed in APS and LCET (Figures 1.2, 1.3, and 1.4).

Figure 1.2 Average East Asia Summit 17's Thermal Efficiency in the Business-as-Usual Scenario



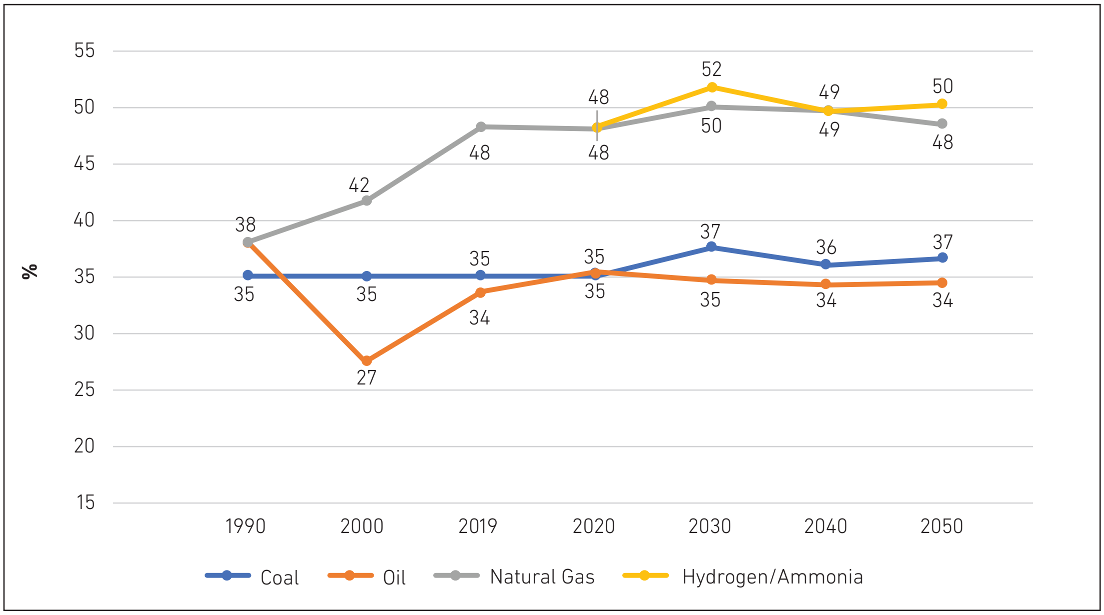
Source: Authors.

Figure 1.3 Average East Asia Summit 17's Thermal Efficiency in the Alternative Policy Scenario



Source: Authors.

Figure 1.4 Average East Asia Summit 17's Thermal Efficiency in the Low-Carbon Energy Transition Scenario



Source: Authors.

3.3. Imported Price Assumption of Oil, Coal, and Natural Gas

Table 1.2 depicts the oil price assumptions used in the modelling adopted by IEEJ from the world energy model price data of IEA (2020). In the reference scenario, crude oil prices were US$41/blue barrel (bbl) in 2020, to rise to US$80/bbl by 2030, and to US$100/bbl in 2050. The increase in the oil price in 2030 and 2050 is due to combined factors such as robust demand growth in non–Organisation for Economic Co-operation and Development countries, full economic recovery from the COVID-19 pandemic, new emerging geopolitical risks and financial factors, and oil supply constraints reflecting rising depletion rates for oil fields, amongst others.

Table 1.2 Imported Price Assumption of Real Oil, Natural Gas, and Coal

Year	Crude Oil (US$/bbl)	Coal (US$/tonne)	Natural Gas (US$/MBtu)		
			US	Europe	Asia
2000	28.66	34.64	4.23	2.71	4.72
2010	79.61	107.14	4.39	6.56	10.91
2015	52.39	79.62	2.60	6.44	10.31

Year	Crude Oil (US$/bbl)	Coal (US$/ tonne)	Natural Gas (US$/MBtu)		
			US	Europe	Asia
2020	41.00	80.03	2.13	3.25	7.77
2030	80.00	96.00	3.30	7.50	7.60
2040	95.00	97.00	3.80	7.50	7.60
2050	100.00	98.00	3.80	7.40	7.50

bbl= blue barrel, MBtu = 1 million British thermal units, toe = tonne of oil equivalent, US = United States.

Notes: 1. The constant price 2020 is used for the energy outlook of Australia, China, India, Japan, Korea, and New Zealand. However, for the outlook of ASEAN countries, we use the nominal price 2020. 2. Crude oil price assumptions start from 2020.

Source: Institute for Energy Economics, Japan (2020) oil price assumptions.

3.4. Energy-saving Goals and Other Policy Assumptions

The working group members from each country included information on the policy assumptions and targets in BAU, APS, and LCET. Since LCET assumes additional technology efficiency improvement above APS, Table 1.3 shows only the policy assumptions for APS. Some countries in EAS17 have clear targets for energy saving or any emission reduction. Table 1.3 summarises the policy assumptions in EAS17.

Table 1.3 Other Assumptions of Energy-saving Target Alignment with Nationally Determined Contributions in the Alternative Policy Scenario by East Asia Summit 17

Country	Assumptions
Australia	Energy efficiency target of 40% improvement in 2015–2030. Further reduction of GHG emissions by 43% below 2005 levels by 2050.
Brunei Darussalam	Reduction of GHG emissions by 20% relative to BAU. Reduction of total energy consumption by 63% from BAU by 2035. A 10% share of renewables in the power mix by 2035.
Cambodia	Total energy saving of 27% from BAU levels by 2030. Specific fuel efficiency target by 2050 included (coal, oil, gas, biomass industry, 10%; electricity-efficiency target, 20%). Reduce estimated total emissions by 2030 under the updated NDC scenario to about 64.6 million tCO_2eq/year (41.7%).
China	Have CO_2 emissions peak before 2030 and achieve carbon neutrality before 2060. Lower CO_2 emissions per unit of GDP by over 65% from the 2005 level, increase the share of non-fossil fuels in primary energy consumption to about 25% and the forest stock volume by 6 billion cubic metres from the 2005 level, and bring total installed capacity of wind and solar energy to over 1.2 billion kW.
India	Reduce emission intensity of GDP by 33%–35% by 2030 from the 2005 level. Achieve about 40% cumulative electric power installed capacity from non-fossil fuel–based energy resources by 2030 with the help of technology transfer and low-cost international finance, including from the Green Climate Fund. Create an additional carbon sink of 2.5 to 3 $BtCO_2e$ through additional forest and tree cover by 2030.

Country	Assumptions
Indonesia	Reduce GHG emissions in 2020–2030 by 29% (unconditional) up to 41% (conditional) against 2030 BAU, an increased unconditional commitment compared with the 2010 pledge of 26%.
Japan	Reduce GHG emissions by 46% in fiscal year 2030 from its fiscal year 2013 levels, setting an ambitious target aligned with the long-term goal of achieving net-zero emission by 2050. Continue strenuous efforts to meet the lofty goal of cutting emissions by 50%.
Republic of Korea	Reduce 24.4% from 2017 total national GHG emissions (709.1 $MtCO_2eq$) by 2030. It is an absolute emission-reduction target that is more predictable and transparent than the target relative to BAU emission projections in the previous NDC. The updated target includes an increased share of domestic reduction, which is facilitated through continued mitigation efforts such as the nationwide ban on construction of new coal-fired power plants.
Lao People's Democratic Republic	Unconditionally reduce GHG emissions in 2030 by 60% compared with BAU. Reduce land use, land-use change, and forestry emissions by 1.1 $MtCO_2eq$/year by reducing deforestation, reach 13 GW of hydropower capacity (5.5 GW capacity is already operational), introduce 50,000 energy-efficient cook stoves, and build a new bus rapid transit system in Vientiane and a new railway to China. With international support (conditionally), the country could increase its forest cover to 70% of total land area, develop 1 GW of wind energy and solar energy capacity, 300 MW of biomass-fired power capacity, and reduce final energy consumption by 10% compared with BAU.
Malaysia	Reduce economy-wide carbon intensity of 45% in 2030 compared with the 2005 level; save 16% electricity by 2050 in industry, commercial, and residential sectors; save 16% of oil in final consumption by 2050; and replace 5% of diesel with biodiesel in road transport.
Myanmar	Target saving by 2050 included (transport and residential by 20%; industrial, commercial, and 'others' by 10%). Replace 8% of transport diesel with biodiesel.
New Zealand	Use the emission budget approach of the updated NDC, which is total net emissions the country will be responsible for in 2021–2030. Managing the NDC through an emission budget means that net emissions will be measured across the whole target period (2021–2030), not only by isolating emissions in a single year (2030). The provisional budget for the updated NDC is 571 $MtCO_2eq$. It represents cumulative net emissions in 2021–2030, if net emissions decline in a straight line from 2020 levels to the point-year target in 2030. The previous NDC target was to reduce net GHG emissions by 30% below gross 2005 levels by 2030.
Philippines	Commit to a projected 75% GHG emission reduction and avoidance, of which 2.71% is unconditional and 72.29% conditional, representing the goal of GHG mitigation in 2020–2030 for agriculture, waste, industry, transport, and energy. The commitment is referenced against a projected BAU cumulative economy-wide emission of 3,340.3 $MtCO_2eq$ for the same period.
Thailand	Reduce GHG emissions by 30% from the projected BAU level by 2030. The level of contribution could increase up to 40%, subject to adequate and enhanced access to technology development and transfer, financial resources, and capacity-building support. Continue vigorous efforts to meet the long-term goal of carbon neutrality by 2050 and net-zero GHG emission by 2065. Energy efficiency targets by 2050 included reduction of final energy demand in transport by 70%; residential, 10%; commercial, 40%; and industrial, 20%. Biofuels to displace 12.2% of transport energy demand.

Country	Assumptions
United States	Set an economy-wide target of reducing net GHG emissions by 50%–52% below 2005 levels by 2030. Reach 100% carbon pollution–free electricity by 2035 through multiple cost-effective technology and investment pathways, each resulting in meaningful emission reductions in this decade. Support decarbonisation of international maritime and aviation energy use through domestic action as well as through the International Maritime Organization and the International Civil Aviation Organization. Invest in new technologies to reduce emissions associated with construction, including of high-performance electrified buildings. The government will support research, development, demonstration, commercialisation, and deployment of very low- and zero-carbon industrial processes and products.
Viet Nam	Strive to achieve net-zero emission by 2050. By 2030, GHG emissions in energy will be lower by 43.5% than in BAU and emissions will not be in excess of 457 $MtCO_2eq$. By 2050, ensure that total national GHG emissions reach net zero and that GHG emissions in energy will be lower than in BAU by 91.6% and will not be in excess of 101 $MtCO_2eq$.

BAU = business as usual, $BtCO_2e$ = British thermal unit of carbon dioxide equivalent, CO_2e = carbon dioxide equivalent, GHG = greenhouse gas, kW = kilowatt, $MtCO_2eq$ = metric tonne of carbon dioxide equivalent, MW = megawatt, NDC = nationally determined contribution, tCO_2eq = tonne of carbon dioxide equivalent.

Source: United Nations Climate Change, 2022.

4. Energy Outlook for the East Asia Summit Region

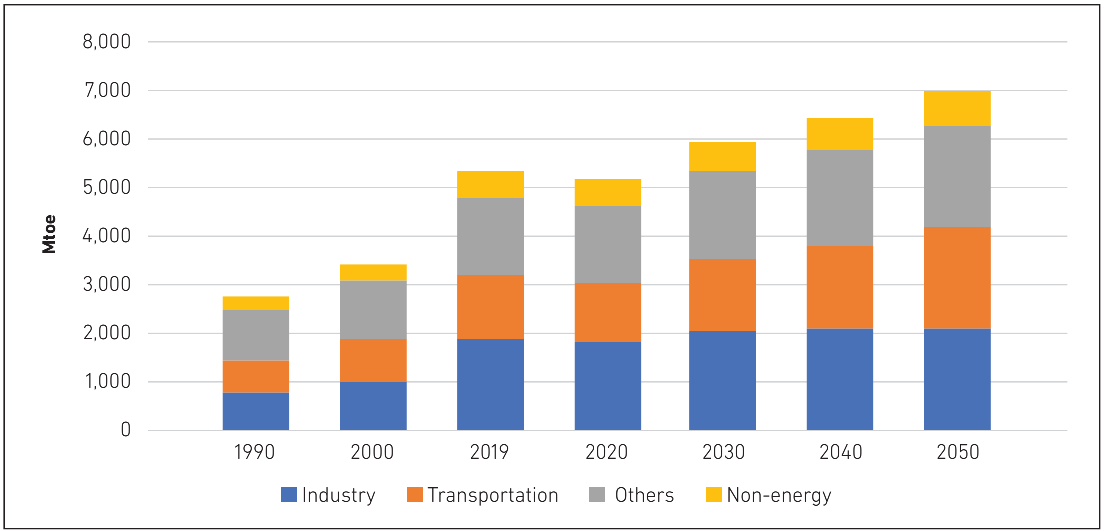
4.1. Business-as-Usual Scenario

4.1.1. Final Energy Consumption

In 2019–2050, total final energy consumption (TFEC)[4] in EAS17 is projected to grow at an average annual rate of 0.9%, reflecting the assumed 3.26% annual GDP growth and 0.32% population growth. Final energy consumption is projected to increase from 5,318 Mtoe in 2019 to 6,966 Mtoe in 2050. Transport energy demand is projected to grow by about 1.3% per year in 2019–2050, and its energy consumption share is projected to be 29.3% by 2050. Industry's annual growth rate in 2019–2050 is about 0.4% per year, but its energy consumption share is projected to be about 30.2% by 2050. Commercial and residential ('others') demand will grow by 0.9% per year, higher than that of industry, but energy consumption share is projected to be 30%, the second largest after industry. Figure 1.5 shows final energy consumption by sector under BAU in EAS17 in 1990–2050, and Figure 1.6 shows details of sector shares in final energy consumption.

[4] Refers to energy in the form in which it is consumed, i.e. including electricity but not fuels and/or energy sources used to generate electricity.

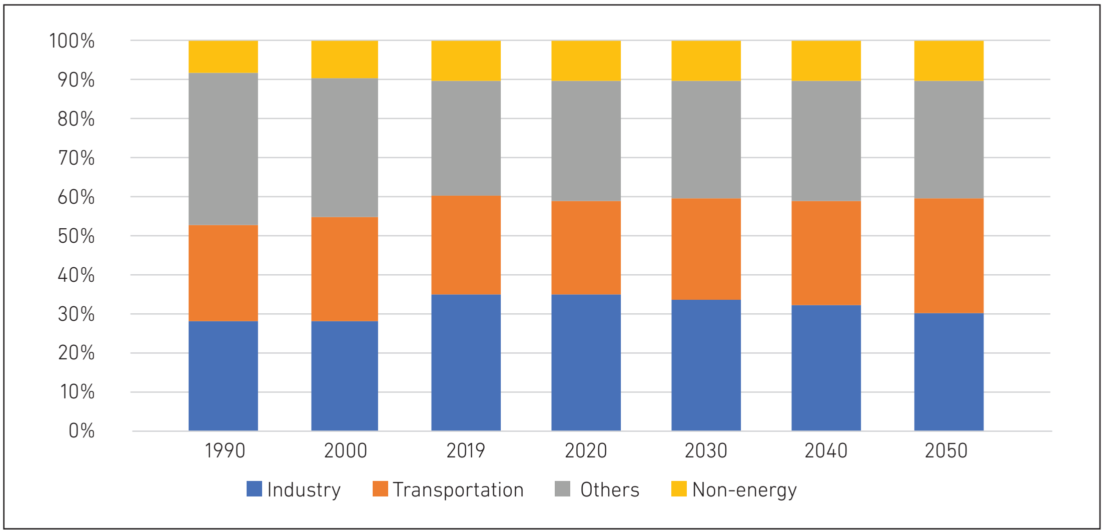
Figure 1.5. Final Energy Consumption by Sector, Business-as-Usual Scenario (1990–2050)



Mtoe = million tonnes of oil equivalent.

Source: Authors.

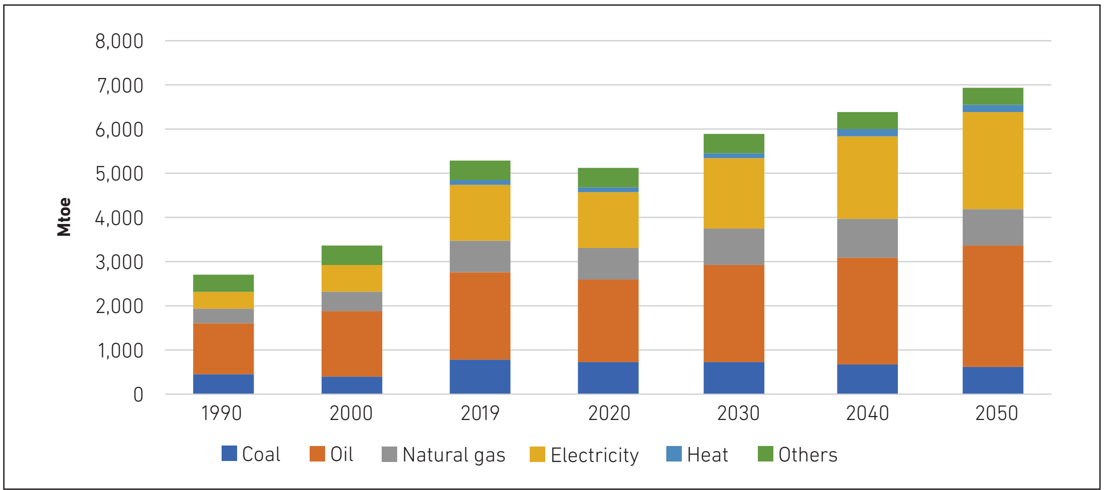
Figure 1.6 Final Energy Consumption Share by Sector (1990–2050)



Source: Authors.

Figure 1.7 and Figure 1.8 show final energy consumption and shares by fuel type in EAS17 under BAU in 1990–2050. By energy source, electricity and natural gas demand in BAU are projected to show the fastest growth, increasing by 1.9% and 0.7% per year, respectively, in 2019–2050, but their shares are just 31.6% and 12.5%. Although oil will retain the largest share, 38.8%, of TFEC, it is projected to grow at a lower rate of 1.0% per year in 2019–2050, reaching 2,706 Mtoe in 2050. Generally, oil share slightly increases from 37.9% in 2019 to 38.8% in 2050. Coal demand will grow at a rate of –0.6% per year on average in 2019–2050, reaching 653.45 Mtoe in 2050. The share of other fuels, such as biomass, will decline from 8.4% in 2019 to 6.0% in 2050. The slow growth is due to the gradual shift from non-commercial biomass to conventional fuels such as liquefied petroleum gas and electricity in the residential sector. Slow growth is observed in the declining share of heat energy demand, projected to drop from 2.3% in 2019 to 1.7% in 2050, in final energy consumption. One reason could be the shift from heat energy demand to more electricity consumption in final energy consumption.

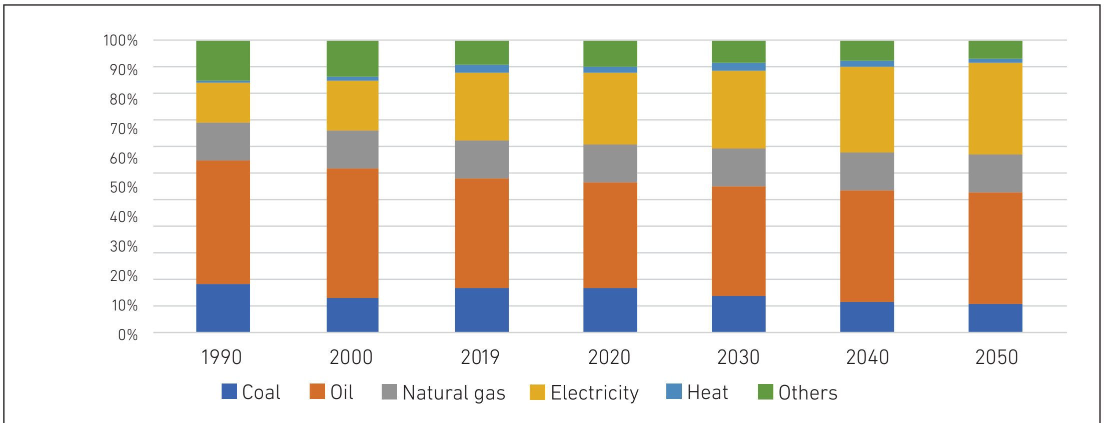
Figure 1.7 Final Energy Consumption by Fuel (1990–2050)



Mtoe = million tonnes of oil equivalent.

Source: Authors.

Figure 1.8 Final Energy Consumption Share by Fuel (1990–2050)

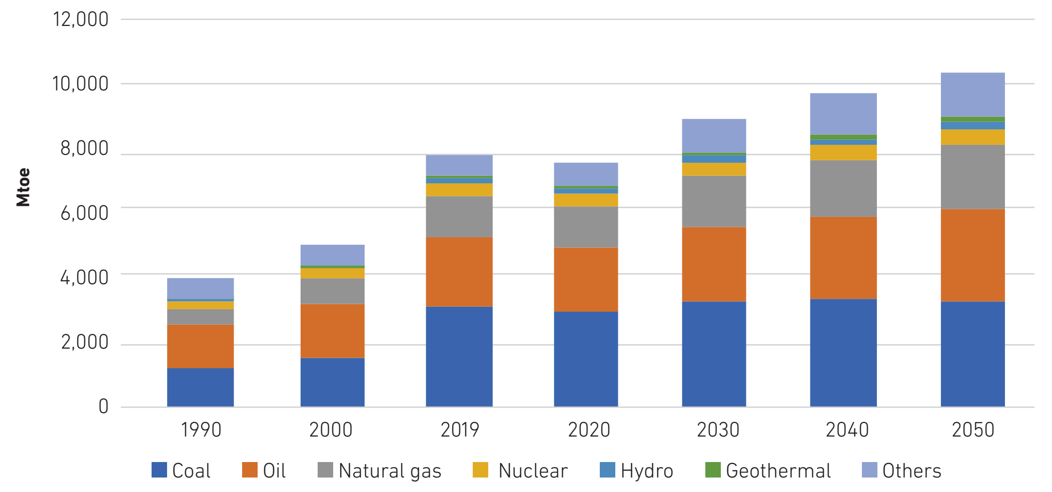


Source: Authors.

4.1.2. Primary Energy Supply

Figure 1.9 shows primary energy supply in EAS17 in 1990–2050. Primary energy supply[5] is projected to grow at a slower pace, 0.9% per year in 2019–2050, the same growth rate of final energy consumption. The EAS17 primary energy supply is projected to increase from 8,046 Mtoe in 2019 to 10,467 Mtoe in 2050. Coal will still comprise the largest share (32.5%) of primary energy supply, but its growth is expected to be slower, increasing at 0.2% per year in 2019–2050. The share of coal in total primary energy supply (TPES) is forecast to decline from 39.7% in 2019 to 32.5% in 2050.

Figure 1.9 Primary Energy Supply in East Asia Summit 17 (1990–2050)



Mtoe = million tonnes of oil equivalent.

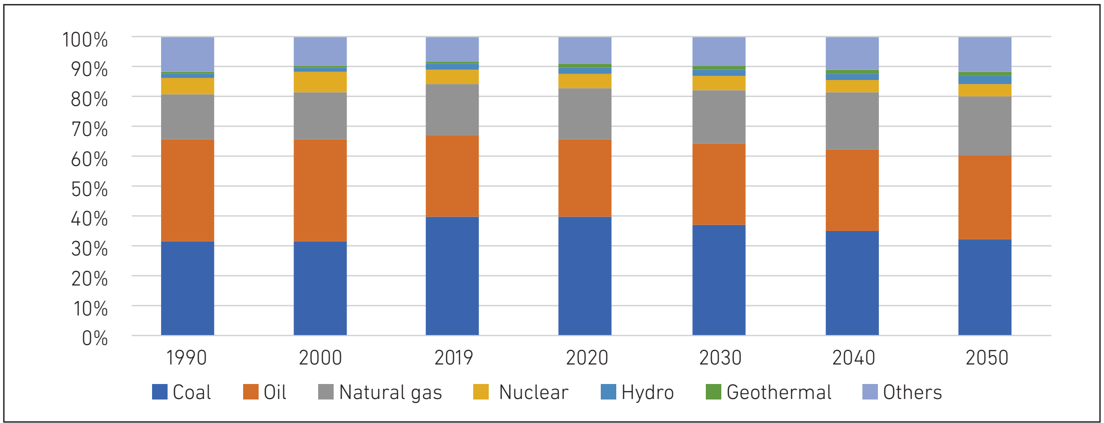
Source: Authors.

Amongst fossil sources of energy, natural gas is projected to see less moderate growth in 2019–2050, increasing at an annual average rate of 1.3%. Its share of the total will increase from 16.9% (1,360 Mtoe) in 2019 to 19.6% (2,047 Mtoe) in 2050. Nuclear energy is projected to increase at a slower rate of 0.8% per year on average in 2019–2050 and its share is projected to slightly drop from 4.7% in 2019 to 4.6% in 2050. Nuclear power generation in Japan and expansion of nuclear power generation capacity in China and India are assumed to resume. The share of hydropower is projected to slightly increase from 2.2% in 2019 to 2.3% in 2050. Geothermal energy is projected to grow at 3.3% per year in 2017–2050, which is the fastest growth rate amongst energy sources. However, its share is projected to be small, about 0.7% in 2019, increasing from 1.6% by 2050.

[5] Refers to energy in its raw form, before any transformation, most significantly the generation of electricity.

Amongst the energy sources, 'others' – solar and wind energy, and solid and liquid biofuels – will grow at 1.9% in 2019–2050. Consequently, their share will increase from 8.4% in 2019 to 11.6% in 2050. Most remarkably, wind and solar energy will see the largest average annual growth rate, 4.5%, in 2019–2050. The share of wind and solar energy in primary energy supply will increase from 1.7% in 2017 to 5.3% in 2050. Figure 1.10 shows the shares of each energy source in the total primary energy mix in 1990–2050.

Figure 1.10 Share of Primary Energy Mix by Source (1990–2050)

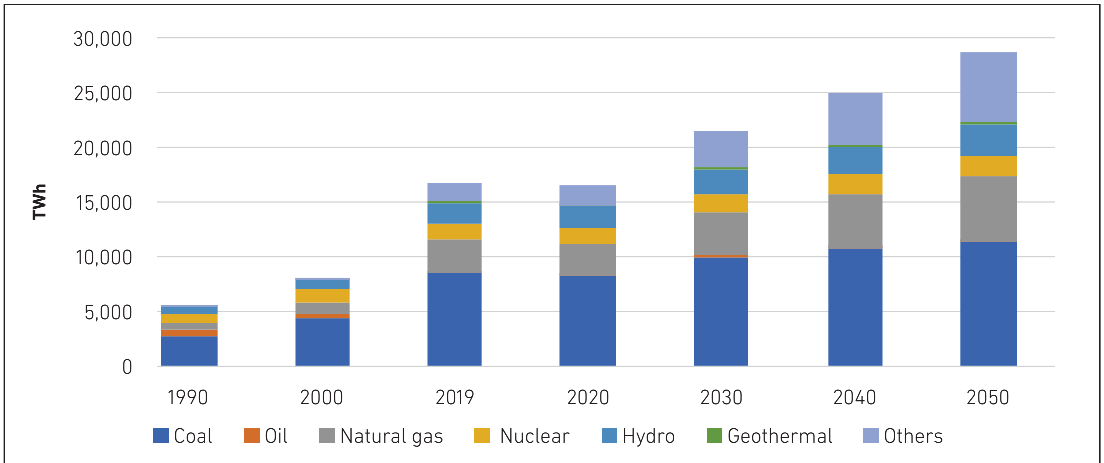


Source: Authors.

4.1.3. Power Generation in East Asia Summit 17

Figure 1.11 shows power generation output in EAS17. Total power generation is projected to grow at 1.8% (16,534 terawatt-hours [TWh]) per year on average in 2019–2050 (equivalent to 28,515 TWh). However, the growth rate in 1990–2019 was 3.9%, more than twice as high as the projected growth rate in 2019–2050.

Figure 1.11 Energy Mix of the Power Generation in East Asia Summit 17 (1990–2050)

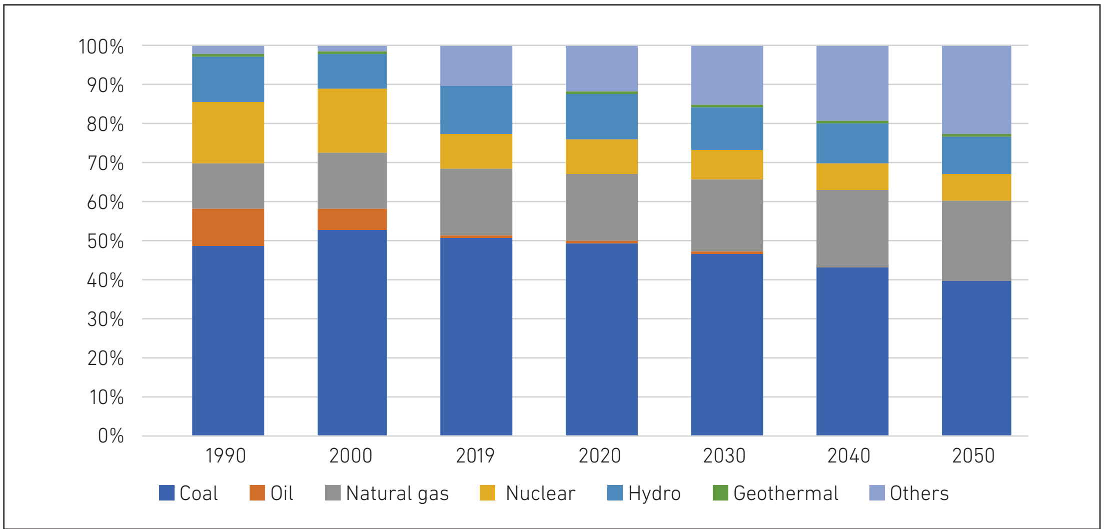


TWh = terawatt-hour.

Source: Authors.

Figure 1.12 shows the shares of each energy source in electricity generation in 1990–2050. The share of coal-fired generation is projected to continue to be the largest and will be about 39.5% in 2050, a large drop from the 50.5% share in 2019. The share of natural gas is projected to increase from 17.5% in 2019 to 20.8% in 2050. Nuclear power share (8.8% in 2019) is forecast to decrease to 6.5% in 2050. The share of geothermal power was 0.3% in 2019 and is projected to increase to 0.8% in 2050. Other sources (wind, solar, and biomass energy, amongst others) will record the highest average annual growth rate, 4.5%, in 2019–2050. The share of combined wind, solar, and biomass energy in the power mix is expected to be 22.4% in 2050, from 9.9% in 2019. The share of oil will drop from 0.7% in 2019 to 0.1% in 2050, with an average annual growth rate of –4.1% in 2019–2050 due to its higher fuel cost and limited use in power generation. The share of hydropower in the power mix is projected to decrease from 12.2% in 2019 to 9.9% in 2050. The average annual growth rate of hydropower is expected to slow down to 1.1% in 2019–2050.

Figure 1.12 **Share of Power Generation Mix in East Asia Summit 17 (1990–2050)**



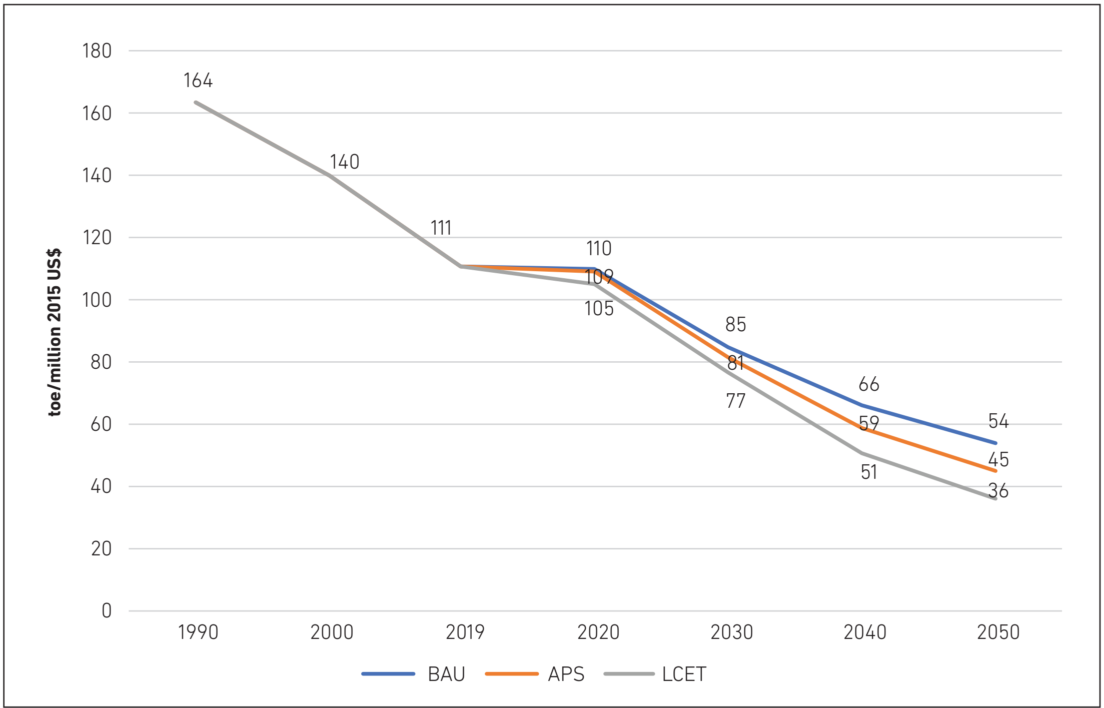
Source: Authors.

4.2. Comparison of Business-as-Usual, Alternative Policy, and Low-carbon Energy Transition Scenarios

4.2.1. Energy Indicators in East Asia Summit 17

Figure 1.13 and Figure 1.14 show the final energy intensity and primary energy intensity in 1990–2050 for BAU, APS, and LCET. The final energy intensity (toe/million 2010 US dollars) in EAS17 is projected to decline by 51.4% in BAU, 59.5% in APS, and 67.6% in LCET in 2050 from the 2019 level. The final energy intensity indicator shows how the economy becomes more efficient in using final energy consumption to produce a unit of the GDP. In general, final energy intensity has been remarkably improved, pointing to the gradual increase of energy efficiency in all final energy sectors such as industry, transport, commercial, and residential (Figure 1.13).

Figure 1.13 Final Energy Intensity – Final Energy Consumption per Unit of Gross Domestic Product (toe/million 2015 US$)



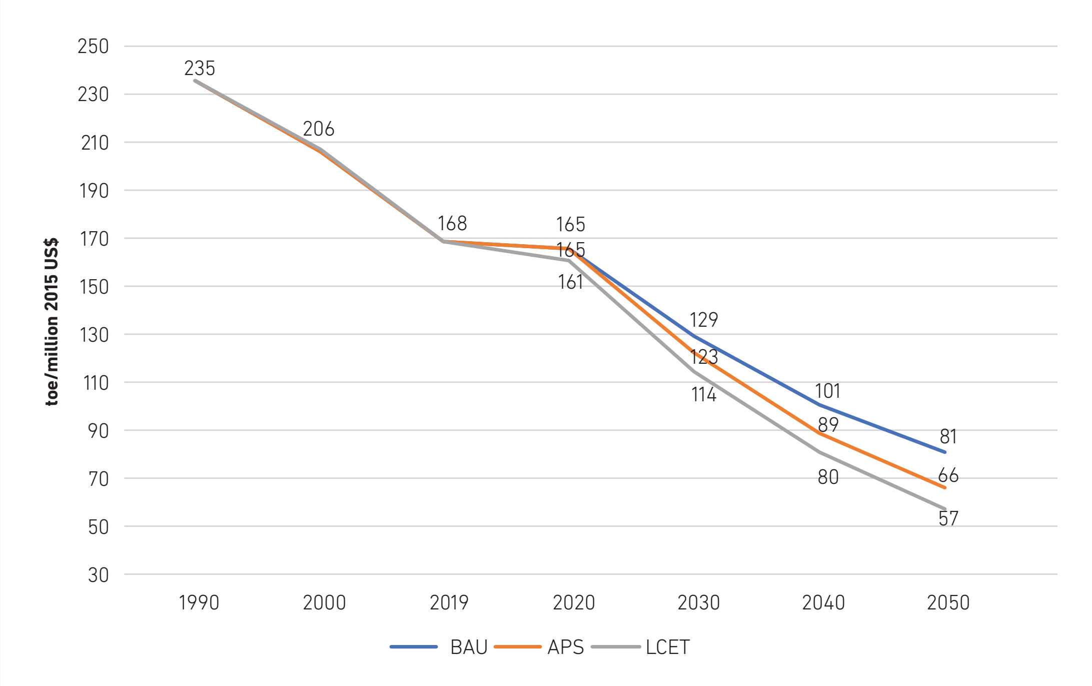
APS = alternative policy scenario, BAU = business as usual, LCET= low carbon energy transition, toe = tonne of oil equivalent

Source: Authors.

Primary energy intensity measures the whole economy efficiency in using a unit of energy to produce a unit of GDP and shows the efficiency of transformation plus the final energy consumption sectors. Figure 1.14 shows that EAS17 is projected to see a large improvement in primary energy intensity, which is expected to decline by 51.8% in BAU, 60.7% in APS, and 66.1% in LCET in 2050 compared with the 2019 level.

The improvement in primary energy intensity is reflected in improved carbon intensity (t-C/million 2015 US dollars).

Figure 1.14 Primary Energy Intensity – Final Energy Consumption per Unit of GDP (toe/million 2015 US$)

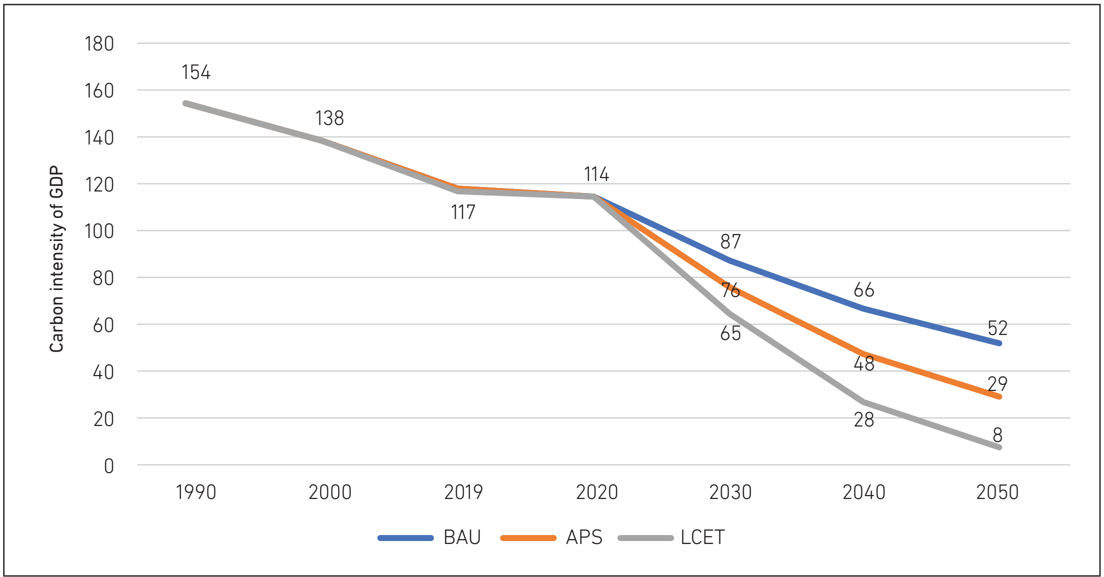


APS = alternative policy scenario, BAU = business as usual, LCET= low carbon energy transition, toe = tonne of oil equivalent

Source: Authors.

The carbon intensity of GDP is expected to drop 55.56% in BAU, 75.2% in APS, and 93.2% in LCET in 2050 from the 2019 level (Figure 1.15). The differences of the carbon intensity of GDP between BAU, APS, and LCET in 2019–2050 reflect the fundamental shift from fossil fuels to more renewables and clean technologies.

Figure 1.15 **Carbon Intensity of Gross Domestic Product**
(t-C/million 2015 US$)

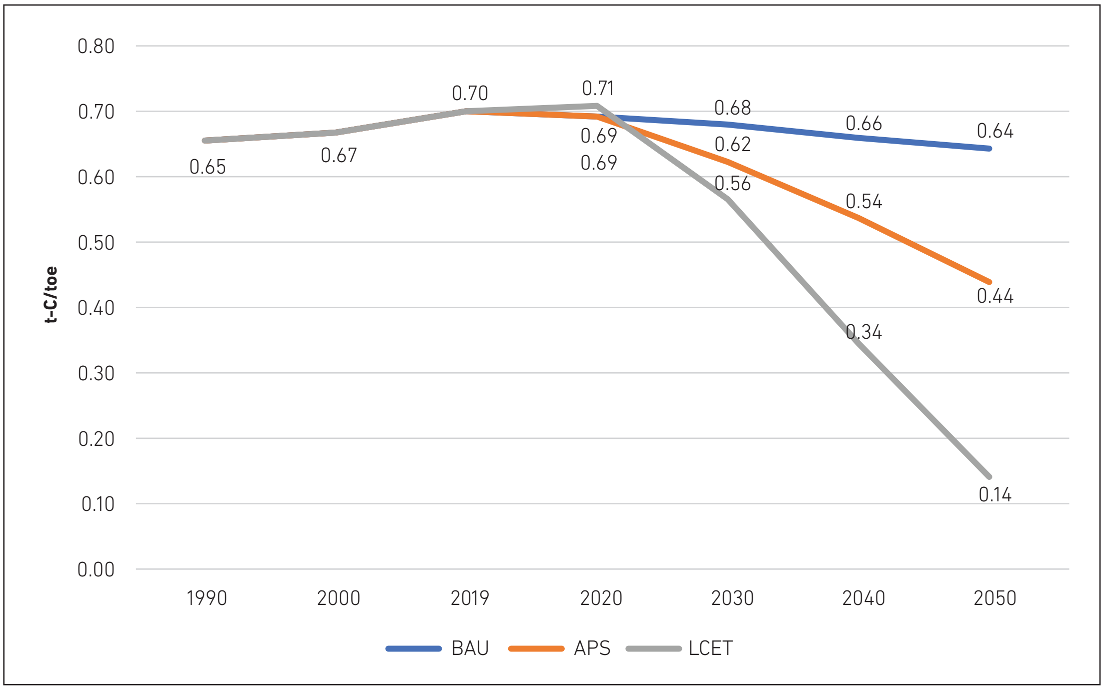


APS = alternative policy scenario, BAU = business as usual, GDP = gross domestic product, LCET= low carbon energy transition, t-C = tonne of carbon.

Source: Authors.

The carbon intensity of primary supply measures how a country or region is performing in terms of CO_2 emission per unit of energy use. If a country or region shifts to renewables and clean energy, intensity will be lower; it is an indicator of a country's energy system's shift to cleaner energy. Some countries in ASEAN, such as Lao PDR, have low final energy intensity but high primary energy intensity. In Lao PDR, the reason is its export of electricity from coal-fired power plants to neighbouring countries. Thus, primary energy intensity is crucial in evaluating the gross intensity in relation to the environment. In EAS17, the carbon intensity of primary supply is projected to decline by 8% in BAU, 37% in APS, and 78% in LCET in 2050 from the 2019 level (Figure 1.16). If the region can achieve LCET, the energy system of EAS17 will become cleaner as result of less emissions per unit of primary energy use.

Figure 1.16 Carbon Intensity of Primary Energy Supply



APS = alternative policy scenario, BAU = business as usual, LCET= low carbon energy transition, t-C = tonnes of carbon, toe = tonnes of oil equivalent.

Source: Authors.

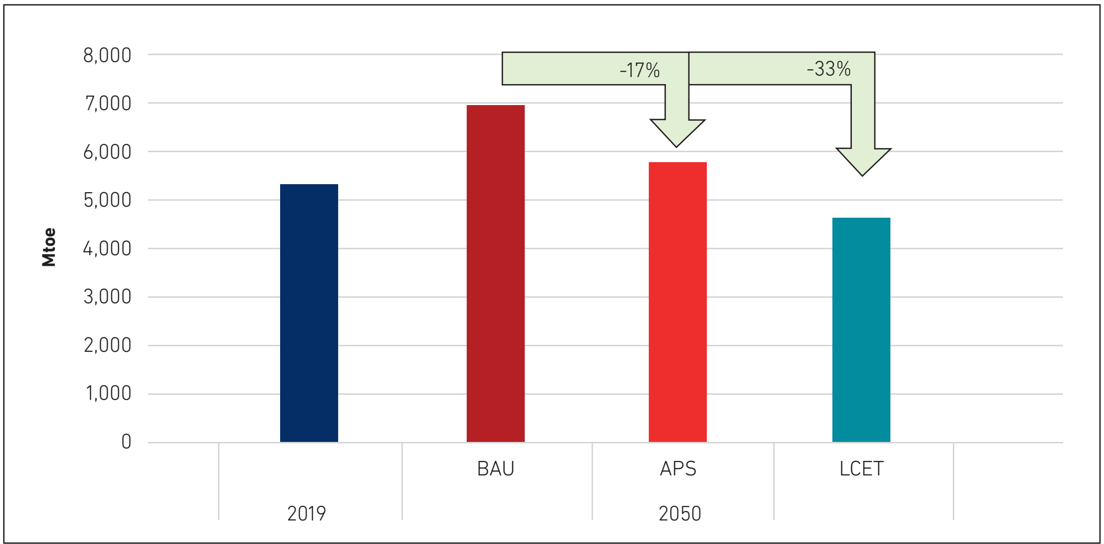
Per capita energy demand in BAU is projected to increase by 15% in 2050 compared with 2017. In APS and LCET, per capita energy demand is expected to decrease by 3.7% for APS and 20.8% for LCET in 2050 compared with 2019. The differences in per capita energy demand between BAU, APS, and LCET in 2019–2050 explain the fundamental change in terms of energy efficiency from BAU to APS to LCET. The decrease per se of per capita energy in 2050 compared with 2019 could be attributed to energy conservation as a result of energy saving and conservation awareness in EAS17, or could reflect the effective energy price that triggers demand response behaviour in EAS17. Because EAS17 comprises large economies with high per capita energy use, such as Australia, China, Japan, Korea, New Zealand, and the US, projected per capita energy demand is expected to decline as consumers reach a saturated level of energy consumption. However, if per capita energy demand for developing countries is projected, per capita energy demand is expected to rise, bringing about a more energy-intensive lifestyle as people are able to purchase vehicles, household appliances, and other energy-consuming devices as a result of greater disposable income.

4.2.2. Final Energy Consumption

TFEC in APS is projected to rise from 5,317.5 Mtoe in 2019 to 5,773.8 Mtoe. In 2050, comparing BAU and APS, the difference is 1,192 Mtoe or 17% lower in APS than in BAU. In LCET, TFEC is predicted to be about 2,321 Mtoe or 33.3%, which is lower than in BAU (Figure 1.17). TFEC in APS and LCET are expected to be lower than in BAU because of expected achievements of various energy efficiency plans and programmes, and the effective deployment of innovative technologies for the supply and demand sides.

Potential energy saving in TFEC of EAS17 (1,192 Mtoe in APS) in 2050 is almost triple ASEAN's TFEC in 2019 (447 Mtoe). In LCET, energy saving is expected to be 2,321 Mtoe or more than sixfold greater than ASEAN's TFEC in 2019. The achievement in energy saving in EAS17 is largely expected from the transport, industry, commercial, and residential sectors.

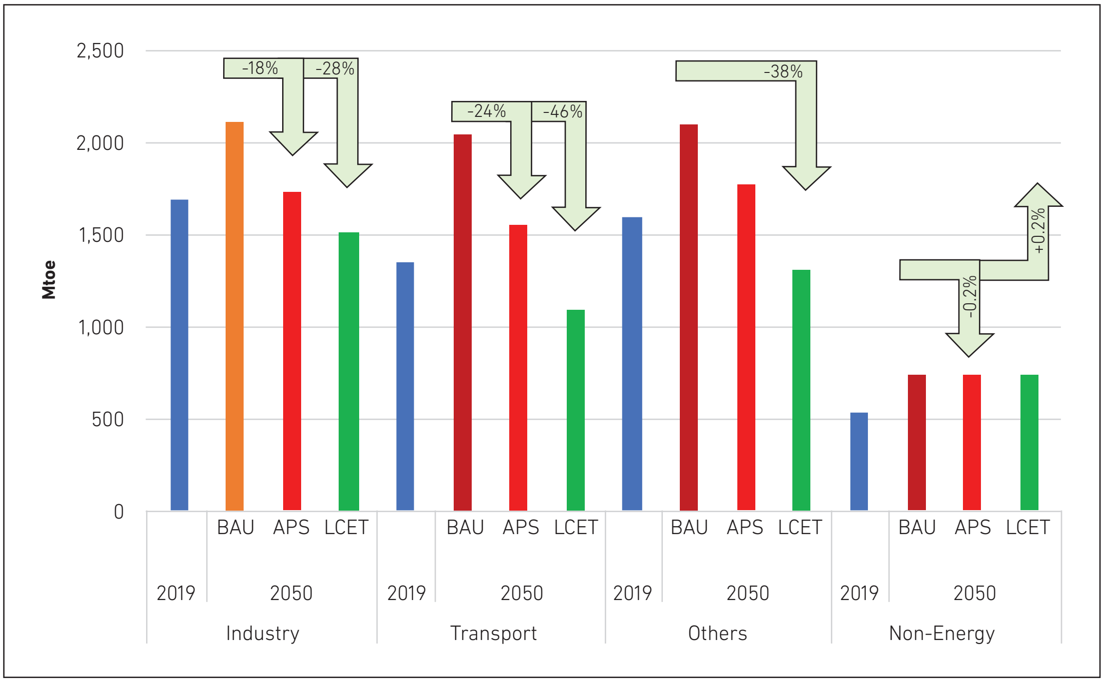
Figure 1.17 Total Final Energy Consumption, Business-as-Usual Scenario vs Alternative Policy Scenario vs Low-carbon Energy Transition



APS = alternative policy scenario, BAU = business as usual, LCET= low carbon energy transition, Mtoe = million tonnes of oil equivalent.
Source: Authors.

Figure 1.18 shows the composition of final energy consumption by sector in BAU, APS, and LCET. TFEC in most sectors is significantly reduced in APS and LCET compared with BAU. In percentage terms, the reduction is largest in transport (24% in APS, 46% in LCET), followed by 'others' (16% in APS, 38% in LCET) and industry (18% in APS, 28% in LCET). Non-energy demand will slightly drop by 0.2% in APS compared with BAU, but will slightly increase by 0.2% in LCET compared with BAU. Hydrogen and ammonia fuel will play an important role in LCET as they are expected to be used in cogeneration with coal and natural gas.

Figure 1.18 Final Energy Consumption by Sector, Business-as-Usual Scenario vs Alternative Policy Scenario vs Low-carbon Energy Transition



APS = alternative policy scenario, BAU = business as usual, LCET= low carbon energy transition, Mtoe = million tonnes of oil equivalent.

Source: Authors.

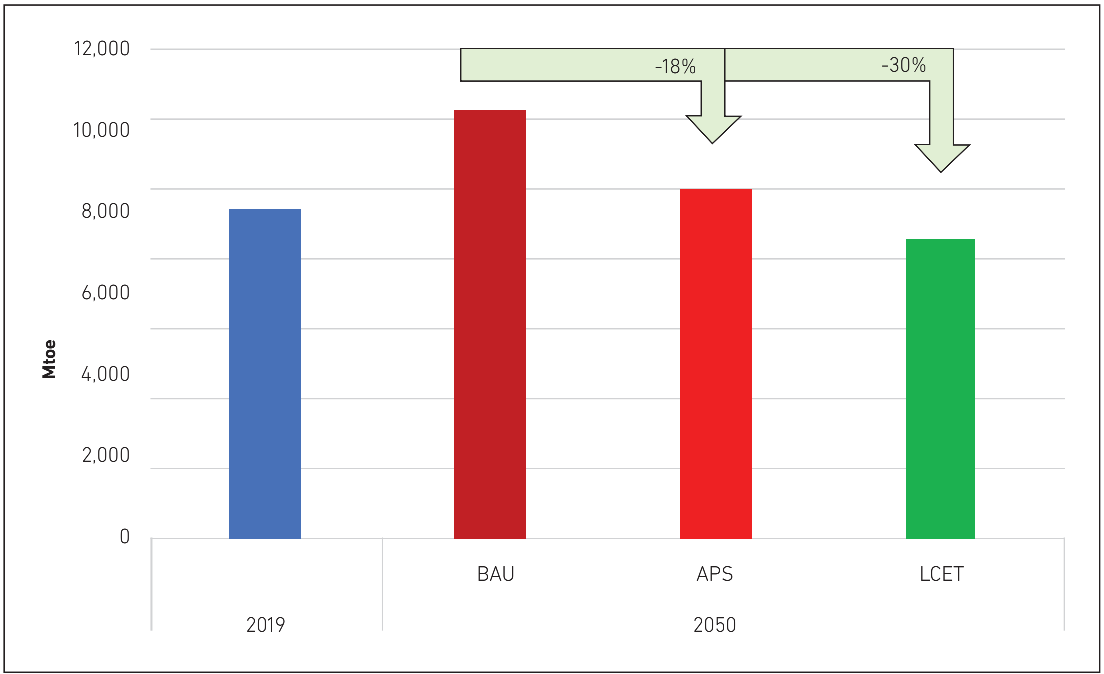
4.2.3. Primary Energy Supply

The large energy saving in LCET is due to technological innovation on the energy supply side, which is highly expected to produce more clean energy as a result of shifting from coal-fired power generation to more efficient gas-fired combined cycle, and the introduction of cogeneration of gas with hydrogen or coal with ammonia. LCET is expected to have a high share of renewables and clean technologies that will bring down emissions, as well.

Figure 1.19 shows TPES in BAU, APS, and LCET. It is projected to grow from 8,046 Mtoe in 2019 to 10,467 Mtoe in BAU, 8,558 Mtoe in APS in 2050, and 7,347 Mtoe in LCET in 2050. Total savings potential is the difference between BAU and APS, and BAU and LCET in 2050. Total savings potential in TPES is expected to be 1,909 Mtoe in APS and 3,120 Mtoe in LCET, representing an 18% and a 30% reduction from BAU to APS and from BAU to LCET, respectively, in 2050.

The energy savings potential in TPES is brought about by improvements in the transformation sector, particularly in power generation, and the final energy consumption sectors such as transport, industry, and residential and commercial, where efficiencies are expected. The large energy saving in LCET is due to technological innovation on the energy supply side. More clean energy is highly expected to be produced as a result of shifting from coal-fired power generation to more efficient gas-fired combined cycle, and the introduction of cogeneration of gas with hydrogen or coal with ammonia. LCET is expected to have a high share of renewables and clean technologies that will bring down emissions, as well.

Figure 1.19 Total Primary Energy Supply, Business-as-Usual Scenario vs Alternative Policy Scenario vs Low-carbon Energy Transition



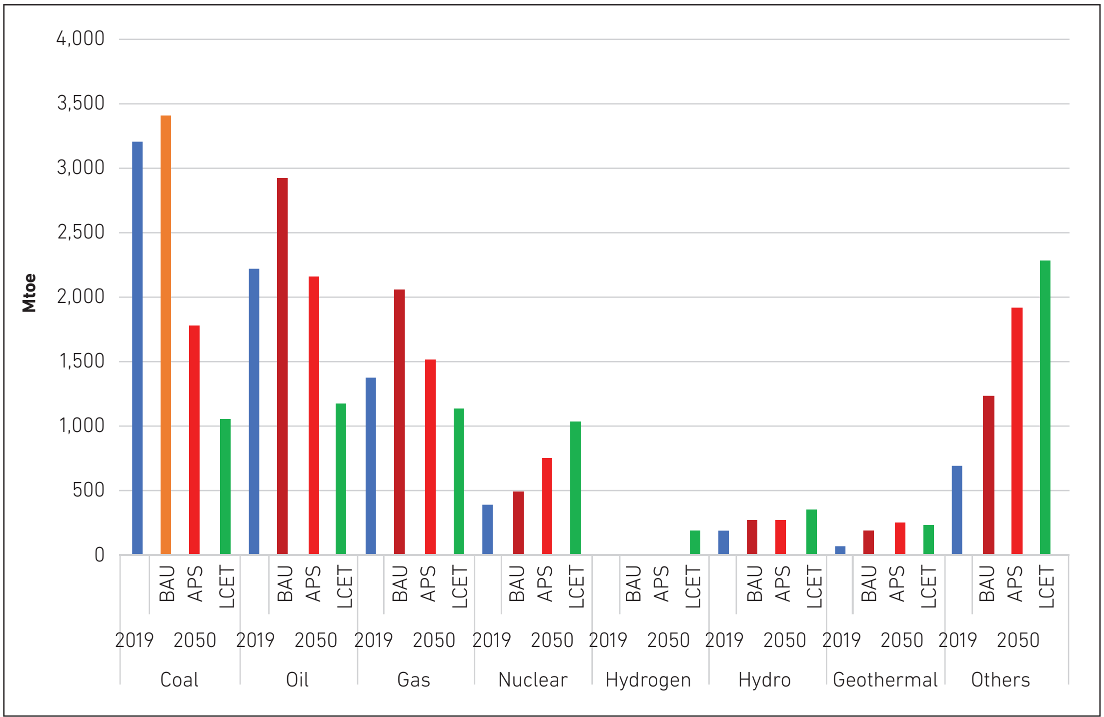
APS = alternative policy scenario, BAU = business as usual, LCET= low carbon energy transition, Mtoe = million tonnes of oil equivalent.
Source: Authors.

Figure 1.20 shows primary energy supply from all energy sources. New clean fuels, such as hydrogen and ammonia, are in the supply mix in LCET (Figure 1.20). Combined solar, wind, and biomass energy – 'others' – is projected to be 2,271 Mtoe, which is higher than the 2,047 Mtoe of natural gas supply in BAU (Figure 1.20).

In APS and LCET, growth in primary energy supply for fossil fuels is lower than in BAU. Growth rates in primary energy supply in APS and LCET are projected to be 0.2% and –0.3%, respectively, per year on average in 2019–2050. The rates are lower than in BAU, where the growth rate is projected to be 0.9%. In absolute terms, the largest reduction from BAU will be in coal demand, by 1,636 Mtoe or 48% in APS and by 2,364 Mtoe or 67% in LCET (Figure 1.21).

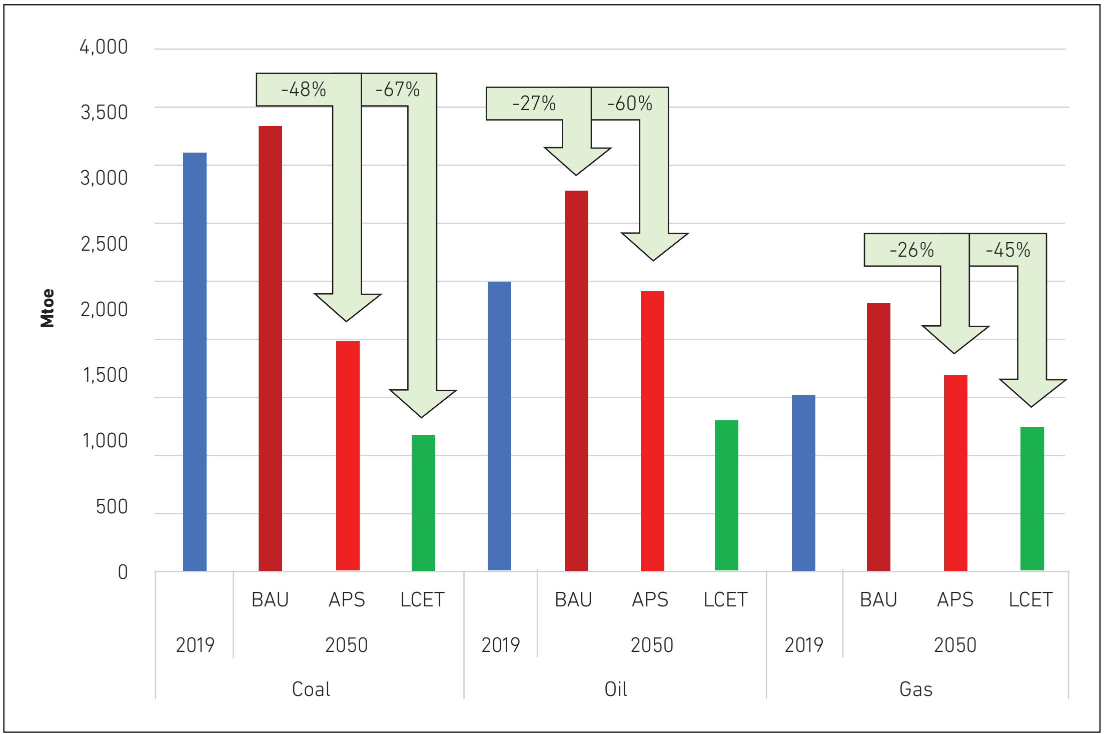
TPES of oil is expected to be lower than in BAU by 27% and 60% in APS and LCET, respectively. The large reduction of oil supply consumption from BAU to LCET is calculated, in real terms, to about 1,749 Mtoe. The reason is the large shift to electricity consumption for most sectors, especially transport, where electric vehicles are expected to be rolled out starting early 2040. The use of natural gas is expected to drop from BAU to about 26% and 45% in APS and LCET, respectively, by 2050 (Figure 1.21), even though it will remain an important fuel in 2050.

Figure 1.20 Primary Energy Supply by All Energy Sources, Business-as-Usual Scenario vs Alternative Policy Scenario vs Low-carbon Energy Transition



APS = alternative policy scenario, BAU = business as usual, LCET= low carbon energy transition, Mtoe = million tonnes of oil equivalent.
Source: Authors.

Figure 1.21 **Primary Energy Supply by Fossil Fuel Source, Business-as-Usual Scenario vs Alternative Policy Scenario vs Low-carbon Energy Transition**



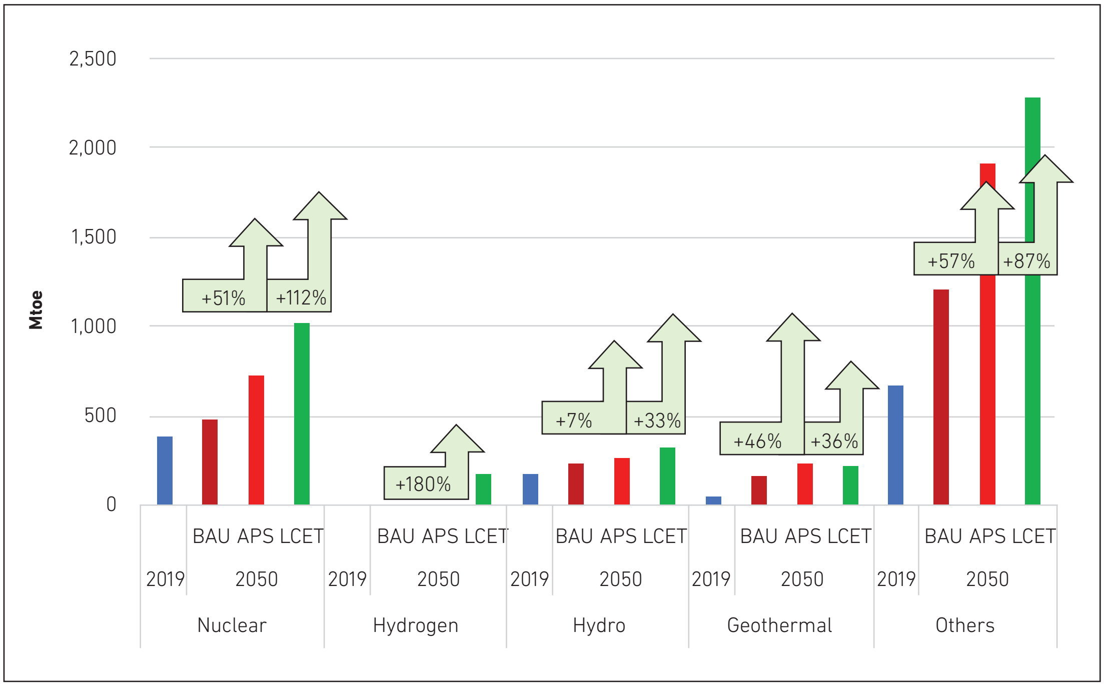
APS = alternative policy scenario, BAU = business as usual, LCET = low-carbon energy transition, Mtoe = million tonnes of oil equivalent.

Source: Authors.

The introduction of renewables, such as nuclear energy, hydropower, geothermal energy, and 'others' (solar, wind, and biomass energy) is projected to increase significantly in APS and LCET (Figure 1.22). Nuclear energy is projected to increase from BAU by 51% and 112% in APS and LCET, respectively. Nuclear energy will become vital in the energy mix in East Asia. Some countries in ASEAN will keep nuclear energy as an energy option by 2050.

Hydropower has fully developed in some countries and is expected to develop in some countries where potentials are yet to be tapped. In LCET, hydropower is predicted to increase by 33% from BAU (Figure 1.22). Geothermal potential is expected to increase from BAU by 46% and 36% in APS and LCET, respectively. Geothermal potential is expected to increase greatly in APS and to slowly reduce in LCET because some geothermal fields will eventually be depleted. Amongst renewables, solar and wind energy make up the largest contribution in LCET. 'Others' (solar, wind, and biomass energy) will increase from BAU by 57% and 87% in ASP and LCET, respectively (Figure 1.22). In ASEAN, solar energy is abundant in all countries and clean energy will be a big game-changer in helping decarbonise ASEAN's energy system.

Figure 1.22 Primary Energy Supply by Clean Fuel and Renewable Sources, Business-as-Usual Scenario vs Alternative Policy Scenario vs Low-carbon Energy Transition



APS = alternative policy scenario, BAU = business as usual, LCET= low carbon energy transition, Mtoe = million tonnes of oil equivalent.

Note: Hydrogen in the primary energy supply reflects imported hydrogen only and does not include domestic production for end-use. All domestic hydrogen production is secondary energy, and its feedstock, such as electricity or natural gas, has been accounted for in the transformation sector.

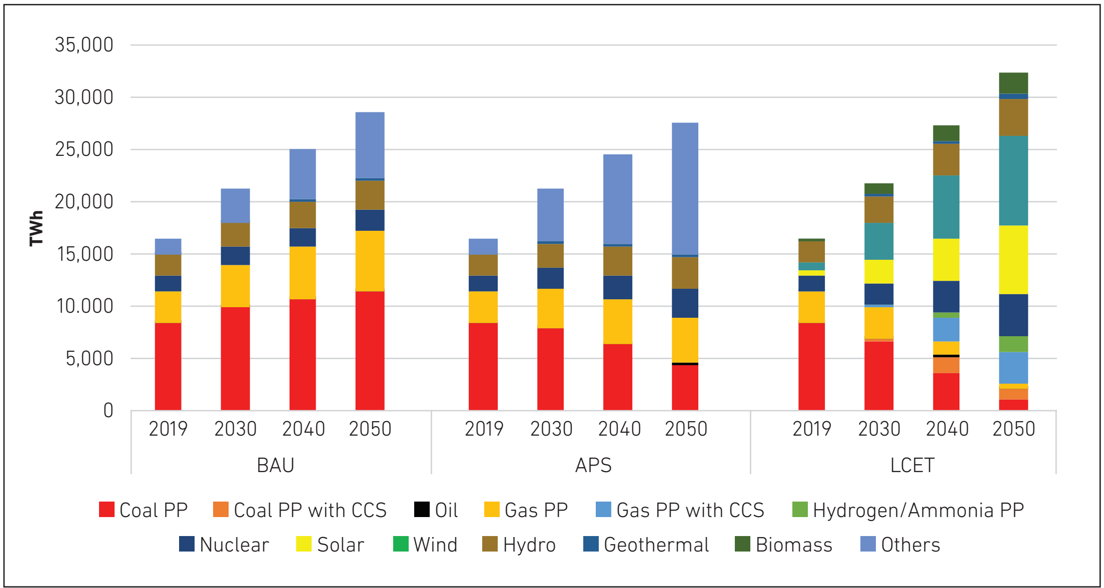
Source: Authors.

4.3. Power Generation, Business-as-Usual vs Alternative Policy vs Low-carbon Energy Transition Scenarios

In the power generation mix output, coal and natural gas are predicted to be dominant, contributing 11,268 TWh (39.5%) and 5,932 TWh (20.8%), respectively, in 2050 (Figure 1.23 and Figure 1.24). 'Others' comprise wind, solar, and biomass energy in BAU and APS. In LCET, 'others' are broken down into solar, wind, and biomass fuels. 'Others' generation output is predicted to change significantly from 6,380 TWh (22.4%) in BAU to 12,543 TWh (45.6%) in APS in 2050. In LCET, generation output from solar, wind, and biomass energy is expected to contribute about 6,752 TWh (21%) for solar energy, 8,298 TWh (25.8%) for wind energy, and 2003 TWh (6.2%) for biomass energy in the generation mix in 2050.

Hydrogen and ammonia power generation is expected to enter the generation mix by 2030, and its share will increase by 0.1% in 2030, 2% in 2040, and 4.8% in 2050 (Figure 1.24). Other clean energy, such as hydropower, geothermal, and nuclear, will play a significant role in decarbonising power generation in LCET, with shares of 11.6% for hydropower, 1% for geothermal energy, and 12.3% for nuclear energy.

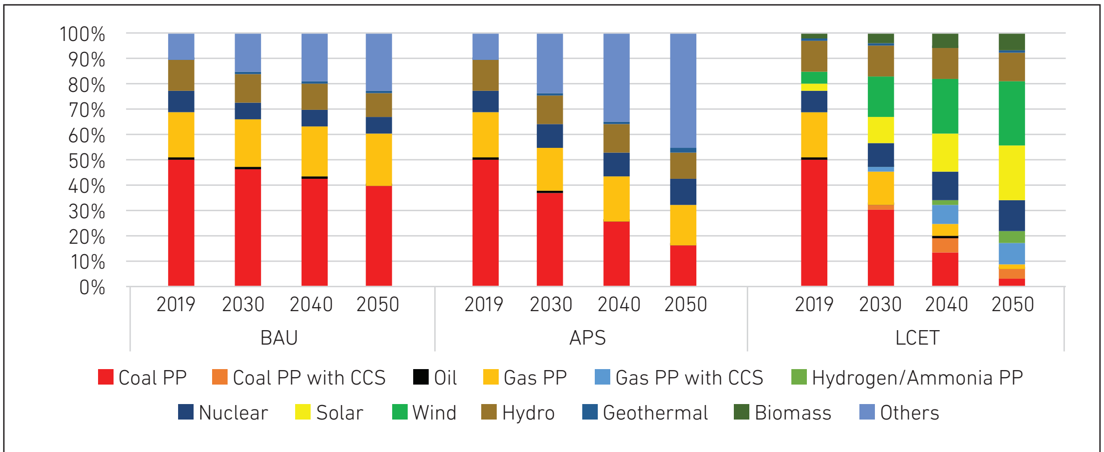
Figure 1.23 Power Generation, Business-as-Usual Scenario vs Alternative Policy Scenario vs Low-carbon Energy Transition (Terawatt-hours)



APS = alternative policy scenario, BAU = business as usual, CCS = carbon capture and storage, LCET= low carbon energy transition, PP= power plant, TWh = terawatt-hours.

Source: Authors.

Figure 1.24 Power Generation, Business-as-Usual Scenario, Alternative Policy Scenario, and Low-carbon Energy Transition (%)



APS = alternative policy scenario, BAU = business as usual, CCS = carbon capture and storage, LCET= low carbon energy transition, PP = power plant.

Source: Authors.

4.4. CO_2 Emissions from Energy Consumption

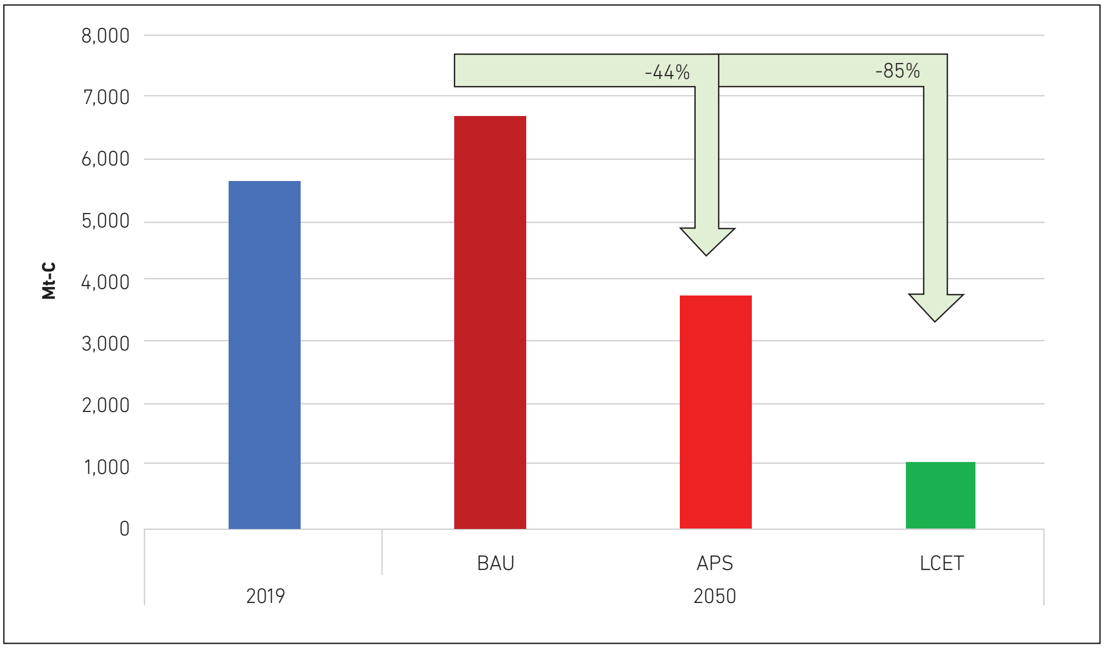
Consumption of fossil fuels such as coal, oil, and natural gas has discharged emissions largely into the atmosphere, which are the sole cause of temperature rise, causing global warming that is threatening the planet. The impacts of global warming have already been seen in sudden changes of temperatures; seawater rise; and natural catastrophic events such as severe storms, rains, landslides, and many others, which take lives and cause damage to habitats and infrastructure. During the Conference of the Parties 21 (COP 21) in December 2015, global leaders committed to reduce GHG emissions as outlined in the Paris Agreement, the first-ever universal and binding global climate deal, which was adopted by 195 countries. The agreement presents a global action plan aimed at limiting global warming to well below 2°C compared with pre-industrial levels by mid-century (2050s). The agreement pledges to further reduce emissions preferably to 1.5°C by the 2050s. The Paris Agreement represents a crucial step in bridging the gap between current policies and achieving climate neutrality before the end of the century.

LCET aims to introduce clean fuels and technologies and renewables into the entire energy system to reduce emissions in the EAS region. Figure 1.25 shows CO_2 emissions in BAU, APS, and LCET. CO_2 emissions from energy consumption in BAU are projected to drop from 6,709 million tonnes of carbon (Mt-C) in 2019 to 3,760 Mt-C in 2050 in APS, representing about 44% reduction (Figure 1.25). Emissions are expected to further drop by about 85% largely from BAU (6,709 Mt-C) to LCET (1,026 Mt-C) due to the significant improvement in energy efficiency, introduction of large share of renewables and clean fuels, and innovative technologies.

Negative emission growth is expected from BAU to APS to LCET. The average annual emission growth rate in 2019–2050 for APS is –2.1% for coal, –0.3 for oil, and –0.4% for natural gas. For combined coal, oil, and natural gas, the average annual growth rate in 2019–2050 is expected to be –1.3%. The annual emission average growth rate in LCET is expected to be –6.2% for coal, –3.9% for oil, and –5.5% for natural gas. For combined fossil fuels, the average annual growth rate is expected to be –5.3% in 2019–2050.

The CO_2 emissions in APS and LCET are lower than the 2019 emission level. In real terms, emissions in 2050 are 3,760 Mt-C in APS and 1,026 Mt-C in LCET, much lower than the 2019 emission level (5,606 Mt-C). LCET's trend of reducing emissions is partly in line with scientific evidence that such reductions are necessary to prevent severe impacts from climate change. The Intergovernmental Panel on Climate Change (2015) analysis indicates that global CO_2 emissions must fall by 45% from 2010 levels by 2030 to limit the global temperature increase to 2°C compared with pre-industrial levels. The Paris Agreement commits to 'pursuing efforts' to limit the temperature increase to 1.5°C, which, scientists suggest, will require achieving zero emission in 2030–2050. However, EAS members, including ASEAN Member States, must balance mitigating climate change with ensuring energy access and affordability. Innovative technologies such as clean coal technology, co-combustion of coal and natural gas with ammonia and hydrogen, and CCUS will play a central role in carbon sink worldwide. Some developing countries in ASEAN have significant potential for negative carbon sinks.

Figure 1.25 Total CO_2 Emissions, Business-as-Usual Scenario, Alternative Policy Scenario, and Low-carbon Energy Transition



BAU = business as usual, APS = alternative policy scenario, LCET= low carbon energy transition, Mt-C = million tonnes of carbon equivalent.

Source: Authors.

5. Conclusions and Recommendations

Despite the COVID-19 pandemic's significant impact on EAS17 and world economies from 2020 to late 2022, the ASEAN region and East Asia are expected to rebound starting in 2023. Sustained economic growth in ASEAN and all EAS17 countries is crucial for improving well-being. Economic growth is expected to be positive from 2023 onward, making the post-pandemic era an age of growth, leading to increased energy consumption. Decades of sustained economic growth, particularly in ASEAN and India, have increased per capita incomes, significantly reduced poverty rates, and improved living standards of hundreds of millions.
Two key drivers – population and economic growth in EAS – contribute to the projected increase in primary energy supply in 2019–2050 in BAU, APS, and LCET. TPES was 8,036 Mtoe in 2019 and is predicted to increase by 2050 to 10,457 Mtoe in BAU, 8,497 Mtoe in APS, and 4,795 Mtoe in LCE. The average annual growth rate of TPES is 0.9% in BAU, 0.2% in APS, and 0.1% in LCET iin 2019–2050.

Energy intensity is expected to drop from 168 toe/US$ million in 2017 to 66 toe/US$ million in 2050 for APS and 79 toe/US$ million in 2050 for LCET, representing 60% and 53% energy intensity reduction, respectively, in 2019–2050. Emission intensity is expected to drop from 0.70 t-C)/toe in 2019 to 0.44 t-C/toe, and to 0.16 in 2050, representing 37% and 77% emission intensity reduction in APS and LCET, respectively, in 2019–2050. The economy will be more efficient and a clean energy system will exist, especially in LCET.

As economic growth continues, demand for electricity will rise and vehicle ownership increase. However, unless low-emission technologies are used, reliance on fossil fuels to meet increased energy demand could lead to higher GHG emissions and climate change challenges. Even if fossil fuel resources are sufficient, the importation of oil from other regions may not be secure or affordable. Consequently, the ASEAN region is diversifying fuel supply sources, strengthening strategic stockpiling, and enhancing energy connectivity.

The Comprehensive Asia Development Plan 3.0 (CADP 3.0) emphasises that sustainability is not just a long-term concern but also an immediate response to urgent problems. Speedy energy infrastructure development, such as transmission and distribution networks and the Trans-ASEAN Gas Pipeline, including the LNG supply chain, and stable economic and demographic expansion in ASEAN will boost ASEAN and EAS energy demand. Even with higher crude oil prices, the region is expected to rely on coal, oil, and gas until 2050 under BAU. ASEAN and many developing countries need to explore a variety of options and use all available fuels and technologies to pursue their carbon neutrality goals. The outlook includes options in APS and LCET, where key innovative technologies, clean fuels, and renewables will be introduced at high levels by 2050.

Below are the key findings suggested by the results of the outlook in BAU, APS, and LCET.

5.1. Key Findings

Based on projected changes in socio-economic factors, energy consumption, and CO_2 emissions in BAU, APS, and LCET, the working group identified several key findings:

(i) The TFEC of APS and LCET are expected to be lower than that of BAU due to expected achievement of various energy efficiency plans and programmes, and the effective deployment of innovative technologies for the supply and demand sides. TFEC in most sectors is significantly lower in APS and LCET than in BAU. In percentage terms, the reduction is largest in transport (24% in APS, 46% in LCET), followed by 'others' (16% in APS, 38% in LCET), and industry (18% in APS, 28% in LCET).

(ii) Total power generation is projected to grow at 1.8% per year on average, from 2019 (equivalent to 16,534 TWh) to 2050 (equivalent to 28,515 TWh) in BAU. In the power generation mix output of BAU, coal and natural gas are predicted to be dominant, contributing 11,268 TWh (39.5%) and 5,932 TWh (20.8%), respectively, in 2050. 'Others' generation output is predicted to change significantly from BAU (6,380 TWh or 22.4%) to 12,543 TWh (45.6%) in APS in 2050. In LCET, generation output from solar, wind, and biomass energy is expected to contribute about 6,752 TWh (21%), 8,298 TWh (25.8%), and 2003 TWh (6.2%), respectively, into the generation mix in 2050. Hydrogen and ammonia power generation is expected to enter the generation mix by 2030; its share will increase by 0.1% in 2030, 2% in 2040, and 4.8% in 2050 (Figure, 1-24). Other clean energy such as hydropower, geothermal energy, and nuclear energy play a significant role in decarbonising power generation in LCET, with 11.6%, 1%, and 12.3%, respectively.

(iii) Potential energy saving in TFEC of EAS17 (1,192 Mtoe in APS) in 2050 is almost triple ASEAN's TFEC in 2019 (447 Mtoe). In LCET, energy saving and technological achievement is expected to save energy (2,321 Mtoe), more than sixfold greater than ASEAN's TFEC in 2019. The achievement in energy saving in EAS17 is largely expected from the transport, industrial, commercial, and residential sectors. The total savings potential in TPES is expected to be 1,909 Mtoe in APS and 3,120 Mtoe in LCET, representing 18% and 30% reduction from BAU, respectively, in 2050. In LCET, efficiency and technological innovations are not the only factors contributing to savings. A significant increase is expected in clean energy, such as shifting from coal-fired power generation to more efficient gas-fired combined cycle, as well as the introduction of cogeneration of gas with hydrogen or coal with ammonia. LCET is projected to have a substantial share of renewables and clean technologies, further reducing emissions.

(iv) TPES of oil is expected to be lower by 27% in BAU and 60% in APS and LCET. The large reduction in oil supply consumption from BAU to LCET is calculated, in real terms, at about 1,749 Mtoe. The reason is the large shift to electricity consumption in most sectors, especially transport, where electric vehicles are expected to be rolled out by the early 2040s. Although the use of natural gas is expected to decline to about 26% in BAU and 45% in APS and LCET by 2050 (Figure 1.21), it will continue to be an important fuel source.

(v) Projected final energy intensity (toe/million 2010 US dollars) in EAS17 is expected to decline significantly by 51.4% in BAU, 59.5% in APS, and 67.6% in LCET in 2050 compared with 2019. Final energy intensity is an indicator of the economy's efficiency in using final energy consumption to produce a unit of GDP without considering efficiency in the transformation sector. In general, final energy intensity is remarkably improved, pointing to gradual enhancement in energy efficiency across all final energy sectors, such as industry, transport, commercial, and residential sectors.

(vi) The CO_2 emissions from energy consumption in BAU are projected to drop from 6,709 Mt-C in 2050 to 3,760 Mt-C in 2050 in APS, representing about 44% reduction from BAU to APS. The emissions are expected to further drop, largely from BAU (6,709 Mt-C) to LCET (1,026 Mt-C), representing about 85%, due to significant improvement in energy efficiency, introduction of a large share of renewables and clean fuels, and innovative technologies.

5.2. Policy Implications

Based on the above findings, the working group identified five major categories of policy implications aimed at enhancing action plans in specific sectors, preparing appropriate energy efficiency policies, shifting from fossil to non-fossil energy, rationalising energy pricing mechanisms, and improving energy consumption statistics. Appropriate policies will vary between countries based on their unique circumstances, policy objectives, and market structures, and not all members may agree to all recommendations. The following are the implications outlined by the working group:

(i) Energy efficiency action plans in final consumption sectors. The industry, transport, and commercial sectors will be major sources of energy savings. Several EEC action plans will need to be introduced, implemented, and accelerated in EAS17. The policies are listed by area and sector:

- Industry will need to become energy efficient. Energy service companies (ESCOs) will play a crucial role in energy savings. Some ASEAN countries will need to accelerate the introduction of ESCOs through a national energy policy that will make it compulsory for industries with large energy consumption to have energy managers and to conduct energy auditing.
- Transport greatly contributes to the growth of final energy consumption, with oil being the primary fuel source for passenger light-duty vehicles, buses, and trucks in LCET. Although a major share of passenger vehicles are expected to shift to electrification by 2050 in LCET, long-distance alternative vehicle technologies, such as battery electric vehicles and fuel cell vehicles, remain expensive, which means that oil consumption will continue until 2050. The use of biofuels in internal combustion engines and hybrid vehicles is expected to increase. The infrastructure for electric vehicles will need to be accelerated to accommodate the fast-growing market for them worldwide.
- Known as hidden fuel, energy efficiency translates as energy resources to the region as energy will be available for other economic activities and for more people. EAS17 countries are encouraged to review their regulations or to formulate effective policy on energy efficiency to define the legal and organisational basis for energy efficiency activities and create conditions to reduce energy consumption in all sectors. The policy is to promote energy efficiency as part of a country's sustainable development policy by (i) applying a system of activities and measures to improve energy efficiency, especially for end-use of energy; (ii) introducing schemes of obligations for energy savings; (iii) developing a market of energy efficiency services and encouraging provision of energy efficiency services; and (iv) introducing financial mechanisms and schemes to attain the national objective of energy efficiency. Amongst the known policies are (i) green building codes for energy-efficient buildings, (ii) standards and labelling systems, (iii) demand management systems for households and buildings that can be managed by energy managers and energy service companies, and (iv) improved thermal efficiency in power generation by constructing or replacing facilities with new and more efficient generation technologies.

(ii) Renewable energy policies. Low-carbon fuels must be increased and can be achieved by raising the share of renewables and clean fuels, such as hydrogen and nuclear energy, in the energy mix of each country. Several policies and actions will need to be considered:

- Setting targets and sharing renewables such as wind, solar, and biomass energy in the energy mix. Supportive renewable energy policies such as feed-in-tariff, renewable portfolio standard, and net metering are suggested based on the situation and evolution of the cost perspective of the renewables and clean technologies. Other supportive frameworks are needed, such as international financing of the Clean Development Mechanism (CDM)[6] and Joint Credit Mechanism (JDM)[7] for renewables and energy efficiency.
- The intermittent nature of renewable energy sources poses significant challenges to integrating renewable energy generation with existing electricity grids. Electricity storage technologies, combined with solar and wind energy, and on-site hydrogen production for curtailed renewable electricity will be highly important, although the combination cost is still high and needs the right policy and framework to drive down the cost.

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[6] The CDM allows emission-reduction projects in developing countries to earn certified emission reduction credits, each equivalent to 1 tonne of CO_2.

[7] The JDM is a project-based bilateral offset crediting mechanism initiated by the Government of Japan to facilitate the diffusion of low-carbon technologies.

(iii) Power connectivity and smart grid.

- An ASEAN power pool, with proper institutions guided by regional electricity market rules and procedures, will need to be established and operated. Once up and running, it can avoid the cost of building new generation plants, more efficiently use the region's energy resources, help utilities companies balance their excess supply and demand, improve access to energy services, reduce costs of developing energy infrastructure, accelerate the development of renewable power generation capacity and integrate it into the regional grid, reduce the need for investment in power reserves to meet peak demand, and attract additional investment to the region's interconnection by signalling a price to catalyse investors. Geographical limitations, however, hinder the creation of an ASEAN power pool, making it a distant possibility. But the Mekong sub-region (Cambodia, Lao PDR, Myanmar, Thailand, and Viet Nam) could be the first potential physical power connectivity and power pool in ASEAN. Connecting the Mekong sub-region to Malaysia and Singapore is the most feasible option to explore.
- To facilitate the future power market, the electricity sector will require policy reforms, particularly deregulation of national rules and procedures to harmonise with the regional power pool's rules and procedures. Unbundling ownership in electricity market segments, non-discriminatory third-party access to transmission and distribution networks, and gradual removal of subsidies in fossil fuel–based power generation will ensure the pre-conditions for market competition and level the playing field for new technologies and renewables. To attract foreign investment to renewables and clean technologies, fiscal policy incentives such as tax holidays and reduced market barriers and regulatory burdens are essential. Other policies, such as a rebated payment system through government subsidies and guarantees, should be implemented to reduce upfront investment costs, making such investments feasible and low risk.
- The ASEAN region and East Asia can greatly benefit from investing in the smart grid system. The grid can protect, monitor, and ensure the most efficient use of energy by having an integrated technology system from the demand side and the generation side. The grid is a complex arrangement of infrastructure with functions that depend on many interconnected elements. The grid's first layer is the physical component, which covers generation, transmission, and the distribution network as well as energy storage facilities. The second layer is telecommunications, which monitor, protect, and control the grid, including wide, field, home, and local area networks. The third layer is data management, which ensures proper data mining and utilisation to facilitate grid applications. The fourth layer consists of tools and software technologies that use and process collected information from the grid to monitor, protect, and control the hard infrastructure layer, and reinforce the grid to allow integration of renewable energy.

(iv) Technological innovations. Environmental technologies will need to be considered to curb increasing CO_2 emissions:

- The development of CCUS technology will be highly important in controlling GHG emissions. With strong government leadership, continued research and development, including the CCUS value chain, will ensure the economic viability of deploying carbon capture and storage technology.
- Through electrolysis using renewable energy, hydrogen can be extracted from fossil fuels such as low-ranked coal and natural gas. However, it is still more expensive than existing fuels. Hydrogen fuel development is promising and can be commercialised. Continued research and development in fuel cells and hydrogen power generation will be important for future clean fuel use.
- The ASEAN region will need to accelerate technological cooperation and technology diffusion, including the hydrogen value chain.

(v) Energy supply security policies. Based on the Organisation for Economic Co-operation and Development's practice of strengthening energy security by increasing the oil stockpiling requirement (IEA, 2020), several measures are identified:

- Promote regional energy connectivity, such as the Trans-ASEAN Gas Pipeline, using a virtual pipeline (LNG) including ship and road transport.
- Diversify sources of import.
- Strengthen energy infrastructure, including construction of LNG-receiving terminals and regasification plants.
- Look into the strategic reserve or stockpiling requirement on public and private bases.

(vi) Appropriate transition financing technologies. ERIA's (2022) The Technology List and Perspectives for Transition Finance in Asia seeks to support smooth energy transitions in developing Asia with realistic approaches. The approaches can help many countries move to carbon neutrality whilst considering energy security, affordability, accessibility, and environmental protection.

- Financial institutions might find the list useful as a reference point to assess potential transition technologies submitted by project developers. The list will continue to serve financial institutions until stakeholders and regulators (such as ASEAN and governments of member states) are prepared and have established their technology road maps or taxonomies, which will guide energy investment to achieve net-zero emission.
- Although the first version of the study's list does not cover all transition technologies, it at least covers major potential transition technologies in the power sector and its upstream, which together account for more than 50% of Asia's CO_2 emissions.
- The list provides key information about each transition technology, including six key elements, such as cost and reliability of technology, and additional considerations, such as social benefits and potential emission reductions. ASEAN countries are recommended to use the list to support their energy infrastructure financing in the medium term and transition to carbon neutrality by 2050.

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