Chapter 17

Energy Infrastructure Development

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Overview of Energy Demand and Supply in East Asia

From the outset of this study, members of the working group on the Energy Outlook for ASEAN and East Asia, who are experts from the countries of the East Asia Summit (EAS)[1] plus the United States (US) (EAS17), aimed to predict the growth of medium- to long-term energy demand and supply in 2017–2050. At the time of writing, the world economy and energy demand have been hit hard by the coronavirus disease (COVID-19) pandemic, but energy demand is expected to bounce back strongly in 2021 as the economy recovers. The Economic Research Institute for ASEAN and East Asia (ERIA) will release the short-term energy outlook in a separate report.

In the medium to long term, population and economic growth in the EAS17 are the key drivers of projected increasing primary energy supply, from 7,625 million tons[2] of oil equivalent (Mtoe) in 2017 to 10,780 Mtoe under the business-as-usual (BAU) scenario and to 8,860 Mtoe under the alternative policy scenario (APS) by 2050, reflecting annual growth rates of 1.1% under BAU and 0.5% under the APS in 2017–2050. In the BAU scenario, the energy intensity in final energy consumption is expected to drop by 46% from 122 tons of oil equivalent (toe) per million US dollars in 2017 to 64 toe/$ million in 2050. In the primary energy consumption, the emission intensity is expected to drop from 0.70 tons of carbon (t-C)/toe in 2017 to 0.65 t-C/toe in 2050 for the BAU scenario. The economy will become more energy-efficient, but increasing energy demand will threaten the region's energy security. Potential energy saving is, therefore, key to reducing energy demand and carbon dioxide (CO_2) emissions.

In 2007, leaders from the Association of Southeast Asian Nations (ASEAN) Member States, Australia, China, India, Japan, the Republic of Korea (henceforth, Korea), and New Zealand adopted the Cebu Declaration on East Asian Energy Security (ASEAN, 2007). They agreed to promote energy efficiency, new forms of renewable energy, and the clean use of coal. The EAS Energy Ministers Meeting (EAS-EMM) formed the EAS Energy Cooperation Task Force in response to the declaration, and Japan proposed studying energy saving and the potential for reducing CO_2 emissions. The topic is an area of cooperation for which ERIA officially requested support through the EAS-EMM.

[1] The EAS is a regional forum held annually by leaders of, originally, 16 countries: the 10 Association of Southeast Asian Nations (ASEAN) Member States (Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam); Australia; China; India; Japan; the Republic of Korea; and New Zealand. EAS membership expanded to 18 countries, including Russia and the United States (US), at the Sixth EAS in 2011. EAS17 refers to the 10 ASEAN+7 countries: the original EAS plus the US. Since its establishment, ASEAN has led the forum. EAS meetings are held after the annual ASEAN leaders' meetings and play an important role in the regional architecture of Asia and the Pacific.

[2] tons of oil equivalent (toe) is a unit of energy, defined as the amount of energy released by burning one metric ton (1,000 kilograms) of crude oil. The toe is used to describe large amounts of oil or natural gas in transport or consumption, and a prefix of millions tends to be used to communicate this as Mtoe.

This study shows the energy saving potential of the BAU scenario and the APS. A BAU scenario was developed for each EAS country, outlining future sector and economy-wide energy consumption, assuming no significant changes to government policies. The APS was set to examine the potential impacts if additional energy-efficiency goals, action plans, or policies being considered or likely to be considered were developed. The difference between the BAU scenario and the APS in final and primary energy supply represents potential energy saving. The difference in the two scenarios' CO_2 emissions represents the potential to reduce them. The outlook's analysis covers the EAS17. Underlying the EAS energy cooperation initiative is the Energy Research Institutes Network, of which the US is a member. Therefore, the outlook's analysis includes the US.

The study's findings shed light on the policy implications for decision-making to ensure that the region can enjoy economic growth and investment without compromising energy security and producing harmful CO_2 emissions.

Economic Landscape of the EAS

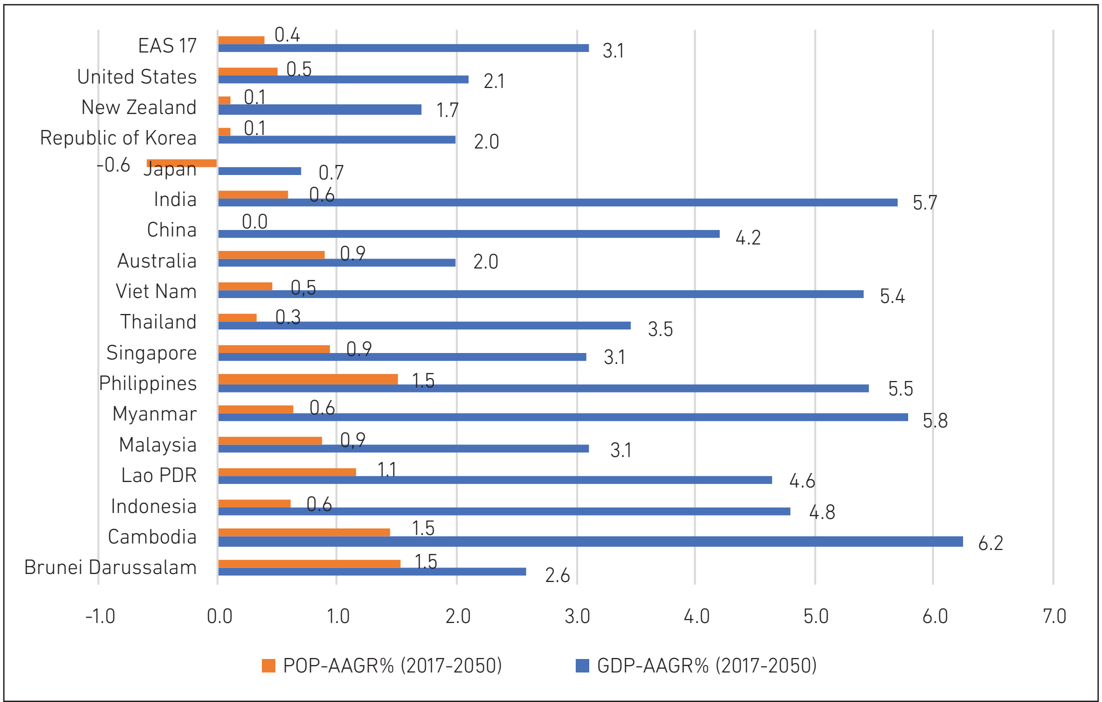
The EAS17 countries are diverse, with widely varying per capita incomes, standards of living, energy resources, climate, and energy consumption per capita. Some EAS17 countries are mature economies; most are developing. Several EAS17 countries had per capita gross domestic product (GDP) of less than $1,500 (in 2010 constant prices)[3] in 2017, whilst some mature economies had GDP per capita of more than $53,000. Mature economies have higher energy consumption per capita than developing ones. A large percentage of people in developing countries still meet their energy needs mainly with traditional biomass fuels.

These differences partly explain why energy efficiency and conservation (EEC) goals, action plans, and policies are assigned different priorities across countries. Developed economies might be keen to reduce energy consumption, whilst developing countries emphasise economic growth and improving standards of living. As developing economies grow, however, their energy consumption per capita is expected to grow as well.

In 2017, the total EAS17 population was about 3.89 billion. It is projected to increase at an average annual rate of about 0.4% to about 4.43 billion in 2050.

[3] All US dollars in this document are in constant 2010 values unless otherwise specified.

Figure 17.1 Average Annual Growth Rate of GDP and the Population in EAS17 Countries



ASEAN = Association of Southeast Asian Nations, EAS = East Asia Summit, GDP = gross domestic product, GDP-AAGR = annual average growth rate of the gross domestic product, POP-AAGR = annual average growth rate of the population.

Note: EAS17 refers to the 10 ASEAN+7 countries – the original EAS plus the United States.

Source: Authors.

Brunei Darussalam, Cambodia, the Lao People's Democratic Republic (Lao PDR), and the Philippines are generally assumed to have the fastest average annual population growth rate, at 1.1%–1.5%, in 2017–2050 (Figure 17.1). Indonesia, Malaysia, Singapore, Thailand, Viet Nam, Australia, India, and the US are expected to have a moderate average annual population growth rate, at 0.5%–0.9%. Korea and New Zealand are expected to have an extremely slow average population growth rate, at just 0.1%. Japan's population is assumed to decline slowly as it continues to age, resulting in an average annual population growth rate of –0.6%.

Long-term economic growth rates are assumed to be high in developing countries, with the highest in Cambodia, India, Myanmar, the Philippines, Viet Nam, and the Lao PDR (Figure 17.1). Economic growth in other developing countries is assumed to be rapid. Brunei Darussalam is expected to have a moderate average annual GDP annual growth rate of 2.6% in 2017–2050. The US, Japan, Korea, New Zealand, and Australia are expected to have a moderate annual GDP growth rate. Rapid growth in China, India, Indonesia, and the US is likely to be especially significant for energy demand in these large economies.

In 2017, total GDP in the EAS17 was about $42 trillion in 2010 US dollar constant prices and accounted for about 52% of global GDP. The region's GDP is assumed to grow at an average annual rate of about 3.1% in 2017–2050, implying that, by 2050, the region's total GDP will reach about $114.6 trillion in 2010 US dollar constant prices. China is projected to be the largest economy, with real GDP of about $39.7 trillion in 2010 US dollar constant prices, followed by the US with about $33.9 trillion by 2050. India and Japan are projected to be the next largest economies, with projected GDPs of about $16.3 trillion and $7.7 trillion, respectively, in 2010 US dollar constant prices by 2050 (Table 17.1).

Table 17.1 GDP and Population in EAS17 Countries, 2017–2050

Country	**GDP** (billion, 2010 US dollar constant prices)		Population (million)		Per capita GDP	Per capita GDP
	2017	2050	2017	2050	2017	2050
Brunei Darussalam	13.5	29.0	0.4	0.7	33,750.0	41,428.6
Cambodia	20.0	144.0	16.2	26.2	1,234.6	5,496.2
Indonesia	1,090.5	5,131.2	264.6	324.3	4,121.3	15,822.4
Lao PDR	12.6	80.6	7.1	11.4	1,774.6	7,070.2
Malaysia	364.6	992.5	31.1	41.4	11,723.5	23,973.4
Myanmar	79.5	510.9	53.4	65.8	1,488.8	7,764.4
Philippines	303.3	1,463.9	105.1	164.4	2,885.8	8,904.5
Singapore	318.4	871.1	5.6	7.7	56,857.1	113,129.9
Thailand	424.2	1,304.6	69.2	76.8	6,130.1	16,987.0
Viet Nam	175.3	995.7	93.7	108.9	1,870.9	9,143.3
Australia	1,432.7	2,776.2	24.6	32.8	58,239.8	84,640.2
China	10,161.1	39,687.5	1,386.4	1,403.2	7,329.1	28,283.6
India	2,650.8	16,319.9	1,339.1	1,639.8	1,979.5	9,952.4
Japan	6,157.7	7,786.5	126.8	105.2	48,562.3	74,016.2
Republic of Korea	1,345.9	2,299.9	51.5	50.1	26,134.0	45,906.2
New Zealand	181.1	314.6	4.8	6.1	37,729.2	51,573.8
United States	17,348.6	33,922.1	325.1	384.1	53,363.9	88,315.8
EAS17	42,079.8	114,630.2	3,904.7	4,448.9	10,776.7	25,766.0

ASEAN = Association of Southeast Asian Nations, EAS = East Asia Summit, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, US = United States.

Note: EAS17 refers to the 10 ASEAN+7 countries – the original EAS plus the United States.

Source: Authors.

Average real GDP (2010 US dollar constant prices) per capita in the EAS17 is assumed to increase from $10,776.70 in 2017 to $25,765.00 in 2050. However, there are, and will continue to be, significant differences in GDP per capita amongst EAS17 countries. In 2017, per capita GDP (2010 US dollar constant prices) ranged from $1,234.60 in Cambodia to more than $48,000.00 in Japan, the US, Singapore, and Australia. In 2050, per capita GDP is assumed to range from $5,496.20 in Cambodia to more than $113,000.00 in Singapore.

Rationale and Key Scenarios

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

The study supports the Cebu Declaration, the goals of which include the following:

i. Improve the efficiency and environmental performance of fossil fuel use.
ii. Reduce dependence on conventional fuels through intensified EEC programmes; increased share of hydropower; and expansion of renewable energy systems, biofuel production and/or utilisation, and, for interested parties, civilian nuclear power.
iii. Mitigate GHG emissions through effective policies and measures to help 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 coordinates the energy-efficiency work stream under the Energy Cooperation Task Force. ERIA convened the working group to analyse energy saving potential. All EAS17 countries are represented in the working group.

Like the annual studies since 2007, the present study examines two scenarios: BAU, reflecting each country's current goals, action plans, and policies; and the APS, including additional goals, action plans, and policies reported every year to the EAS-EMM. The latest updated policies were reported at the 13th EAS-EMM on 5 September 2019 in Bangkok. One might be tempted to call the APS a 'maximum effort', but that would not be accurate. One reason is that goals, action plans, and policies for reducing energy consumption are still new in most countries. Many potential EEC policies and technological options have not been examined or incorporated in the APS.

In 2014, the APS assumptions were 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). The APS is the total of APS1 to APS4.

The energy models can estimate the individual impacts of the assumptions on primary energy supply and CO2 emissions. The combination of the assumptions constitutes the APS assumptions. The main report highlights only the BAU scenario and APS. However, each country report will analyse all APS.

Detailed assumptions for each APS are as follows:

i. APS1 assumes the setting of reduction targets for sector final energy consumption, and the use of efficient technologies and implementation of energy saving practices in the industry, transportation, residential and commercial, and even agriculture sectors in some countries. This scenario results in less primary energy and CO_2 emissions in proportion to the reduction in final energy consumption.
ii. APS2 assumes the utilisation of more efficient thermal power plant technologies, resulting in lower primary energy supply and CO_2 emissions in proportion to thermal power efficiency improvement. 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 to electricity generation and utilisation of liquid biofuels in transportation. The scenario results in lower CO_2 emissions as NRE is carbon-neutral or will not emit additional CO_2. However, the primary energy supply might not decrease because NRE, like biomass and geothermal energy, is assumed to be less efficient than fossil fuel-fired generation in converting electricity into primary energy equivalent.
iv. APS4 assumes the introduction of nuclear energy or a higher contribution of nuclear energy in countries already using it. The scenario produces less CO_2 emissions as nuclear energy emits minimal CO_2. However, as thermal efficiency in converting nuclear energy output into primary energy is assumed to be only 33%, the primary energy supply is not expected to be lower than under BAU.

All EAS17 countries are developing and implementing EEC goals, action plans, and policies, but progress has varied widely. Some countries are advanced in their efforts, while others are just getting started. A few countries have significant energy saving goals, action plans, and policies built into BAU, while others have only started to quantify their goals. However, significant potential exists in these countries at the sector and economy levels.

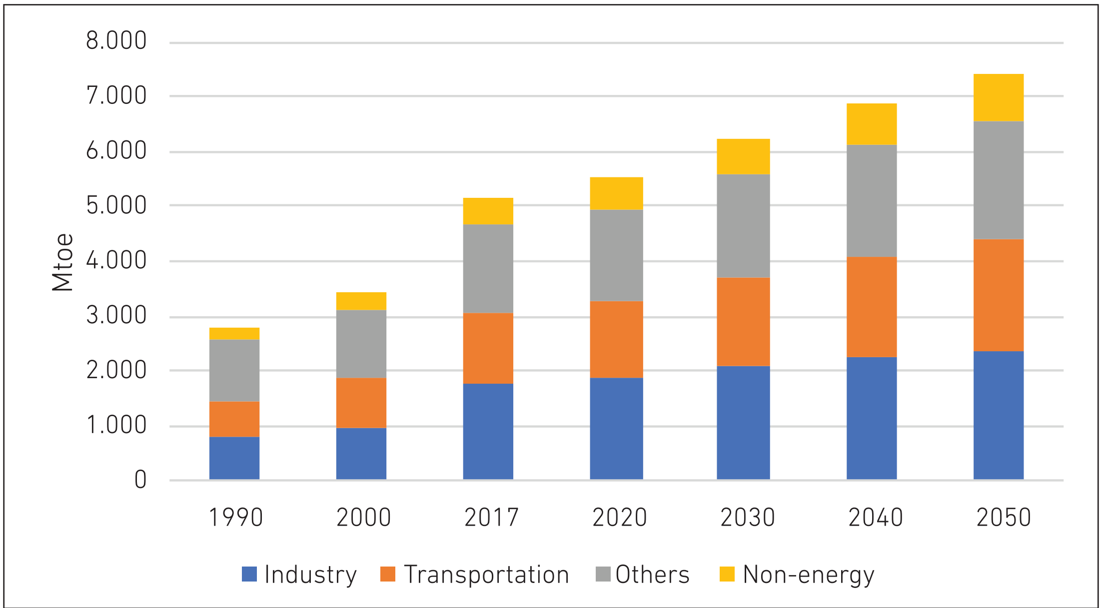
Every country still has a great deal to learn about what works and what does not. It is worthwhile updating this study periodically, as the quality and scope of national goals, action plans, and policies are likely to improve considerably, allowing for collaboration across countries.

Energy Demand/Supply and Power Generation (BAU)

Energy Demand: Final Energy Consumption

In 2017–2050, the total final energy consumption[4] in the EAS17 is projected to grow at an average annual rate of 1.1%, reflecting the assumed 3.1% annual GDP and 0.4% population growth. Final energy consumption is projected to increase from 5,159 Mtoe in 2017 to 7,416 Mtoe in 2050. Transportation energy demand is projected to grow moderately by about 1.4% per year, and its energy consumption share is projected to be 27.7% by 2050. Industry's annual growth rate in 2017–2050 is projected at about 0.9% per year, but its energy consumption share is projected to be the largest, at about 31.7%, by 2050. Commercial and residential demand will grow by 1.0% per year, higher than that of industry. However, the commercial and residential energy consumption share is projected to be 29.3%, the second largest after industry. Figure 17.2 shows the final energy consumption by sector under BAU in the EAS17 from 1990 to 2050, and Figure 17.3 shows details of the sector final energy consumption and its shares.

Figure 17.2 Final Energy Consumption by Sector, BAU, 1990–2050

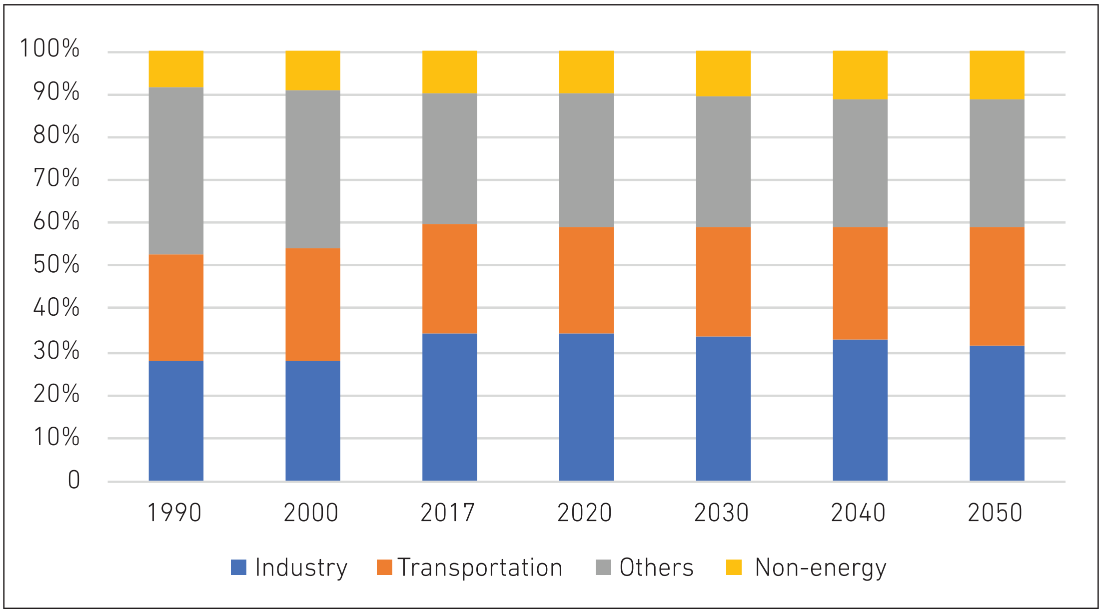


BAU = business as usual, Mtoe = million tons of oil equivalent.

Source: Authors.

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

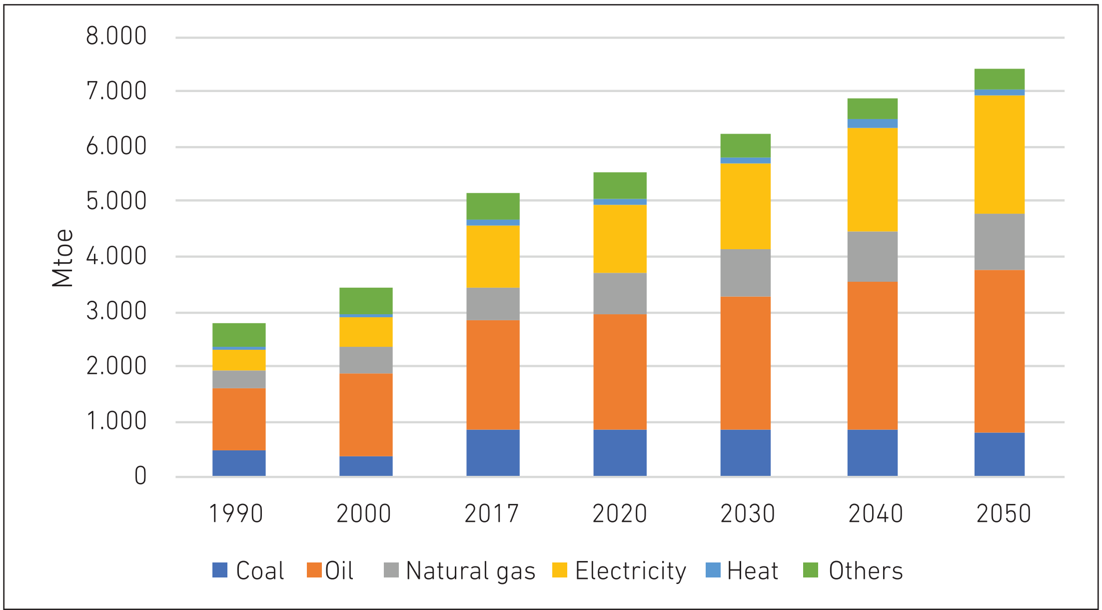
Figure 17.3 Final Energy Consumption Share by Sector, 1990–2050



Source: Authors.

Figures 17.4 and 17.5 show the final energy consumption and shares by fuel type in the EAS17 under BAU from 1990 to 2050. By energy source, electricity and natural gas demand under BAU are projected to show the fastest growth, increasing by 1.9% and 1.5% per year, respectively, from 2017 to 2050, but their shares are just 28.4% for electricity and 14.0% for natural gas. Although oil will retain the largest share, at 39.9% of total final energy consumption, it is projected to grow by only 1.2% per year in 2017–2050, reaching 2,960 Mtoe in 2050. Generally, the oil share increases slightly from 38.3% in 2017 to 39.9% in 2050. Coal demand will grow at –0.2% per year on average from 2017 to 2050, reaching 800.5 Mtoe in 2050. The share of other fuels such as biomass will decline from 9.2% in 2017 to 5.2% 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.

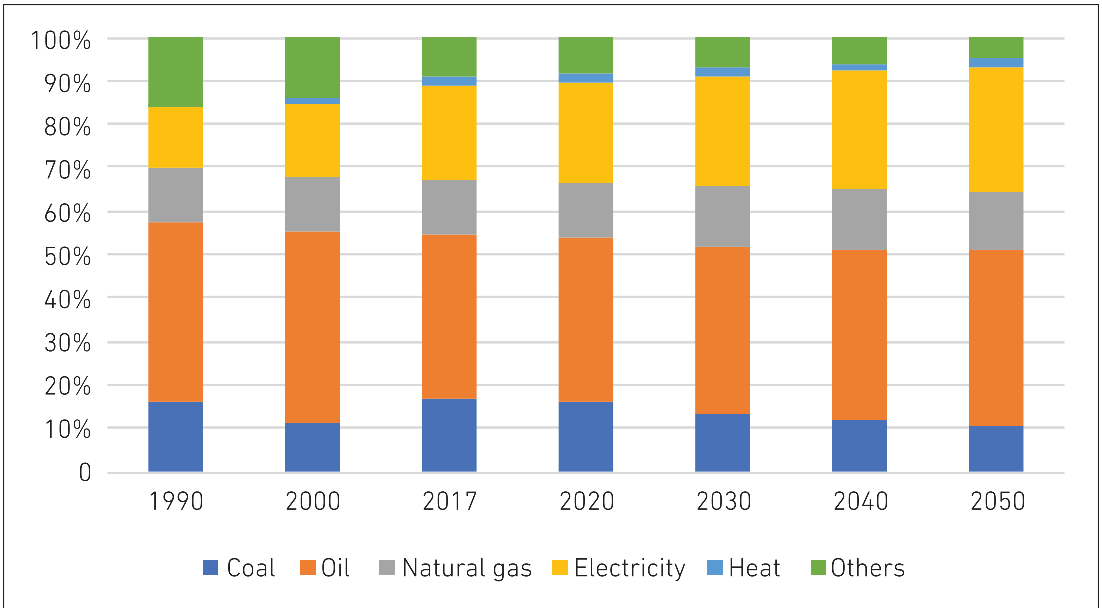
Figure 17.4 **Final Energy Consumption by Fuel, 1990–2050**



Mtoe = million tons of oil equivalent.

Source: Authors.

Figure 17.5 **Final Energy Consumption Share by Fuel, 1990–2050**

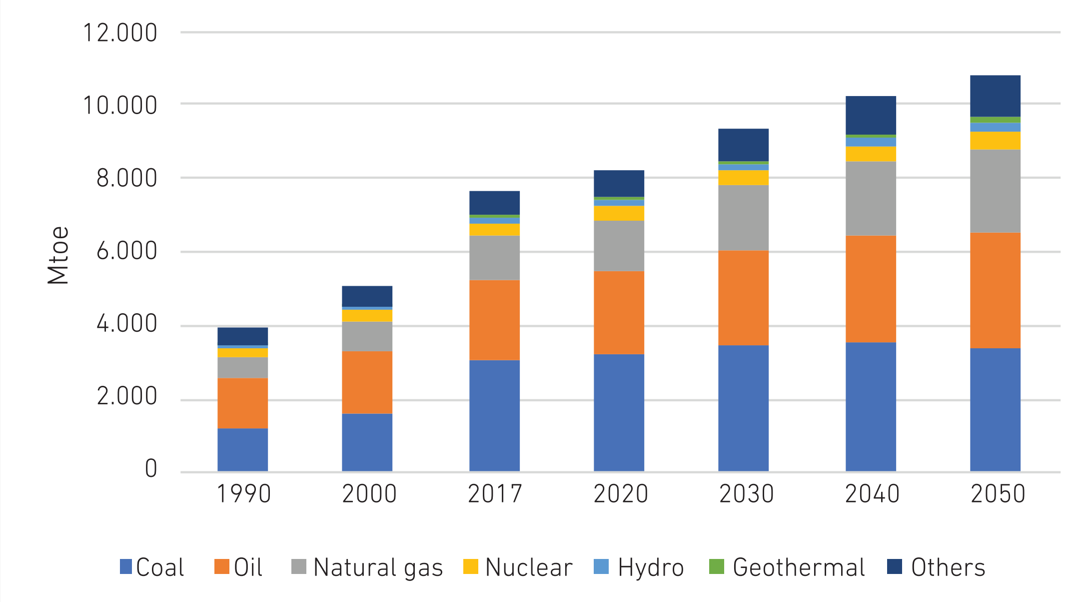


Source: Authors.

Energy Supply: Primary Energy Supply

Figure 17.6 shows the primary energy supply in the EAS17 from 1990 to 2050.[5] It is projected to grow slowly, at 1.1% per year, in 2017–2050 – the same growth rate of final energy consumption. EAS17 primary energy supply is projected to increase from 7,625 Mtoe in 2015 to 10,780 Mtoe in 2050. Coal will still comprise the largest share of primary energy supply, but its growth is expected to be slower, increasing by 0.3% per year in 2017–2050. Consequently, the share of coal in total primary energy supply (TPES) is forecast to decline from 40.2% in 2017 to 31.7% in 2050.

Figure 17.6 Primary Energy Supply in EAS17, 1990–2050



ASEAN = Association of Southeast Asian Nations, EAS = East Asia Summit, Mtoe = million tons of oil equivalent.

Note: EAS17 refers to the 10 ASEAN+7 countries – the original EAS plus the United States.

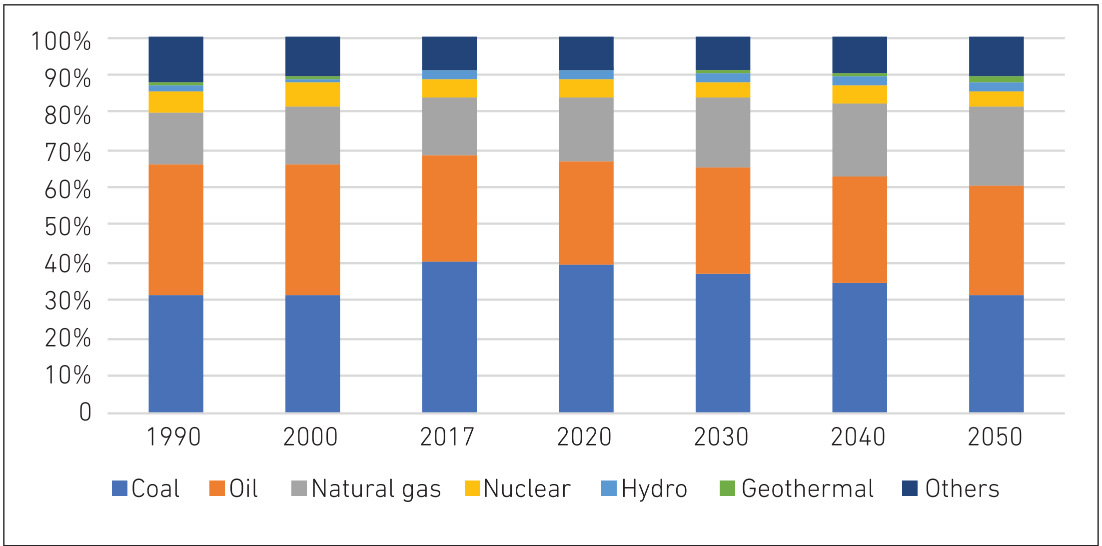
Source: Authors.

[5] Refers to energy in its raw form, before any transformation.

Amongst fossil sources of energy, natural gas is projected to see moderate growth in 2017–2050, increasing at an annual average rate of 1.9%. Its share in the total will consequently increase from 15.7% (equivalent to 1,199 Mtoe) in 2017 to 20.6% (2,217 Mtoe) in 2050. Nuclear and hydropower energy are projected to increase slowly, at 1.1% per year on average, in 2017–2050; the share of nuclear energy will stay at 4.5% and that of hydropower at 2.2%. It is assumed that nuclear power generation in Japan and the expansion of nuclear power generation capacity in China and India will resume. Geothermal energy is projected to grow at 3.3% per year in 2017–2050, but its share is projected to be small: about 1.3% by 2050, increasing from 0.6% in 2017.

Amongst the energy sources, 'others' – which are made up of solar, wind, and solid and liquid biofuels – will see a growth rate of 1.8% in 2017–2050, with their share increasing from 8.6% in 2017 to 10.8% in 2050. Most remarkably, wind and solar energy will see the largest average annual growth rate: 5.2% in 2017–2050, with their share in the primary energy supply increasing from 1.4% in 2017 to 5.4% in 2050. Figure 17.7 shows the share of each energy source in the total primary energy mix in 1990–2050.

Figure 17.7 Share of Primary Energy Mix by Source in EAS Countries, 1990–2050



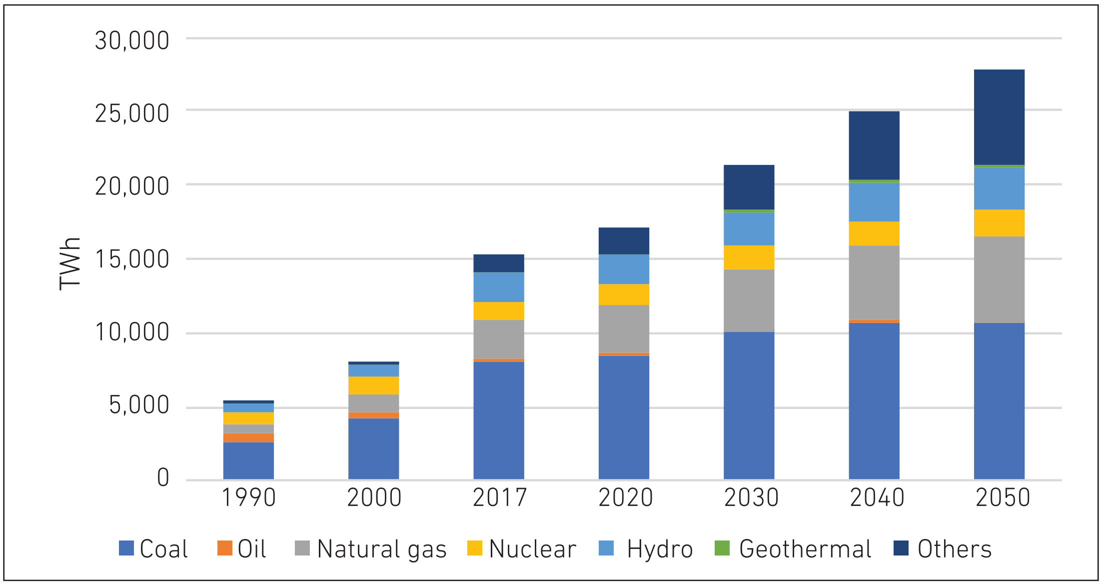
EAS = East Asia Summit.

Source: Authors.

Power Generation

Figure 17.8 shows the power generation output in the EAS17. Total power generation is projected to grow at 1.8% per year on average from 2017 (equivalent to 15,365 terawatt-hours [TWh]) to 2050 (27,812 TWh). However, the growth rate in 1990–2017 was 3.9%, more than twice that projected in 2017–2050.

Figure 17.8 Energy Mix of Power Generation in EAS17, 1990–2050



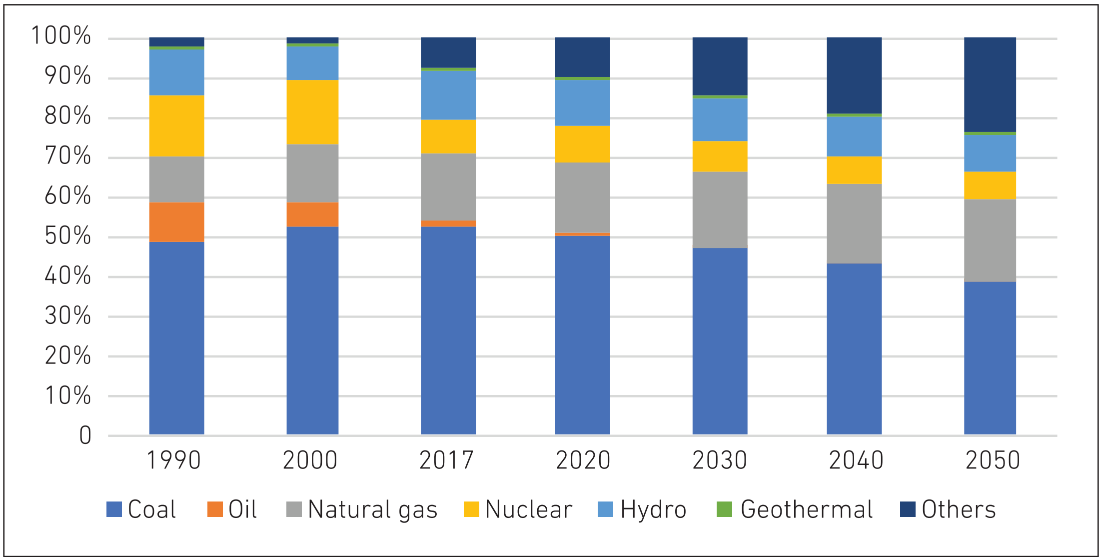
ASEAN = Association of Southeast Asian Nations, EAS = East Asia Summit, TWh = terawatt-hour.

Note: EAS17 refers to the 10 ASEAN+7 countries – the original EAS plus the United States.

Source: Authors.

Figure 17.9 shows the share of each energy source in electricity generation from 1990 to 2050. The share of coal-fired generation is projected to continue to be the largest, at 38.4% in 2050, a large drop from 52.7% in 2017. The share of natural gas is projected to increase from 16.8% in 2017 to 20.8% in 2050. The share of nuclear power (8.5% in 2017) is forecast to decrease to 6.7% in 2050. The share of geothermal energy was 0.3% in 2017 and is projected to increase to 0.6% in 2050. Other sources (wind, solar, biomass, etc.) will record the highest average annual growth rate, at 5.2%, in 2017–2050. The share of combined wind, solar, and biomass energy in the power mix is expected to be 23.6% in 2050, a large increase from 8.0% in 2017. The share of oil will drop from 1.2% in 2017 to 0.1% in 2050. Oil is expected to grow at an average annual rate of –4.4% in 2017–2050 due to its higher fuel cost. The share of hydropower is projected to decrease, from 12.4% in 2017 to 9.7% in 2050. The average annual growth rate of hydropower is expected to be slow, at 1.1%, in 2017–2050.

Figure 17.9 Share of Power Generation Mix in EAS17, 1990–2050



ASEAN = Association of Southeast Asian Nations, EAS = East Asia Summit.

Note: EAS17 refers to the 10 ASEAN+7 countries – the original EAS plus the United States.

Source: Authors.

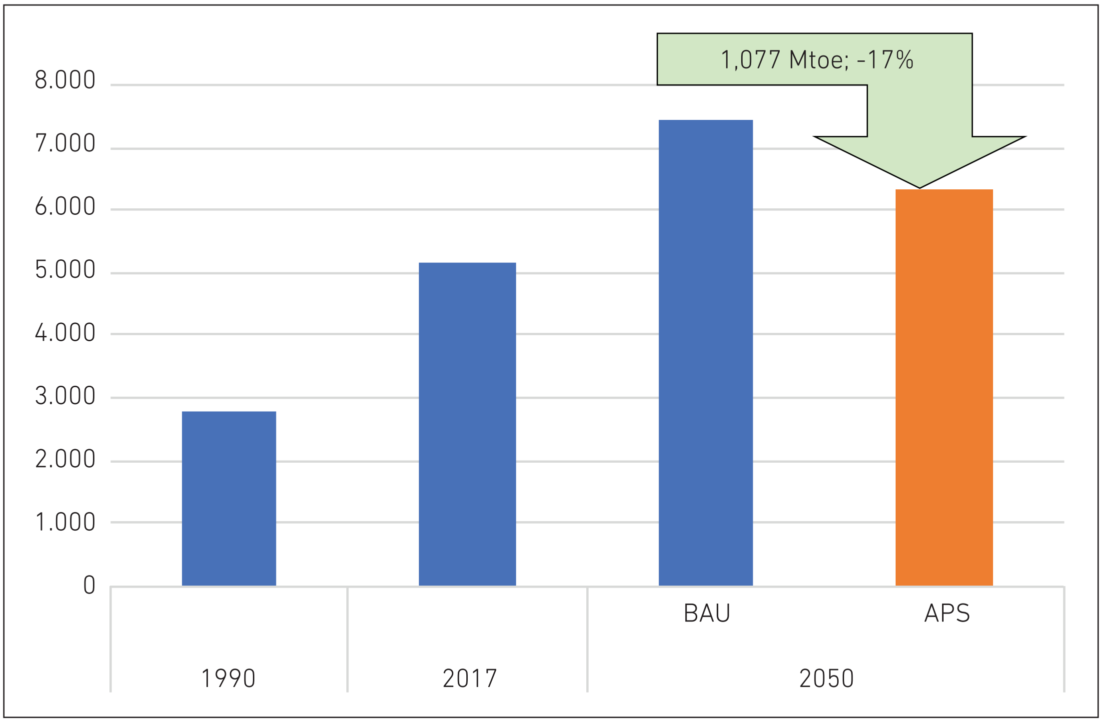
Comparison of Energy Demand and Supply (BAU vs APS)

Energy demand (BAU vs APS)

Under the APS, final energy consumption is projected to rise from 5,160 Mtoe in 2017 to 6,338 Mtoe in 2050. In 2050, the difference between the BAU scenario and the APS is 1,077 Mtoe, with the APS 17% lower than BAU because of energy-efficiency plans and programmes for the supply and demand sides to be implemented by EAS17 countries. Figure 17.10 shows final energy consumption in 1990–2050 under BAU and the APS.

Potential energy saving in total final energy consumption in the EAS17 (1,077 Mtoe) in 2050 is more than double ASEAN's total final energy consumption in 2017 (480 Mtoe). Energy saving in the EAS17 is expected largely from the transportation, industry and commercial, and residential sectors.

Figure 17.10 **Total Final Energy Consumption, BAU and APS**

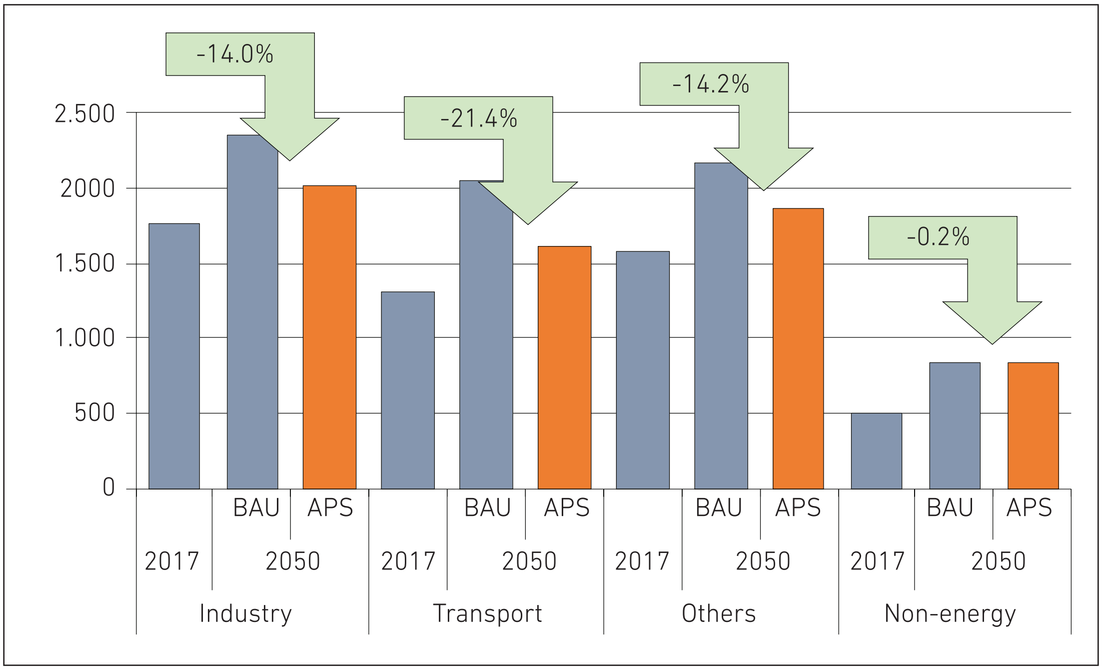


APS = alternative policy scenario, BAU = business as usual, Mtoe = million tons of oil equivalent.

Source: Authors.

Figure 17.11 shows the composition of final energy consumption by sector under BAU and the APS. Final energy consumption in most sectors is significantly more reduced under the APS than under BAU. The reduction is largest in transportation (21.4%), followed by 'others' (14.2%) and industry (14.0%). Non-energy demand will drop slightly by 0.2% from BAU.

Figure 17.11 **Final Energy Consumption by Sector, BAU and APS**



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

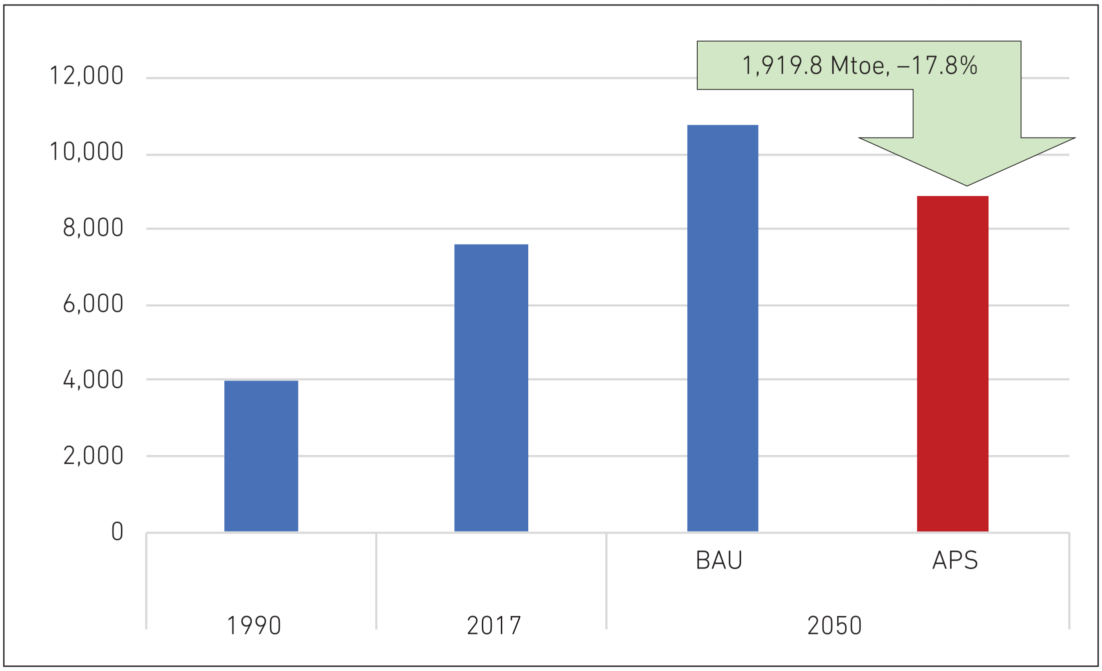
Source: Authors.

Energy Supply (BAU vs APS)

Figure 17.12 shows TPES of 10,779.6 Mtoe under BAU and 8,859.7 Mtoe under the APS in 2050. The total saving potential is the difference between BAU and the APS in 2050. The total saving potential in TPES is expected to be 1,919.8 Mtoe, representing a 17.8% reduction from BAU to the APS.

The energy saving potential results from improvements in the transformation sector, particularly power generation, and final energy consumption sectors such as transportation, industry, and the residential and commercial sector, where efficiencies are expected.

Figure 17.12 Total Primary Energy Supply, BAU and APS

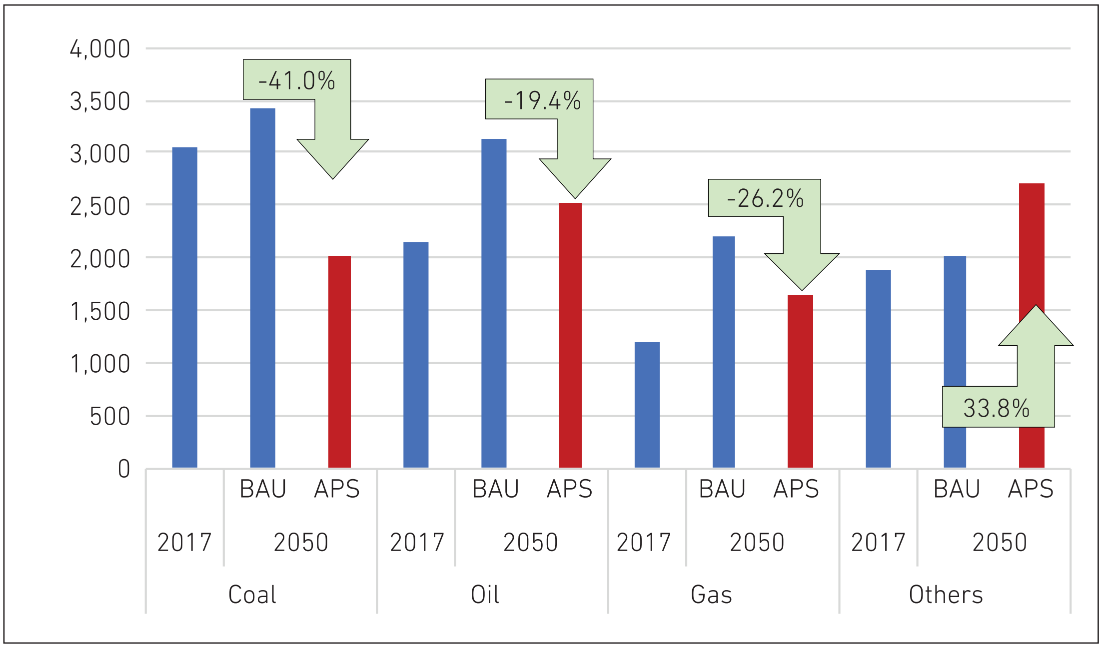


APS = alternative policy scenario, BAU = business as usual, Mtoe = million tons of oil equivalent.

Source: Authors.

Figure 17.13 shows primary energy supply by fuel source. Under the APS, growth in the primary energy supply for fossil fuels is lower than under BAU. The growth rate in the primary energy supply under the APS is projected at 0.5% per year on average in 2017–2050, which is lower than under BAU, projected at 1.1%. In absolute terms, the largest reduction will be in coal demand, by 1,401 Mtoe or 41% from 3,414.7 Mtoe under BAU to 2,013.7 Mtoe under the APS. Potential savings for other fuels are projected at 608.9 Mtoe for oil (equivalent to a 19.4% reduction under BAU) and 580.6 Mtoe for gas (26.2% reduction under BAU). Due to increased renewable energy in the primary supply, renewable energy supply, including solar wind and biomass, is projected to increase by 33.8% from BAU to an APS of aggressively including more renewables in the supply mix.

Figure 17.13 **Primary Energy Supply by Source, BAU and APS**



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

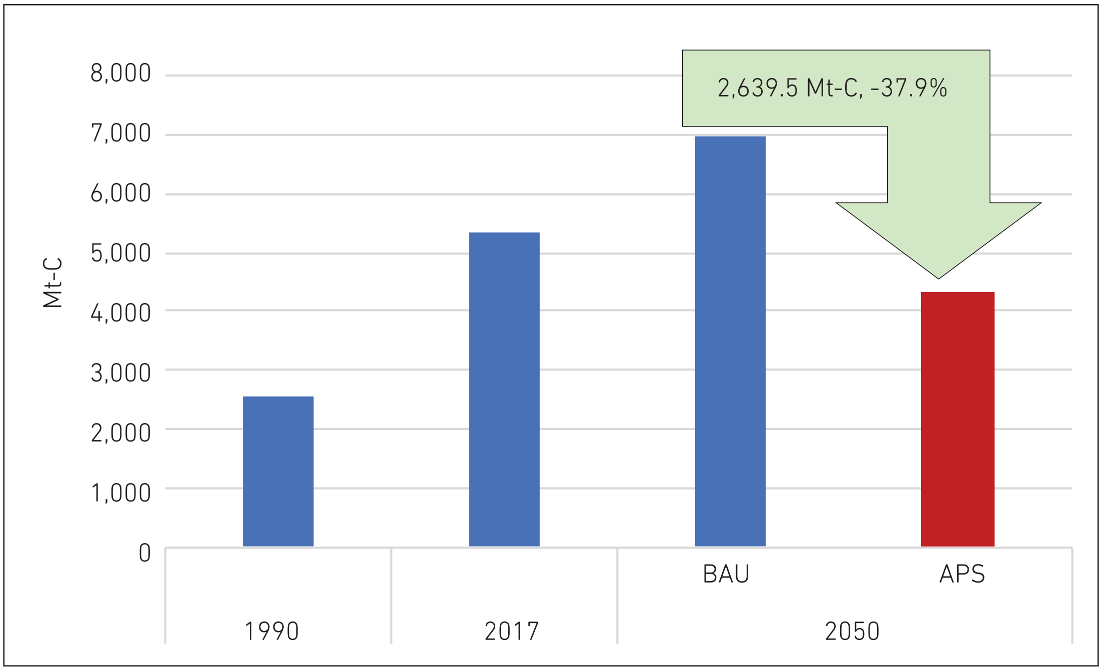
Source: Authors.

CO_2 Emissions from Energy Consumption (BAU vs APS)

Figure 17.14 shows CO_2 emissions under BAU and the APS. CO_2 emissions from energy consumption under BAU are projected to increase from 5,352.4 million tons of carbon (Mt-C) in 2017 to 6,957.3 Mt-C in 2050, implying an average annual growth rate of 0.8% in 2017–2050. The growth rate of emissions is lower than that of the TPES of 1.1% per year. This is because the share of renewables is increasing in the energy mix. Under the APS, CO_2 emissions are projected at 4,317.8 Mt-C in 2050, 37.9% lower than under BAU. At the 21st Conference of the Parties (COP21) in Paris in December 2015, 195 countries adopted the first universal binding global climate deal. The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2 degrees Celsius (°C) compared with pre-industrial levels. The Paris Agreement could bridge today's policies and climate neutrality before the end of the century.

The CO_2 emission reductions under the APS in 2050 are significant, but the emission level is still higher than in 2017. CO_2 emissions due to energy demand under the APS in 2050 will still be higher than 1990 levels. Scientific evidence suggests that these reductions will not be adequate to prevent severe climate change impacts. Analysis by the Intergovernmental Panel on Climate Change suggests that to keep the increase in global mean temperature to not more than 2°C compared with pre-industrial levels, global CO_2 emissions would need to fall by 45% from 2010 levels by 2030. Under the Paris Agreement, the parties will 'pursue efforts' to limit the temperature increase to 1.5°C, which will require zero emissions in 2030–2050 (IPCC, 2014). However, the EAS, especially the ASEAN Member States (AMS), will need to balance abating climate change with energy access and affordability. Thus, the clean use of fossil fuels through innovative technologies such as clean coal technology and carbon capture, utilisation, and storage (CCUS) will a play central role in developing carbon sinks around the globe.

Figure 17.14 Total CO_2 Emissions, BAU and APS



APS = alternative policy scenario, BAU = business as usual, CO_2 = carbon dioxide, Mt-C = million tons of carbon equivalent.

Source: Authors.

The transport sector plays an important role in the transition to a low-carbon economy. Under the BAU scenario in ASEAN during 2017–2050, the fastest average annual growth of final energy demand can be expected to happen in the transport sector (4.1%), followed by the industry sector (3.4%). By 2050, the share of transport sector energy use is projected to reach around 36% whilst that of industry and other sectors is projected to reach 33% and 22%, respectively (Purwanto, 2021). The objective of the ASEAN transport sector road map is to reduce the average fuel consumption per 100 kilometres of new light-duty vehicles sold in ASEAN by 26% between 2015 and 2025. More long-term objectives in ASEAN would be developing common indicators and methodologies and baseline data for a low-carbon fuel economy; building regional cooperation; aligning fuel economy labelling; enhancing CO_2 emission reductions based on fiscal policies; and adopting national fuel consumption standards in all markets, striving towards a regional standard in the long term. These strategic objectives in the road transport sector are embedded in the ASEAN (2019) and Global Fuel Economy Initiative (2021) blueprints.

Clean and Renewable Energy Technologies

Evolving Context of Clean and Low-Carbon Technologies

Under the Paris Agreement, each of the ASEAN and East Asian countries has made a voluntary pledge – nationally determined contributions (NDCs) – to reduce its GHG emissions. Implementation of the NDCs is not only a global commitment but also an opportunity for these countries to take decisive, inclusive, and coordinated actions for reshaping the economy and energy systems. The energy sector, accounting for some two-thirds of world GHG emissions, is the central pillar of NDC commitments. NDCs, bolstered by the Sustainable Development Goals (SDGs) and the ASEAN Economic Community, will impact the deployment of clean energy systems to a scale. Together, NDCs and SDGs provide a global, regional, and local agenda which is coherent and integrated for clean technology pathways. To seize this opportunity, their proposed plans must be translated into national policies and actions.

Table 17.2 shows the common but differentiated responsibilities of the NDCs submitted by the EAS16 countries. Their targets for emission reductions differ greatly in terms of their ambition and the way they are expressed as sectoral actions. The NDCs of Cambodia, Indonesia, the Philippines, and Viet Nam, as well as China, contain absolute targets – either for total emissions or for the year in which the emissions will peak. Other goals are expressed as a decrease in emissions against BAU baselines. The intended nationally determined contribution (INDC) commitments also take the form of a target for emissions intensity, or emissions per unit of GDP.

Table 17.2 Composition of NDC and Energy Sector Targets in EAS16 Countries

Country (Entry into force)	NDC target	Current renewable energy target	Scope of NDC target
Australia (9 Dec 2016)	Reduce emissions 26%–28% by 2030 (Reference: 2005)	- 33,000 GWh by 2020 - 23.5% of electricity generation in 2020	Targets include energy, industrial processes and product use, waste, agriculture, and LULUCF sector
Brunei Darussalam (4 Nov 2016)	Reduce energy consumption 63% by 2030 (Reference: BAU)	- 10% of power generation by 2035 - Total power generation mix: 954,000 MWh by 2035	- Reduce CO_2 emissions from morning peak hour vehicle use by 40% by 2035 - Increase the total forest reserves to 55% of total land area
Cambodia (8 March 2017)	Reduce emissions, conditional 27% by 2030 (Reference: BAU) Reduction of 3,100 $GtCO_2$ from baseline of 11,600 $GtCO_2$ by 2030	Hydro 32,500 MW by 2020	Emissions reduction by 2030: - Energy industries 16% - Manufacturing industries 7% - Transport 3% - Other 1% - Total savings 27%
China (4 Nov 2016)	Reduce emission intensity by 60%–65% by 2030 (Reference: 2005)	Increase the share of non-fossil fuels in primary energy consumption to around 20%	Increase forest stock volume by around 4.5 billion cubic meters on the 2005 level
India (4 Nov 2016)	Reduce emission intensity by 33%–35% by 2030, conditional (Reference: 2005)	40% electric power installed capacity from non-fossil fuel by 2030	An additional carbon sink of 2.5 billion–3.0 billion tCO_2e through additional forest and tree cover by 2030
Indonesia (30 Nov 2016)	Reduce emissions by 29% and 41% conditionally by 2030 (Reference: BAU)	23% energy from new and renewable energy (including nuclear) by 2025, at least 31% by 2050	12.7 million hectares of forest area have been designated for forest conservation
Japan (8 Dec 2016)	Reduction by 26% by 2030 (Reference: 2013)	Renewables of power supply account for 22%–24% by 2030	Removal target by LULUCF is 37 million tCO_2e
Lao PDR (4 Nov 2016)	Increase share of small-scale renewable energy to 30% of energy consumption by 2030, estimated to reduce emissions by 1,468,000 $ktCO_2$ by 2025	Increase the share of renewable energy to 30%	Increase forest cover to 70% of land area by 2020

Country (Entry into force)	NDC target	Current renewable energy target	Scope of NDC target
Malaysia (16 Dec 2016)	Reduce emissions intensity by 35% and conditional 45% by 2030 (Reference: 2005	Cumulative total renewable energy (MW): - 2020: 2,065 (9%) - 2030: 3,484 (10%) - 2050: 11,544 (13%)	Targets include energy, industrial processes, waste, agriculture, and LULUCF sector
Myanmar (yet to be ratified)	By 2030, boost hydropower capacity by 9.4 GW to achieve rural electrification, using at least 30% renewable energy sources; expand forest area to 30% by 2030	Increase the share of hydroelectric generation to 9.4 GW by 2030	- Reserved forest and protected public forest: 30% of total national land area - Protected area systems: 10% of total national land area
New Zealand (4 Nov 2016)	Reduce emissions by 30% by 2030 (Reference: 2005)	Increase renewable generation to 90% by 2025	Continue to achieve a rate of energy intensity improvement of 1.3% per annum
Philippines (yet to be ratified)	Conditional reductions up to 70% by 2030 (Reference: BAU)	Capacity installation targets by 2012–2030: 8,902 MW	Targets cover all sectors, including LULUCF
Republic of Korea (3 Dec 2016)	Reduce emissions 37% by 2030 (Reference: BAU)	22%–29% of electricity generation from nuclear by 2035	Reduce energy intensity by 46% between 2007 and 2030
Singapore (4 Dec 2016)	Reduce emission intensity by 36% by 2030 (Reference: 2005)	Raise solar power in the energy system up to 350 MW by 2020	Energy intensity improvement (from 2005 levels) target of 35% by 2030
Thailand (4 Nov 2016)	Reduce emissions by 20% and conditional 25% by 2030 (Reference: BAU)	Targeted renewable generation: 13,927 MW by 2021	Reduce energy intensity by 25% in 2030
Viet Nam (3 Dec 2016)	Reduce emissions by 8% and conditional 30% by 2030 (Reference: BAU)	Targeted capacity by 2030 - Wind power: 6,200 MW - Biomass power: 2,000 MW - Other renewables: 5,600 MW	Forest cover will increase to the level of 45%

BAU = business as usual; CO_2 = carbon dioxide; EAS = East Asia Summit; $GtCO_2$ = gigaton of carbon dioxide; GW = gigawatt; GWh = gigawatt-hour; $ktCO_2$ = kiloton of carbon dioxide; LULUCF = land use, land-use change, and forestry; MW = megawatt; MWh = megawatt-hour; NDC = nationally determined contribution; tCO_2e = ton of carbon dioxide equivalent.

Source: UNFCCC (n.d.), INDCs as Communicated by Parties.

https://www4.unfccc.int/sites/submissions/INDC/Submission%20Pages/submissions.aspx (accessed 17 January 2022).

Most of the NDCs come with a conditional or contingent component, meaning a further reduction in emissions will come with international technology and financial support. This clause of the Paris Agreement is important because international support measures, including capacity building, will help emerging EAS countries to implement their NDCs in a more ambitious way. For example, Indonesia intends to reduce GHG emissions unconditionally by 29%, while pledging to reduce up to 41% with bilateral and multilateral provision of technology, finance, and capacity building support. Thailand emphasises its intention to reduce carbon emissions by 20% by 2020. Singapore commits to reducing carbon emissions unconditionally by 36%. The Philippines' INDCs plan to reduce carbon emissions by 70% by 2030. This commitment is conditional on international support and will rely heavily on the renewable energy, waste, transport, and forestry sectors.

The pledges by EAS countries under the Paris Agreement and the commitment to implementing INDCs are important for global emission reductions by 2030. Historically, this region's GHG emissions have been relatively low, but following a period of rapid economic development and increased energy use, the region has become a substantial source of global emissions. A transition to a global low-carbon economy requires Asia's positive engagement in implementing clean technology and renewable energy technology options.

Assessing the Role of Low-Carbon Energy System Technologies

Low-carbon energy systems are processes or technologies that produce power with substantially lower amounts of CO_2 emissions than emissions from conventional fossil fuel power generation. They include renewable energy systems such as solar and wind power, biomass, hydropower, and clean coal, coupled with carbon capture and storage systems and energy efficiency improvements across the sectors. The term 'clean energy systems' largely excludes other subsets of fossil fuel power sources like nuclear, oil, and gas. Since 2016, tremendous strides have been made to advance low-carbon energy systems – innovating, scaling up investment, reducing system costs, implementing appropriate policy frameworks, and interconnecting large amounts of variable renewable energy supply into the grid. Reflecting this, many countries have put forward ambitious plans to increase renewable energy in their NDCs (Anbumozhi and Kalirajan, 2017).

In addition, a number of promising initiatives that are being implemented have the potential to buttress the NDC implementation. Some 40 implementing agreements are being carried out in the areas of renewable energy (solar, wind, bioenergy, and geothermal); fossil fuels (clean coal, enhanced oil recovery, and carbon capture and storage); fusion power (tokomaks, materials, technologies, and safety); and energy efficiency (building, electricity, industry, and transport). Technology-focused alliances, such as the International Solar Alliance, Global Geothermal Alliance, and Mission Innovations, will play an important role in enabling countries to harness the full potential of low-carbon energy resources at their disposal.

The movement towards 100% low carbon is growing, with more than 600 cities having committed to this target, and an increasing number of companies joining this initiative. Thus, NDCs can provide an important impetus to enhance global efforts to mitigate carbon emissions, double the share of low-carbon energy in the supply mix, and accelerate green growth. To find solutions, the public and private sectors must work together to stimulate accelerated absorption of low-carbon technologies, which is the key to achieving NDC targets.

INDCs can and must change the current trends in energy supply and use, which are patently carbon-intensive. This will require a revolution, and low-carbon technologies will have a crucial role to play. However, although energy-related goods account for more than 10% of international trade, policymakers, academics, and the business community perceive several barriers to the diffusion of these low-carbon technologies at the national, regional, and global level. This chapter aims to identify opportunities and barriers within NDCs for effective diffusion of low-carbon energy technology and to propose the incentive mechanisms required at different levels. To ensure that critical aspects are covered, the following questions need a closer look:

- What are the key low-carbon technologies that can significantly influence the INDC targets in the short and medium term?
- Will the transition to a low-carbon energy future by 2030 be economically feasible and viable under NDCs?
- How could regional and international technology cooperation accelerate investments on the scale required for achieving the NDC targets?

A Critical Analysis of NDC and Low-Carbon Technology Deployment Scenarios

Developing countries of ASEAN and East Asia have much to gain from NDCs. Emissions will be reduced mainly from transforming their energy sectors. The required energy transition has substantial implications for countries with vast fossil fuel reserves such as coal. NDC targets imply more energy supply in 2030 from low-carbon resources that will replace conventional coal and gas. The rise of low-carbon energy in the mix depends on the declining cost of technology over time. This complexity makes it difficult to define detailed development and deployment scenarios for low-carbon technologies. On the other hand, NDC targets motivate countries in prioritising, choosing, and adopting a combination of technologies such as solar, wind, bioenergy, and clean coal. Indeed, they aim to reduce the emission intensity of the economy (TPES/GDP) and the carbon intensity of the economy (CO_2/GDP).

In general, for ASEAN, China, and India, the energy and carbon intensity decreased by 18% and 27%, respectively, between 1990 and 2015. The decreasing trend is, however, not enough to compensate for the increase in economic activity, so the absolute effect is an increase in total emissions in those 12 countries, making it difficult to meet NDC targets by 2030. The carbon intensity of the energy sector (CO_2/TPES) in those countries is increasing slightly – a consequence of the still strong, and in some cases even growing, role of coal in the energy sector. This trend may not continue, as fluctuations in the energy and electricity market can strongly influence the use of fossil fuels.

The NDCs analysed are heterogeneous mitigation targets that feature different ambitions in energy transformation. In essence, they are concerned with the diffusion of low-carbon technologies. Table 17.3 summarises the current level of low-carbon technology deployment in the emerging economies of Asia. A substantial and thriving market already exists for wind and solar technology. Greater deployment of other low-carbon technologies would create new pathways for achieving NDC targets. This would result in a low-carbon technology paradox – a situation in which the potential of technology is understood but its connection with socioeconomic development is not recognised. This paradox arises when technological progress leads to the development of backstop technology that substitutes fossil fuels perfectly. Developing economies of the EAS have a good record of technological innovation in low-carbon energy. Breaking down the regional strengths by specific technologies suggests that renewables, clean coal, energy-efficient lighting, and energy storage offer comparative advantages at the global level.

Table 17.3 Development and Deployment Characteristics of Various Low-Carbon Technologies in Asia

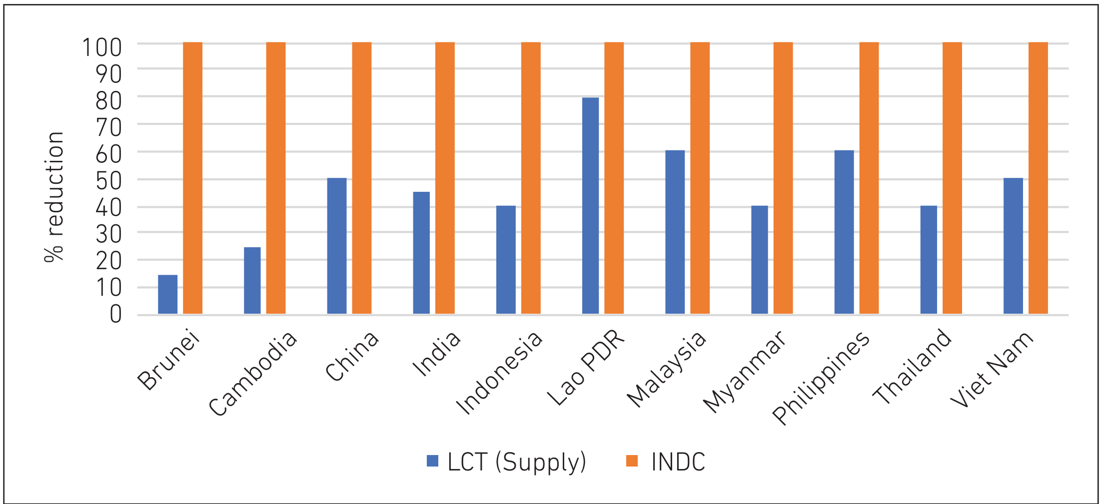
Technology	Cost	Stage of development	Diffusion in advanced countries	Diffusion in developing countries	Technology competition
Solar PV	Medium to high	Commercial	Low to medium	Low	Diffuse
Solar CSP	High	Commercial	Low	Low	Diffuse
Wind onshore	Low to medium	Commercial	Medium	Low	Diffuse
Wind offshore	Medium to high	Commercial	Low	Low	Concentrated
Hydropower	Low to medium	Commercial	High	High	Diffuse
Wave and tidal	Medium to high	Research	Low	Low	Concentrated
Geothermal	Medium to high	Commercial	Low	Low	Diffuse
Biomass steam turbine	Medium	Commercial	Medium	Low	Diffuse
Cook stoves	Low	Commercial	Low	High	Diffuse
Distributed fuel cells	High	Research	Low	Low	Concentrated
Electric vehicles	High	Near mature	Low	Low	Concentrated
Bioethanol from sugar and starch	Medium	Commercial	Medium	Low	Diffuse
Biodiesel from oil crops	Medium	Commercial	Medium	Low	Diffuse
Next-generation biofuels	High	Research	Low	Low	Concentrated
Supercritical pulverised coal combustion	Medium	Mature	High	Low	Diffuse
Ultra-supercritical	Medium	Mature	Medium	Low	Concentrated
Integrated gasification combined cycle	High	Research	Low	Low	Concentrated
Natural gas combined cycle	Low	Commercial	High	Low to medium	Moderately concentrated
Nuclear	Medium	Mature	High	Low	Concentrated

CSP = concentrated solar power, PV = photovoltaic.

Source: Modified by the authors based on Rai, Schultz, and Funkhouser (2014).

Using a harmonised set of BAU projections across the countries, Figure 17.15 shows the estimated Asian NDC scenario, reflecting the cuts in emissions by 2030. The potential reductions vary across the countries. Indonesia has the potential for a reduction of more than 30% by exploiting the available low-carbon energy supplies. Thailand and the Lao PDR have high reduction potential, while the remaining countries have lower targets. The variability in reductions by the employment of technologies suggests that several countries may have the scope for larger ambitions, especially with demand-side energy modifications. Furthermore, their energy consumption per capita is still low, offering further opportunities to achieve INDC targets in a much more cost-effective way. In other words, if today's energy investment decisions do not consider low-carbon technology deployment options, developing ASEAN and East Asia countries may find themselves on a high emissions trail of no return.

Figure 17.15 Carbon Emission Reductions under INDC and Low-Carbon Energy Supply Scenarios



INDC = intended nationally determined contribution, LCT = low-carbon technology.

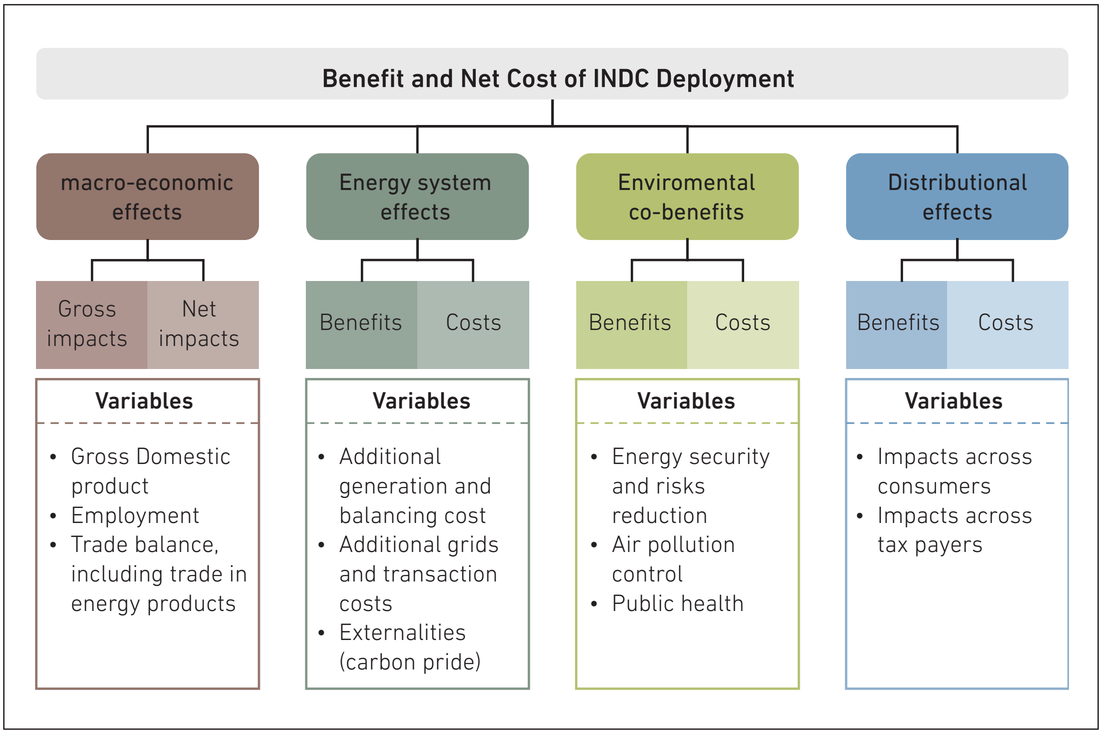
Source: Anbumozhi and Kalirajan (2017).

Estimating Low-Carbon Technology Deployment Costs

High-level cost analysis is vital for the deployment of low-carbon technologies that meet the NDC targets. It is related to technology needs assessments, which provide the foundation for NDC cost analysis by identifying the barriers to the access of technologies and the additional costs involved in removing those barriers. Achieving the NDC targets at the regional and national levels requires a fundamental shift in the energy mix through large-scale investments in low-carbon energy technologies such as wind, solar, biomass, clean coal, and carbon capture and storage. It also depends on investment in energy efficiency.

Environmental and social benefits need to be taken into account when estimating the total cost of low-carbon technologies that will help attain the NDC targets. The implementation of NDCs offers immense benefits through effects other than emission reductions and energy security. Despite short-term economic costs, the diffusion of low-carbon technologies to meet NDC targets can create substantial co-benefits, including the environment and health. The main co-benefits are better air quality, less traffic congestion, a healthier environment, and diversified and enhanced energy security. The socio-economic costs and benefits of low-carbon technology deployment and NDC implementation are shown in Figure 17.16.

Figure 17.16 Estimating the Net Cost of Clean Technology Adoption under INDC Scenarios



INDC = intended nationally determined contribution.

Source: Anbumozhi and Kalirajan (2017).

For low-carbon technology deployment, all stakeholders must bear their share of costs, benefits, and risks. This can happen through appropriate market design and regulations that involve a certain level of administrative costs (Baker et al., 2015). This study used an integrated financial and cost assessment model to estimate the deployment costs of a specific low-carbon technology or combination of low-carbon technologies at the national economy level. That approach also used case study analysis to identify the barriers to and incentives for low-carbon technology diffusion. While there are many studies in the literature, they tend to tilt thinking towards causal factors that are readily measurable and neglect regulatory factors and their feedback – which are more difficult to quantify. The main advantage of combining the case study approach with cost analysis is the ability to examine and reconstruct the process of low-carbon technology acquisition and diffusion in the INDC context. By conducting detailed case studies, it is possible to identify causal factors that prevail across sub-sectors of the energy industry.

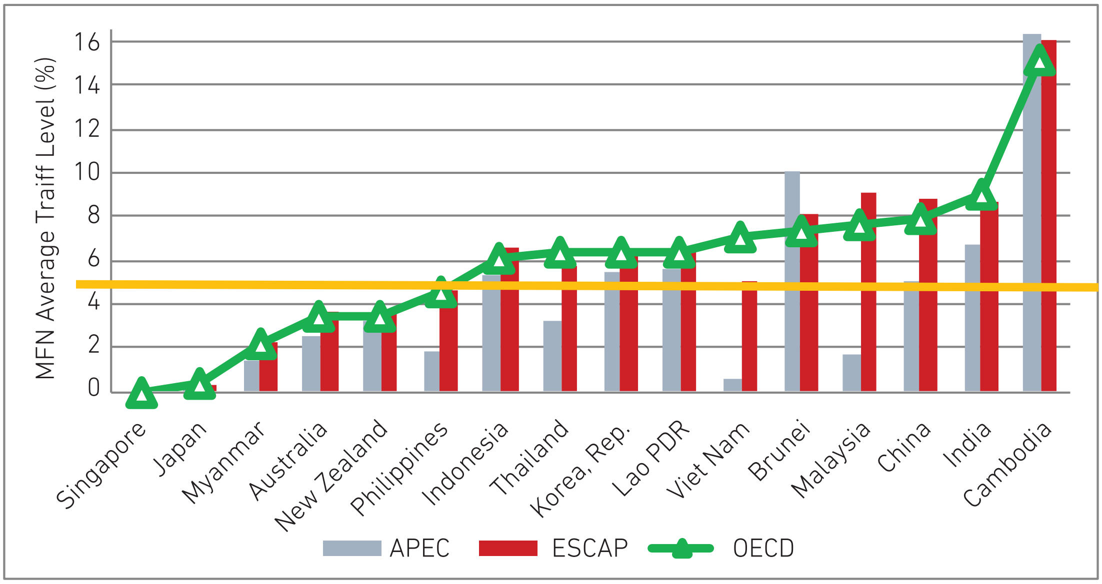
Model simulations demonstrate that for Southeast Asia, new low-carbon energy supply investments from 2016 to 2030 will cost $0.194 billion–$3,527 billion net present value. On average, it will be around $500 billion. Further cost estimation needs to include both the expenditures and benefits in the deployment of low-carbon technologies to meet the INDC targets. Additional investments in energy production using renewables and energy efficiency total $15 billion under the INDC, but about $5 billion of this is offset by reduced investment in fossil fuels, leaving a net increase of $10 trillion, or $300 billion per year. The deployment of other low-carbon energy generation technologies – such as carbon capture and storage, smart grid, and energy storage – could increase the need for investment in new infrastructure, which raises capital expenditure at the economy and sector levels.

Globalisation of Clean Energy Technologies

Most of the countries' submissions to the Paris Agreement assume international support to achieve ambitions targets – encouraging the use of market and non-market measures for instituting technology transfer agreements and setting standards. Developing EAS countries are already large exporters of low-carbon technologies and related services, and in some economies, significant innovators.

Trade policy has an important role to play in securing the low-carbon technologies necessary to facilitate the energy shift, and thus helping countries achieve their NDC targets. Trade data show that emerging Asian economies already account for 35% of low-emission products and services, which is a slightly smaller percentage than Europe, but substantially higher than that of the US. Within the region, China is the leading exporter, followed by Japan, Korea, the Philippines, and India. Removing traditional trade barriers such as tariffs and restrictions to trade in services would help to decrease the cost of low-carbon technologies, making them more affordable for all, and create a viable alternative to high-carbon low-cost fossil fuels. Figure 17.17 illustrates the border obstacles to low-carbon technologies.

Figure 17.17 Tariff Levels on Low-Carbon Technologies in Major Asian Countries, 2016



APEC = Asia-Pacific Economic Cooperation, ESCAP = Economic and Social Commission for Asia and the Pacific, MFN = most favoured nation, OECD = Organisation for Economic Co-operation and Development.

Source: Anbumozhi and Kalirajan (2017).

Tariff barriers can largely be removed on a unilateral basis. Collaboration between countries is, however, needed to address more complex issues such as cumbersome and uncoordinated standards and their associated testing and certification requirements; or various energy subsidy and pricing schemes, many of which are far more trade restrictive than tariffs. Trade talks on an Environmental Goods Agreement by WTO members could play an important role in the implementation of zero tariffs for low-carbon technologies, despite current limitations. Regional trade agreements such as the

Regional Comprehensive Economic Partnership (RCEP) offer another promising avenue for the diffusion of low-carbon technologies. Whereas mega free trade agreements such as the RCEP could have done more for the globalisation of low-carbon technology diffusion, bilateral agreements such as the European Union (EU)–Viet Nam free trade agreement are more proactive on this matter, and could serve as an inspiration for future regional trade agreements.

Globalisation of low-carbon technologies increases the forms of voluntary cooperation amongst governments and reduces the innovation and investment risks. Investments in the low-carbon energy transition are often perceived as high-risk, mainly due to the uncertainty of public policies. Country reports for an Asian Development Bank Institute study (ADBI, 2013) pointed to problems varying from intellectual property concerns and developing countries' limited access to knowledge and finance. The biggest barrier to the global commercialisation of low-carbon technologies is the failure of governments to create an effective policy incentive structure. Since the benefits of low-carbon technologies mainly accrue to the public, private markets have difficulties in valuing them. It is therefore essential that governments step up in the technology marketplace. Regional institutions such as the Asian Development Bank (ADB) could play an important catalytic role in this regard.

The Paris Climate Agreement and NDCs with contingency clauses for international support also provide a hook for the formation of carbon markets at the national level as well as across borders. The Paris Agreement provides for a carbon club arrangement, whereby a group of countries agrees on a set of common rules and standards in exchange for the right to trade emissions amongst themselves. For EAS developing economies, it provides an additional stepping stone for the formation of an integrated carbon market that will accelerate the pace of achieving the INDC targets. However, the following issues require deep consideration: (i) coordination between INDC executive committees and technology trade centres, (ii) identifying conflicting policies, and (iii) unlocking the potential of regional economic and financial cooperation. Progress on these parameters will also determine the speed of technology transfer.

Various studies (Kennedy and Basu, 2013; Rai and Funkhouser, 2015; Anbumozhi, 2021) have shown that capital flows to low-carbon technology investments are hampered by imperfections and misperceptions in financial markets, as they tend to be prone to risks and their returns are conditional on government policies such as carbon pricing. Moreover, low-carbon investments require high initial capital costs with long paypack periods. To compensate for this, NDC implementation plans should include de-risking instruments and supplementary finance for the globalisation of low-carbon technologies.

Integrated Policies for Low-Carbon Clean Energy Technology Deployment

The Paris Agreement indicates that INDCs present both opportunities and challenges for the emerging EAS economies. A universal commitment to ambitious targets has created momentum in the region for a massive energy shift towards a low-carbon economy. In addition to avoid the worst impacts of global warming, the implementation of INDCs could result in many other benefits – from new economic opportunities to improved health. At the same time, meeting the INDC targets will not be simple. The bottom–up nature of the Paris Agreement, the diversity of the energy sector targets, and the requirements for low-carbon technology transfer raise doubts about the ability of NDCs to achieve ambitious targets at the regional and global levels. In addition, the absence of a strong enforcement and monitoring mechanism poses a challenge for rapid implementation of NDCs.

Implementing the Paris Agreement must also look at increased interactions between the energy and economic policy regimes for effective absorption of low-carbon technologies. Energy sector reforms under the INDC framework will likely test the limits of these policies, along with existing trade, technology, innovation, and financing rules, some of which policymakers need to consider and deal with. Hence, action plans on NDCs should actively mobilise trade policy, including by liberalising trade in low-carbon technologies, fostering innovation, and accelerating technology transfer, as well as informing and facilitating regional carbon markets.

Government commitment to INDCs could take the form of credible and time-bound renewable energy, clean coal, and energy efficiency targets for the absorption of low-carbon technologies – to anchor the confidence of the international community in emerging Asia. Low-carbon technology deployment policies need to be part of a range of cross-cutting energy and economic policy instruments. Tailored to specific country conditions and the level of maturity of the energy and economic sectors, the policy mix should focus on adopting a system level approach, building institutional and human capacity for the globalisation of low-carbon technologies, strengthening domestic industry, and creating a market-friendly environment. The following recommendations are made towards that objective:

- **Integrated energy and economic approach to NDCs:** With greater competitiveness, support will be needed for low-carbon technologies to shift from an exclusive focus on financial incentives to ensure deep integration with the overall design and functioning of the regional economies. Growing low-carbon technology deployment is already transforming the energy sector in some countries. Accelerated transformation under the NDC agenda means that economy-wide effects of the low-carbon energy transition would be distributed across sectors and multiple stakeholders. Taking these developments into account, policymaking will have to adopt an economy-wide approach involving trade, innovation, fiscal, and social development to drive the NDC cost down. This will ensure accelerated absorption of low-carbon technologies.

- **Institutional development to support NDCs:** The pace of low-carbon technology diffusion will be strongly influenced by the ability of individuals and institutions to make informed and effective decisions on the implementation of low-carbon technology road maps. In many countries in the region, the institutional capacities of energy, environment, and economic ministries remain weak – affecting the awareness, policy design, and implementation of NDCs. Where such capacities exist in some developed countries, they are commonly restricted by lack of resources and consensus in mobilising additional resources. Cross-sectoral needs assessments should guide the elaboration of national capacity building programmes for NDCs. Such initiatives should focus on establishing an appropriate steering process, institutionalising inter-sectoral coordination mechanisms, and creating or strengthening specialised institutions for low-carbon technology innovation and transfer.

- **Skills development through education and training:** This requires systematic access across all sectors and layers of the economy to education and training in low-carbon technologies prioritised in each country. Professional training and university curricula must evolve to cover prioritised low-carbon technologies and their integration into NDC implementation. Vocational training programs can also offer opportunities to acquire specialisation and take advantage of the growing low-carbon job market. Planning that integrates innovation, education, and training policies within NDC strategies should be accompanied by continued collaboration between industry, policymakers, and academia.

- **Strengthening regional private sector capabilities and boosting the development of local industries to reduce the cost of NDCs**: As a result of increasing low-carbon technology deployment, new markets will emerge across countries, creating new international trade flows while providing opportunities for all economies to localise different segments of the low-carbon technology value chain. The segments that can be localised depend on the state and competitiveness of local complementary industries as well as the projected demand for low-carbon energy goods and services. Cross-cutting policy interventions such as industrial updates, supplier development programs, and industrial cluster formation, can contribute to increased competitiveness and production quality. Nascent industries can be supported through measures that create demand for local goods and services. However, these measures need to be planned with 2030 NDC target deadlines and designed in a way that ensures technology transfer which leverages existing domestic industrial capacity.

- **Market-friendly environment to overcome financing barriers and attract investors.** To attain the INDC targets, regional annual investments in the low-carbon energy sector need to be $500 billion–$750 billion per year between 2020 and 2030. Most of the investments in low-carbon technologies need to come from private sources. As low-carbon technology deployment grows and new markets emerge, financiers could more accurately assess the risk and design financing products suited for NDC products. Nevertheless, actual and perceived risks continue to slow investment growth. Public funding will continue to remain an important catalyst and will need to increase. Ample evidence shows that public finance can de-risk investment and thus leverage considerable funding from private sources, both domestic and international. Investment strategies on low-carbon technologies need to be tailored to each phase of the NDCs. The success of any investment strategy in low-carbon technologies will rely on the participation of a broad spectrum of private and finance actors, including development finance institutions, private equity funds, institutional investors, export credit agencies, and commercial banks.

Power Grid Connection in ASEAN

Significance of the ASEAN Power Grid

To meet the growing electricity power demand in ASEAN, huge investments in power generation capacity and power system expansion are required. In addition, the ASEAN region has an abundance and diversity of not only fossil energy resources such as natural gas, coal, and oil, but also renewable energy potential such as hydropower, solar power, wind power, and biomass. The Heads of ASEAN Power Utilities/Authorities (HAPUA) recognised this and established a plan for the ASEAN Power Grid (APG) in 1997 as a flagship program under the ASEAN Vision 2020 to enhance cross-border electricity trade. This aims to provide benefits to meet the rising electricity demand and improve access to energy services in the ASEAN region. The HAPUA have vitally promoted the ASEAN Interconnection Masterplan Study (AIMS) to formulate a strategy to accelerate the realisation of the APG.

The study consists of two phases – AIMS I and AIMS II – successfully completed in 2003 and 2010, respectively. The strategy, based on these studies, aims to encourage participation on a cross-border bilateral basis, then gradually expand to a subregional basis (northern subsystem, southern subsystem, and eastern subsystem), and finally move to an integrated APG system. It is expected that power exchanges and purchases will triple the capacity during 2014–2025 and increase to 17,000 megawatts (MW) after 2025.

A fully functioning regional grid brings many benefits. Through such interconnection, cheaper renewable energy resources, which are abundant in the region – especially hydropower in the Greater Mekong Subregion (GMS) – could be developed. A synchronised regional grid could take advantage of the varying peak and non-peak hours in different countries and thus save a large portion of the investment in expensive peak power generation capacities. However, the high up-front cost of new transmission lines for cross-border interconnection and the uncertainty of future demand for electricity imports and exports through these transmission lines complicate financial decisions to invest. The financial feasibility of each proposed cross-border transmission line needs to be studied carefully.[6]

Since 2016, however, the energy landscape in the region has changed. AMS have faced challenges in fulfilling the energy demand, which has increased significantly and will continue to grow at a rate of 5%–6% per year in the coming decades. In addition, the AIMS II study was not able to identify paths to maximise the use of indigenous renewable energy resources in ASEAN, in response to the direction from the ASEAN Plan of Action for Energy Cooperation 2016–2025 that the 33rd ASEAN Ministers on Energy Meeting endorsed in September 2015 in Kuala Lumpur, Malaysia.

[6] Kutani (2013) estimated $11 billion net savings in the cost of electricity generation for all AMS plus two southwest China provinces and northeast India in 20 years, despite the high initial costs of investment in interconnecting transmission lines. The other independent estimation by Chang and Li (2012) projected net savings of $20.9 billion for ASEAN alone in 20 years.

Various studies (ADBI, 2013; Anbumozhi, 2021; ASEAN, 2019; IEA, 2019; and Thincraft, 2019) have asserted that, to integrate a variable renewable energy power source such as solar and wind power generation into a power system in a stable manner, it is necessary to absorb the fluctuation and maintain the balance between supply and demand. This requires synchronous generators to respond more sensitively to the system frequency fluctuation and be prepared to cover the cost. If the APG is properly developed, reserves for supply–demand adjustment and frequency regulation provided from synchronous generators can be widely shared or exchanged throughout the ASEAN region. This would make it possible to maximise economic benefits through effective utilisation of renewable energy sources and reduce the comprehensive generation cost. Moreover, all AMS could enjoy benefits such as the mitigation of environmental pollution and global warming.

Development of Multilateral Power Trade in ASEAN

In 2020, cross-border interconnections amongst AMS, especially in the GMS, were already in place. These interconnections mainly consist of medium/low voltage (115-kilovolt (kV) or less) transmission lines and a few high-voltage transmission lines (500 kV, 230/220 kV). Electricity power trade has been carried out amongst GMS countries, mostly on a bilateral basis or based on power purchase agreements under which independent power producers sell electricity to power utilities via dedicated transmission lines. The cross-border interconnection of a 500 kV transmission line is only installed to dedicated transmission lines for power purchase agreements. Therefore, the electricity power trade in ASEAN has been limited.

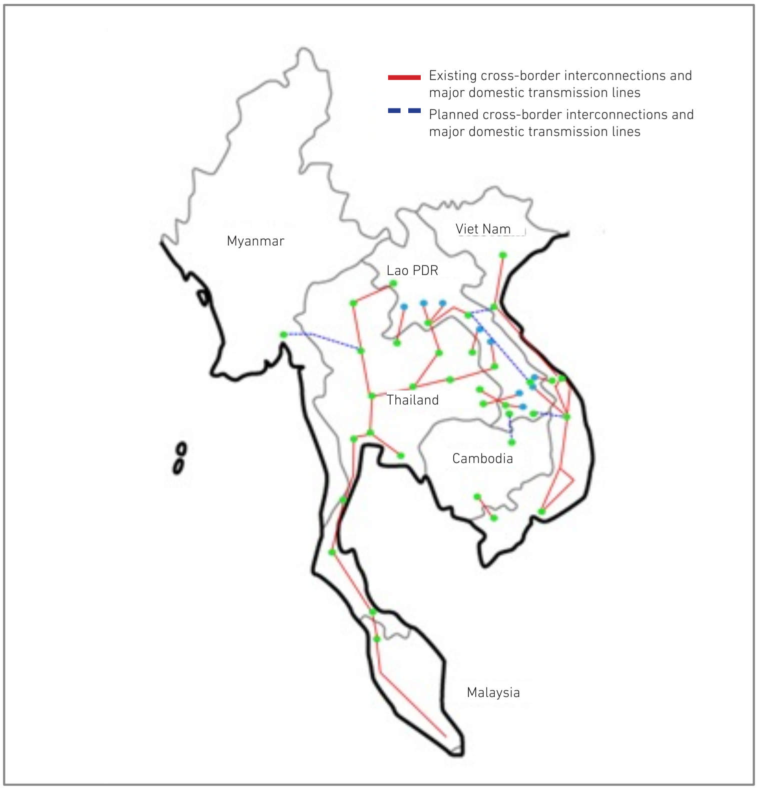
AMS have long recognised the necessity of the APG. To fully unlock the benefits of the APG, they will need to establish multilateral power trade in the ASEAN region. Generally, utilising the value of difference is one of the key reasons for regional integration and cooperation, creating positive effects on the security of supply and hence grid stability. In addition, the economic benefit of having complementary production is one of the main drivers and reasons for building interconnections. As explained in the ASEAN Plan of Action for Energy Cooperation, 2016–2025, an interconnected APG brings multiple benefits (ERIA, 2018).

Multilateral power trade aims to optimise resources on a regional basis instead of a national basis to meet the demand for electricity in the region as a whole at the least possible cost. When it comes to regional cooperation, it is important to emphasise that increasing regional cooperation does not directly correlate to losing national control of the electricity sector (ERIA, 2018). Some key points on the potential benefits of multilateral power trade are:

(i) More efficient use of the region's energy resources, leading to lower overall production costs in the APG since optimal investments can be made on the regional scale instead of suboptimal solutions separately in each country.
(ii) Help utilities in the region to balance their excess supply and demand, improve access to energy services, and reduce the costs of developing energy infrastructure.
(iii) Accelerate the development and integration of renewable power generation capacity into the regional grid.
(iv) Reduce the need for investment in power reserves to meet peak demand, thereby lowering operational costs while achieving a more reliable supply and reducing system losses.
(v) Attract additional investment in the region's interconnection, by providing a price signal as a key catalyst to investors for their financial returns.

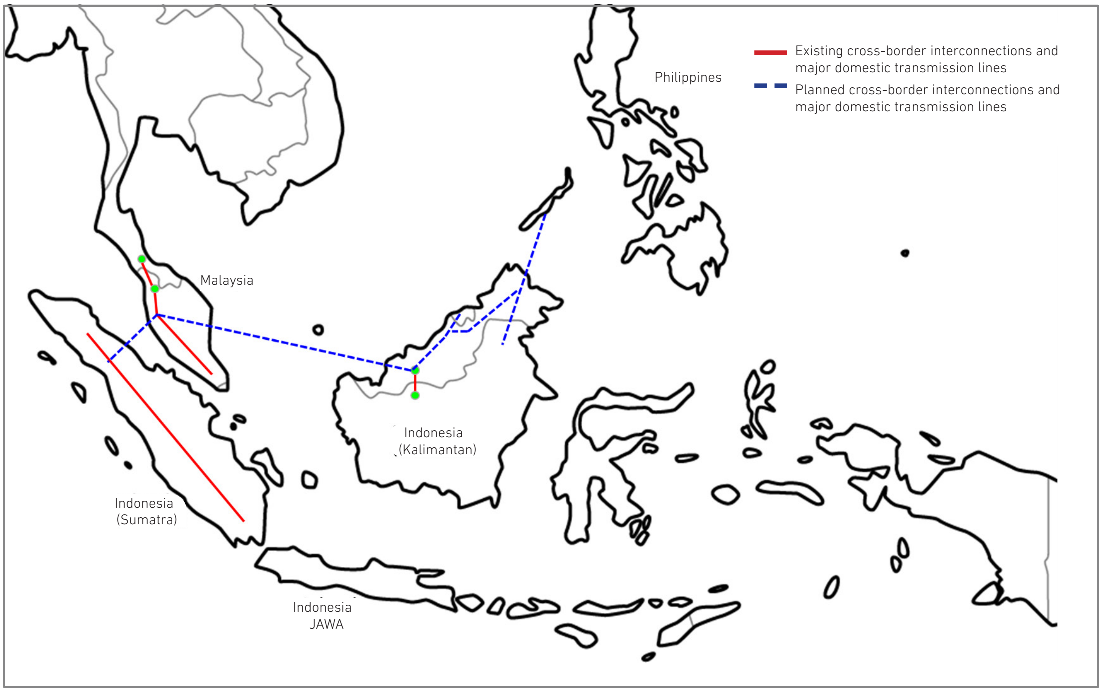
To realise multilateral power trade in ASEAN, AMS are carrying out the Lao PDR, Thailand, Malaysia, Singapore Power Integration Project (LTMS-PIP), the first pilot multilateral power trade project in ASEAN (Figure 17.18 a and b).

Figure 17.18a Existing and Planned High-Voltage Interconnections and Transmission Grid



Source: Diagram based on IEA (2019) and Thorncraft et al. (2019), with modifications by ERIA.

Figure 17.18b Existing and Planned High-Voltage Interconnections and Transmission Grid



Source: Diagram based on IEA (2019) and Thorncraft et al. (2019), with modifications by ERIA.

First Step for Multilateral Power Trade in ASEAN

A study by ERIA (Fukasawa, Kutani, and Li, 2015) identified that a power grid interconnection amongst the Lao PDR, Malaysia, Singapore, Thailand, and Viet Nam is financially feasible and should be prioritised (Table 17.4). This finding coincides with the initiative by the governments of the Lao PDR, Thailand, Malaysia, and Singapore to develop interconnections and demonstrate a multilateral framework for cross-border trade in power.

Table 17.4 Possible Interconnection and Cumulative Costs and Benefits, 2025–2035

Case	Gross benefit (A)		Cost (B)		Net benefit (C) = (A) – (B)		Benefit–cost ratio (D) = (C)/(B)
	($ million)	(US¢/ kWh)	($ million)	(US¢/ kWh)	($ million)	(US¢/ kWh)	[-]
Thailand–Lao PDR	21,387	3.77	1,506	0.26	19,881	3.51	13.2
Viet Nam–Lao PDR–Thailand	24,707	3.68	2,097	0.32	22,610	3.36	10.8
Lao PDR–Thailand–Malaysia–Singapore	27,490	3.88	2,000	0.28	25,490	3.60	12.7

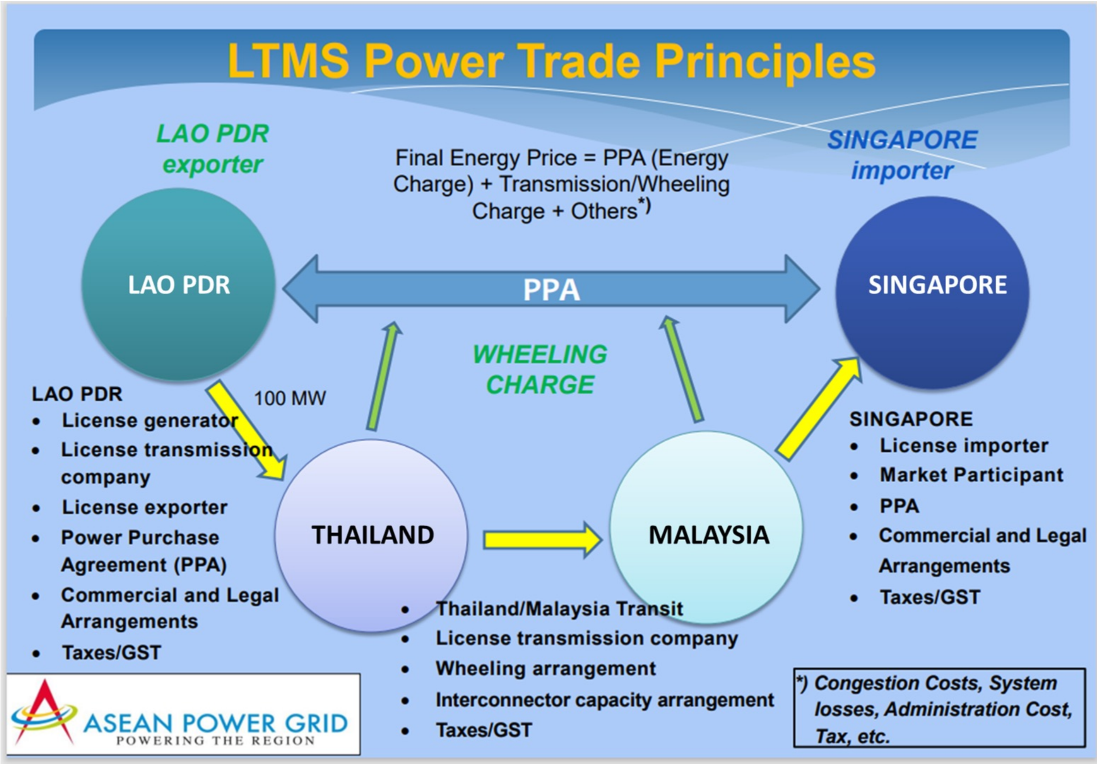
kWh = kilowatt-hour, US = United States.
Source: Fukasawa, Kutani, and Li (2015).

The Ministry of Energy and Mines of the Lao PDR, Ministry of Energy of Thailand, and Ministry of Energy and Green Technology and Water of Malaysia signed the memorandum of understanding of the Lao PDR, Thailand, Malaysia Power Integration Project (LTM-PIP) at the 34th ASEAN Ministers on Energy Meeting in September 2016. This memorandum of understanding facilitated multilateral cross-border power trade up to 100 MW from the Lao PDR to Malaysia via Thailand's transmission grid. The original aim of this project is to transfer electricity from the Lao PDR to Singapore under the LTMS–PIP. The LTMS–PIP will serve as a pathfinder to complement existing efforts towards realising the APG and the ASEAN Economic Community by creating opportunities for electricity trading beyond neighbouring borders. As a pilot project, the focus is primarily on identifying and resolving issues that could affect cross-border electricity trade amongst the AMS more broadly (Thorncraft et al., 2019).

Phase I of the LTMS–PIP started in January 2018, and 17 GWh of energy was transferred from the Lao PDR to Malaysia in cross-border trade. The ASEAN Ministers on Energy welcomed the Joint Statement of the LTM–PIP Phase II announced by the three countries when Thailand chaired the 37th ASEAN Ministers on Energy Meeting in September 2019, where the three countries confirmed the increase in the maximum committed energy capacity trading of the LTM–PIP up to 300 MW. The LTMS–PIP is a multilateral trading arrangement insofar as it includes more than two countries. However, it is also a unidirectional trade, so it is more limited than multilateral trading as defined by this study. However, certain key elements of the LTMS–PIP are very relevant to the broader goals of the APG. Two stand out in particular: the development of the wheeling charge and the underlying process for developing the LTMS–PIP in the first place.

To establish multilateral power trading in the region, it will be necessary to develop a common wheeling methodology. The LTMS–PIP wheeling methodology could be an appropriate start. The LTMS–PIP wheeling charge is based on the following elements: the distance of the trade (MW per mile), a loss charge (charged per megawatt-hour), a balancing charge (per megawatt-hour), and a fixed administrative charge. To generalise this methodology for ASEAN as a whole, the LTMS partner countries will need to share additional details on how each of these components are calculated. It should be emphasised, however, that this can be done without sharing the actual wheeling charge applied to the LTMS–PIP trade, should this information be considered too sensitive to share publicly (Figure 17.19).

Figure 17.19 Conceptual Diagram of LTMS–PIP



GST = goods and services tax; LTMS-PIP = Lao PDR, Thailand, Malaysia, Singapore Power Integration Project; MW = megawatt; PPA = power purchase agreement.

Source: Hermawanto (2017).

The underlying process used to develop this project is also very relevant to the ASEAN-wide discussion. In particular, work on the project was divided across four working groups, which looked at (i) the tax and tariff structure, (ii) commercial arrangements, (iii) a technical viability study, and (iv) regulatory and legal arrangements, each of which was led by a different country. There are two key lessons from this arrangement. First, dividing work across the participating countries is a good way of giving everyone a stake in, and a sense of ownership over, the underlying process and therefore the overall project. Second, it is possible for a particular AMS to be actively involved in the development process even if it does not take part in the trading arrangement itself. This is an important lesson for ASEAN as a whole, because some AMS will participate in multilateral power trade early on (IEA, 2019).

Challenges to ASEAN Grid Connectivity

Significant developments have slowly taken place within the ASEAN region to increase regional trading based on bilateral deals and use the existing infrastructure to move power throughout the region. But there is still a long way to go to establish a full-fledged regional ASEAN power market. One of the reasons for the slow progress is the multitude of types of power sector structures and markets throughout ASEAN, creating problems and barriers on all levels of collaboration. Challenges remain in setting up the following: (i) a regional regulators group/regional regulatory body to harmonise regulations and standards relevant to grid interconnection; (ii) a regional operators group or regional system operator to synchronise actions in balancing the grid and the cross-border power exchange systems; and (iii) a regional system planners' group to coordinate and optimise the future investment plan of power stations and the grid.

To solve these issues, several studies have been conducted by HAPUA, the ASEAN Centre for Energy, and ADB. The findings suggest the need to harmonise the legal and regulatory frameworks and create technical standards and codes relating to planning, design, system operation, and maintenance. ERIA also carried out two research projects.

The first is a 'Study on the Formation of the ASEAN Power Grid Transmission System Operators (ATSO) Institution' (Li, Wada, and Söderström, 2018). There are two layers of objectives: (i) to establish the roles, structures, operational guidelines, and processes of the ATSO institution; and (ii) to provide a detailed implementation plan for the creation and operation of the ATSO. This study provides an overview of the international case examples that have been used as the basis for creating the ATSO, the ASEAN Power Pool (APP) guideline, and the APP Implementation Plan and Roadmap. The second is a 'Study on the Formation of the ASEAN Power Grid Generation and Transmission System Planning (AGTP) Institution' (Li, Wada, and Shinozaki, 2018). The objective is to propose applicable procedures, structures, roles, and mechanisms to establish and maintain the AGTP. The ATSO and the AGTP institutions, once achieved, will be symbolic of the regulatory connectivity in ASEAN. This study provides experiences about this field in Japan, Europe, and the Southern African region refer to and learn from the AGTP guideline and the AGTP implementation plan (ASEAN, 2019).

Necessity of New Regional Institution for Multilateral Power Trade

Multilateral power trade has operated in many regions, such as the Pennsylvania–New Jersey–Maryland Interconnection, Nord Pool, European Network of Transmission System Operators for Electricity, and South African Power Pool. These regions have regional institutions to support multilateral power trade. In the ASEAN region, additional institutional arrangements will be necessary to establish full multilateral power trade at the regional level.

Those two ERIA studies aim to help the AMS achieve consensus on the principles, building blocks, and framework of an integrated regional electricity market. The output from the studies concluded that the function of the AGTP and ATSO should be placed in the same organisation to secure a close relationship between the planning and power system operation. After discussions during the workshops of the AGTP and ATSO studies, the ASEAN Power Grid Consultative Committee and AMS agreed that the functions of the AGTP and ATSO should be merged into one organisation, and the new organisation was named the APP.

The primary role of the APP is to act as a coordinating body between the AMS transmission system operators, focusing on harmonising operational standards across ASEAN to achieve more efficient operation of the future APG. More efficient operations are anticipated to come from better coordination and alignment of the system operation and generation within the region. The APP is expected to be a key institution to enable multilateral trading of electricity amongst AMS, whilst maintaining the balance, stability, and reliability of the interconnected power grids across borders. In addition, the role of coordinating the APG system planning and grid developments will be of great importance to make the APG more efficient and better coordinated.

The APP will resemble a forum where operational, technical, and multilateral trading topics can be discussed and agreed. It will also have an important information-sharing role for the region. The suggested responsibilities of the APP will be to lead and coordinate the development of the regional market, establish and own the APG network codes and guidelines, and produce a regional system planning and development plan which will be continuously revised. The development of the codes by the APP and overall activity will focus on interconnections and how these are to be utilised in the best way. The APP will not have an operational role within the different AMS national transmission grids. The APP is proposed to hold responsibility for operational coordination of the system in the APG, which will be achieved through the 'Control Block Coordination Centre'. The point is that there should be only one coordination centre in ASEAN.

New Integrated Energy System for Smart City

Urban Energy Use

Asia is the world's largest continent, where renewable energy use is expanding fastest (IRENA, 2017). However, until at least 2023, Asia will see growing coal demand, especially in India and Southeast Asian countries (IEA, 2018). The United Nations (2018) projected Asia's level of urbanisation to increase from 45% in 2011 to 64% in 2050, which is faster than other continents' urbanisation rates. In 2050, more than 1.4 billion people in Asia will be living in cities. Compared with rural areas, Asian cities do not only have higher final energy use, but they also generally have much higher incomes.

Looking at the above challenge and current trend, Asia is certainly the continent where governments can most decisively help to curb carbon emissions and mitigate climate change and where the ability of managing rapid urbanisation through the creation of smart cities, amongst others, would have significant and lasting consequences for the environment and human well-being. In this section, we will show some of the main policy trends in Asian countries concerning the new energy system, especially those related to the rapid urbanisation phenomenon in the region which leads to the development of smart cities.

Urban Energy Strategies in Asia

Countries' energy objectives, synthesised in the United Nations SDGs, and the objectives to meet countries' NDCs, signed as parts of the Paris Agreement in 2015, have led Asian countries to decarbonise their energy systems. For that purpose, governments in Asian countries have elaborated policies that can be categorised into two main types: (i) policies that aim at improving energy efficiency, and (ii) policies that aim at increasing the share of renewable energy uses.

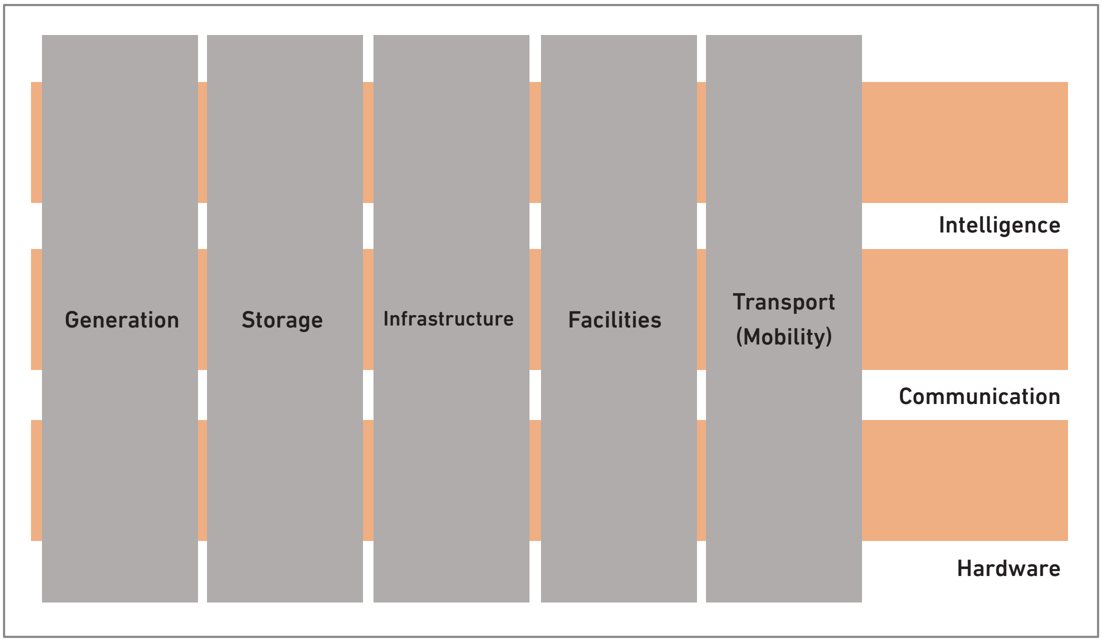
These policies in Asian countries clearly cover urban energy issues. Furthermore, they are consistent with the definition of a modern sustainable urban energy system given by the Asia Pacific Urban Energy Association (APUEA, 2019) – integrated multi-fuelled energy systems that incorporate energy efficiency, renewable energy, and demand-side management. Nevertheless, governments need to overcome many challenges to achieve modern sustainable energy systems in urban areas and cities; and faster transformation can be expected with the deployment of technological and digital solutions in creating smart cities, such as the use of geospatial databases, urban spatial data information systems, data analytics to support city operations and drive innovation, information and communication technology (ICT) networks, automation, and e-payments and digital platforms (Centre for Liveable Cities, 2018). Smart cities also aim to be sustainable cities with modern sustainable energy systems that are to be developed with respect to the economic, social, and environmental needs of the present and the future.

Adhering to this strategy of coping with rapid urbanisation and problems it causes – such as congestion, strained infrastructure, pollution, lack of affordable housing, and socio-economic inequality – the ASEAN Leaders established the ASEAN Smart Cities Network (ASCN) at the 32nd ASEAN Summit in April 2018. The ASCN is a collaborative platform where 26 pilot cities from the 10 AMS work towards the common goal of smart and sustainable urban development (see also chapter 5). A new energy system, together with smart mobility and transportation, is one of the utilities in the 'Built Infrastructure' development focus area.

Development Plans or Actions in the Main Energy-Related Components of Smart Cities

Providing more focus on the energy aspect, Calvillo, Sánchez-Miralles, and Villar (2016) suggested that smart cities are intended to deal with or mitigate, through the highest efficiency and resource optimisation, the problems generated by rapid urbanisation and population growth, such as energy supply, waste management, and mobility. The same authors also classify energy intervention areas that consist of generation, storage, infrastructure, facilities, and transport (mobility) (Figure 17.20). In brief, all these areas are related to each other but contribute to the energy system in different ways.

Figure 17.20 Classification of Energy Intervention Areas in the Smart City



Source: Calvillo, Sánchez-Miralles, and Villar (2016).

Generation provides energy, and this area can be seen in two main activities: (i) the use of renewable energy sources, and (ii) the development of distributed power generation applications and tools (systems). Energy storage systems can be used to store several kinds of energy (e.g. electric, thermal, and kinetic). In the context of smart cities, the systems are expected to serve two purposes: (i) the integration of renewable sources, and (ii) the delivery of demand-response schemes. Infrastructure consists mainly of urban power grids, and this involves the distribution of energy and user interfaces. Finally, facilities (commercial and residential buildings and small-scale infrastructure) and transport are the main final consumers of energy, as they need it to operate.

The strategy of reaching the highest efficiency and resource optimisation could be translated in terms of measures that (i) increase energy efficiency through saving and technological measures, (ii) reduce GHG emissions and/or carbon footprints, and (iii) maximise the use of renewable energy sources to reduce the burning of fossil fuels.

Smart Electricity Grids

Overview of Smart Grid

A power system in a sustainable society integrates more renewable energy to emit less CO_2 through the interaction of several defined components – distributed generation (wind power plants, mega-solar photovoltaic (PV) plants, and rooftop solar PV systems on buildings); a market system; demand response technologies; and information technology (data acquisition and communication).

The power system which enables the coordination of the interplay amongst the above-mentioned components is also known as a 'smart grid system'. The IEA defines a smart grid as an electricity network system that uses digital technology to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users (OECD, 2015). Such grids can coordinate the needs and capabilities of end-users and electricity market stakeholders in such a way that they can optimise asset utilisation and operation and, in the process, minimise both costs and environmental impacts while maintaining system reliability, resilience, and stability.

Main components and features of a smart grid

A smart grid system involves a complex arrangement of infrastructure whose functions depend on many interconnected elements. A smart grid system can be visualised as having four main layers whose elements are combined to create grid features that improve the grid's ability to achieve certain goals, such as integrating more renewables, improving reliability, and reducing energy consumption (Madrigal and Uluski, 2015):

(i) The first layer is the hard infrastructure, which is the physical component of the grid. This covers generation, transmission, and the distribution network as well as energy storage facilities.

(ii) The second layer is telecommunications, which represent the telecommunication services that monitor, protect, and control the grid. This includes wide area networks, field area networks, home area networks, and local area networks.

(iii) The third layer is data management, which ensures proper data mining and utilisation of data to facilitate smart grid applications.

(iv) 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 the integration of renewable energy.

The integration of renewable energy – including wind power, solar power, hydropower, biomass, and geothermal – into the power system to reduce the consumption of fossil fuels has been increasing in recent years and is an essential feature of smart grids as it comes with distributed power generation. Wind and solar power have a characteristic not possessed by other renewables – output fluctuation – which makes this type of power difficult to integrate into conventional power systems.

In conventional systems, load fluctuations are caused by fluctuations in demand, and the load balance is restored by thermal and hydropower plants. When wind power and rooftop solar PV power are integrated, load fluctuations increase as this characteristic of wind and solar PV power combines with demand fluctuations. If thermal and hydropower plants do not have enough balancing capability, large electric storage devices such as batteries are required. However, if demand-side management is introduced, electric storage on a moderate scale suffices to restore load balance. This implies that managing demand introduces additional balancing capability to the supply side of the system.

Policies and Implementation of Smart Power Grids in Asia

In this subsection, we describe smart power grid policies and their implementation in selected Asian countries. We give an overview of the situation in both developed and developing countries of Asia.

Japan

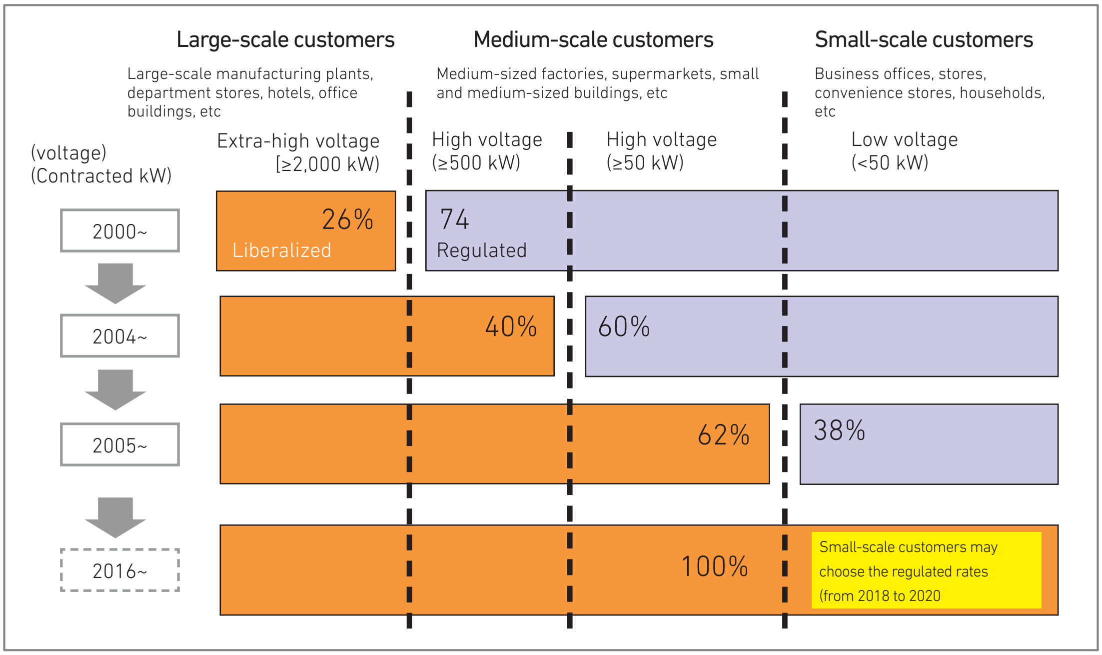
Japan aims to reduce its GHG emissions by 26% by fiscal year 2030 compared to fiscal year 2013, and by 80% by fiscal year 2050,[7] and to meet 35% of its electricity needs with renewable by 2030 while in 2017, about 15% of Japan's total energy consumption is from renewables (Buckley and Nicholas, 2017). Solar PV could grow to reach 12% of the total electricity generation mix by 2030 from the current 4% share.

According to Ling, Kokichi, and Masao (2012), Japan's focus on smart grid development should be on how to stabilise power supplies nationwide as large amounts of wind and solar power start entering the grid. The main objective of smart grid technology adoption is to achieve a total shift from fossil fuels to renewable energy (Ito, 2009). Smart grid development in Japan cannot be separated from the concept of smart community, which refers to a community where various next-generation technologies and advanced social systems are effectively integrated and utilised – including the efficient use of energy, utilisation of heat and unused energy sources, improvement of local transportation systems, and transformation of the everyday lives of citizens. [8]

[7] Cabinet Decision on the New Strategic Energy Plan dated 3 July 2018.
[8] Japan Smart Community Alliance (n.d.).

The approval of the fourth Basic Energy Plan in April 2014 marked the major reform of Japan's energy sector. This plan, aimed at establishing a national grid and fully liberalising the electricity markets, presents the basic energy policy principles of Japan, including energy security, reliability, efficiency, affordability, reduced emissions, and increased consumer choice. In brief, the chronological deregulation process of Japan's power sector began with liberalisation of large-scale customers market in 2000 and completed with small-scale customer market liberalisation in 2016 (Figure 17.21). According to Motoaki (2017), the widescale adoption of internet technologies, combined with deregulation and energy storage improvements, opens the door for Japan to walk into the world of smart grids.

Figure 17.21 Japan's Power Sector Deregulation Timeline



kW = kilowatt.

Source: Author's compilation based on Shinkawa (2018).

Source: Prepared by TEPCO based on METI publications

The Ministry of Economy, Trade and Industry (METI) has played a very important role in implementing smart grids in the framework of smart city projects in Japan. The promotion of smart energy initiatives is amongst the objectives set in the Fourth Strategic Plan released in April 2014 (ANRE, 2014) – to realise an advanced energy saving society and smart and flexible consumer activities. Following this approval, METI established two regulatory government bodies in 2015: the Organization for Cross-Regional Coordination of Transmission Operators and the Electricity Market Surveillance Committee (Brown, Zhou, and Ahmadi, 2018). The Organization for Cross-Regional Coordination of Transmission

Operators oversees utility power generation and exchange as well as the development of regional transmission grids, while the Electricity Market Surveillance Committee monitors the electricity market and is responsible for Japan's smart meter rollout.

According to Shinkawa (2018), the electricity market system in Japan also experienced an important change in April 2016 with the switching from the third-party access model to the balancing group model. In the previous third-party access model, new power generation entrants operated their plants to keep the balance of supply and demand on a 30-minute basis, complementary to the power already supplied by the general electricity utilities. However, in the new balancing group model, both new entrants and general electricity utilities operate their power plants to keep the balance of demand and supply on a 30-minute basis.

One of the most significant developments in smart grid implementation in Japan is the massive deployment of smart meters. According to the Tokyo Electric Power Company (TEPCO) smart meter project, unlike conventional meters, smart meters provide at least three benefits: (i) smart meters have an electricity meter information transmission service that permits the transmission of the meters' measured values to the home energy management systems controller in real time; (ii) with smart meters, it is possible to understand the amount of current by analysing the electricity usage in 30-minute time intervals, which gives higher accuracy on the calculation of the expected load current compared with the conventional system, where estimation is based on a consumer's individual contract; and (iii) smart meter use improves work efficiency, as meter reading is no longer performed manually.

The Government of Japan aims to complete smart meter installation throughout the country in the mid-2020s. However, the current completion rate is just over 35% (Table 17.5).

Table 17.5 Deployment Status of Smart Meters in Japan

Electric power companies	Smart meters to be installed (in million)	Cummulative installation results as of 31 March 2017 (in million)	Percentage of installation results	Completion of installation (scheduled)
Hokkaido	3.70	0.767	20.7%	End of FY2023
Tohaku	6.66	1.480	22.2%	End of FY2023
Tokyo	27.00	10.604	39.3%	End of FY2020
Chubu	9.50	2.898	30.5%	End of FY2022
Hokuriku	1.82	0.373	20.5%	End of FY2023

Electric power companies	Smart meters to be installed (in million)	Cummulative installation results as of 31 March 2017 (in million)	Percentage of installation results	Completion of installation (scheduled)
Kansai	13.00	7.500	57.5%	End of FY2023
Chugoku	4.95	0.909	18.3%	End of FY2023
Shikoku	2.65	0.435	16.4%	End of FY2023
Kyushu	8.10	2.571	31.7%	End of FY2023
Okinawa	0.85	0.110	12.9%	End of FY2024
Nationwide	**78.23**	**27.647**	**35.3%**	**-**

Source: Shinkawa (2018).

Korea

According to the Korean Ministry of Knowledge Economy and the Korea Smart Grid Institute (2011), Korea's 'Smart Grid Road Map 2030', launched in January 2010, is to be implemented in five sectors: (i) smart power grid, (ii) smart consumers, (iii) smart transportation, (iv) smart renewables, and (v) smart electricity services. The following sectoral targets have been set:

(i) Smart power grid: to reduce the blackout time per household from 15 minutes (2012) to 9 minutes (2030) and to reduce the power transmission and distribution loss rate from 3.9% (2012) to 3% (2030).

(ii) Smart consumer: to reach the maximum power reduction by 5% (2020) and 10% (2030) and to reach a penetration rate of advanced metering infrastructure by 5.6% (2012) and 100% (2020).

(iii) Smart transportation: to reach a total number of electric vehicles (EVs) of 152,000 units (2020) and 2.4 million units (2030) while increasing the number of quick-charging stations from 100 units (2012) to 4,300 units (2020) and 27,140 units (2030).

(iv) Smart renewables: to increase the share of renewable energy use in the power sector from 3.1% (2012) to 11.0% (2030) and to increase the household electricity energy self-sufficiency ratio to 10% (2020) and 30% (2030).

(v) Smart electricity service: to allow consumers to choose their electricity rate plan by 2020 and to increase consumers' market participation rate to 15% (2020) and 30% (2030).

Korea's smart grid goals are to build a smart grid test bed, e.g. Jeju Carbon Free Island project (Korea Smart Grid Institute, 2011) for the five aforementioned implementation areas by 2012; to build a smart grid across Korea's metropolitan areas by 2020; and to build a nationwide smart grid by 2030. From 2010 to 2030, around W7 trillion ($6.6 billion) is allocated for technology development and another W20.5 trillion ($19.3 billion) for the construction of infrastructure. Amongst the main expected effects by 2030 are the 230 million tons of GHG reduction and about W47 trillion ($44.2 billion) of energy import reduction.

Jensterle et al. (2019) reported that apart from deploying micro-grids at the national level and accomplishing several complex smart grid experiences (islands and cities), Korea is pushing the penetration rate of smart meter use: by 2018, 6.8 million households in Korea were equipped with smart meters, while the 2020 target was to reach 22.5 million households, equal to 66% market penetration. Korea is also developing an integrated power control system that can better handle power supply from renewable sources, developing integrated top-level platforms that can connect various transmission and distribution systems in real time and significantly increasing its grid-connected battery energy storage, while developing quick EV chargers nationwide.

India

Sinha et al. (2011) documented three major drivers of smart grid development in India: (i) reducing power losses across its electricity system, (ii) providing varying electricity price signals to consumers, and (iii) integrating renewable energy sources. Based on the Central Electricity Authority's strategy blueprint issued in 2016, 57% of India's total electricity capacity will come from non-fossil fuel sources by 2027, which means a total installed renewable power generation capacity of 275 gigawatts by 2027 or 175 gigawatts by 2022. This estimated renewable share in power generation by 2027 is significantly higher than the Paris climate accord target for India, which was 40% by 2030.

Policy goals for smart grids in India's 12th Five Year Plan consist of the deployment of smart meters and advanced meter infrastructure, substation renovation and modernisation, deployment of micro-grids and distributed renewables, creating EV charging infrastructure, provision of harmonic filters and other power quality improvement measures, and real-time monitoring and control of distribution transformers.

The National Tariff Policy of 2006 requires utilities to introduce two-part tariffs and time-differentiated tariffs for large consumers with demand exceeding 1 MW. In January 2016, the Government of India revised the tariff policy, aimed at accelerating the deployment of renewable energy in the country. This included provisions for an 8% solar renewable purchase obligation by 2022, a renewable generation obligation on new coal/lignite based thermal plants, etc. (Ministry of Power, India, 2016). In 2013, the Ministry of Power also developed the 'Smart Grid Vision and Roadmap for India' drafted by the India Smart Grid Task Force (Smart Energy International, 2013). The National Smart Grid Mission, housed in the Ministry of Power, is the major government body that oversees smart grid implementation.

Smart Grid Progress in Asian Developing Countries

According to Brown, Zhou, and Ahmad (2018), in East Asia, the mega smart grid project in Malaysia and the Provincial Electricity Authority smart grid in Thailand are two major smart grid initiatives, but they both face technological challenges.

In Malaysia, RM2.7 billion (more than $650 million) will be invested in the 'Grid of the Future' (GoTF) – a modern grid and smart network that has robust capability for bidirectional flows of electricity, dynamic operations, and self-healing (Suruhanjaya Tenaga, 2018). Apart from advanced metering infrastructure, the GoTF includes other projects such as distribution automation, mobility solutions, geospatial information system, light-emitting diode streetlighting, and volt-vAR optimisation. These projects should increase the grid efficiency, reliability, and resiliency, as well as providing seamless integration with the distributed generation and the emergent technologies of energy storage and micro-grids. Amongst its plans on deploying smart meters, the GoTF will install 340,000 smart meters in Melaka and an additional 1.2 million smart meters in the Klang Valley.

According to Nhede (2017), Thailand's National Energy Policy Council approved a national smart grid plan to enhance the country's grid reliability. Under this plan, state-owned utilities will spend up to 200 billion ($5.6 billion) on implementing smart grid projects to 2036 to reduce utility firms' energy use by 350 MW by that year. The $5.6 billion will fund the deployment of up to five smart grid pilot projects under the guidance of Thailand's Ministry of Energy. Utility firms set to trial smart grid technologies under the approved plan include the Electricity Generating Authority of Thailand, the Provincial Electricity Authority, and the Metropolitan Electricity Authority. The pilot program included in the expedition plan of the Ministry of Energy administration by the Energy Planning and Policy Office comprises three pilot projects, i.e. two district projects in Mae Hong Son Province operated by the Electricity Generating Authority of Thailand, which consists of Muang and Mae Sariang Districts; and a smart grid project in Pattaya area, Chonburi Province, operated by the Provincial Electricity Authority.

The two projects in Mae Hong Son Province, which is mostly preserved forest area, are considered appropriate for the implementation of the pilot program. A total budget of nearly ฿2 billion ($72 million) has been allocated in the two districts aimed at ensuring the delivery of a stable electricity supply and adequate generation capacity. Power in the two districts comes from various sources and generation types previously considered as unstable. The system is expected to maximise the potential of the power system to increase its security, and to ensure reliability and overall power quality.

The smart grid project in Pattaya City Area covers major cities with high electricity demand, wide distribution of power consumers, and integrated communication and technologies. A total budget of ฿1.508 billion ($50 million) has been allocated, and Pattaya City has a policy to develop into a smart city. The Pattaya smart grid project is registered as one of the action plans of the ASCN. According to ASCN (2018a, 2018b), this project aims to move Chonburi forward to be a self-reliant, energy-efficient city with renewable energy sources and sustainable environmental management. It entails the management of electrical networks, generation systems, transmission systems, and power distribution systems, with a systematic energy management and energy storage structure.

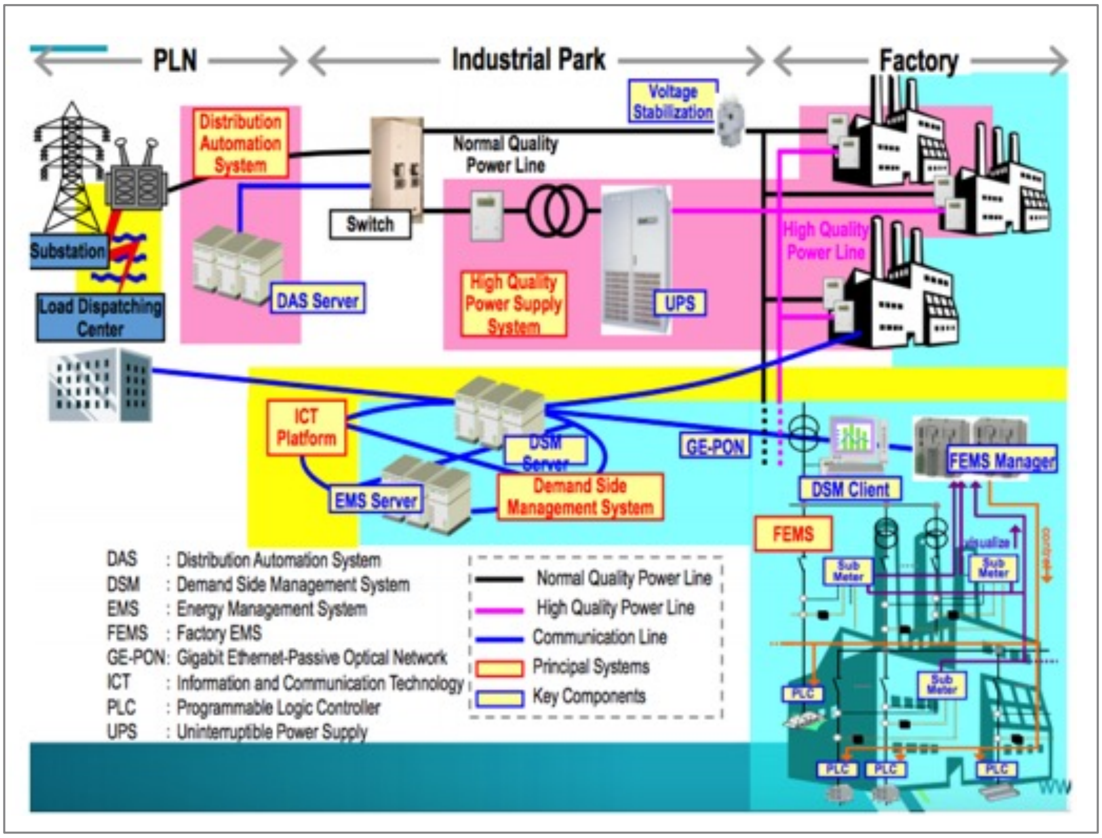
As of 8 July 2018, only two electricity utilities-related projects were registered in the action plans of the ASCN – the Pattaya city smart grid project and a waste-to-energy plant project in Chonburi Province. The latter project aims to address the waste treatment and management issues arising from the generated waste at Chonburi, and to source renewable energy integration and regional smart micro-grids, in line with the relevant national plans on built infrastructure development in Thailand.

In Indonesia, the state-owned electricity utility, PLN, is coordinating the plan, strategy, and implementation of smart grid development in the country. According to Arifin (2019), amongst the power sector issues in Indonesia are: transmission and distribution losses of around 8.75% (2017), which are higher than the ASEAN average of 7.24% (2016); data and information inaccuracy over the situation and functioning of the low-voltage network; service reliability, e.g. under 30% reserve margins in small systems outside Java and Bali; and the delivery of low-carbon energy and sustainability, e.g. limited reserve of fossil fuel based energy sources and low penetration rate of renewable energy use. Arifin (2018) divided the PLN smart grid road map into two phases:

(i) 2016–2021: PLN will focus on the formulation of strategies, introductory and pilot projects, defining standard capacity, and process building, as well as putting in place ICT and smart metering as the foundation of the smart grid.
(ii) 2021–2026: PLN will focus on more advanced features of the smart grid.

In collaboration with certain third parties, PLN is developing several pilot projects, most of which are in remote areas such as islands, with the deployment of micro-grid systems in combination with renewable-based power generation, e.g. the use of solar PV power generation. Amongst the most relevant smart city themes is the deployment of Advanced Metering Infrastructure (AMI) for customers in Jakarta and the development of a smart community in Karawang Industrial Estate in West Java. The project aims to find an appropriate business scheme that enables demand response management, which should result in better reliability and productivity of the system (Figure 17.22).

Figure 17.22 Smart Community of Karawang Industrial Estate



Source: Arifin (2018).

Conclusions and Recommendation

Based on the above analysis, we conclude that energy consumption in the EAS region will increase remarkably due to stable economic and population growth. It will continue to depend largely on fossil fuel energy, such as coal, oil, and gas until 2040 (BAU) even under a tough scenario of higher crude oil prices (about $120 per barrel in 2040 at 2016 constant prices). But the COVID-19 pandemic outbreak will have many short- and medium-term implications on energy infrastructure investment and the climate agenda in the ASEAN and East Asia region. The economic downturn is already contracting energy demand by 10%–15% in major economies and CO2 emissions in the short term (IEA, 2020). However, there will certainly be a rebound when the economy recovers. This effect is compounded by extremely low oil prices, which were triggered by rivalries amongst the major oil producing countries, damaging the supply capacity of several small producers in the region. While low oil prices could push down liquefied natural gas (LNG) bills, this would also bring down the production cost of domestic coal. Cheaper fossil fuels would make renewable energy less competitive.

Governments that are preoccupied with fighting the pandemic, and restoring jobs and the economy, are likely to treat energy conservation and climate change issues as lower priorities. Revisiting technology dependence on China could affect the high reliance on Chinese solar modules. The surge of nationalism and retreat of globalism will also have a negative impact on national, regional, and global endeavours for tackling climate change. Since governments prioritise public expenditure on fighting the pandemic and rescuing impacted families and small businesses, the financial resources available for clean energy investment or subsidies will become extremely limited. Since cheap energy would be an even higher priority in economic difficulties, reliance on domestic energy resources and coal could last longer than expected before the pandemic.

On the other hand, ongoing social distancing practices – such as moving almost all activities to the internet (e.g. meetings, works, and shopping), the modal shift from mass to private transport, and avoidance of long-distance air travel – could change the energy consumption pattern and lessen energy use, air quality, and carbon emissions. The ASEAN and East Asian region should have been able to take advantage of the low fossil fuel prices, especially during 2020, to initiate efforts for phasing out inefficient fossil fuel subsidies.

Nevertheless, if the countries dedicate themselves to implementing their EEC policies and increase low-carbon energy technologies, such as nuclear power generation and solar PV/wind, the region could achieve remarkable energy savings – especially through lower use of fossil fuels – and significantly reduce carbon emissions. The APS of many countries in the region is very appropriate because its expected carbon reduction is the same or larger than the countries' INDC targets. Therefore, ASEAN and East Asian countries need to apply the Plan-Do-Check-Act (PDCA) cycle approach to promote their EEC and renewable energy policies, specifically energy saving targets and action plans according to their respective timetables.

Natural gas will grow at the highest rate up to 2040 amongst the fossil fuels, and will be an important fuel as the transition to a new energy system occurs because of lower prices than crude oil, various import sources, and lower carbon emissions compared with oil and coal. To realise this increase, the establishment of a transparent LNG market in Asia, the removal of the destination clause, and consumers' participation in LNG development, amongst others, are recommended.

The outlook analysis of future energy demand also shows that a lot of energy savings, especially on oil and electricity consumption by final users, will come from energy efficiency activities. So, the following EEC policies are recommended: (i) standardise the labelling system for appliances and energy facilities such as boilers and compressors; (ii) develop energy saving companies; (iii) increase next-generation vehicles including hybrid vehicles, EVs, plug-in hybrid vehicles, and fuel cell vehicles; (iv) establish and implement a green building index; and (v) develop an advanced energy management system.

Increasing the share of renewable energy – such as hydro, geothermal, solar PV, wind, and biomass – will contribute to reduced fossil fuel consumption and mitigate carbon emissions, and thus contribute to global trends, via the INDCs and SDGs. This will require appropriate government policies such as renewable targets, legal approaches such as feed-in tariffs/Renewable Portfolio Standards, and revised feed-in tariffs to include bidding and tendering processes.

Energy supply security in the EAS17 region is a top-priority energy issue. EEC and renewable energy contribute to maintain regional energy security by reducing fossil fuel consumption and increasing the use of domestic energy. Moreover, energy supply sources can be diversified through regional energy networks such as the Trans-ASEAN Gas Pipeline, including LNG transportation as a virtual pipeline, and the APG with the region-wide electricity trade market. The LTM (Lao PDR, Thailand, and Myanmar) is a starting point of the APG. Oil stockpiling and nuclear power generation is another option to secure energy supply in the region. Greater use of clean coal technology and the development of carbon capture and storage technology is also critical for the region because it will make coal power plants in the region carbon-free. Hydrogen technology also has a key role as an alternative to the use of fossil fuels, as it can be applied across sectors, such as in the power generation, industry, and road transport sectors.

The EAS countries will need around $4 trillion for the construction of power plants, refineries, and LNG-receiving terminals under BAU, but power generation plants will be the largest share – estimated at around $3.5 trillion. ASEAN needs about $686 billion under BAU for the total energy infrastructure of combined power generation, refineries, and LNG-receiving terminals, and $605 billion in the APS. The difference comes from refineries and LNG-receiving terminals due to savings in oil and gas consumption. Under

BAU, a lot of money will be allocated to coal power plants (clean coal technology), whereas under the APS, more money will be allocated to low-carbon energy electricity, such as nuclear, geothermal hydropower, solar PV/wind, and biomass.

Consequently, financing schemes to develop energy infrastructure – such as public–private partnerships, public financing by international/regional banks, the Clean Development Mechanism, and/or the Joint Credit Mechanism – will be essential. Moreover, economic stimulus packages being designed by governments as part of the COVID-19 recovery could offer opportunities for high-quality low-carbon infrastructure investments that will bring more socio-environmental benefits. AMS should capture this opportunity. A domestic and cross-border electricity network could be a promising candidate, offering both energy security and climate benefits.

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