5. Secure, Affordable, and Sustainable Energy for All

Jun Arima, Yanfei Li, Han Phoumin, and Shigeru Kimura

May 2019

This chapter should be cited as
Arima, J., Y. Li, H. Phoumin, and S. Kimura (2019), 'Secure, Affordable, and Sustainable Energy for All', in Kimura, F., V. Anbumozhi, H. Nishimura. (eds.), *Transforming and Deepening the ASEAN Community*, Jakarta: ERIA, pp.105-146.

Secure, Affordable, and Sustainable Energy for All

Jun Arima,
Yanfei Li,
Han Phoumin
Shigeru Kimura,
Economic Research Institute for ASEAN and East Asia

1. Vision Statement

Energy is one of the most basic inputs for any kind of economic activity and, more broadly, human life. As the Association of Southeast Asian Nations (ASEAN) aims at further prosperity towards 2040 through the ASEAN Single Market (ASM), secure, affordable, and environmentally sustainable energy supply for all is crucial in each country and the region. However, the Economic Research Institute for ASEAN and East Asia (ERIA) Energy Outlook and Saving Potentials in East Asia Summit[1] (ERIA, 2018a) forecasts rapid growth in energy demand, higher oil import dependence, and a still dominant share of fossil fuels, notably coal and higher carbon dioxide (CO_2) emissions, towards 2040. This could threaten a stable supply of affordable energy and the national, regional, and global environment.

[1] The East Asia Summit (EAS) is a meeting of 18 regional leaders for strategic dialogue and cooperation on the key political, security, and economic challenges facing the Indo-Pacific region. The EAS comprises the 10 member-states of ASEAN along with Australia, China, India, Japan, the Republic of Korea (henceforth, Korea), New Zealand, the Russian Federation, and the United States.

ASEAN member countries have a lot to do to change this pathway. They need to be well prepared for possible oil supply disruption; enhance energy efficiency; reduce oil demand, particularly in the transport sector; clean the use of fossil fuels; promote energy diversification to such sources as natural gas and renewable energy; alleviate local air pollution; and minimise the growth of CO_2 emissions. Most fundamentally, as a basic input for economic and human activities, energy needs to be accessible to all at affordable prices. These goals cannot be achieved simply through target setting (e.g. energy mix, CO_2 emissions), but require concrete actions. Given multiple uncertainties (e.g. the international and domestic political and economic situation, technology development, scientific knowledge), the plan–do–check–act (PDCA) cycle is recommended, with sufficient flexibility and multiple pathways.

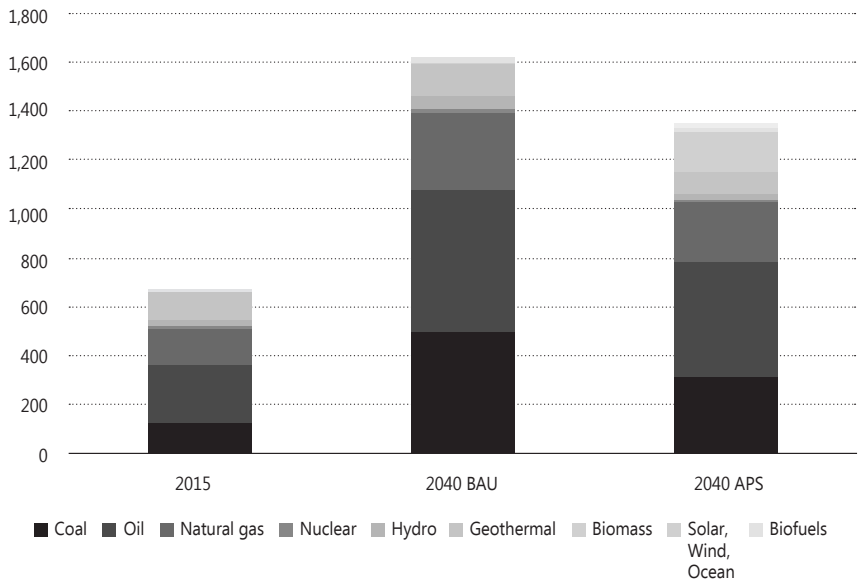
Some of the above goals could be more efficiently and effectively pursued through regional collaboration (ASEAN-wide, plurilateral, or bilateral), including emergency response measures, cross-country energy interconnections, and harmonisation of energy-related standards and a regulatory environment for energy industries. They also require capacity building of policymakers and enhanced public awareness. Again, regional collaboration through learning from each other and sharing best practices, including via peer review, could make a significant difference. The concept of an 'ASEAN Energy Community' is a remote vision given different national circumstances (e.g. the energy endowment, economic development, and energy mix to be pursued) and sovereignty in energy policy making, but if ASEAN ultimately aims in that direction, it should start with areas where regional collaboration is feasible.

2. Energy Outlook in 2040

ERIA (2018a) projects ASEAN's total primary energy supply (TPES) to grow by 143% from 667 million tons of oil equivalent (Mtoe) in 2015 to 1,624 Mtoe in 2040 under the business-as-usual (BAU) scenario, reflecting each country's current goals, action plans, and policies. Even under the alternative policy scenario (APS), assuming (i) more efficient final energy consumption, (ii) more efficient thermal power generation, (iii) higher consumption of new and renewable energy and biofuels, and (iv) the introduction of higher utilisation of nuclear energy for countries which

have chosen to do so, the TPES is projected to grow by 102% to 1,346 Mtoe in 2040. During the same period, ASEAN's total power generation will achieve higher growth, at 184% under BAU and 139% under the APS. Figure 1 shows total primary energy supply in ASEAN of the base year of 2015 and the estimated year of 2040 for both BAU and APS.

Figure 1: Total Primary Energy Supply in ASEAN (Mtoe)

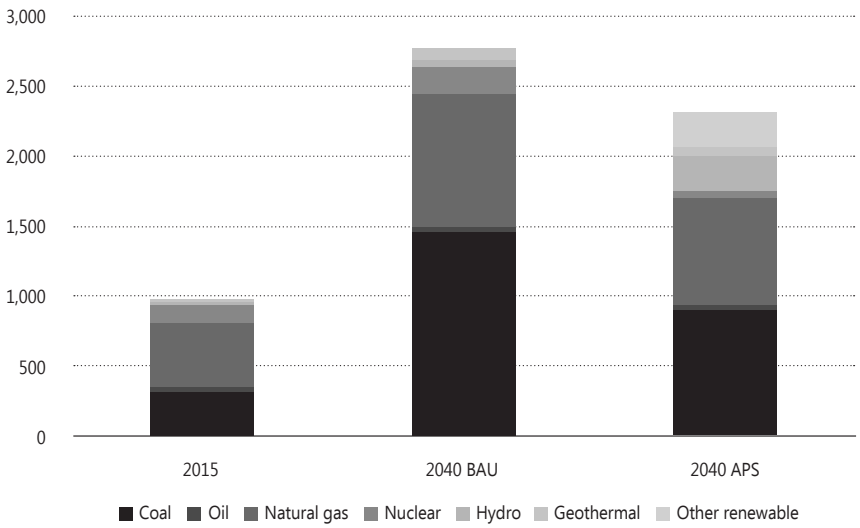


APS = alternative policy scenario, ASEAN = Association of Southeast Asian Nations, BAU = business as usual, Mtoe = million tons of oil equivalent.

Source: ERIA (2018a).

Regarding the energy mix, the share of fossil fuels will grow from 76% (coal 19%, oil 35%, gas 22%) to 86% (coal 31%, oil 36%, gas 19%) under BAU. While this trend is the same in the power generation mix as shown in the Figure 2, where the share of fossil fuels will grow from 83% (coal 33%, oil 3%, gas 47%) to 88% (coal 53%, oil 1%, gas 34%), the high growth of coal deserves attention. Under the APS, where a higher share of non-fossil fuels is envisaged, the share of fossil fuels out of the total primary energy supply is still dominant at 76% in 2040 (coal 23%, oil 36%, gas 18%). In power generation, where more rapid growth of renewable energy is envisaged in 2040 (25%), the share of fossil fuels in 2040 will decline to 73% (coal 39%, oil 1%, gas 33%), but still be dominant.

Figure 2: ASEAN Power Generation Mix (TWh)

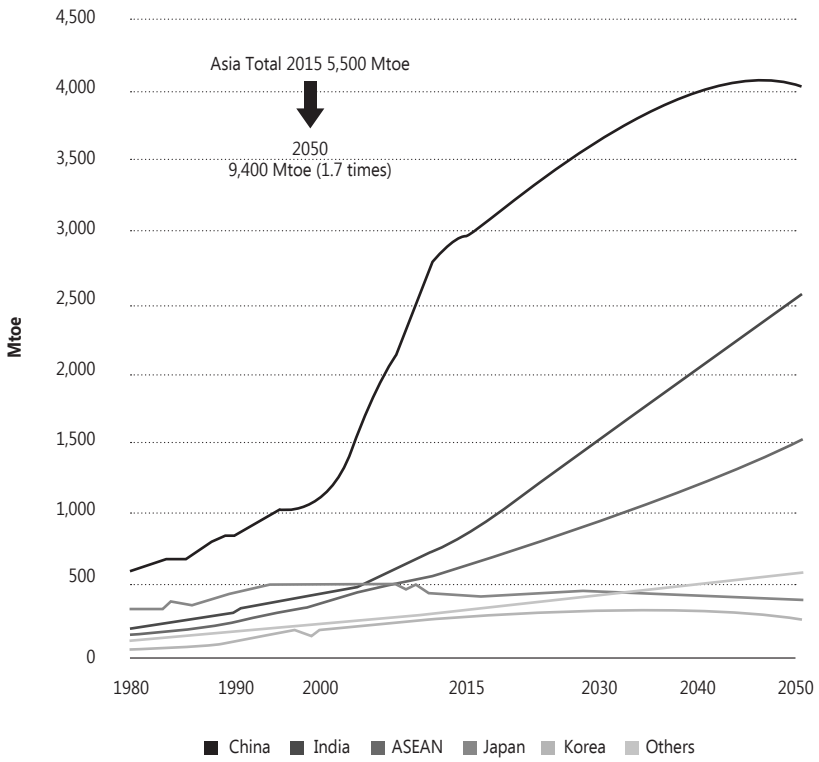


APS = alternative policy scenario, ASEAN = Association of Southeast Asian Nations, BAU = business as usual, TWh = terawatt-hour.

Source: ERIA (2018a).

Consistent with robust economic growth, energy demand growth in the ASEAN region will be higher than in other regions as shown in Figure 3. The Institute of Energy Economics, Japan (IEEJ, 2018) projects annual growth of total primary energy consumption from 2015 to 2050 to be 2.6% in ASEAN and 3.2% in India, compared with 1.1% for the world total, 1.7% in non-Organisation for Economic Co-operation and Development (OECD) Asia, and 0.9% in China.

Figure 3: Energy Demand Growth in Asia by Country

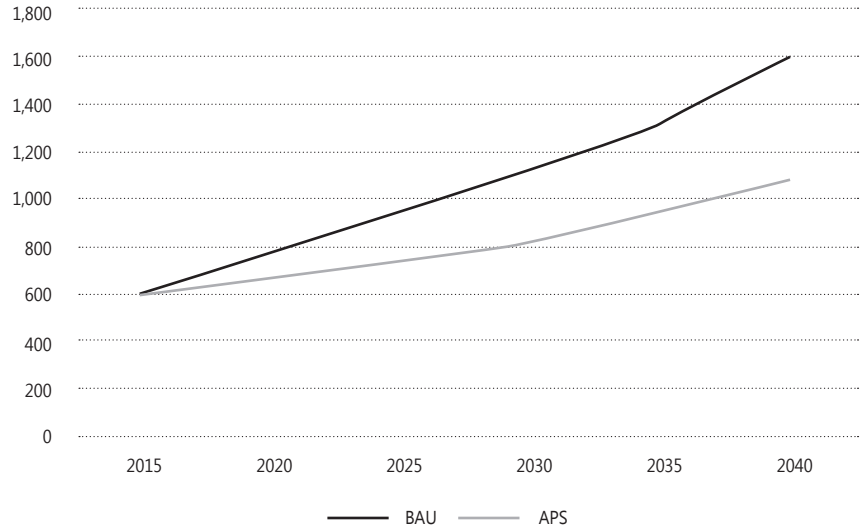


ASEAN = Association of Southeast Asian Nations, Mtoe = million tons of oil equivalent.

Source: IEEJ (2018).

Given the robust growth in energy demand and the continued dominance of fossil fuels in the energy mix, energy-related CO_2 emissions in ASEAN as shown in Figure 4 will grow by 169% from 587 million tons of carbon (Mt-C) in 2015 to 1,581 Mt-C in 2040 under BAU. Under the APS, assuming higher energy efficiency and a higher share of non-fossil fuels, CO_2 emissions will increase by 84% to 1,077 Mt-C in 2040. More than 70% of the CO_2 emissions reduction from BAU to the APS are attributed to improved energy efficiency in the end use sectors.

Figure 4: ASEAN Energy-Related CO2 Emissions (Mt-C)

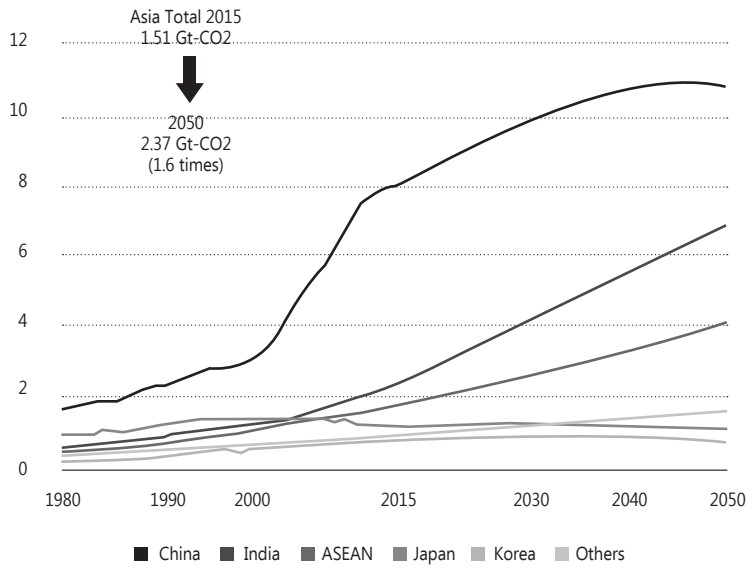


APS = alternative policy scenario, ASEAN = Association of Southeast Asian Nations, BAU = business as usual, CO_2 = carbon dioxide, Mt-C = million tons of carbon.

Source: ERIA Energy Outlook 2018a.

Like the energy demand trend, Figure 5 shows how ASEAN and India will show higher growth of energy-related CO_2 emissions than other regions. IEEJ (2018) projects the annual growth of CO_2 emissions from 2015 to 2050 to be 3.0% in ASEAN and 3.4% in India, against 0.8% for the world total, 1.4% in non-OECD Asia, and 0.3% in China.

Figure 5: CO_2 Emissions in Asia by Country (Gt-CO_2)



ASEAN = Association of Southeast Asian Nations, Gt-CO_2 = gigatons (1 billion tons) of carbon dioxide.
Source: IEEJ (2018a).

3. Secure and Affordable Energy System Towards 2040

Securing Affordable Energy Access

Access to a modern type of energy is one of the most basic human needs. In 2016, 65 million people did not have access to electricity and 252 million relied primarily on the traditional use of biomass in the ASEAN region. This situation could threaten the region's sustainable economic growth. Energy is strongly linked to economic opportunity, as electricity is used as an input to generate economic goods and services. Table 1 shows access to modern energy services in ASEAN. Of the ASEAN countries, Cambodia and Myanmar still have very low access to electricity in rural areas. In some remote areas of ASEAN countries, the root cause of energy poverty is not just the energy price and poverty, but the lack of access to modern energy because of inadequate energy infrastructure. Intermittent energy supply and/or electricity blockades is a challenge in urban centres. Electricity access at affordable prices is more challenging in small islands of archipelagic countries like Indonesia and the Philippines. Research suggests that energy poverty has important consequences if

not addressed, such as impacting health, entrenching poverty, adversely affecting the Human Development Index indicators, and making most of the Sustainable Development Goals (SDGs) less attainable. Therefore, achieving energy access for all in an equitable manner is a high priority for most ASEAN countries.

Table 1: Access to Modern Energy Services in ASEAN

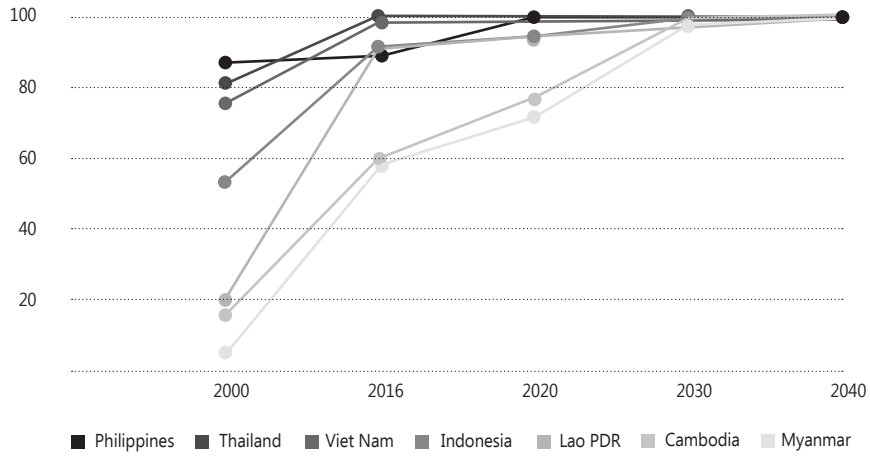
Country	Population without access to electricity (2016)		Population primarily relying on traditional use of biomass (2015)	
	Million	Share (%)	Million	Share (%)
Brunei Darussalam				
Cambodia	6	40%	13	83%
Indonesia	23	9%	67	26%
Lao PDR	<1	9%	7	96%
Malaysia	<1	1%		
Myanmar	22	41%	51	94%
Philippines	11	10%	61	60%
Singapore				
Thailand			18	26%
Viet Nam	2	2%	36	39%
Total ASEAN	65	10%	252	40%

ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.
Source: IEA (2017b).

As shown in the Figure 6, the International Energy Agency (IEA) projects that universal electricity access will be achieved by the early 2030s in all ASEAN countries. Globally, 67% of people who gained access to electricity from 2000 to 2015 did so via fossil fuels (coal, gas, and oil), while the share of renewable energy (hydropower, geothermal, solar, and wind) is increasing. Figure 7 shows how estimate from IEA (2017a) on the number of people gaining electricity access by fuel type in developing countries. As the cost of renewable energy technologies falls, universal electricity access in ASEAN will be achieved using a wide range of fuels and

technologies, as well as centralised and decentralised solutions (Figure 8). The IEA projects that mini-grid or off-grid technologies will fulfil more than half of additional electricity demand for ensuring universal access. Varying resource distribution, distance from existing demand centres, and population density mean that there is no one-size-fits-all approach.

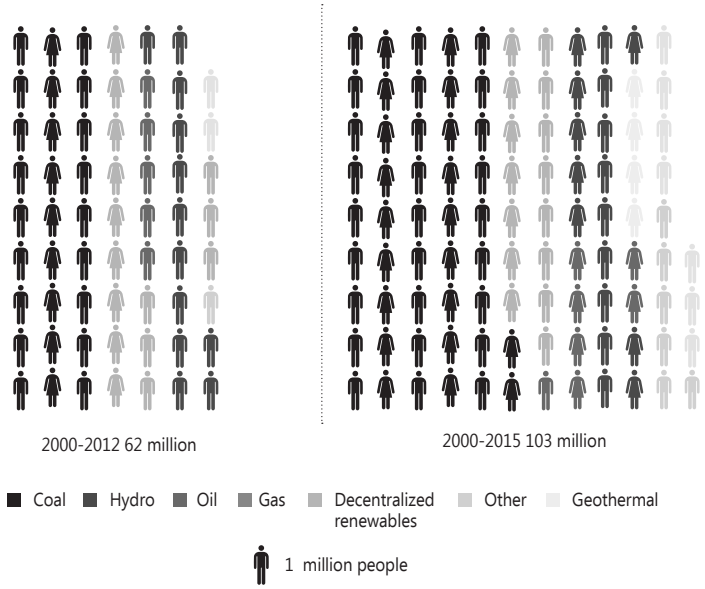
Figure 6: Electricity Access Rates of Southeast Asia (%)



Lao PDR = Lao People's Democratic Republic.

Source: IEA (2017b).

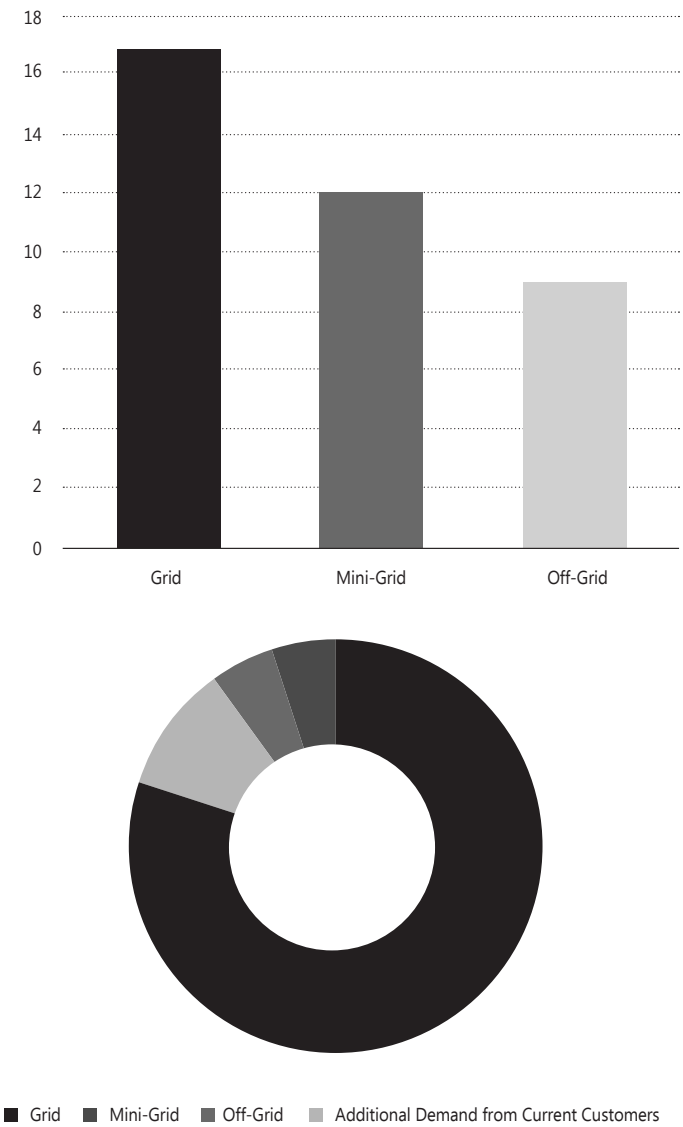
Figure 7: Annual Number of People Gaining Electricity Access by Fuel Type in Developing Countries



Solar PV: Solar photovoltaic

Source: IEA (2017a).

Figure 8: Additional Demand for Access and its Share of Total Incremental Demand in 2030 in ASEAN (TWh)



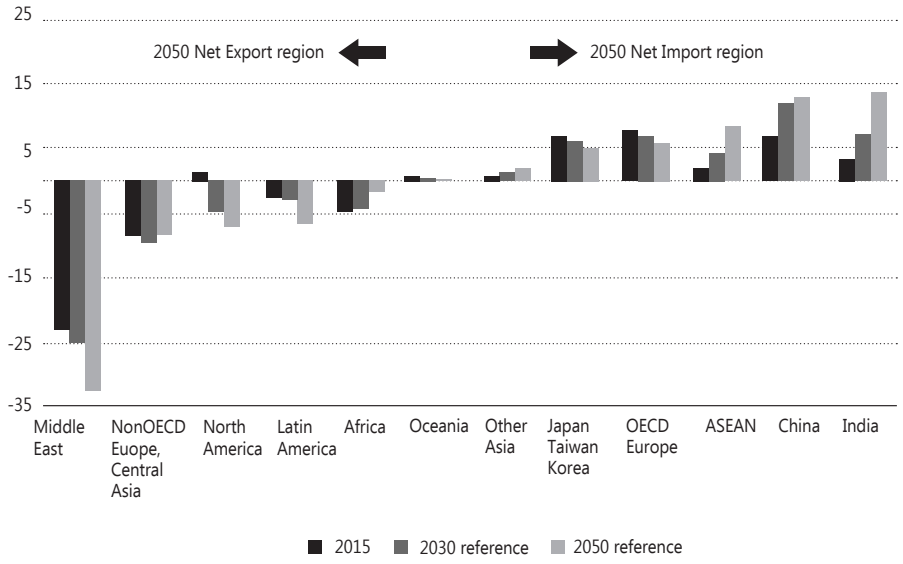
ASEAN = Association of Southeast Asian Nations, TWh = terawatt-hour.
Source: IEA (2017b).

In ensuring energy access for all, affordability is crucial. Basic electrification is largely considered a public good to be provided by the government. It is not fair that the poor in rural or isolated areas have to pay higher energy costs than the rich in urban areas because of the high cost or difficulties of electrification. Economically, an orthodox approach is to provide direct income support to the low-income population instead of subsidising energy prices. However, some countries may find it difficult to bridge the electrification gap while ensuring affordable prices given limited fiscal space. For example, Myanmar is estimated to need more than $30 billion to achieve universal access while its annual tax revenue is less than $5 billion. To mobilise private funds into infrastructure for electrification, governments may consider a cross-subsidy approach to improve the affordability and reliability of energy infrastructure development. For example, differentiated electricity prices, such as step-wise electricity tariffs, can collect more revenue from rich social groups or well-developed areas to subsidise poor social groups or remote rural areas. ERIA (2018c) indicates that the private sector and international community have the potential to help rural electrification, but more technological and financial innovations and stronger support are needed to enhance synergies.

Enhancing Emergency Preparedness

Since regional oil demand will increase rapidly (2.5 times) from 2016 to 2040 and regional production will not be able to keep pace with it, the ASEAN region and India will see a rapid increase in net oil imports. Most incremental oil imports come from the Middle East through such choke points as the Strait of Hormuz and the Strait of Malacca, even taking into account the prospect of shale oil imports from the United States (US), so the ASEAN region will be particularly vulnerable to supply disruptions caused by events such as natural disasters, accidents, regional conflict, terrorist attacks, and piracy. Figure 9 shows net exports and imports of world's major regions.

Figure 9 : Net Exports and Imports of Major Regions
(million barrels per day)



ASEAN = Association of Southeast Asian Nations, OECD = Organisation for Economic Co-operation and Development.
Source: IEEJ (2018).

In safeguarding against supply disruptions, the ASEAN region needs to enhance its emergency preparedness through developing early warning systems, oil stockpiling, preparing measures for demand restraint and fuel switching in each country, and establishing regional cooperative arrangements for coping with emergencies.

Stockpiling is the typical countermeasure that addresses oil supply security and resilience. All countries recognise the need to develop stockpiling. Establishing stockpiling is a lengthy and costly business, but it is the basis of any supply security policy. Several stockpiling options are available. The traditional approach, which obliges industry to maintain stocks followed by institutionalised government stockpiling, will be the main path for stockpile development mainly because of national security concerns. However, low-cost options such as tickets and/or investments from third parties (tank companies and crude exporters) could expand tank capacity. Given domestic financial (budget) constraints, it is necessary to tap into the dynamics and capability of third parties by creating a favourable investment environment. It is critical for governments in the region to address oil stockpiling with a portfolio

of traditional and low-cost approaches to expand storage capacity and institutionalise oil stockpiling.

Infrastructure development is important. It should include not only oil-related infrastructure such as refineries and pipelines but also general social infrastructure like roads and ports, which are prerequisites for oil transportation. Given the multi-utility of roads, ports, and other social infrastructure, it is the government's responsibility to develop such infrastructure.

Planning, an institutional and legal framework, and education are very important for oil supply resilience, aside from hardware such as refineries, tanks, and pipelines. Developing this framework is a time-consuming process, and governments in ASEAN member countries are encouraged to start before the next disaster happens. In terms of the institutional and legal framework, industries can work on enhancing their resilience to natural disasters and other risk factors associated with oil supply. They could start by making a business continuity plan under the PDCA cycle.

It is important to utilise or revitalise existing institutional platforms for oil supply resilience. ASEAN member countries have been working on the ASEAN Petroleum Security Agreement (APSA) since 1986 and these countries generally value a regional oil-sharing scheme. However, its functionality during an emergency is questionable. In addition, the ASEAN Council on Petroleum (ASCOPE) recently revealed the uncertain future of APSA after it expires in 2023. While APSA remains important, the uncertainty reflects varied views on the scheme among ASEAN member countries. Therefore, it may be realistic to start with an oil-sharing scheme by selected countries that are willing to participate. In this sense, it is worth considering international cooperation on a stockpiling facility and crude oil terminal in Kalimantan, which Indonesia is planning to develop.

More broadly, the East Asia Summit (EAS) region as a whole is vulnerable to oil supply disruption. This means that EAS regional cooperation on emergency preparedness makes sense. Various initiatives related to emergency preparedness in Asia are ongoing, such as the Oil Stockpiling

Roadmap under ASEAN+3[2] and the Oil and Gas Security Initiative under the Asia-Pacific Economic Cooperation (APEC) Energy Working Group. However, the Oil Stockpiling Roadmap does not cover two big players: (i) India, whose oil demand growth will be much faster than the EAS average; and (ii) the US, which has growing export potential to Asia. Meanwhile, the Oil and Gas Security Initiative does not cover Cambodia, India, the Lao People's Democratic Republic (Lao PDR), and Myanmar. Taking into account the membership coverage of the EAS, its share of global oil demand, and the presence of both producers and consumers, it is the most appropriate forum for addressing emergency preparedness in the region. The EAS Energy Cooperation Task Force (ECTF) is focusing its efforts on three workstreams: (i) energy efficiency and conservation, (ii) biofuel for transport and other purposes, and (iii) renewable and alternative power generation. However, it does not address emergency preparedness. The Cebu Declaration (2007), on which the ECTF was established, clearly reaffirmed the 'collective commitment to ensuring energy security for our region' and its intention to explore 'possible modes of strategic fuel stockpiling such as individual programmes, multi-country and/or regional voluntary and commercial arrangements'. Given the increasing dependence on oil imports from the Middle East and growing vulnerability to supply disruptions, the ECTF should address oil emergency preparedness, including taking stock of progress in the ongoing APEC and ASEAN+3 initiatives and avoiding duplication of efforts.

Mobilising Huge Investment Needs

Investment is vital in both energy supply and demand to mitigate the security of supply concerns as well as transitions to a more sustainable energy system towards 2040.

ERIA (2018a) estimates that $430 billion–$440 billion is necessary in the power generation sector, $149 billion–$226 billion for refinery, and $0.16–$28 billion for liquefied natural gas (LNG) terminals. As shown in Table 2, IEA (2017b) estimates that $2.1 trillion is required for oil, gas,

[2] ASEAN + China, Japan, and Korea.

coal, and power supply. Power sector investment accounts for 60% of the total energy supply investment needs since robust economic growth and reaching universal electricity access require significant financial resources. Investment in transmission and distribution accounts for more than half of the total investment needs in the power sector. Figure 10 from IEA (2017) shows a breakdown of necessary energy supply investment in ASEAN between 2017 and 2040.

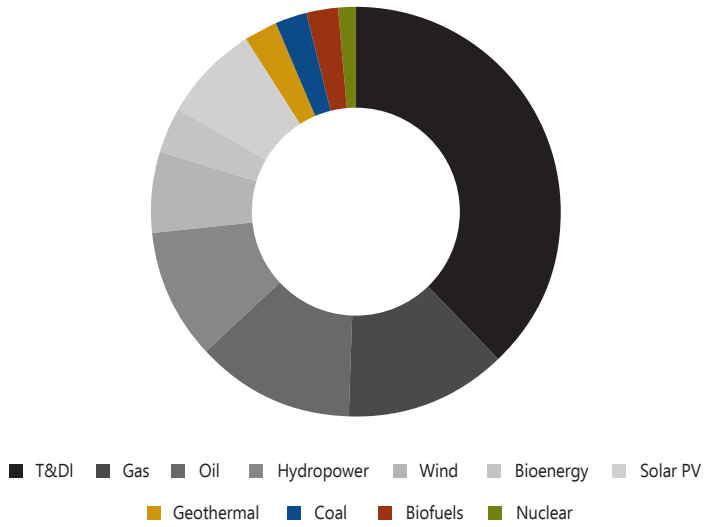
Table 2: Cumulative Investment in Energy Supply in ASEAN, 2017–2040 (2016 $ billion)

Energy source	2017–2025	2026–2040	2017–2040	2017–2040
Oil	146	206	352	15
Gas	120	303	423	18
Coal	14	25	39	2
Power	387	855	1,242	52
Fossil fuel	82	149	231	10
Nuclear	-	9	9	0
Hydropower	46	99	145	6
Bioenergy	11	21	32	1
Wind	9	34	44	2
Geothermal	7	10	17	1
Solar PV	26	62	88	4
T&D	207	470	677	28
Biofuels	7	18	25	1
Total	**674**	**1,407**	**2,081**	**87**

PV = photovoltaic, T&D = transmission and distribution.

Source: IEA (2017b).

Figure 10: Net Exports and Imports of Major Regions
(million barrels per day)



PV = photovoltaic, T&D = transmission and distribution.
Source: IEA (2017b).

The magnitude of investment needs poses a major challenge for the ASEAN region. For example, IEA (2017b) estimates that $1.2 trillion investment is necessary in the power sector towards 2040, which requires annual investment of $50 billion. Since this is equivalent to about 10% of the total ASEAN countries' government revenue, it represents a large burden for government budgets which are facing expenditure demands in multiple areas. Therefore, private sector participation is essential for mobilising the necessary investment resources. One way to mobilise private sector participation is through independent power producers, but their limited role in the power markets of many ASEAN countries could hinder this option. As the huge investment needs exceed what governments can afford, expanding the role of the private sector in power markets should be seriously considered. The feasibility of different innovative models of private financing should be considered for the region, such as a regional transition fund, best regulatory practices, and third-party warranty programs. These require various regulatory and institutional reforms, including electricity market deregulation, liberalisation of electricity pricing, phasing out of energy price subsidies, innovative models of private financing (e.g. regional transition fund, third-party warranty programs), and stronger capacity building of the private sector and financial institutions.

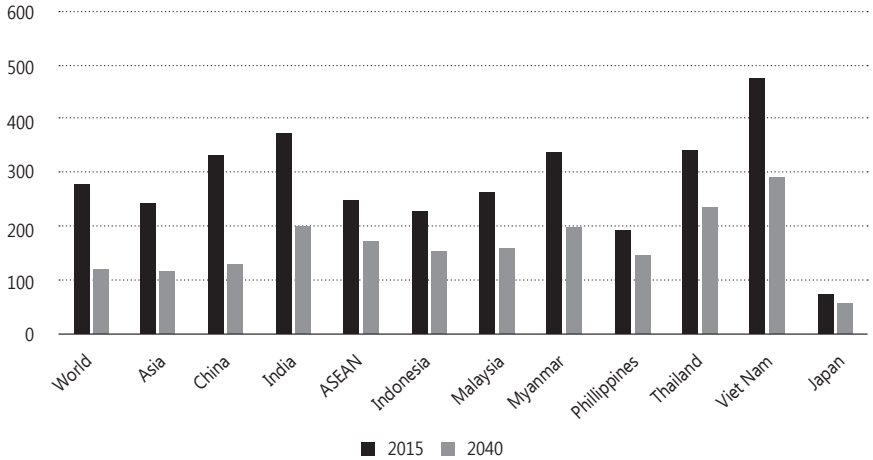
At the same time, policies promoting energy efficiency in the power sector have significant potential for reducing energy costs. Policies and measures to reduce the perceived risks (e.g. policy as well as technology uncertainty and public acceptance issues) of energy projects could also reduce energy costs since the costs of financing these projects could be cut. Such policies are also typically more feasible in achieving near-term policy targets. In such countries as Philippines, reforming the power sector and enable legacy power generation assets to compete in the market, thus get dispatched on real cost basis, has significant potential to reduce the cost of electricity This may help bring down the system cost further.

Improving Energy Efficiency

Improving energy efficiency is the most cost-effective way to achieve energy security, climate mitigation, and economic growth simultaneously, underpinned by industrial competitiveness. Therefore, it should be promoted with the highest priority as a 'no-regrets' policy.[3] Despite continuous efforts by ASEAN countries for improving energy intensity, the ASEAN region still has ample potential for improving energy efficiency. In Figure 11, IEEJ (2018) indicates that the energy intensity (primary energy consumption per gross domestic product at 2010 prices) of the ASEAN region was higher than the global and Asia averages in 2015 and will continue to be so in 2040. The ASEAN Plan of Action for Energy Cooperation (APAEC) sets an aspirational target of reducing energy intensity by 30% by 2025.

[3] No regrets options are greenhouse gas (GHG) emissions reduction options that have negative net costs, because they generate direct or indirect benefits that are large enough to offset the costs of implementing the options.

Figure 11: Regional Comparison of Energy Intensity
(toe/million, 2010 US dollar prices)



ASEAN = Association of Southeast Asian Nations, toe = ton of oil equivalent, US = United States.
Source: IEEJ (2018).

The industry sector is a major source of energy savings since it is the largest energy-consuming sector. Its share of total final energy consumption will grow from 30% in 2015 to 35% in 2040. Large factories and power plants consuming large amounts of energy should be required to measure and report their energy consumption levels as well as consider investment plans for improving their overall energy efficiency levels. Improving thermal efficiency in the power generation sector, by constructing or replacing existing facilities with new and more efficient generation technologies and introducing high-efficiency industrial motors, will be instrumental. Small and medium-sized enterprises require special attention because of their significant presence in the regional economy.

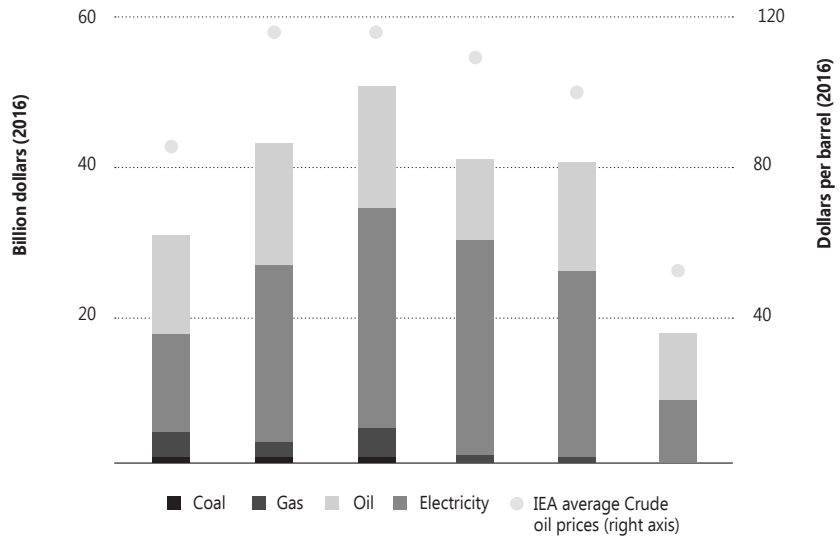
In accordance with population growth and urbanisation, energy efficiency in the building sector will play a crucial role. Since the demand for new buildings is likely to grow, governments should set up and enforce mandatory building codes as well as reward green buildings. They could also provide financial support for retrofitting technologies to improve energy efficiency in existing buildings and establish funds for supporting the utilisation of Energy Service Company (ESCO) services for accelerated diffusion of energy saving technologies, using levies on petroleum.

Minimum efficiency performance standards of appliance, machinery, and equipment are instrumental for improving efficiency in the residential, commercial, and industrial sectors. Since ASEAN is aiming at a common market, it could play a leading role in exploring the harmonisation of minimum efficiency performance standards in the region.

Across the sectors, information and communication technology (ICT), the internet of things (IoT), and artificial intelligence (AI) have great potential for improving energy efficiency without sacrificing final consumers' utility. For example, energy efficiency in houses, offices, and factories could be optimised through household, building, and factory energy management systems. ERIA's case studies in Indonesia, Malaysia, Singapore, Thailand, and Viet Nam identify energy-saving potential through household, building, and factory energy management systems as well as policy recommendations for incentivising their deployment (e.g. mandatory reporting and target setting on energy management, and capacity building of energy managers). Consumers' behaviour and consumption patterns could also be drastically changed by ICT, IoT, and AI, which will also affect energy consumption levels. For example, the penetration of car sharing, facilitated by ICT, could reduce the number of individual passenger vehicles and hence oil demand in the transport sector.

Cost-reflective energy pricing is a prerequisite for effectively incentivising energy efficiency. Electricity and oil are still subsidised in the region as shown in Figure 12. Energy price subsidies often encourage wasteful use of energy, discourage energy efficiency investment, and increase energy-related CO_2 emissions. While ASEAN countries are taking steps towards subsidy reforms, the recent reduction in fossil fuel subsidies is largely attributable to the drop in crude oil prices. Continuous subsidy reforms, with better targeting for vulnerable groups, are crucial. Credible information, including end user data and a harmonised/coordinated policy approach by the ASEAN countries, is essential.

Figure 12: Fossil Fuel Subsidy in Southeast Asia



IEA = International Energy Agency.

Source: IEA (2017).

Reduction of Oil Demand in Transport Sector

Energy efficiency in the road transport sector is crucial. Since the bulk of incremental oil demand will come from this sector, improving energy efficiency would enhance resilience for oil supply security. Setting mandatory fuel efficiency standards and their periodic revision is indispensable for improving road transport efficiency. For example, ASEAN could take an initiative for developing a regional Top Runner Program[4] on the fuel efficiency of heavy vehicles and two-wheelers.

To reduce oil demand in passenger transport, a modal shift to public transport should also be promoted. A key element in promoting such a shift is accessibility and economic attractiveness, i.e. to extend/expand the public transport network and to make public transport cheaper or increase the cost of private car ownership. Kutani et al. (2015) indicates that a megacity like Jakarta requires mass rapid transit such as the metro, with dedicated lines to mitigate traffic congestion and oil consumption.

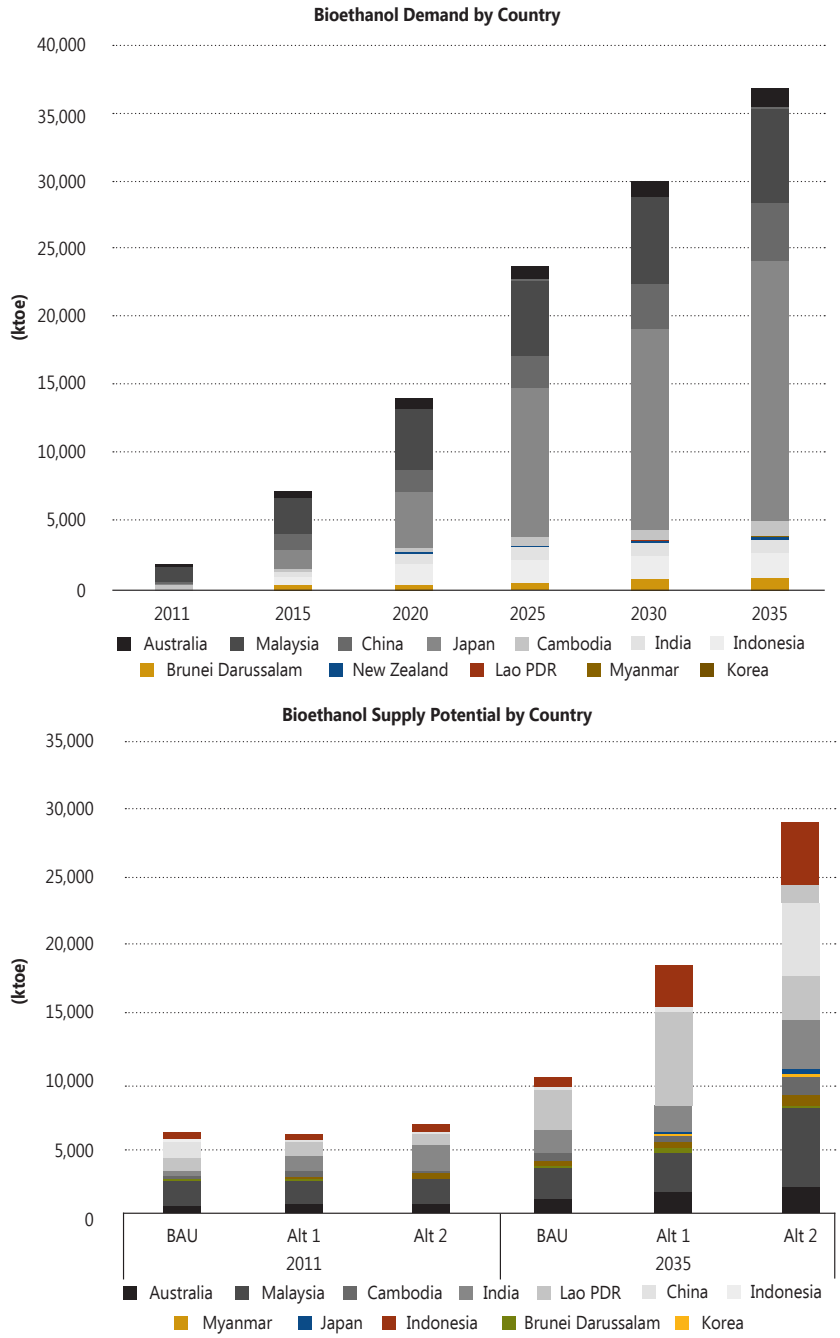
[4] The Top Runner Program is a set of mandatory energy efficiency standards in Japan for appliances and vehicles set on the basis of the most efficient model in the market (the Top Runner).

As it will take considerable time and funds to construct sufficient mass rapid transit capacity, expanding the bus rapid transit network or improving its convenience would be effective as a short- to mid-term measure.

In addition, governments could consider such measures as promoting eco-driving, telecommuting and flexible work schedules, and carpooling and driving restrictions (e.g., odd-even license plate driving bans) for managing energy demand in the road transport sector. IEA (2017b) projects that freight activity in Southeast Asia will more than double by 2040, boosted by growing economies and expanded road infrastructure, and that fuel consumption by trucks will account for about 40% of transport energy demand growth to 2040. Logistical improvement is one of the key strategies to reduce oil demand in freight transport. This might include inter-modality, i.e. improving transhipment in ports or terminals to promote long-haul trip shifting to rail and sea, creating and/or optimising urban area consolidation/distribution centres, and increasing the use of information technology to optimise goods transport (e.g. avoiding empty running vehicles and reducing truck overloading).

Biofuel is one possible option to address the oil security issue, since expanding the use of biofuels will not only result in reducing demand for oil but will also contribute to the diversification of import sources for liquid fuels. Biofuel production also provides an additional way to increase the income of farmers. According to the Yamaguchi (2013) study on regional bioethanol and biodiesel demand and supply potential, countries with large biofuel demand in the future do not necessarily have sufficient supply potential, and vice versa. For example, Indonesia is expected to have the largest bioethanol demand, accounting for 52% of the region's total aggregated bioethanol demand in 2035, while its supply potential of bioethanol is estimated to be only 5.8% of the region's total. On the other hand, while Malaysia is supposed to be the region's largest biodiesel supplier with 42% of the region's total supply in 2035, its domestic biodiesel demand is projected to account for only 2% of the region's total. This mismatch of demand and supply indicates that cross-country biofuel trade is necessary to optimise the region's biofuel utilisation. The following Figures 13 and 14 show demand and supply outlook respectively for bioethanol and biodiesels.

Figure 13: Regional Bioethanol Demand and Supply Outlook (ktoe)

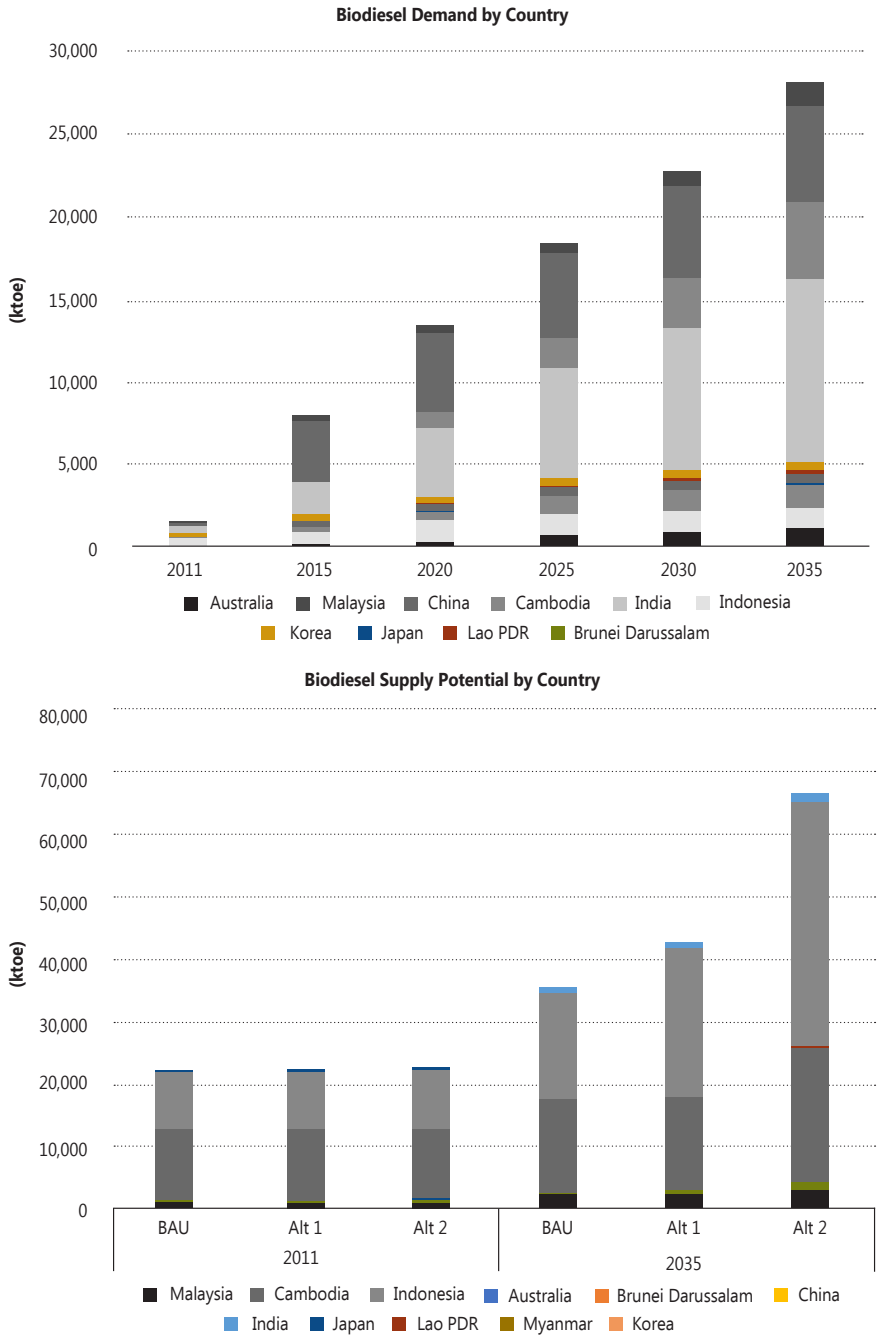


ktoe = kiloton of oil equivalent, Alt. = alternative, BAU = business as usual, Lao PDR = Lao People's Democratic Republic.

Note: Alt. 1 is a case where the land use for each crop in this region is maximised by 2035 by increasing the cultivated area and maximising the use of arable land, following the definition of the Food and Agriculture Organization of the United Nations. Alt. 2 is a case where the land use and productivity per cultivated area for each crop in this region is maximised by 2035. The most advanced productivity of each crop in this region has been assumed as the baseline value, and technology and high productivity varieties are available to be shared and transferred in the region.

Source: Yamaguchi (2013).

Figure 14: Regional Biodiesel Demand and Supply Outlook (ktoe)



ktoe = kiloton of oil equivalent, Alt. = alternative, BAU = business as usual, Lao PDR = Lao People's Democratic Republic.

Note: Alt. 1 is a case where the land use for each crop in this region is maximised by 2035 by increasing the cultivated area and maximising the use of arable land, following the definition of the Food and Agriculture Organization of the United Nations. Alt. 2 is a case where the land use and productivity per cultivated area for each crop in this region is maximised by 2035. The most advanced productivity of each crop in this region has been assumed as the baseline value, and technology and high productivity varieties are available to be shared and transferred in the region.

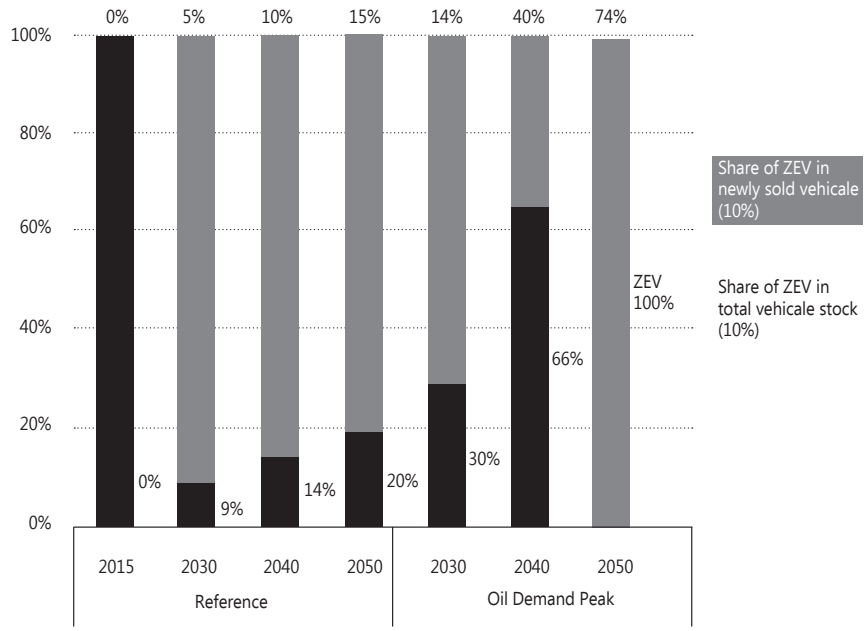
Source: Yamaguchi (2013).

Various policies should be promoted for maximising the potential of biofuel utilisation. On the supply side, incentives should be provided for increasing productivity and utilising unused agricultural land as energy–agriculture joint policy initiatives as well as improving conversion efficiency from solid to liquid biomass. Agriculture and municipal waste-to-energy programs should be targeted, along with enforcing stringent sustainability criteria in the production of biofuels. On the demand side, best local practices of the sustainable consumption/utilisation of biofuels should be promoted as well as preparing enabling market conditions through the mandatory use of biofuel. Regional energy security should be promoted through regional biofuel trade while sharing biofuel standards. In addition, ASEAN countries should collaborate in developing next-generation biofuel technologies to achieve energy security, food security, and sustainability via academia–industry partnerships, incubation programs, and international innovation networks.

Zero emissions vehicles (ZEVs) have been gaining attention for curbing oil consumption as well as preventing air pollution. Figure 15 shows estimates from IEEJ (2018) on the global level share of ZEVs in Reference and Oil Demand Peak Scenarios. An increasing number of ASEAN member countries are developing policies for promoting the penetration of ZEVs. For example, Thailand is aiming at 1.2 million electric vehicles (EVs) in 2036 based on its EV Strategy, while France and the United Kingdom announced that sales of new gasoline and diesel vehicles will be prohibited in 2040. However, it remains to be seen whether these ambitious targets can be achieved. Banning internal combustion engines could be particularly challenging in the ASEAN region where the public has a strong aspiration for mobility. Market penetration of ZEVs could be promoted by providing incentives to both producers and users, particularly in the initial stage and through public–private partnerships, on establishing necessary supporting infrastructure. However, it is not fiscally sustainable to promote widespread penetration relying on heavy subsidies. This means that wide penetration of ZEVs will be possible only when they are price competitive with conventional vehicles. Government regulations (e.g. banning sales of internal combustion engines) without due regard for market conditions could result in unintended consequences such as a significant expansion of the used car market or slower retirement of less efficient vehicles. This would

be counterproductive in terms of energy security and environmental protection.

Figure 15: Share of ZEVs in Reference and Oil Demand Peak Scenarios

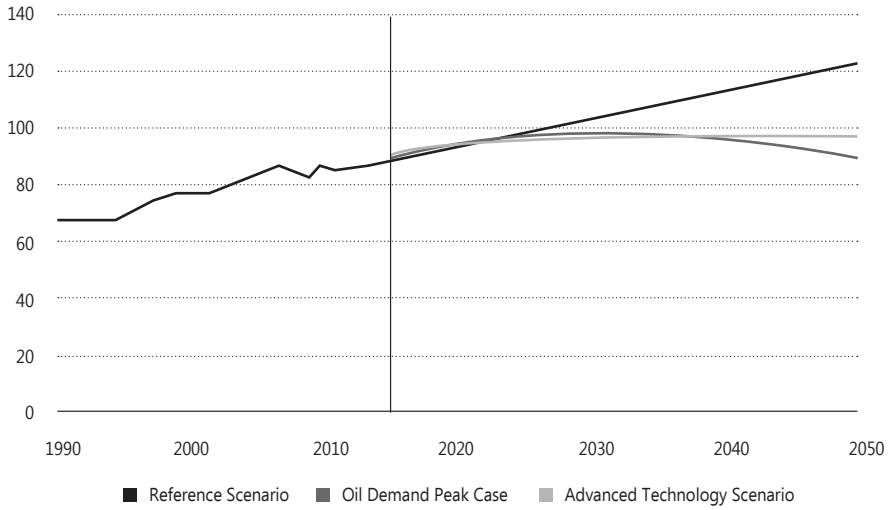


ZEV = zero emissions vehicle (electric vehicle, plug-in hybrid vehicle, fuel cell vehicle).

Source: IEEJ (2018).

IEEJ (2018) projects that global oil demand will stay at the current level, even under an extremely ambitious scenario in which all the global sales of new passenger vehicles are ZEVs in 2050 (Figure 16). This suggests that oil will continue to be the major energy source even in 2050, so governments should enhance emergency preparedness as well as enhancing the fuel efficiency standards of gasoline vehicles.

Figure 16: Global Oil Demand in Reference and Oil Demand Peak Scenarios (million barrel per day)



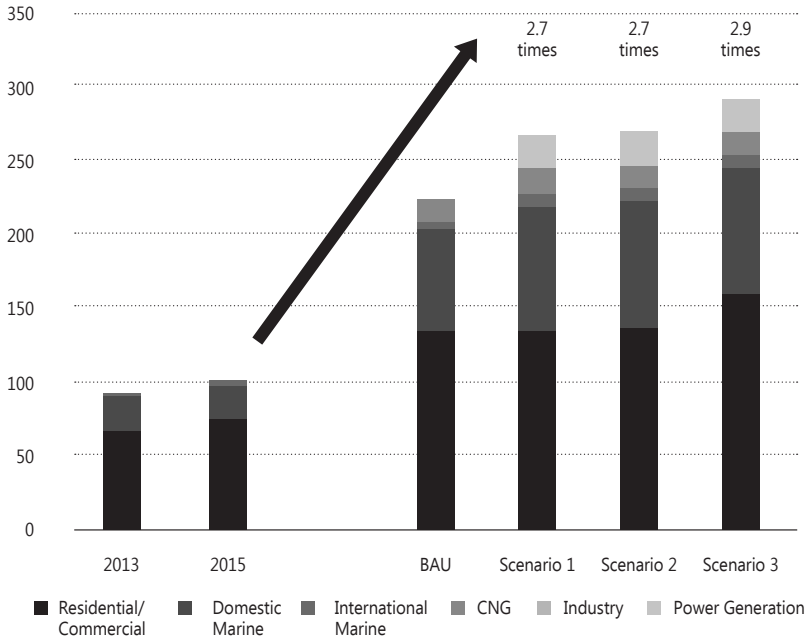
Source: IEEJ (2018).

Expanded Use of Natural Gas

As the world moves towards the aspirations of the Paris Agreement, natural gas is expected to play a more important role in the regional energy mix as the fossil fuel with the lowest carbon content.

While ERIA (2018b) projects that natural gas demand in the ASEAN region will expand by 1.2–1.5 times by 2030, while demand in the EAS region could expand by 2.7–2.9 times by 2030. With a view to maximising natural gas penetration in the energy mix, it is crucial to ensure the efficiency of the LNG market and improve the competitiveness of LNG prices in the region. Figures 17 and 18 show ASEAN natural gas demand potential consecutively by sector and by country.

Figure 17: ASEAN Natural Gas Demand Potential by Sector (Mtoe)

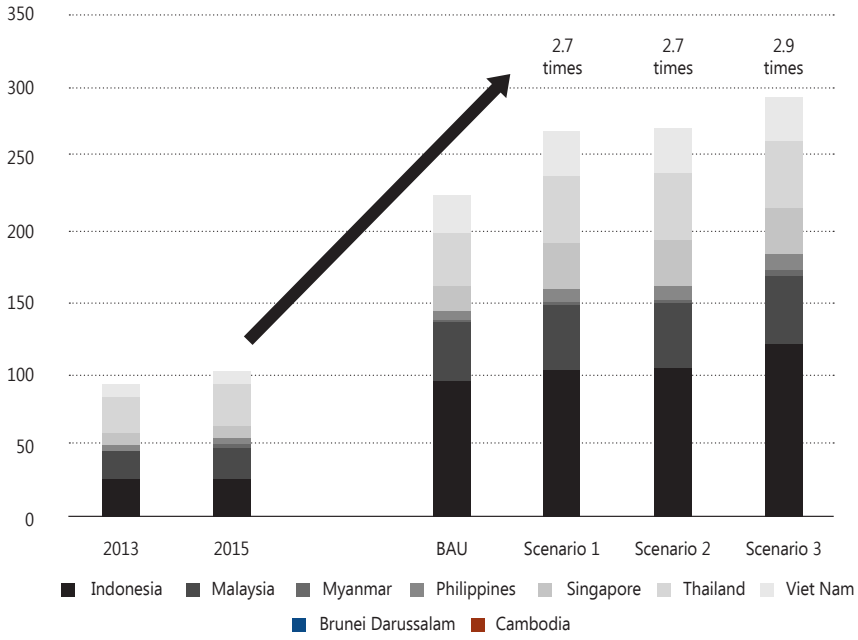


ASEAN = Association of Southeast Asian Nations, BAU = business as usual, CNG = compressed natural gas, Mtoe = million tons of oil equivalent.

Scenarios 1, 2, and 3 assume that 15%, 30%, and 60% of coal thermal power capacity addition from 2015 to 2030 is substituted with natural gas power.

Source: ERIA (2018b).

Figure 18: ASEAN Natural Gas Demand Potential by Country (Mtoe)



Mtoe = million tons of oil equivalent, ASEAN = Association of Southeast Asian Nations, BAU = business as usual.

Scenarios 1, 2, and 3 assume that 15%, 30%, and 60% of coal thermal power capacity addition from 2015 to 2030 is substituted with natural gas power.

Source: ERIA (2018b).

The liberalisation of natural gas markets, through shared third-party operated infrastructure, would encourage new players to enter the market. A rising number of gas-receiving terminals around the region would open opportunities for a more flexible LNG market. This would allow gas prices to be more market-driven and competitive and create more gas interconnectivity.

The establishment of gas hub(s) in Asia, as a focal point of active LNG spot trading, could help stabilise markets by enhancing supply flexibility, thus making gas more competitive in the region. An Asian LNG hub should have its own benchmark price representing the Asian LNG market, reflect the physical LNG market balance, and have various types of market participants. Experiences in the American and European hubs and lessons for creating an Asian hub should be carefully examined while noting similarities and differences with the EAS region and the lack of a simple cut-and-paste solution. The LNG market in the ASEAN region should be designed as a win–win situation for all players, assuring both the

producer and consumer ends of the chain. At the same time, innovative use of natural gas should be promoted to achieve the maximum demand potential.

In addition to its low-carbon content, natural gas could serve as a fuel to generate zero-carbon energy sources, such as the production of hydrogen gas for fuel cells.

Enhancing the Regional Energy Network

The interconnection of energy networks across the ASEAN region is essential for more resilient and secure energy systems as well as the efficiency of the ASM. In this regard, the ASEAN Power Grid (APG) and Trans-ASEAN Gas Pipeline (TAGP) play a vital role.

Development of the APG is tasked to the Heads of ASEAN Power Utilities/ Authorities (HAPUA), as a specialised energy body. The construction of the APG is initially motivated on cross-border bilateral terms. It is envisioned that the APG will expand to a subregional basis and then to an integrated ASEAN-wide regional system. Ongoing collaboration between the Lao PDR, Myanmar, and Thailand symbolises the initiation of multilateral trading of power in the region. However, several preconditions must be fulfilled to enable multilateral power trading in a level-playing field, including (i) the harmonisation of technical standards of grid operation; (ii) the harmonisation of relevant regulations and institutions, such as third-party access agreements; and (iii) the coordination of the estimation, allocation, and compensation of available interconnection capacity for trading purposes, ideally applying commonly accepted business/market models. HAPUA is leading initiatives to study such harmonisation and coordination among ASEAN countries. One of the ongoing efforts is the study on the ASEAN Power Grid Generation and Transmission System Planning Institution (AGTP) as well as the ASEAN Power Grid Transmission System Operators Institution (ATSO).

The development of a fully functioning TAGP requires harmonised and flexible third-party network or access code across the region. The latest

development of the TAGP, according to the APAEC 2016–2025, envisions an extension of the concept to cover the transportation infrastructure of LNG as virtual pipelines to interconnect ASEAN countries as well as other Asian gas consumers in a regional market.

Complementary to the progress of the TAGP, new technological solutions such as floating storage and regasification units and small-scale LNG are receiving attention to enhance ASEAN's downstream natural gas infrastructure capacity.

4. Climate Change Challenge

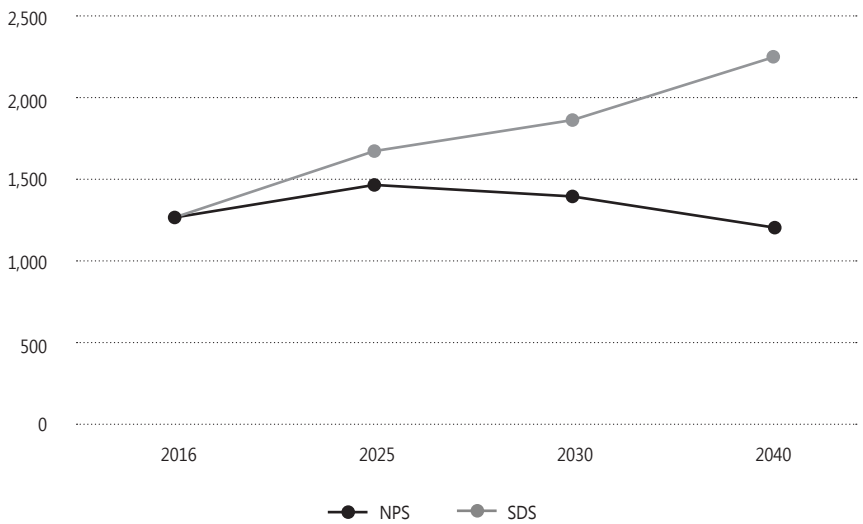
In considering the ASEAN 2040 Energy Vision, the most daunting challenge is how to achieve secure and affordable energy supply and CO_2 emissions reductions simultaneously.

As discussed above, robust energy demand growth and still dominant fossil fuel, notably coal in power generation, will significantly expand regional energy-related CO_2 emissions by 169%. The APS includes the following assumptions: (i) more efficient final energy consumption (APS1), (ii) more efficient thermal power generation (APS2), (iii) higher consumption of new and renewable energy and biofuels (APS3), and (iv) the introduction or higher utilisation of nuclear energy (APS4). Under all scenarios, incremental CO2 emissions are lower, mostly because of cost-effective energy efficiency improvement. Nevertheless, CO_2 emissions will grow by 84% from 2015 to 2040.

The United Nations Framework Convention on Climate Change (UNFCCC, 2016) projects that the Parties' nationally determined contributions (NDCs) are not sufficiently ambitious to bring the global greenhouse gas (GHG) mitigation path on track for achieving the target of 1.5–2.0 degrees Celsius (°C). On the other hand, ASEAN countries' projected CO2 emissions under the APS are, in some cases, higher than their respective NDCs. This indicates a huge gap between climate aspirations and energy reality.

IEA (2017b) presents the New Policies Scenario (NPS), factoring in NDCs and the Sustainable Development Scenario (SDS) consistent with the target of well below 2°C under the Paris Agreement as shown in the Figure 19. While the NPS projects an 80% increase in CO_2 emissions from 2016 to 2040, the SDS will mark a significant reduction from 2016 levels.

Figure 19: ASEAN Energy-Related CO_2 Emissions under NPS and SDS (Mt-CO_2)

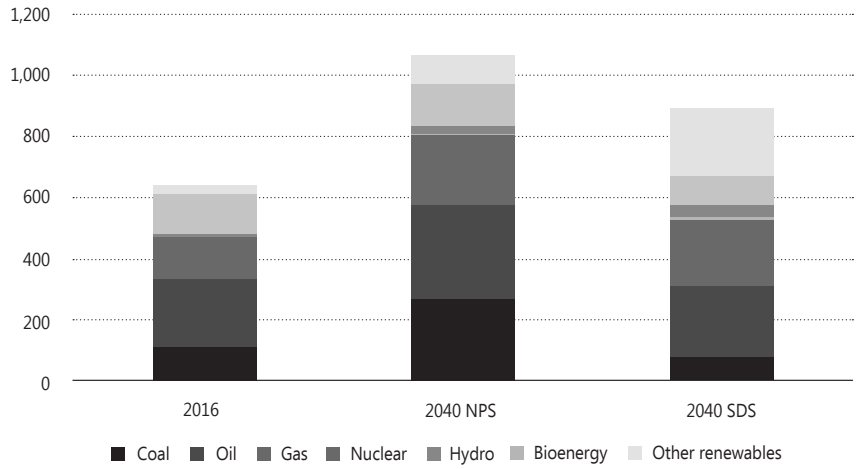


ASEAN = Association of Southeast Asian Nations, Mt-CO_2 = million tons of carbon dioxide, NPS = New Policies Scenario, SDS = Sustainable Development Scenario.

Source: IEA (2017b).

However, a tremendous gap exists between the NPS and SDS in terms of the share of coal and renewable energy. It should be noted that the demand projection under the IEA scenarios is lower than the ERIA (2018a) because of a lower assumption of economic growth. This means that the distance towards the 2°C pathway is even greater. ERIA's Outlook and IEA's NPS have been developed on a bottom–up basis, considering each country's energy reality, while the SDS has been developed as a top–down scenario for achieving the below 2°C target. The feasibility of the SDS is subject to various conditions, notably how much people are willing to pay for combating climate change. Figures 20 and 21 show respectively ASEAN energy and power generation mix under both NPS and SDS.

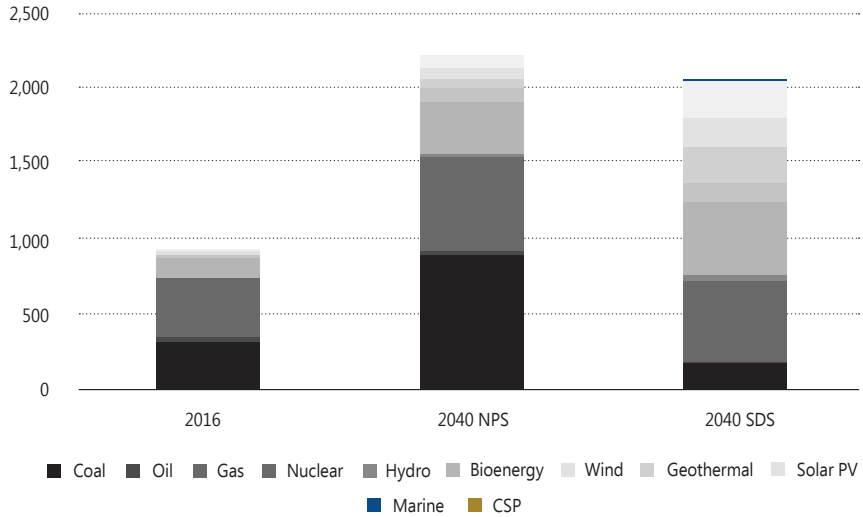
Figure 20: ASEAN Energy Mix under NPS and SDS (Mtoe)



ASEAN = Association of Southeast Asian Nations, Mtoe = million tons of oil equivalent, NPS = New Policies Scenario, SDS = Sustainable Development Scenario.

Source: IEA (2017b).

Figure 21: ASEAN Power Generation Mix under NPS and SDS (TWh)



ASEAN = Association of Southeast Asia Nations, CSP = concentrated solar power, NPS = New Policies Scenario, PV = photovoltaic, SDS = Sustainable Development Scenario, TWh = terawatt-hour.

Source: IEA (2017b).

In general, capacity and willingness to pay for combatting climate change in developing economies tends to be low since they are predominantly occupied with energy access at affordable prices. Given that energy prices are subsidised in many ASEAN countries and their phasing out is posing political challenges, raising energy prices by adding carbon costs could be even more difficult. While climate change is one of the 17 SDGs, it is not the supreme objective taking precedence over other policy objectives such as economic growth, higher living standards, and energy access at affordable prices. In fact, many SDGs are achievable only when robust economic growth is achieved underpinned by cheap and reliable energy.

As presented in section I, ASEAN's energy mix will continue to rely on fossil fuels. Radical energy transition, as envisaged in the SDS, could occur only when non-fossil fuels become economically viable and reliable.

Renewable Energy: Promising, but Subsidy Cost Needs Attention

A climate-driven energy vision requires far more aggressive penetration of renewable energy (e.g. solar, wind, and biomass) in power generation. It is encouraging that the cost of renewable energy technologies is rapidly declining. Distributed power generation using renewable technologies could present a more economically viable option in rural electrification than grid extension for remote areas. Enhancing regional interconnections could expand further penetration of renewable energy such as large hydro.

On the other hand, a large portion of incremental power demand in the region would come from industrialisation and urbanisation, which rely on grid-based power supply. A significant expansion of intermittent renewable energy in the power system, as envisaged in the SDS, would need direct and/or indirect subsidies (e.g. feed-in tariffs and renewable portfolio standards) as well as system integration costs (e.g. back-up power, batteries, and expansion of the transmission and distribution network). These costs need to be borne by final consumers or governments. If governments bear such costs to avoid an additional cost burden for final consumers, the fiscal burden will grow in accordance with the higher penetration of renewable energy. This could be challenging for

governments facing multiple budget expenses, even taking into account some role of international financial institutions.

Renewable energy will play a more important role in the regional energy mix in the coming decades. The cost of supporting renewable energy could be regarded as a domestic investment for the future. At the same time, promoting renewable energy is one of the means for achieving energy policy objectives, not the ultimate objective in itself. Formulating renewable energy policies beyond the power sector to focus on the final energy consumption become imperative, particularly in the manufacturing and residential sectors. In designing and implementing support schemes for renewable energy, governments should regularly examine their cost-effectiveness taking into account the most recent trends of their production and integration costs. Deployment policies seeking an overly quick transition from the pace of development of cost-effective technologies will result in inefficient and expensive pathways, which is not politically or economically sustainable.

Coal: Stigmatised, but Cannot Be Simply Dismissed

ERIA (2018) indicates that coal will continue to be the dominant energy source in the region because of its abundance and reliable supply. With fast-growing electricity demand, ASEAN countries are inclined to build coal-fired power plants (CPPs) with less capital cost since the emissions standards of sulphur dioxides (SOx) and nitrogen oxides (NOx) are far more lenient than in OECD countries. These low-efficiency CPPs will harm the environment because of air pollution and greenhouse gas emissions. Stringent environmental regulations need to be introduced and enforced effectively so that investors select better technologies. Ultra-supercritical technology for CPPs, considered clean coal technology, uses coal more efficiently and cleanly than traditional coal power plants, such as sub-critical technology. Raising the level of public acceptance is a precondition to the future use of CPPs in ASEAN countries. To this end, the emission of air pollutants from CPPs must be minimised. ASEAN should raise the current emissions standards of air pollutants from CPPs to the level of OECD countries. In this case, clean coal technology would be selected automatically, enabling ASEAN to advance towards the common environmental standard for coal-fired power generation.

While the air pollution problem could be largely resolved by introducing clean coal technologies, environmental groups are advocating the phasing out of coal because of its high carbon content. Scenarios driven by the Paris Agreement (e.g. SDS) envisage a drastic reduction in coal use in the coming decades. As discussed above, the feasibility of such a large reduction depends highly on people's readiness to bear higher energy costs as well as the cost trends of competitors such as natural gas and renewable energy. Coal cannot be simply dismissed because its abundance, low cost, and widespread global distribution could contribute to better energy access at affordable costs. As long as coal stays in the energy mix, what matters is to explore how to use it in an environmentally sustainable manner as a bridge to a carbon-free energy future, rather than simply ruling out coal altogether. The deployment of high-efficiency low-emissions technologies and the development of carbon capture and storage are essential.

Research, Development, Demonstration, and Deployment: Key for Ultimate Energy Transition

Most of the technologies to push a transformation until 2040 already exist and some are emerging. These include advances in science, hardware and software, and technical system configurations. The research, development, demonstration, and deployment of more cost-effective low and zero emission technologies hold the key to ultimate energy transition and decarbonisation.

To date, governments have tended to establish targets and timetables (e.g. X% GHG reduction by 20XX) and to pick particular technology winners through prescriptive intervention. Such an approach could well result in high costs and fail to garner public support, in particular in developing countries where the bulk of incremental energy demand and GHG emissions would occur.

Given multiple uncertainties, it is more sensible and pragmatic to invest in a wide range of technologies including cleaner use of fossil fuels; carbon capture, utilisation, and storage (CCUS); renewable energy; storage battery; new generation of biofuels; hydrogen; energy efficiency; smart

grids; and next-generation nuclear, taking into account each country's competence. More broadly, innovation in energy and environment technologies increasingly emerges from a combination of a wide range of technologies not limited to the energy and environment arena. While ICT, IoT, and AI could have a tremendous impact on energy production and consumption patterns, they have not been developed by prescriptive government policies. Rapid innovation is needed at the ASEAN level to create the business practice. Governments should provide an ecosystem which will encourage basic expenditure on scientific and technological research and development by private industries. Policy frameworks both at the systemic level (market design, regulatory instruments, and new business models) and the operation level (consumer engagement, supply-side management, and demand-side responses) need to be established.

Climate change is a global agenda, so greater international collaboration should be promoted in developing, sharing, and applying best available technologies which are suitable for specific national circumstances. There is little certainty on how this will transpire in policy practices. Important questions remain regarding the optimal functionality and integration strategies. New financial challenges in meeting the NDC are expected to emerge. Multilateral development banks and finance institutions should be encouraged to facilitate private investment through guarantees and risk sharing mechanisms and technology transfer at sector level or economy wide.

Long-Term Strategy: Flexibility in Responding to Many Uncertainties

The inherently uncertain and complex nature of climate change indicates the need for a flexible and adaptable policy approach. Such an approach will need to respond to a deeper understanding of climate science; the cost trends of various energy options; the development of new technologies; and domestic, regional, and/or international political and economic situations. As encouraged by the Paris Agreement, ASEAN countries are considering their respective long-term low-carbon development strategies towards 2050. Such strategies should be pragmatic, flexible, adaptable, and affordable in striking a balance between economic growth and climate goals. In tackling long-term

decarbonisation, several alternative pathways (e.g., target, timetable, and energy mix) should also be considered.

Markets need to innovate to meet specific needs in scale and time. New regulatory approaches and cooperation policies are needed to facilitate the creation of new energy markets as well as the improvement of existing markets. At the same time, flexibility is needed in policy design, as the end points, pathways, technology options, and palatable costs will differ across countries as well as subnational levels.

5. Capacity Building, Public Awareness, and Public Acceptance

The pursuit towards the ASEM (Asia-Europe Meeting) must be underpinned by the rapidly growing ASEAN energy system. Lack of human resources and expertise in utilising advanced and sophisticated energy technologies, such as clean coal technology, new and renewable energies, nuclear energy, and LNG, has been one of the biggest hurdles in planning and deploying new energy infrastructure as well as financing them. The evolving nexus between IT, AI, and IoT will be a defining feature of the energy transformation, enabling ASEAN to take a new systematic approach to manage regional supply and demand systems. Lack of experience and expertise not only exists with the energy industries in ASEAN, but also with regulation and policy design. The following actions are recommended:

Providing Training to Government and Industrial Officials in Asia

Capacity building programs, including training programs and technical assistance, should be conducted by relevant international agencies in a coordinated manner. Topics could include policy, regulations, technologies, technical standards, operational safety guidelines, environmental regulation, and financing, among others. In developing such programs, countries could be grouped with peers that have similar characteristics and stages of development.

Regulatory Development

Relevant international agencies should help Asian governments to develop a regulatory system in adopting and utilising advanced energy technologies. Environmental regulation is one of the key areas in this regard. A clear and consistent environmental regulatory system would clarify the role and the task of project investors and facilitate investment through lowered regulatory risk. Another important regulatory area concerns safety regulations. Training programs on safety issues would help Asian governments to develop a well-organised safety regulation to monitor operational safety to avoid unexpected accidents.

Public Awareness and Acceptance

Public awareness and public acceptance are equally important. The public should be educated with knowledge and information about available new technologies as well as the benefits of adopting such technologies. Understanding should also be built regarding the factors that drive public acceptance of new energy technologies in each country, given the respective social and political backgrounds. Public awareness and acceptance are particularly crucial for strengthening people's willingness to pay for the energy and environment agenda.

Taking good care of the above-mentioned factors would significantly improve the perception of project risk by financial institutions, thus promoting the financing of new energy projects.

6. Conclusion

As a high economic growth region, ASEAN has an important role to play in the global energy and climate agenda. Secure, affordable, and sustainable energy is a prerequisite for ASEAN's prosperity. The regional energy outlook towards 2040 indicates multiple challenges in terms of the security of energy supply and climate change mitigation. These are fundamental dynamics in national development and ASEAN's integration in the global energy market. Many actions need to be taken on both the demand and supply sides and in the domestic, regional, and international

arena. As ASEAN is making a giant stride towards the ASM, it is logical to envisage enhanced ASEAN-wide collaborative initiatives in the energy field while acknowledging member countries' unique situations in terms of economic development and resource endowment. Enhancing emergency preparedness, promoting regional interconnection, regulatory harmonisation, technology collaboration, and sharing long-term visions are the most promising areas for such collaboration. In addition, learning from each other and sharing best practices is instrumental for building the capacity of policymakers and effective regional policy collaboration. ASEAN could consider a peer review process with the help of relevant international organisations (e.g. ERIA and the Asia Pacific Energy Research Centre) in key energy policy agenda such as energy efficiency, renewable energy promotion, electricity and gas market reform, and so forth. If ASEAN is ultimately aiming at the ASEAN Energy Community, enhanced regional collaboration as indicated above is a necessary first step.

In the coming decades, the ASEAN region will need to bear an additional cost for internalising environmental externalities. This is only possible when the public becomes more willing to pay in accordance with better living standards backed by robust economic growth. When policies focused on economic growth confront policies focused on emissions reductions, the former will almost always win. Energy transition in ASEAN must be based on pragmatism, not advocacy.

References

ASEAN (2007), *Cebu Declaration on East Asian Energy Security*. https://asean.org/?static_post=cebu-declaration-on-east-asian-energy-security-cebu-philippines-15-january-2007-2 (accessed 10 December 2018).

ASEAN Centre for Energy (2015), *ASEAN Plan of Action for Energy Cooperation*. Jakarta: ASEAN Centre for Energy. http://www.aseanenergy.org/wp-content/uploads/2015/12/HighRes-APAEC-online-version-final.pdf (accessed 10 December 2018).

ERIA (2018a), *Energy Outlook and Saving Potential of East Asia Summit Countries 2018*. Jakarta: ERIA. http://www.eria.org/RPR_FY2015_No.5.pdf (accessed 10 December 2018)

ERIA (2018b), *Formulating Policy Options for Promoting Natural Gas Utilization in the East Asia Summit Region. Volume I: Demand Side Analysis*. Jakarta: ERIA. http://www.eria.org/research/formulating-policy-options-for-promoting-natural-gas-utilization-in-the-east-asia-summit-region-volume-i-demand-side-analysis/ (accessed 10 December 2018).

ERIA (2018c), *Electricity Futures in the Greater Mekong Subregion: Towards Sustainability, Inclusive Development and Conflict Resolution*. Jakarta: ERIA. http://www.eria.org/uploads/media/!ERIA_RPR_2017_08.pdf (accessed 10 December 2018)

IEA (2017a), *Energy Access Outlook 2017: From Poverty to Prosperity*. Paris: IEA. https://webstore.iea.org/weo-2017-special-report-energy-access-outlook (accessed 10 December 2018).

IEA (2017b), *Southeast Asia Energy Outlook 2017*. Paris: IEA. https://www.iea.org/southeastasia/ (accessed 10 December 2018).

IEEJ (2018), I*EEJ Outlook 2018 – Prospects and challenges until 2050 – Energy, Environment and Economy*. Tokyo: IEEJ. https://eneken.ieej.or.jp/data/7748.pdf (accessed 10 December 2018).

Iida, Y., I. Shota, and Y. Li, (eds.) (2017), *Study on the Advancement of the Energy Management System in the East Asia Summit Region*, ERIA Research Project Report 2015, No. 17. Jakarta: ERIA. http://www.eria.org/research/study-on-the-advancement-of-the-energy-management-system-in-the-east-asia-summit-region/ (accessed 10 December 2018).

Kimura, S., T. Morikawa, and H. Phoumin, (eds.) (2017), *Oil Supply Resilience in ASEAN*, ERIA Research Project Report 2016, No. 3. Jakarta: ERIA. http://www.eria.org/research/oil-supply-resilience-in-asean/ (accessed 10 December 2018).

Kutani, I. and Y. Li, eds. (2014), *Investing in Power Grid Interconnection in East Asia*. Jakarta: ERIA. http://www.eria.org/publications/investing-in-power-grid-interconnection-in-east-asia/ (accessed 10 December 2018).

Kutani, I., Y. Sudo, and Y. Li, (eds.) (2015), *Energy Efficiency Improvement in the Transport Sector through Transport Improvement and Smart Community Development in Urban Areas*, ERIA Research Project Report 2014, No. 38. Jakarta: ERIA. http://www.eria.org/research/energy-efficiency-improvement-in-the-transport-sector-through-transport-improvement-and-smart-community-development-in-urban-areas/ (accessed 10 December 2018).

de Langre, G. (2018), *'The real cost of Myanmar's electricity'*, Myanmar Times, 31 May. https://www.mmtimes.com/news/real-cost-myanmars-electricity.html (accessed 10 December 2018).

Li, Y., ed. (2015), *Advancing the Energy Management System in the East Asia Summit Region*, ERIA Research Project Report 2014, No. 39. Jakarta: ERIA. http://www.eria.org/publications/advancing-the-energy-management-system-in-the-east-asia-summit-region/ (accessed 10 December 2018).

Li, Y. and S. Kimura, (eds.) (2016), *Achieving an Integrated Electricity Market in Southeast Asia: Addressing the Economic, Technical, Institutional, and Geo-political Barriers*, ERIA Research Project Report 2016, No. 16. Jakarta: ERIA. http://www.eria.org/publications/achieving-an-integrated-electricity-market-in-southeast-asia--br-addressing-the-economic-technical-institutional-and-geo-political-barriers/ (accessed 10 December 2018).

Motokura, M., J. Lee, I. Kuyani, and H. Phoumin, (eds.) (2017), *Improving Emission Regulation for Coal Fired Power Plants in ASEAN*, ERIA Research Project Report 2016, No. 2. Jakarta: ERIA. http://www.eria.org/research/improving-emission-regulation-for-coal-fired-power-plants-in-asean/ (accessed 10 December 2018).

Rakhmah, T.F. and Y. Li (2016), *'A review on Institutional Framework, Principles, and Key Elements for Integrated Electricity Market: Implications for ASEAN', ERIA Discussion Series*. No. 26. Jakarta: ERIA. http://www.eria.org/publications/a-review-on-institutional-framework-principles-and-key-elements-for-integrated-electricity-market-implications-for-asean/ (accessed 10 December 2018).

UNFCCC (2015), *Paris Agreement*. UNFCCC: Bonn. https://unfccc.int/sites/default/files/english_paris_agreement.pdf (accessed 10 December 2018).

UNFCCC (2016), *'Aggregate effect of the intended nationally determined contributions: an update', Synthesis report by the secretariat, Conference of the Parties, Twenty-second session*, Marrakech, 7–18 November. https://unfccc.int/sites/default/files/resource/docs/2016/cop22/eng/02.pdf (accessed 10 December 2018).

Yamaguchi, K., (ed.) (2013), *Study on Asia Potential of Biofuel Market*, ERIA Research Project Report 2012, No. 25. Jakarta: ERIA. http://www.eria.org/research/study-on-asia-potential-of-biofuel-market/ (accessed 10 December 2018).