Energy Security in Asean +6

International Energy Agency

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Abstract

The ASEAN+6 group comprises the ten countries of the Association of Southeast Asian Nations (ASEAN) and six other countries in the Asia-Pacific region: Australia, the People's Republic of China ("China"), India, Japan, Korea and New Zealand. This group includes the world's fastest-growing and most dynamic energy consumption centres. They are led by China, India and ASEAN, the emerging Asian economies, whose share of global energy demand is expected to reach 40% by 2040, up from only 20% in 2000.

Energy demand in the ASEAN+6 countries is set to take diverse paths. In India, for example, low per capita energy use and a high population growth rate indicate the potential for substantial energy demand growth. In Japan, by contrast, a declining population and increasing energy efficiencies are contributing to a continuous fall in energy consumption. Countries of the region also differ in their natural resource wealth and their levels of socio-economic and technological development.

These countries share common challenges, however, in ensuring the security of their energy supplies. Given their shared geographical location, they could help one another meet these energy security challenges by deepening regional co-operation.

This report starts by giving an overview of the energy security issues of the region. Subsequent chapters cover the key energy sectors of oil, natural gas and electricity. They identify the main energy security issues, including a high level of vulnerability to natural disasters and heavy dependence on imports of fossil fuels, which must pass through major global chokepoints. The report provides policy advice, primarily for the region's developing countries, based on the emergency response systems and accumulated experience in energy security of the International Energy Agency and its member countries.

Highlights

- Developing economies in the Asia-Pacific region are expected to account for almost two-thirds of global energy demand growth between now and 2040. These economies will increasingly rely on energy imports, especially of oil and gas, to sustain economic growth. A significant share of these imports has to pass through two of the world's most strategic chokepoints for global energy trade, the Strait of Hormuz and the Strait of Malacca. Every country in the region faces the question of how to mitigate the associated risks to security of energy supply.

- As oil demand surges and import dependence rises, notably in the People's Republic of China, India and ASEAN countries, there is a critical need to strengthen emergency response capabilities in these emerging economies and incorporate them into global supply security.

- Developing emergency oil response capabilities and integrating them into IEA collective response mechanisms will take time and money. In parallel, regional co-operation offers flexible and pragmatic pathways towards improving domestic and regional oil supply security, such as cross-border stockholding arrangements and joint stockpiling models.

- Natural gas security is also a mounting concern in the region, as it is expected to account for 85% of the growth in global gas trade between now and 2040. The growing role of liquefied natural gas (LNG) in global gas trade is improving the flexibility and liquidity of gas supply. As a result, investments in LNG import infrastructure, such as floating storage and regasification units, can help to improve supply security.

- The prevention of power outages is the primary focus of short-term electricity security; the ASEAN+6 region is one of the most disaster-prone in the world. Some IEA member countries in the region, notably Australia, Japan and Korea, have considerable experience in mitigating the impacts of earthquakes or extreme weather events on power systems. These countries can offer valuable insights to others in the region.

Executive summary

Maintaining reliable and resilient energy supply is a constant challenge for any country. The ASEAN+6 region, which contains the world's largest and fastest-growing market for energy, faces a particularly pressing need to ensure secure, affordable and sustainable supplies of energy. Countries in the region face common security challenges: high dependence on fossil fuel imports that must pass through major chokepoints, inflexible market arrangements, and high vulnerabilities to natural disasters. Priorities and potential solutions differ among countries depending on their circumstances, but the paths that International Energy Agency (IEA) member countries have taken in recent decades could provide valuable lessons for the region.

Oil

The impressive economic growth of the emerging economies in the Asia-Pacific region has led to an equally impressive increase in energy consumption. The People's Republic of China's ("China") rapid industrial growth has made it the world's largest energy consumer since 2009. India's economy is growing faster than any other country's. Between now and 2040, India's economy will increase to five times its current size and its energy demand is expected to more than double. India will overtake China as the leader of global oil demand growth in the mid-2020s. Its net oil imports are expected to reach 9.3 million barrels a day (mb/d) by 2040, up from 3.8 mb/d in 2017. By that time, despite efforts to increase domestic oil production, India will depend on imports for 90% of its oil. As Southeast Asia's economy more than triples in size, the region's energy demand will also grow, by almost two-thirds between now and 2040.

As IEA member countries' collective share of global oil demand declines, discussions have begun about broadening the IEA's oil security umbrella. These conversations are focusing on the emerging economies in the Asia-Pacific region, notably China, India and the Association of Southeast Asian Nations (ASEAN) countries that represent the majority of global oil demand growth. The IEA emergency oil stockholding system is gradually losing its effectiveness, highlighting the need to strengthen emergency response capabilities in the emerging economies and eventually to include them in the collective IEA system. Establishing oil stockpiles is costly and time-consuming, especially in countries where it is necessary to build up domestic storage capacities. Some options for regional co-operation, such as cross-border stockholding arrangements and joint stockpiling models, offer flexible and pragmatic near-term alternatives.

Natural gas

Gas security is also a mounting concern, as the region is expected to account for 85% of the global growth in natural gas net imports between now and 2040, underpinning a shift in inter-regional gas trade from the Atlantic Basin to Asia. While geography limits the possibilities of linking countries in the Asia-Pacific region with pipelines, there is considerable scope within these countries to improve pipeline links between demand centres and liquefied natural gas (LNG) terminals. China is expected to take over from Japan as the world's largest LNG importer by 2040, quadrupling its LNG imports of today. The increasing share of LNG in gas trade promises to bring more flexibility, transparency and liquidity to the gas market, which could bolster energy security and put pressure on countries to improve the investment climate for gas infrastructure. Japan has promoted removing destination clauses, which restrict where gas can be resold, an initiative followed by other countries in the region, like China and India. Cities like Shanghai, Singapore, and Tokyo are seeking to become LNG trading hubs. Countries that have many islands – and hence fewer pipeline options – can take advantage of floating LNG technologies. These facilities offer an affordable, fast and flexible way to get access to natural gas supplies. They can help create pockets of growth in countries that were not targeted by LNG exporters until recently.

Electricity

Economic growth in the Asia-Pacific region has pushed up income levels and accelerated urbanisation. As a result, electricity consumption has risen rapidly, propelled by increased ownership of electric appliances and greater demand for space cooling. At the same time, this region is one of the most disaster-prone in the world, so short-term electricity security is focused on preventing power outages. Some IEA member countries in the region, notably Australia, Japan and Korea, have considerable experience in dealing with the power supply consequences of earthquakes or extreme weather events. These countries can offer valuable insights to others in the region.

Renewable energy has become an indispensable part of the electricity mix in emerging economies as they seek to accommodate growing electricity demand with low-carbon supply. The variable power of renewable sources such as wind and solar needs to be carefully integrated to protect the stability of the power system. The establishment of a regional power grid through co-ordination between neighbouring countries can enhance security of electricity supply. This requires complex system operation and strong political will to create a harmonised regulatory framework.

1. Overview

Introduction

The trend towards a greater proportion of energy consumption being concentrated in the Asia-Pacific region is of global significance. The People's Republic of China ("China"), India and countries in Southeast Asia are expected to account for almost 60% of the global increase in energy demand between now and 2040. As these developing economies in Asia will be critical in determining the future trajectory of global energy demand, it is of prime importance to identify the common challenges and risks they face, and how best to respond to these challenges in ensuring regional and thus global energy security. Although countries in the Asia-Pacific region differ widely in their resource wealth, development priorities and governance structures, they share the common challenge of meeting rising energy demand in a secure, affordable and sustainable manner.

The International Energy Agency (IEA) was founded with the primary mission of ensuring and improving global energy security in 1974, when demand patterns and market frameworks were very different from those of today. However, energy security remains at the centre of the IEA mandate. The accumulated skills and experiences within the agency serve as a means to identify and share best practices among and beyond IEA members – particularly in the area of emergency response and the powerful stockholding system for preventing oil supply disruption.

Among ASEAN+6 countries, only Australia, Japan, Korea and New Zealand are IEA members. Of the other 12 countries, five are now Association[1] countries of the IEA: China, India, Indonesia, Singapore and Thailand. As part of wide-ranging IEA efforts to modernise and adapt to the evolving energy landscape, an "open door" policy has been approved by IEA member countries to strengthen institutional ties with major emerging players in global energy markets, with the hope of creating a broader commitment to energy security.

Current market features and the evolving energy landscape

According to IEA forecasts, emerging economies in Asia will account for two-thirds of global energy growth between now and 2040. The ASEAN+6 share of global energy demand grew from 30% in 2000 to 40% in 2017, and it is forecast to reach 45% by 2040.

China

China has been the world's largest energy consumer since 2009, due to rapid industrial and economic growth that has required enormous energy supplies, primarily of coal and oil. Today, China is by far the largest source of coal demand and the country that imports the most oil,

[1] As of May 2019, the IEA has eight association countries: Brazil, China, India, Indonesia, Morocco, Singapore, South Africa and Thailand (www.iea.org/countries/association/).

having surpassed the United States in 2017. China is also home to the largest power generation fleet in the world, with one out of four gigawatts (GW) of global installed power capacity. Even now, China's per capita energy use is still only about half that of the average of developed countries. There is still room for its energy demand to grow and continue to shape global trends over the next two decades, given the scale of its energy sector and its weight in global energy affairs. However, China is shifting into a much less energy-intensive phase in its economic development. As it puts priority on reducing air pollution and emissions of carbon dioxide (CO_2), China is moving towards cleaner, high-efficiency and low-carbon energy generation. China is already the world's largest investor in renewable-based generation; a leader in energy efficiency policies, new technologies and other areas where energy is intersecting with the digital economy; and the world's largest market for electric vehicles. Coal use in China peaked in 2013 and is set to decline by almost 15% by 2040. China's energy demand, which grew by an average of 4.3% per year between 2000 and 2017, is forecast to increase by an average of only 1.0% per year between 2017 and 2040 (IEA, 2018a).

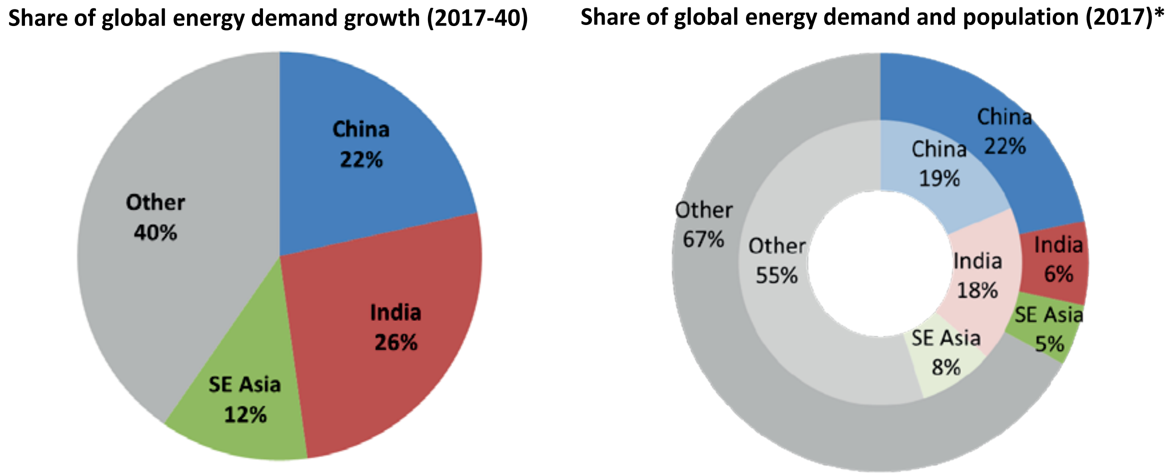
India

As China's growth pace slows, the largest contribution to global demand growth – more than 25% – is forecast to come from India, whose share of global energy use will rise to 11% by 2040 from the current 6%. While impressive, this proportion is still well below India's anticipated share of global population of nearly 18%, which shows the potential for further growth (Figure 1). For the entire period to 2040, India's economy is expected to grow faster than any other in the world, by an average of 6.5% per year. By 2040, the economy will be more than five times its current size, leading to a fourfold increase in gross domestic product (GDP) per capita. Peak electricity demand has grown nearly 13% over the past two years as a growing middle class seeks new services, such as air conditioning, which continue to place higher demands on the system. Over the next 25 years, energy demand is expected to more than double as a result. India will lead global coal demand and is also set to overtake China in the mid-2020s to lead global oil demand growth: 74% of global net oil demand growth will come from India between 2025 and 2040. India's growing dependence on fossil fuel imports is raising energy security concerns. Net oil imports are expected to rise dramatically to 8.4 mb/d by 2040, equal to an import dependence of greater than 90%. Almost three-quarters of Indian energy demand is met by fossil fuels, a share that has increased since 2000 because of a rapid rise in coal consumption and a decreasing role for bioenergy, as households move away from the traditional use of solid biomass for cooking. India is looking to renewable energy to meet growing demand and improve its energy security by diversifying fuel sources, while reducing environmental impacts. It also aims to increase the robustness and sustainability of power supplies while expanding affordable energy access.

Southeast Asia

Southeast Asia is another rising heavyweight in global energy, with energy demand growing at twice the pace of China's. Between now and 2040, the region's energy demand is expected to grow by almost two-thirds, contributing to 12% of global demand growth. At the same time, the regional economy will more than triple in size, and population will rise by a fifth, with the urban population alone growing by over 150 million people. There are wide disparities in circumstances and energy trends among the ten countries of ASEAN. Brunei Darussalam is similar in size to Luxembourg in terms of population (less than 0.5 million) and per capita energy use, which exceeds the average of IEA member countries by 45%, while Cambodia, Myanmar and the Philippines are still below one-eighth of the IEA average. But taken together, per capita energy use has now reached around half of the world average, suggesting great scope for future growth in energy demand. Indonesia has the highest energy demand, accounting for over 35% of the region's total, followed by Thailand. Fossil fuels dominate the region's primary energy mix, accounting for almost 75% of the total in 2016. This share is expected to remain steady to 2040. However, Southeast Asia will change from a net exporting region into a region that will need to import to satisfy its growing energy demand. Oil demand will rise by around 40% and natural gas consumption by almost 60%, while oil production falls by one-third and gas production remains virtually level. Coal alone accounts for almost 40% of the energy demand growth, and overtakes gas in the electricity mix. Low-carbon energy also grows strongly. The share of renewables will almost double as their deployment helps to meet rising electricity demand and extend energy access.

Figure 1. Developing countries in Asia's share of global energy demand growth



* Outer circle shows the share of global energy demand and inner circle shows the share of global population.

Sources: IEA (2018a), *World Energy Outlook 2018* (New Policies Scenario); UN DESA (2017), *World Population Prospects: The 2017 Revision*.

Developing economies in Asia-Pacific represent almost two-thirds of global energy demand growth, as their current share is small relative to the size of their population.

Japan

In Japan, which has long been a major consumer and importer of energy in the world, energy demand is expected to decrease from 2017 to 2040 by an average of 0.5% per year, in part because its population is ageing and declining. Japan is the third-largest electricity user in Asia, after China and India, but has one of the lowest growth rates of electricity demand in the region. Its electricity demand peaked in 2007 and has declined continuously since then. This decline resulted partly from the nationwide energy efficiency and conservation efforts that were carried out in 2011 and 2012 mainly to cope with the tight balance between electricity supply and demand after the 2011 earthquake and the subsequent Fukushima nuclear accident. One consequence of the accident was a gradual shutdown of all nuclear power plants, which has led to significant increases in fossil fuel use, fuel imports and CO_2 emissions. It has also brought electricity prices to unsustainable levels. Faced with these challenges, the government of Japan has revised its energy policy in recent years to focus on further diversifying its energy mix by using fossil fuels less, relying more on renewable energy, and restarting nuclear plants when they have been declared safe.

Korea

Korea also relies heavily on fossil fuel imports because it lacks domestic resources. Nevertheless, in the 1990s it experienced rapid economic growth driven by energy-intensive industries such as petrochemicals, steel and cement. Korea's highly developed economy drives its energy consumption. Economic growth is now fuelled by exports, most notably of electronics, semiconductors, and transport vehicles (cars and ships), particularly to the markets within Asia. In the longer term, Korea faces the prospect of an ageing population, which will dampen its energy demand. Responding to recent public concerns over air pollution, reducing CO_2 emissions and nuclear safety, President Moon Jae-in, who took office in May 2017, is determined to make drastic energy policy changes. An energy transition from coal and nuclear to renewable sources and liquefied natural gas (LNG) is now foreseen. The government's latest long-term electricity generation mix plan seeks to boost the use of renewable sources in power generation to 20% by 2030, from an estimated 6.7% in 2017.

Australia

Australia has abundant energy resources and is a leading exporter of coal, uranium and LNG, sustaining energy demand growth in emerging economies in Asia. Yet, Australia's energy sector is undergoing a significant transformation. Concerns about affordable and secure energy supplies have grown in recent years, following several power outages, a tightening gas market on the east coast and rising energy prices. As domestic oil production is dwindling, dependence on oil product imports and the oil supply chain are growing steadily.

New Zealand

With its unique resource base, New Zealand is a success story for the development of renewable energy, notably hydro and geothermal. Without any direct subsidies or public support, renewables' share in electricity and heat supply has grown in recent years, as a result of cost-competitive geothermal and hydro and very good conditions for wind power. Renewable energy's share of power generation reached 84% in 2016. The country hopes to expand it still further to the ambitious level of 90% by 2025.

Increasing regional interdependence and risk factors (bottlenecks, inflexibilities)

With increased globalisation, energy markets have evolved considerably into ever more complex systems. They include highly interdependent, diverse and dynamic mixes of participants, supply chains and fuel types. Systemic risk management has placed a greater focus on the possibility of contagion when one component of a complex and highly interconnected system fails. Energy shortages, price volatility and supply disruptions anywhere threaten economic growth everywhere. Stronger institutional ties are required to improve collaboration on energy security issues.

Import dependence

The Asia-Pacific region relies on vast quantities of energy imports to sustain economic growth. As the centre of global energy demand growth shifts to this region, this increasing dependence on fossil fuel imports is a key risk factor, raising significant energy security concerns apart from the mounting import bill. How to diversify supply sources and routes are challenges common throughout the region. The dual challenges of energy security and rising energy import bills are pressuring emerging economies to seriously consider ways to allocate capital more efficiently, for both supply- and demand-side energy investments, and to establish stronger links across the region to optimise management of energy systems.

Asia-Pacific's combined crude oil import volume will rise by 9 mb/d to around 30 mb/d by 2040, with strong growth in China, India and Southeast Asia more than offsetting declines in Japan and Korea. By 2040, China and India together will be importing nearly half of internationally traded oil, up from just over 25% today. China alone is expected to import more oil than any country ever has, with its import dependence rate reaching 82% in 2040 (Table 1). India's import dependence will continue to increase, reaching 91% by 2040. Southeast Asia's oil import dependence on average is expected to increase from the current 60% to reach 80% in 2040. By the early 2020s, there will be no net crude exporting country in Asia-Pacific.

While Asia's import volume grows, it is forecast that Middle Eastern exporters will only be able to provide an additional 1 mb/d to Asian importers because the exporters' domestic demand will also grow as their refinery capacity expands. Therefore, most of the incremental import requirements will have to come from the Atlantic Basin. The United States will emerge as a crude oil exporter, but shipments will take longer and incur additional shipping costs, raising energy security challenges for the Asian economies. The chokepoints, especially the Strait of Malacca, will become even more critical.

Table 1. Import dependence rates of ASEAN+6 countries

	Oil		Natural Gas	
	2017	2040	2017	2040
China	69%	82%	42%	54%
India	82%	91%	46%	52%
ASEAN	60%	80%	n.a.	18%
Japan	100%	100%	97%	98%
Korea	99%	99%	99%	99%
Australia	72%		n.a.	
New Zealand	78%		1%	

Notes: Import dependence rates are calculated as net imports divided by primary demand; n.a.= non-applicable.
Source: IEA (2018a), *World Energy Outlook 2018* (New Policies Scenario).

Increasing dependence on fossil fuel imports raises significant energy security concerns.

The Asia-Pacific region is also expected to account for 85% of the growth in natural gas net imports between now and 2040, underpinning a shift in inter-regional gas trade flows from the Atlantic Basin to Asia. Both China's and India's import dependence for natural gas is set to increase from around 40-45% today to more than 50% by 2040. Southeast Asian countries' domestic demand will grow faster than production, turning some countries into net importers. The global gas market is becoming both more fragmented and more interconnected, with LNG's share of gas trade set to rise from 42% in 2017 to around 60% in 2040. This transformation underlines the greater need for flexibility in both physical LNG production infrastructure and contractual arrangements. At the same time, LNG overcapacity is expected to ebb, retightening the supply-demand balance. The increased interdependence between markets is likely to challenge security of supply for both mature and new importers, requiring appropriate policy responses. Even in the well-supplied, diversified and interconnected market environment, importing countries can still experience unexpected shocks that put strong pressure on the market. It is also imperative to think of the implications of a massive redirection of LNG cargoes towards Asia, putting major chokepoints in the spotlight.

Chokepoints

The increased fossil fuel trade between the Middle East and Asia brings two major chokepoints in global energy trade into focus: the Strait of Hormuz and the Strait of Malacca (Table 2). If the current flows out of the Middle East or into Asia, especially of crude oil and oil products, are not modified through land-based infrastructure or alternative sea routes, both of these straits could see 3-5 mb/d of incremental traffic volume. Geopolitical issues aside, this could result in operational safety issues due to congestion.

Table 2. Two major chokepoints in global energy flows

Strait	Geographical location	Oil flow	Gas flow
Strait of Hormuz	Situated between Oman and Iran, connecting Persian Gulf oil producers with the Gulf of Oman and the Arabian Sea. The strait is 54 km wide at its narrowest point, consisting of 4 km-wide navigable channels for inbound and outbound shipping as well as a 4 km-wide buffer zone.	Just over 20 mb/d in 2018 (consisting of 16 mb/d crude and 4 mb/d of products)	124 bcm in 2017 (32% of global LNG trade)
Strait of Malacca	Situated between Indonesia, Malaysia and Singapore, it connects the Indian Ocean with the Pacific Ocean through the South China Sea. The strait is 3 km wide at its narrowest point, raising a potential for piracy, collisions, grounding or oil spills.	16 mb/d in 2016 (the volume is expected to reach 25 mb/d by 2040)	130 bcm in 2014

Sources: EIA (2017); *World Oil Transit Chokepoints*, Kpler shipping data, Reuters, IEA estimates.

The Strait of Hormuz is the main export route for oil and gas produced in the Gulf region, representing the vast majority of exports from Iraq, Iran, Kuwait, Qatar, the United Arab Emirates (UAE) and Saudi Arabia (Figure 2). Alternative export routes available in case of strait closure are limited. Only Saudi Arabia and the United Arab Emirates have pipelines that can ship crude oil outside of the Gulf and have additional pipeline capacity to circumvent the Strait of Hormuz (Table 3). The 380-km ADCOP pipeline carries crude from the Habshan field in Abu Dhabi (UAE) to the Fujairah oil terminal on the Gulf of Oman, effectively bypassing the Strait of Hormuz. Saudi Arabia's 1 200-km East-West pipeline carries crude oil from Dhahran to the port of Yanbu, for export via the Red Sea. At the end of 2018, the total available crude oil pipeline capacity from the two countries combined was estimated at 6.6 mb/d, of which roughly 3.7 mb/d was unused. A blockage or a closure of the Strait would not only physically disrupt normal oil exports from Gulf producers, but would also render unavailable the vast majority of spare production capacity of the Organization of the Petroleum Exporting Countries (OPEC). As of January 2019, OPEC spare production capacity stood at around 2 mb/d, of which 1.4 mb/d comes from Saudi Arabia. The rest of OPEC's spare capacity is spread out in small parts among OPEC members, and it is unclear whether and at what pace this can become available under the current OPEC production agreement. Even adding the unused bypass capacity, the closure of the Strait of Hormuz would still result in the blockage of 16 mb/d of oil – well beyond the largest disruption to date, of 5.6 mb/d in the late 1970s.

Figure 2. Strait of Hormuz

Note: These maps are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.
Source: IEA 2019. All rights reserved.

Table 3. Operating pipelines that bypass the Strait of Hormuz, 2018

Pipeline	Country	Status	Capacity (b/d)	Throughput (b/d)	Unused capacity (b/d)
Petroline (East-West) pipeline	Saudi Arabia	Operating	4.8	2.0	2.8
Abu Dhabi crude oil pipeline (ADCOP)	United Arab Emirates	Operating	1.5	0.6	0.9
Abqaiq-Yanbu NGL pipeline	Saudi Arabia	Operating	0.3	0.3	0.0
Iraqi pipeline in Saudi Arabia (IPSA)	Saudi Arabia	Converted to Natural Gas	0.0	0.0	
Total			**6.6**	**2.9**	**3.7**

Note: In 2016, Saudi Aramco announced that it plans to expand the capacity of the East-West pipeline to 7 mb/d, with a scheduled completion by end-2018. To date, there has been little progress on the pipeline expansion. The UAE government also plans to increase the capacity of ADCOP pipeline to 1.8 mb/d.
Sources: EIA (2019), Kpler shipping data, IEA estimates.

The alternatives to the Strait of Malacca are not very feasible and much less used (Figure 3). Sunda Strait between Java and Sumatra is only 20 metres deep at its shallowest and hence cannot accommodate large oil vessels. Lombok Strait between Bali and Lombok islands is wider and much deeper than the Malacca and Sunda Straits. However, it is also further to the east and adds three days to the voyage for oil coming from the Middle East or Suez Canal and heading to the Pacific. The distance from the bunkering facilities of Singapore is also an issue for vessels on a long voyage. However, with both West Africa and South America increasing their oil exports to Asia, and with LNG exports expected to start from East Africa, Lombok may become a more used alternative to Malacca, especially if the necessary infrastructure is developed around it. The long-proposed Kra Isthmus canal in Thailand would bypass Malacca, not only avoiding traffic jams and potential collisions but also saving on voyage duration. However, the proposed canal is subject to economic and geopolitical debates that are likely to involve countries not only in Asia but also on other continents.

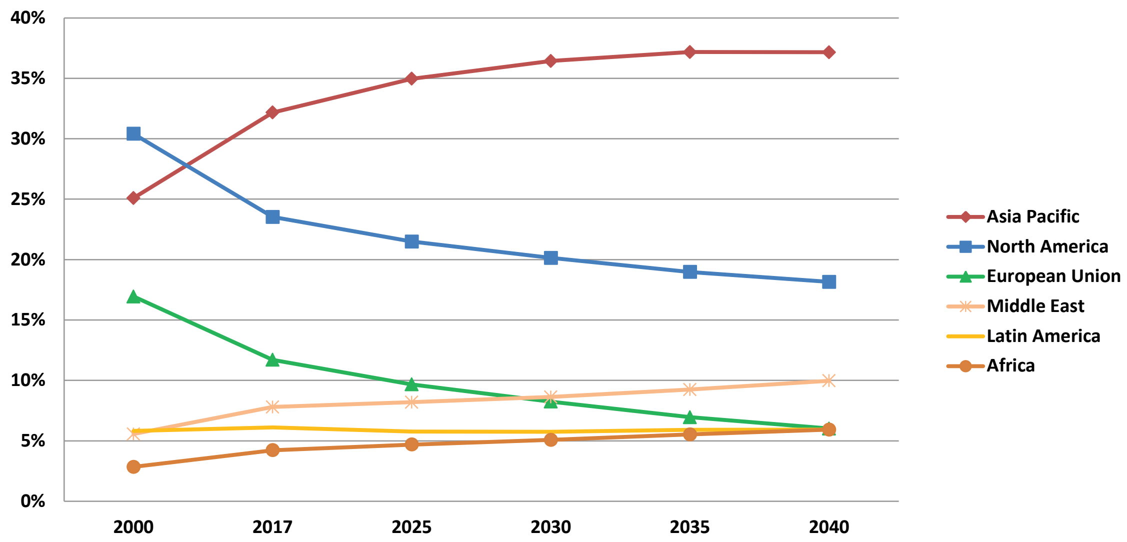
A closure of the straits would also significantly constrain global gas trade. It would prevent LNG exports from Qatar and United Arab Emirates, which together represent roughly one-third of global LNG exports. India, Japan and Korea depend entirely or significantly on LNG imports and have no alternative. Japan and Korea depend on trade through the Strait of Malacca for more than 30% of their gas imports which come from Africa and Oman on top of Qatar and United Arab Emirates. Unlike in the oil market, there is very little spare LNG capacity, as LNG producers tend to produce at the maximum level.

2. Oil security in ASEAN+6

Evolving oil market situation

The Asia-Pacific region consumes more oil than any other region in the world. It now accounts for more than one-third of global oil demand, surpassing that of North America. Robust growth, led by China, India and Southeast Asia, is projected to add 10 mb/d in oil demand between 2017 and 2040, more than offsetting the long-term oil demand decrease in the advanced economies of this region. Between now and 2040, this region is expected to account for 78% of global growth and its share of global oil demand is set to increase to 37% (Figure 4).

Figure 3. Evolution of regional share in global oil demand (2000-40)



Source: IEA (2018a), *World Energy Outlook 2018* (New Policies Scenario).

Led by robust growth in China, India and Southeast Asia, the Asia-Pacific region gains a majority share of global oil demand.

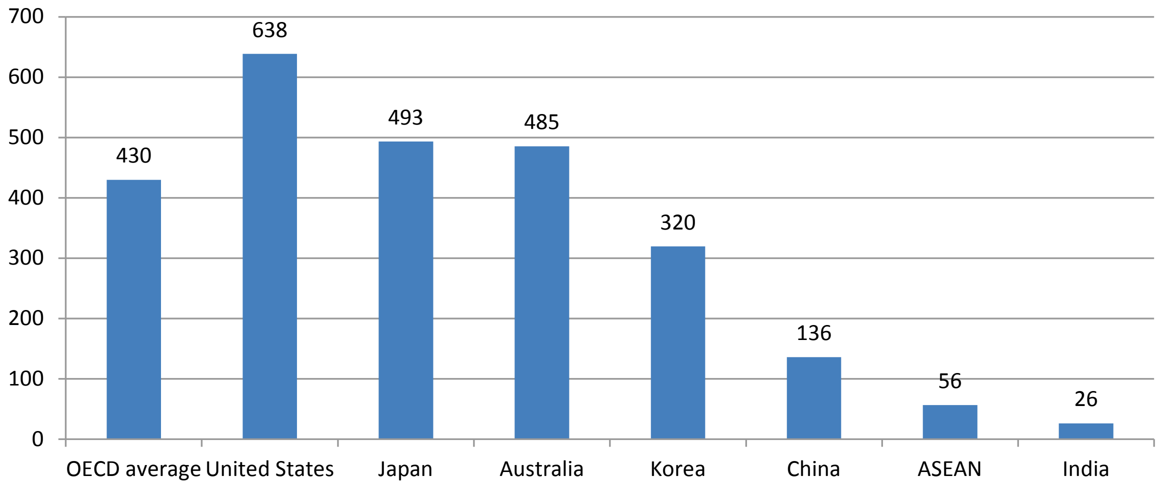
As the world's second-largest economy, China maintains impressive oil demand growth. Its rate of growth is falling, however, as China transforms itself from an energy-intensive industrial economy to a more consumer-focused economy, with a higher rate of growth for petrochemicals and transport fuels. India's oil demand will grow faster than that of any other country, surpassing China by the late 2020s; its oil consumption will more than double from 2017 to 2040.

Global oil demand by sectors

Growing demand for transport, which increases consumption of oil products, will be one of the main sources of oil demand growth, as the global car fleet is expected to double, reaching 2 billion by 2040. Oil demand will grow robustly in Southeast Asia, where the number of passenger vehicles per 1 000 people is 56, less than half of the world average, signalling the potential for further growth. India lags still further behind, with just 26 cars per 1 000 people, compared with 136 in China and 493 in Japan (Figure 5).

At the same time, oil demand is likely to be curbed by measures to improve urban air quality, especially in **China**, such as fuel and emission standards that restrict vehicle use, and switching to electric vehicles (EVs). In big cities in China, licence plates for gasoline vehicles are awarded by lottery or sold through auctions, and their price can be higher than that of the car. Sales of EVs are booming – 777 000 EVs were sold in 2017, 50% more than in 2016 – and the stock of passenger EVs was close to 1.3 million at the end of 2018, about one-third of the global total. China has set a goal of deploying 5 million EVs by the end of 2020. China is also host to the world's largest number of compressed natural gas vehicles (NGVs), of which almost 6 million were operational in 2018. EVs and NGVs together could displace at least 20 kb/d of gasoline demand per year from now to 2024. The growth of LNG trucks and electric buses will displace at least 20 kb/d of diesel demand per year (IEA, 2019).

Figure 4. Passenger vehicles per 1 000 people, 2017



Source: IEA MoMo estimates.

Growth potential is significant for oil demand for transport in developing countries of ASEAN+6.

As in China, **India**'s rapid increase in car usage has led to severe air pollution and the government is determined to promote EVs, starting with public transport and taxis. India is now the world's fourth-largest automobile market after China, the United States and Japan. Although the number of EVs being sold in India is still very small, the government initially pushed hard to have a "100% electric vehicle" policy by 2030. This ambitious policy was recently scaled back to a target of 30% of newly sold cars, while reaching 100% for public transport (at least in bigger cities) by 2030. Among the Southeast Asian countries, **Thailand** has set a goal of 1.2 million registered EVs on the roads by 2036, compared with only 132 registered by the end of 2016. **Malaysia** has set a target of 100 000 EVs, 2 000 electric buses and 125 000 charging stations on the road by 2030, compared with just over 100 EVs today.

According to the *WEO 2018* New Policy Scenario, the number of EVs is forecast to increase globally from 3 million in 2017 to around 300 million by 2040. Oil use in buildings and for power generation will also decline. Despite the long-term declines in oil use for passenger vehicles, buildings and power, however, total oil demand will rise to 106 mb/d by 2040 because of continued growth in other sectors. Oil use for petrochemicals will be the largest source of growth, adding 5 mb/d between 2017 and 2040. Asia-Pacific will account for 60% of this increase, with China at the centre due to robust growth in its overall manufacturing output as well as its gradual shift to a consumer-driven economy. Rising consumption of fuels for trucks will add 4 mb/d, as fuel-efficiency standards for trucks are less effective than those for passenger cars. India will account for 40% of this increase. Consumption in the aviation sector will increase by over 3 mb/d because of robust increases in travel demand, particularly in developing Asian economies, as well as the lack of readily available alternatives to oil in aviation.

Global oil supply

On the supply side, production growth in the medium-term will be dominated by non-OPEC countries, particularly the United States, which will account for 80% of the net increase in oil supply to 2025. The abundance of oil supply in recent years has created considerable competition among traditional exporters to win or secure market share in the Asia-Pacific region, where demand growth is concentrated. The rise of the United States as a major crude oil exporter is shifting trade flows from the Atlantic Basin to Asia-Pacific. However, these dynamics have proved not to be a lasting sign of improved oil security, as there are ongoing uncertainties in the market with US sanctions against Iran and Venezuela.

While the upstream spending increases are directed mainly towards US shale, the exploration and development phases of conventional resources are seeing little investment. Production from conventional fields is declining, removing 3 mb/d from the global oil balance every year. Large-scale investments are needed to develop 670 billion barrels of new resources between now and 2040, mostly to make up for declines at existing fields rather than to meet the increase in demand. Growth in US tight oil – oil extracted from low permeability rock – may offset much of this decline for some years to come, but once US tight oil plateaus in the late 2020s and non-OPEC production as a whole falls back, the market will become increasingly reliant again on the Middle East to balance the market.

The industry in the Middle East is also undergoing significant changes, however. Middle Eastern output will continue to grow as crude production increases by 4.5 mb/d between 2017 and 2040, but less than 1 mb/d will become available for exports, due to rising consumption within the region itself and the expansion of refining capacity. The Middle East will lead on global refining capacity additions in the near-term, overtaking China and India, both of which are slowing pace. Crude oil volumes exported from the Middle East will not be enough to satisfy the appetites of Asian refiners, who will increasingly import additional crude from Africa, Eurasia and Latin America.

Production from the Asia-Pacific region will not be enough to supply its rising domestic demand. Oil supply from this region is expected decline steeply, with output from all producers falling, except Australia and India to some extent. Few new discoveries have been made in recent years and output from mature assets is declining rapidly. China is the world's seventh-largest oil producer, but its output has been falling sharply since 2015 and is expected to drop from 4.0 mb/d in 2017 to 3.1 mb/d by 2040. Steep declines are also expected in Southeast Asia.

Indonesia's crude supply is forecast to fall to 575 kb/d by 2023, 225 kb/d lower than in 2017. Malaysian production is expected to decline by 120 kb/d over the same period, while Viet Nam will record a 100 kb/d drop.

Trade: Increasing import dependence for crude oil

The changing patterns of oil production and consumption underpin a profound shift in trade flows heading east. The Asia-Pacific region will account for the lion's share of oil demand growth and crude oil imports over the coming 25 years. Asia-Pacific's combined crude oil imports will rise by 9 mb/d to around 30 mb/d by 2040, with strong growth in China, India and Southeast Asia more than offsetting declines in Japan and Korea. Asia-Pacific's share of global crude oil imports will rise from 50% today to 67% by 2040, not only because domestic oil production is declining but also because of new refinery capacity, growing appetite for petrochemical feedstocks and strategic inventory stockpiling, notably in China. China now has more refining capacity than any other country except for the United States. As its capacity additions started to outpace demand growth from the late 2000s, China became a net exporter of key refined products, with combined exports of gasoline, diesel and kerosene reaching over 500 kb/d in 2016. Its position as an exporter of refined products is now one of the factors driving its crude oil imports. China's net crude import requirement surpassed that of the United States in 2017 and is expected to almost double by 2040 to reach 11.3 mb/d, while the country's dependence on imported crude oil will rise from 70% to more than 80%. India's crude oil imports will increase to more than 4.5 mb/d, and will match those of the United States by the early 2020s. Indonesia will become the third-largest country in terms of crude oil import growth, as imports soar from 50 kb/d to over 700 kb/d due to declining crude oil production and higher refining capacity. With new refining capacity coming online in Malaysia, Viet Nam and Brunei, there will be no net crude exporting country in Asia-Pacific by the early 2020s.

In the past, Asia-Pacific's total crude import needs have never outpaced the available export volume from the Middle East, which is set to remain, by far, the world's largest crude-exporting region. But the availability of additional crude from the Middle East for international trade is being squeezed by rising domestic consumption and new refinery capacity. With the commissioning of several new refineries, the Middle East is set to become not only the largest crude oil exporter but also the largest product exporter in the world. Meanwhile, Asia-Pacific's crude oil import needs are expected to increase by 9 mb/d by 2040 – outpacing by far the available exports from the Middle East – and most of the incremental import requirements will have to come from the Atlantic Basin, taking longer sailing times. The expanding volume of trade passing through the Strait of Malacca, the world's second largest chokepoint, adds another layer of complexity to Asian importers' oil security concerns.

These concerns suggest that Asia-Pacific countries need to strengthen strategic and long-term ties with the largest suppliers in the Middle East, while carefully assessing the risks from geopolitical developments. Taken together, these evolving patterns of oil trade, production and consumption call for a major reappraisal of how best to ensure oil security.

Emergency oil stockholding

Maintaining a well-functioning and robust system of emergency oil stockholding that can be used to respond to supply disruptions is a major task for the IEA, the custodian of today's global oil security mechanism. Emergency oil stocks are a powerful policy tool for mitigating short-term physical supply disruptions and providing liquidity to allow market recovery (Box 1). The

IEA stockholding system has undeniably worked well in the past, providing significant economic benefits primarily by offsetting oil supply losses, thereby reducing potential GDP losses and import costs by avoiding significant oil price increases.

Box 1. Assessing the costs and benefits of holding oil stocks

Since 2013, when the IEA published a study on the costs and benefits of holding emergency oil stocks, global energy markets have been shaken by volatility in crude and oil product prices and changes in the production profile of the United States. Oil continues to be traded in a market where uncertainty and sudden supply shocks are common occurrences. To assess the net benefits of holding emergency oil stocks under these new market conditions, the IEA has published an updated study, *The Costs and Benefits of Emergency Stockholding* (IEA, 2018b).

A sharp decrease in crude and oil product prices since the time of the first study has substantially reduced the overall costs of holding emergency stocks, overshadowing the impact of changes in any of the other cost categories. The costs of storing emergency stocks, including the cost of purchasing the liquid fuels, have decreased for all storage types. Underground storage (in rock caverns or salt caverns) remains cheaper than above-ground storage. Stockholding costs range from USD 7 to USD 8.6 per barrel per year for a storage using a 3% discount rate (base case assumptions) (IEA, 2018b).

Emergency oil stocks provide economic benefits by enabling oil supply to be restored during disruptions, thereby dampening oil price increases. Preventing price increases avoids substantial import costs and GDP losses.

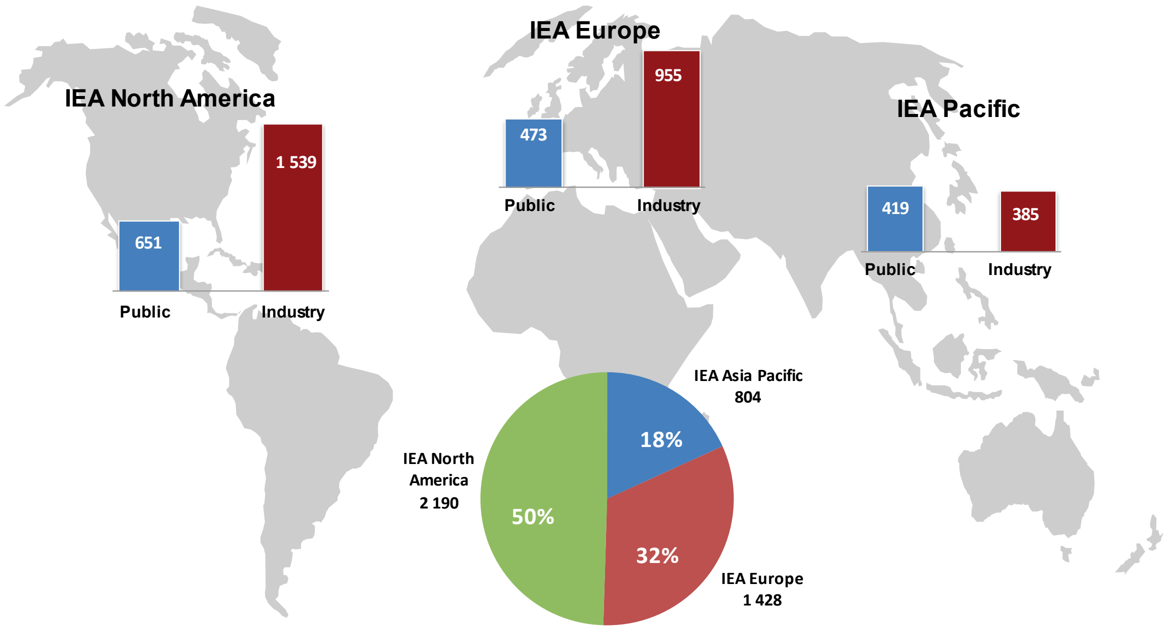
Under the base case assumptions in this report, the total expected benefit of IEA stocks to all global importing regions is about USD 60 per barrel per year. Accumulated over 30 years, the total benefit to all countries that are net importers of oil is USD 3.9 trillion. This estimate is an average payoff from the "insurance" provided by stocks. The actual benefits would depend on the particular oil market future ultimately realised.

In this analysis, IEA emergency stocks benefit non-IEA importing countries more than IEA member countries. The principal reason for this is that non-IEA oil consumption and GDP are projected to grow significantly over the 30-year horizon of the simulation, eventually exceeding collective consumption and GDP of IEA member countries. Thus, while these countries will become more vulnerable to global oil supply disruptions, their greater share of oil consumption and GDP of these countries is reflected in a higher share of the benefits derived from the release of emergency stocks.

In accordance with the International Energy Programme (IEP Agreement), all IEA members are required to hold emergency oil stocks equivalent to at least 90 days of their net imports. This basic oil stockholding obligation of IEA member countries was first formulated in 1974 to establish a "common emergency self-sufficiency in oil supplies". The IEA minimum stockholding obligation is based on net imports of all oil, including both primary products (such as crude oil and natural gas liquids, or NGLs) and refined products. It does not cover naphtha and volumes of oil used for international marine bunkers. The 90-day commitment of each IEA country is based on the average daily net imports of the previous calendar year. This commitment can be met through stocks held exclusively for emergency purposes and stocks held for commercial or operational use, including stocks held at refineries, port facilities and in tankers in ports. The obligation specifies several types of stocks that cannot be counted towards the commitment, including military stocks, and volumes in tankers at sea, in pipelines, at service stations or held by end-consumers (tertiary stocks).

Total oil stocks in IEA member countries amounted to around 4.4 billion barrels at the end of January 2019. More than 1.5 billion barrels of this amount was in the form of public stocks, held exclusively for emergency purposes. The 2.9 billion barrels of industry stocks include both stocks held to meet government-imposed minimum stockholding obligations and stocks held for commercial purposes (Figure 6).

Figure 5. Regional oil stockholding of IEA member countries, January 2019



Source: IEA (2019), *Monthly Oil Statistics*, *January*.

Asia-Pacific accounts for 18% of the total IEA oil stocks, where public and industry stocks are held almost equally.

Different stockholding structures in IEA member countries

Stockholding regimes vary among IEA member countries, reflecting differences in oil market structure, geography and national policy choices related to emergency response (Figure 7). In general, there are three approaches to ensuring that overall stock levels meet minimum requirements: government stocks, agency stocks and industry stocks. Some countries use only one category of these, whereas most countries use a combination of categories to meet the minimum obligation.

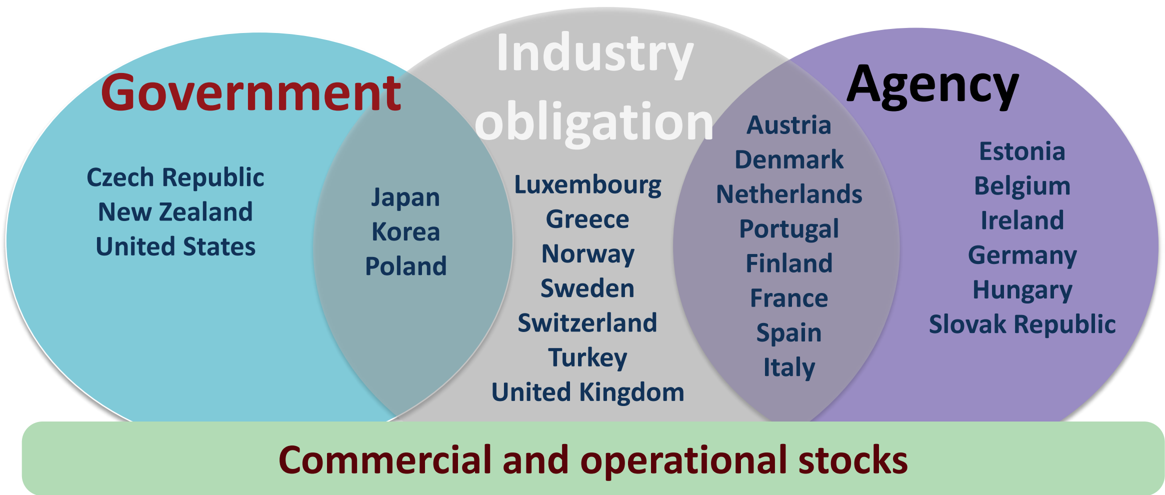
Government-owned stocks are one way countries can ensure their IEA minimum stockholding requirement. These are typically financed through the central government budget and held exclusively for emergency purposes.

Agency stocks are also considered as public stocks where a stockholding arrangement involves the establishment of a separate agency endowed with the responsibility of maintaining all or part of the stock obligation. The agency structure and arrangements vary from country to country; some are administered by the government while others are led and/or owned by industry. Public stocks offer the advantage of providing a clear indication of oil available solely for emergency purposes.

Industry stocks include both stocks held to comply with national stockholding rules and for commercial purposes. For emergency stockholding, a government generally requires certain companies, such as importers, refiners, product suppliers or wholesalers, to hold a minimum amount of stocks. The required amount is set in proportion to the company's oil import share or its share of sales in the domestic market.

One general attraction of a mixed system, where both public and industry stocks are held, is that it can improve overall visibility of emergency stocks while maintaining an operational link with the oil companies. However, in some cases it can be difficult to distinguish between companies' operational and obligatory stocks and thus difficult to monitor the stockholding obligation and the availability of these stocks in a crisis. By contrast, it is easier to monitor stocks that are totally segregated from operational stocks. Another approach is to hold emergency stocks in tanks within commercial tank farms, where the location of the volume of emergency stocks can be pinpointed at any moment and made available during a crisis. This approach may offer the dual benefits of the held stocks being visible and easy to check, yet also readily available to be quickly brought into the operational system in times of emergency.

Figure 6. Oil stockholding regimes of IEA member countries



Stockholding choices vary by market structure, geography and national policy.

Crude or products

The IEA stockholding obligation does not specify whether stocks should be held in the form of crude or refined oil. By contrast, the EU directive on oil stockholding stipulates that the member states must ensure that at least one-third of stocks are held in the form of specific products. The most appropriate choice between holding reserves in either crude oil or refined products depends on factors in each country. Countries with a large refining industry are likely to hold more crude oil, which provides greater flexibility in times of crisis. In countries that have limited domestic refining capacity or rely on product imports to meet a large share of domestic demand, there is a greater tendency to hold reserves of refined products.

Holding at least some portion of emergency stocks as product stocks makes sense, however, even for countries with a substantial refining sector, despite the higher costs of holding such stocks. This is because in the event of supply disruptions such as natural disasters, particularly those affecting refineries or import terminals, product stocks may be more rapidly available to secure quick distribution to the affected area. The IEA recommends that its member countries hold a certain amount of refined product stocks to ensure their timely drawdown and distribution in an emergency. In the case of Hurricane Katrina, which struck Florida and Louisiana in 2005, the IEA Initial Assessment emphasised a preference for product stock releases (particularly gasoline) as the disruption was mostly derived from US refinery shutdowns.

Stocks held abroad and tickets

Holding emergency oil stocks outside a country's boundary can be a critical means of more cost-effective stockholding, particularly for countries in which storage capacity constraints or supply logistics make domestic storage insufficient. The interconnectivity of the oil market infrastructure can also facilitate cost-effective use of spare storage capacity in neighbouring countries.

IEA member countries can arrange to store oil outside their national boundaries and include such stocks in meeting their minimum requirement. To exercise this option and count the stocks held abroad towards the obligation, the governments involved must sign bilateral agreements assuring the viability of the stocks in an emergency. "Tickets" account for a large part of the stocks held abroad under bilateral agreements. Tickets are stockholding arrangements under which the seller agrees to hold (or reserve) an amount of oil on behalf of the buyer in return for an agreed fee. The buyer of the ticket (or reservation) effectively owns the option to take delivery of physical stocks in times of crisis, according to conditions specified in the contract. Tickets can be issued for either crude oil or refined products; the agreement specifies the quantity, quality and location of the oil for a specified period. Tickets can also be domestic contracts, most notably in cases where the government has placed a minimum stockholding requirement on domestic market participants such as importers or refiners. In such cases, a company holding stocks in excess of its obligation can offer these excess amounts to cover the obligation of another company or agency. Ticketing is a flexible and generally cost-effective way for companies or agencies with insufficient stocks to meet stockholding obligations. It essentially provides an alternative to acquiring oil stocks directly and building and/or renting necessary storage capacity.

IEA emergency response

In the event of an actual or potentially severe oil supply disruption, IEA member countries together may choose to release their emergency oil stocks. The IEA Secretariat has a mandate to initiate and co-ordinate the stock release. After exchanging information with producers and international organisations such as the Organization of the Petroleum Exporting Countries (OPEC), the Secretariat assesses the market impact by estimating the market's net loss of oil and taking into account any spare production capacity that can quickly be brought on line. This assessment is the basis on which the IEA Executive Director then consults with and provides advice to the IEA Governing Board (GB), the IEA's highest political decision-making body, which comprises representatives of all 30 member countries. If the IEA Executive Director determines that the situation warrants collective action, GB members will be sent an assessment that includes the suggested volume of oil and each country's proposed share (based on consumption) in order to respond to the global market's net supply loss, for an initial period of 30 days. Then the GB representatives will be asked to respond within a given period, usually 24 hours.

Once there is a decision to activate emergency measures, it takes most IEA member countries two to seven days to implement the necessary approvals for the release. Physical delivery to markets can take as little as one day or as long as three weeks, depending on the emergency stock structure. It can take member countries holding significant proportions of their emergency stocks overseas up to six weeks to take delivery of those stocks. Such countries may opt instead to swap stocks with another country, which can significantly reduce this period. The exact method of emergency stock release varies considerably among member countries. Most countries would make stocks available at prevailing market prices. Some countries also use a tender bidding process or loans.

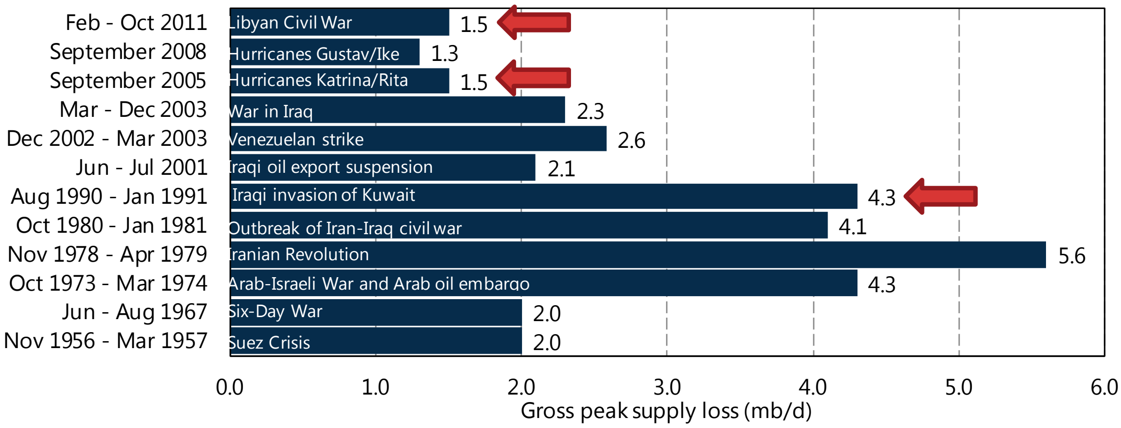
Following a disruption, markets would eventually balance on their own but with significant economic costs. Emergency oil stocks cannot replace market mechanisms. Instead they mitigate the economic impacts of short-term supply disruptions by providing additional liquidity, allowing time for markets to recover.

Past supply disruptions and collective actions

There have been many supply interruptions since oil became the dominant energy source in the 1950s, but not every disruption has resulted in collective action to implement emergency response measures. The IEA and member countries have acted three times to bring additional oil to the market, in response to the Iraqi invasion of Kuwait (1990-91), Hurricanes Katrina and Rita in the United States (2005) and the Libyan civil war (2011) (Figure 8, Table 4). The first significant disruption was the Suez Canal Crisis in 1956-57, which blocked the passage of half of the canal's shipments of oil of around 2 mb/d. The largest has been the Iranian revolution of 1978-79, with a disruption of around 5.6 mb/d. The severity of an oil supply disruption depends not only on how much oil is lost but also on factors such as the level of commercial inventories, the likely duration of the disruption and the available spare production capacity. More technical factors play a role as well, such as the quality of the crude oil lost, seasonality trends and logistical issues.

When there is sufficient volume of spare capacity in major oil producing countries and high commercial inventory levels are maintained, the market can function well and balance the deficit smoothly. For example, Hurricanes Katrina and Rita in 2005 and Hurricanes Gustav and Ike 2008 caused substantial disruptions to North American oil supply flows, yet collective action was instigated only in 2005. The main reason collective action was not taken in 2008 was that global demand was declining sharply because of the global financial crisis, while in 2005 oil demand was rising. Furthermore, spare capacity and inventory levels were higher in 2008 and there was plenty of idle refining capacity outside the United States, while the market situation was tight in 2005. Compared with sudden supply disruptions, it is more difficult to assess the impact of gradually escalating events like the 2011 Libyan crisis. In such a case, dialogue to develop a shared understanding of the situation becomes more critical.

Figure 7. Major oil supply disruptions



Source: IEA (2014), *Energy Supply Security: The Emergency Response of IEA Countries 2014*.

Not every disruption initiates a collective action – the IEA and member countries have acted three times to bring additional oil to the market.

Table 4. Past IEA collective actions

Date	Occasion (supply loss)	Stock release details
Aug 1990-Feb 1991	Iraqi invasion of Kuwait (4.3 mb/d)	Given the risk of further supply loss from the Gulf in the event of hostilities, the Governing Board, with the participation of France, Finland (not yet IEA members at that time) and Iceland (a non-member), unanimously decided in January 1991 to make available to the market 2.5 mb/d of oil, (including 0.4 mb/d from demand restraint and 0.1 mb/d from fuel switching).
Sep-Dec 2005	Hurricanes Katrina and Rita (1.5 mb/d)	On 2 September 2005, in the immediate aftermath of Hurricane Katrina in the Gulf of Mexico, the IEA announced the agreement of member countries to make available to the market 60 mb of oil (2 mb/d for 30 days).
June 2011	Libyan crisis (1.5 mb/d)	On 23 June 2011, the IEA announced the agreement of member countries to make available to the market 60 mb of oil (2 mb/d for 30 days) in response to the ongoing supply disruption of Libyan light sweet crude and an anticipated increase in oil demand, and to act as a bridge to incremental supplies from major producers.

Sources: IEA (2014), *Energy Supply Security: The Emergency Response of IEA Countries 2014*.

Of course, IEA member countries hold emergency oil stocks not only to release in an IEA collective action but also to deal with a domestic supply disruption (Table 5). Each country's ability to respond to domestic oil market crises is a key component of regional and even global oil supply security.

Table 5. Examples of IEA member countries releasing emergency stocks in domestic crises

Country	Date	Occasion	Stock release details
France	Sept-Oct 2010	Oil industry strike	A five-week strike affecting the oil sector resulted in panic buying and fuel shortages in many regions. The government responded by drawing down strategic stocks, reallocating reserves to the affected areas (6 mb reallocated, 8 mb leased) and lowering the industry obligation.
Japan	March-May 2011	The Great East Japan Earthquake	At least six of Japan's 27 refineries, with a combined capacity of 1.4 mb/d or 31% of the country's total, halted operations after the disaster. The industry obligation was lowered from 70 days to 45 days (around 66 mb). At the disruption's peak in mid-March, industry stock volume decreased by around 25 mb.
France	Dec 2013	Oil industry strike	Refinery strikes resulted in a halt in supplies equivalent to 70% of total French domestic consumption. The government used 2.7 mb of stocks, two-thirds via swaps and one-third via loans.
Switzerland	Oct 2015	Low water levels on the Rhine river and other logistical issues	An unplanned shutdown of Switzerland's only operating refinery, low water levels on the Rhine and railways being used at full capacity combined to disrupt domestic supply. In total, 1.5 mb (3% of the country's total emergency stocks) was released, although only 882 kb was used.
France	May-June 2016	Oil industry strike	The government released public stocks via swaps and loans and authorised industry to use their security stocks up to 9 days. In total, around 1.7 mb were released.
United States	Aug-Sep 2017	Hurricane Harvey	Harvey, the wettest hurricane on record, made landfall near Rockport, Texas on 25 August 2017. The refinery capacity blocked by Harvey peaked at 4.4 mb/d on Aug 30. By 28 September, 5 mb of oil from the strategic petroleum reserve (SPR) had been delivered to Gulf Coast refineries, helping to continue their processing operations and prevent further supply disruptions.
Germany	Oct-Dec 2018	Low water levels on the Rhine river	German oil stockholding agency, EBV, released 518 kb of gasoline, 1.1 mb of diesel and 414 kb of jet fuel.
Switzerland	Oct-Dec 2018	Low water levels on the Rhine river and other logistical issues	The historically low level of the Rhine river as well as with import capacity constraints (including the quota system applied on the product pipelines from France) led to a national shortage of oil imports. A total of 2.3 mb of oil products from the compulsory industry stocks were released in stages. About 1.6 mb was taken up by the market.
France	Jul-Dec 2018	Low water levels on the Rhine river	Due to low water levels, France faced oil product supply disruptions and resorted to the use of strategic stocks to ensure oil product supply in the east of France. Stocks released included 1.1 mb of diesel, 138 kb of heating oil and 54 kb of gasoline.

Country	Date	Occasion	Stock release details
Poland Hungary Czech Rep Germany Slovak Rep	Apr-May 2019	Contamination of oil in the Druzhba pipeline system	After crude coming from Russia via the Druzhba pipeline was found to be contaminated, flows were halted and supply shortages affected refineries in Eastern and Central Europe. Poland, Hungary and Czech Republic released emergency stocks at the end of April to maintain refinery operation. Germany and Slovak Republic used commercial stocks for operation.

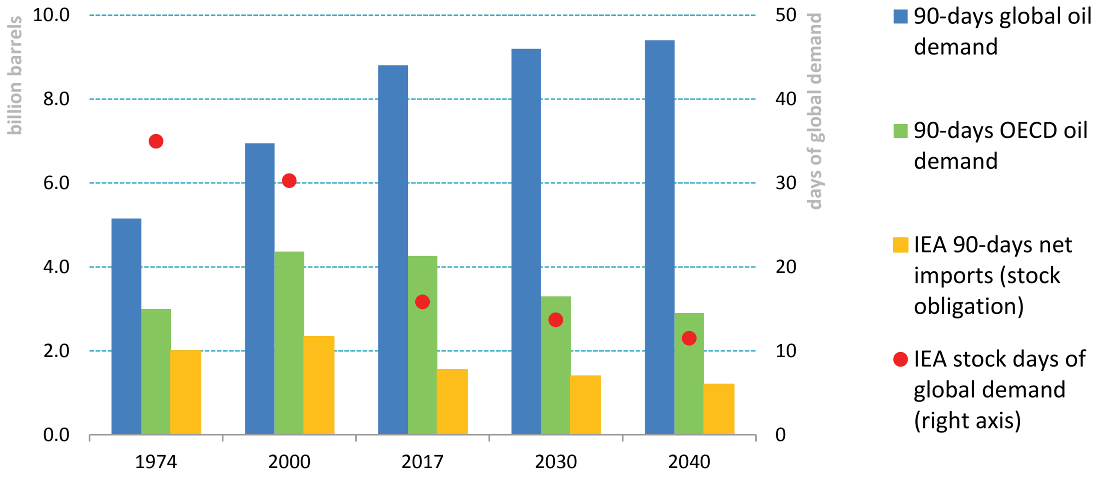
Sources: Government administrations; Platts.

Broadening collective security

Since its foundation in 1974, the emergency response system co-ordinated by the IEA has provided a key means of safeguarding oil security and mitigating the effect of disruptions. The global energy landscape has been significantly altered, however, by surging demand and rising import dependence in emerging economies, notably China, India and ASEAN countries. At the same time, oil demand in many IEA member countries is waning and the IEA oil net imports that are the basis for the IEA stockholding obligation are declining. These changes pose a risk that the emergency response system will become progressively less effective, making global oil security more vulnerable.

When the IEA was founded in 1974, the stockholding obligation of IEA member countries represented around 40% of 90 days of global oil demand. This coverage fell to around 20% in 2016 and is expected to fall further to around 11% by 2040, too little to compensate for a large supply disruption (Figure 9). There is a strong case to broaden the IEA oil security umbrella to cover the contingencies that might arise in tomorrow's oil market. One option would be to gradually bring the rising oil-consuming countries – many of which are in the ASEAN+6 group – closer to the collective oil security system. The IEA now works closely with non-member countries to find solutions to shared energy security concerns. Part of this work involves sharing IEA expertise and exchanging information on policy updates, best practices, and lessons learned about how member countries and non-member countries can handle major oil supply disruptions. Such collaborative work beyond IEA borders is already bearing fruit (Box 2). The most recent emergency response exercise in 2018 increased the extended IEA family's share of global energy demand to more than 70%.

Figure 8. 90 days net imports vs. global demand



Source: IEA (2017), *World Energy Outlook 2017*, adjusted.

In the future, IEA stocks alone will no longer be able to compensate for global supply shortfalls.

The need to broaden oil security is clear, so the IEA will continue to work ever more closely with countries seeking to establish emergency response systems. As countries outside the IEA attain a substantial share of the world's oil consumption, integrating them into an IEA collective response becomes more and more essential to maintaining an effective safety net for the global oil market. Nowhere is this truer than in the cases of China, India and the ASEAN member states. Fully integrating these countries' emergency response capabilities into the IEA collective response mechanisms will take time. There are several steps, outlined below, which countries can take now, and in some cases have already begun taking, to improve their domestic and regional oil supply security.

Box 2. Sharing experience in emergency response

Emergency response simulation exercises for oil supply disruptions (EREs) are the primary tool with which the IEA ensures that delegates and Secretariat staff are capable of implementing its emergency system quickly and effectively in the event of a major global oil supply disruption. EREs make use of hypothetical disruption scenarios to help familiarise participants with the main components of the IEA response system, as well as the key trends and risk factors affecting the global oil market. These are done both remotely, with participants working from their respective capitals, and in meetings at IEA headquarters in Paris, France. EREs have been organised every two years since 2002 to include participants from countries who are not members of the IEA. The 2018 ERE drew the largest-ever participation, with 44 countries taking part including IEA Association countries such as China, India, Indonesia, Morocco and Thailand.

The IEA has also provided more tailor-made assistance to help individual countries improve their emergency response, including Joint Emergency Response Exercises with Thailand in Bangkok in 2009, with India near Delhi in 2012 and with China in Ningbo in 2015. The agency has also conducted Emergency Response Assessments (ERA) of Thailand in 2010, Chile in 2011, India in 2013 and Indonesia and Colombia in 2014. The IEA participates in the annual domestic Emergency Response Exercise of Thailand and APEC's Oil and Gas Security Exercises (OGSE) as part of the Experts Review Team. Recent OGSEs were held in the Philippines (2015), Australia (2017), and Chile (2019).

Building emergency preparedness: Operational bodies

To respond effectively in an oil supply crisis, a country must have in place a central body responsible for preparing and implementing emergency response policies. The IEA refers to this body as the National Emergency Strategy Organisation (NESO). While its specific overall structure will differ from one country to another, reflecting their particular market and political structure, the NESO is the central focal point for emergency preparedness in both normal times and crisis periods. In normal times, its principle role is to develop and maintain the institutional infrastructure related to emergency preparedness and crisis response. One of its key functions is to develop the necessary communication links among the national statistics office, industry and other bodies relevant to responding to an oil crisis. When a country is still in the early stages of developing an emergency response system, the core staff of the NESO must play a central role in building up capacities for essential data reporting, building critical communication links, and designing an emergency response plan.

Improving energy security through better data

Timely and reliable data are another foundation of energy security. Accurate statistics provide the basis for understanding normal supply and demand conditions, identifying trends that could exacerbate vulnerabilities (e.g. future capacity needs and supply bottlenecks), and determining appropriate emergency preparations (e.g. desirable emergency stocks levels). In a disruption, having the most up-to-date information on main supply flows is essential for assessing the impact and appropriate responses.

The IEA Monthly Oil Statistics (MOS) questionnaire is the international standard for robust data collection necessary to support the analysis and assessments required in an effective emergency response system. The MOS is a basic supply/demand balance, including detailed stock levels, collected on an "M-2" basis (within 55 days of the end of the month). Developing the capacities to successfully collect data for this questionnaire each month, in a timely and sustained manner, is an integral part of developing effective emergency response policies. Policy makers responsible for oil supply security should work closely with their appropriate national statistics office and industry to ensure priority and sufficient resources are dedicated to efforts to establish MOS reporting.

An important step in building progressively towards this capacity is active participation in the Joint Organisation Data Initiative (JODI). JODI is a co-operative effort among international organisations to establish a common basis for data collection worldwide. ASEAN+6 countries already participate in JODI oil, with the exception of Cambodia and the Lao People's Democratic Republic (Lao PDR). Occasionally, rigid confidentiality criteria imposed by companies prevent governments from gaining access to more accurate data. In such cases, companies should be encouraged to waive data confidentiality, with assurances that individual company data remain confidential, as companies themselves benefit from greater market transparency. JODI oil, while a simpler version of JODI, is fully consistent with the MOS reporting. A key milestone for countries, in building up their emergency response policies, is reaching the ability to provide quality JODI oil data questionnaires on an "M-2" basis.

If supply is disrupted and IEA member countries are contemplating collective action, data contacts are required to speed up data collection through the so called Emergency Data Questionnaire (QuE). This questionnaire will be tailor-made to the disruption at hand and will collect only the data needed to assess and monitor that disruption. IEA countries will be requested to submit these data on an M-1 basis to the IEA Secretariat.

Emergency response plan and strengthening communication links

To be effective, emergency measures should be planned before a crisis and include responses that take the pressure off supplies by rapidly curbing demand (Box 3). Each NESO should elaborate a national emergency response plan that clearly defines the roles and responsibilities of all main actors and includes contingency plans for crises of varying types and degrees. Appropriate legislation should be in place that underpins this response plan and allows for its activation regardless of whether a national state of emergency is declared. Such a distinction for activation is critical for being able to respond swiftly to an oil supply disruption. A well-prepared communication strategy is another key part of an emergency response plan. Information is critical in an emergency – not only domestic oil data gathered with monthly statistics but also data from key actors such as oil industry representatives, government officials in neighbouring countries, and international experts. Sharing market intelligence and information on emergency actions with neighbouring countries can help ensure that countries reinforce, rather than counteract, one another's effectiveness.

It is vital to establish hotlines or reliable communication links in normal times so that key actors can be quickly consulted in times of crisis. An important responsibility of a country's NESO is to maintain such communication links with the relevant domestic actors (e.g. oil industry, national statistical office and various relevant ministries). These communication links must also extend beyond national boarders, linking with NESOs of other countries, regional bodies such as the ASEAN Council on Petroleum (ASCOPE), and with the IEA Secretariat. Hotline contacts on emergency preparedness between the IEA and the Association countries have been established as a voluntary and flexible means of communication and are expected to facilitate a rapid and harmonised response in case of global supply disruption.

Box 3. Demand-side response measures: Saving oil in a hurry

If oil supplies are disrupted, measures that reduce demand can help stave off a crisis. Demand-side policies are not restricted to any particular sector of consumption, but most measures target transport because it accounts for a high proportion of oil use. The degree to which demand-side measures are implemented can also vary significantly. Measures can be light-handed, such as encouraging voluntary reductions in oil use (for example, campaigns to promote car-pooling or use of public transportation). Or governments can impose heavy-handed measures such as driving bans, rationing or allocation of oil. Key to the success of demand-side measures is thorough preparation and planning well in advance of any crisis. This begins with an analysis of the potential oil savings as well as the potential economic or social harm of restrictive measures.

In 2018, IEA published *Saving Oil in a Hurry* (IEA, 2018c) a study that provides a set of recommendations for governments on how to reduce oil demand if oil supply is disrupted. The study aims to include the latest developments using digital technologies. The demand restraint toolbox is structured around different measures that countries can choose from to determine the most appropriate short-term way of saving oil rapidly when facing a crisis. In addition to the short-term benefits, the report explores briefly how demand restraint measures might be implemented in a mid- to long-term timeframe to encourage low-carbon transport.

Regional co-operation to improve energy security

The need to develop a joint strategy to address oil security issues and co-ordinate emergency response measures was one of the key drivers for the establishment of the IEA in the 1970s. This is no less true today, so ASEAN+6 countries should explore the potential for regional approaches to improve collective supply security. ASEAN member states have already taken significant steps in this respect, as oil security and emergency preparedness have been an integral part of the common agenda of ASEAN since its creation. ASEAN countries agreed to establish the ASEAN Petroleum Security Agreement (APSA) (Box 4).

Box 4. Implementing the ASEAN Petroleum Security Agreement

The key principle of the ASEAN Petroleum Security Agreement (APSA) is to mitigate the impact of an oil supply disruption in one or more of the ASEAN member countries by activating a sharing scheme for crude oil and petroleum products. It aims to be a framework for regional consultations and co-ordination to facilitate oil allocation in case of an emergency, under which assistance is made on a voluntary and commercial basis. APSA represents a substantial achievement among ASEAN member states, laying the foundation for responding collectively in the event of a severe disruption of oil supplies.

APSA was originally formulated in 1986. It officially entered into force in early 2013, following final ratification by all 10 ASEAN member states. It will remain in force until March 2023, a period that may be extended if agreed upon by all member states. Amendments to the provisions of APSA are also possible with the written consent of all ASEAN member states.

A task force chaired by the ASEAN Council on Petroleum (ASCOPE) has been tasked by ASEAN ministers to explore ways to make APSA operational. Such work will need to consider possibilities for developing a dedicated APSA Secretariat as a permanent body with clear responsibilities for co-ordinating its implementation. There are also technical aspects that hinder APSA from being operational, including an overly strict activation threshold of 10% of consumption for both oil and natural gas to be disrupted for a period of 30 days. Furthermore, if APSA is to be operational and effective, there is an urgent need for each member country to establish emergency response measures, including building up emergency oil stocks, which could be used to contribute to a collective ASEAN emergency response.

The release of emergency oil stocks, for all practical purposes, is the only short-term measure that can bring immediate additional supply to a disrupted market. Therefore, the establishment of emergency oil stockholding is one of the primary objectives, at least in the medium term, of countries committed to creating oil supply security. However, a substantial amount of time can be required for some countries to establish oil stockpiles and, particularly where it is necessary to build up domestic storage capacities, substantial costs can create obstacles. For these reasons, a regional approach could be explored within ASEAN+6 to set up a framework for cross-border stockholding, as a pragmatic and flexible pathway that will eventually strengthen the response capacity of the region as a whole (Table 6). Some options are explained below.

Bilateral ticketing

Tickets offer particularly interesting opportunities for ASEAN+6 countries. While the emerging economies within ASEAN+6, such as China, India and the ASEAN countries, are increasingly reliant on oil imports to fuel their economic growth, IEA member countries such as Japan and Korea are likely to encounter a significant surplus in their oil stocks in the near future due to declining oil demand. The effective use of this oil stock surplus in emerging economies under a bilateral stockholding ticket arrangement provides an opportunity for both parties to benefit. Tickets are an effective way to enhance the capacity and flexibility of regional oil stockholding, while providing lower-cost options for building emergency stocks. In an example of existing regional co-operation using tickets, the New Zealand government held tickets with companies in Japan that counted towards New Zealand's 90-day IEA obligation. New Zealand held 400 000 barrels of stocks in the form of tickets in 2014 (the contract had expired at the time of writing).

As a way to increase the volume, range and diversity of cost-effective stockholding options, the IEA Secretariat, in collaboration with IEA member countries, has developed a set of criteria for allowing interested IEA member countries to hold bilateral oil stocks in non-OECD countries and have those stocks counted towards their 90-day IEA oil stockholding obligation. This new initiative would also encourage increased stockpiling in some non-OECD countries, most notably in the Asia-Pacific region, and help countries like Australia and New Zealand to build up dedicated emergency stocks.

Table 6. Examples of regional co-operation in emergency stockholding *

Types of regional co-operation	Example	Who owns oil?	Who owns storage facilities?	Physical location of oil stocks	Who has access in case of emergency?
Bilateral tickets	New Zealand buys emergency stocks as tickets from Japan	Japanese industry	Japanese industry	Japan	New Zealand
Long-term use of storage facilities abroad	Indonesia uses storage facilities in Singapore to hold its strategic stocks	Indonesia	Singaporean industry	Singapore	Indonesia
Joint stockpiling	Saudi Aramco stores commercial stocks in Japan	Saudi Aramco	Japanese industry	Japan	Japan

* The case of Indonesia using storage facilities in Singapore is a hypothetical example offered to facilitate understanding.

Long-term use of storage facilities in other countries

Governments could also explore the possibility of holding owned volumes of strategic stocks in storage facilities in neighbouring countries. Within ASEAN, Singapore and Malaysia may have the potential to play more important roles as regional oil storage hubs for strategic stocks, given their geostrategic location and ability to supply logistic services, including storage capacities and export infrastructure. In such a scenario, a country seeking to establish emergency oil stocks could put out a call for tender for commercial storage operators in these countries for long-term storage of oil stocks. Conditions could include guaranteeing volumes (e.g. covering for tank bottoms, evaporation losses) and maintaining product specifications (e.g. by allowing comingling with commercial volumes).

For storage operators, such tenders would represent a business opportunity, offering a steady revenue stream. For the country utilising the storage service, it can ensure professional storage services for its strategic oil stocks through independent third-party auditing, and the interconnection to the commercial supply network allows for the efficient release of these stocks in a crisis. Moreover, such long-term storage arrangements can incentivise storage operators to expand their capacities, as revenues would be guaranteed from a fixed, long-term period, and could provide the financial leverage for expanding their business model. Such storage arrangements can also help to expand opportunities for oil stock ticketing as well as joint oil stockpiling schemes.

Joint stockpiling arrangements

Joint stockpiling (JS) is an innovative way for countries to augment regional stockpiling and hence improve oil supply security. For ASEAN+6 countries, the JS agreements between Middle Eastern producers and large Asian importers could provide another opportunity to build emergency oil stocks more cost-effectively via regional co-operation (Box 5). In such instances, the oil could be considered "de-risked", in that it has already passed through the critical chokepoints of the Straits of Hormuz and Malacca. Such arrangements could offer both the sellers and buyers the flexibility for opportunistic access to spot markets, benefiting both the producer and consumer countries.

Box 5. Examples of joint stockpiling projects in Asia

Japan and Korea, the IEA member countries most dependent on Middle Eastern crude oil, have sought to enhance their energy security by bolstering political and trade ties with Gulf suppliers. Korean National Oil Corporation (KNOC) was the first to promote the international joint stockpiling (JS) model when it leased storage capacity to international oil companies. Such a model brings mutual benefits, offering the Korean side a priority option to purchase crude oil in case of an oil emergency and offering international companies opportunities for market development, logistics optimisation and supply adjustment by having bases in their customer region. Japan has also been promoting JS projects with the Abu Dhabi National Oil Company (ADNOC) of the United Arab Emirates and Saudi Arabia's Saudi Aramco by leasing Japanese private oil tanks in Okinawa. Japan considers JS stock as the "third stockpile" in addition to government stocks and industry stocks, as stipulated in the Strategic Energy Plan approved by the Cabinet in April 2014. In both cases, however, JS stocks are not counted towards the IEA 90-day stockholding obligation.

In January 2017, ADNOC and Indian Strategic Petroleum Reserves Limited (ISPRL) signed a contract to store around 6 mb of ADNOC crude oil at the strategic petroleum reserve (SPR) site in Mangalore, the first JS case that has been applied in India. In an emergency, the entire amount of stored oil would be available for India. The agreement also allows ADNOC to sell part of the crude oil to Indian refineries on a commercial basis. In November 2018, a second joint stockpiling contract was signed with ADNOC to store 9.2 mb of oil at the SPR site in Padur.

Year of initial deal	Importing country in Asia	Producing country in the Middle East	Location of stockpile	Contracted volume (mb)
2006	Korea	Kuwait	n/a	2 (expired)
2009	Japan	United Arab Emirates	Kiire, Okinawa	6.3 (extended)
2010	Japan	Saudi Arabia	Kiire, Okinawa	8.3 (extended)
2012	Korea	United Arab Emirates	Yeosu	6 (expired)
2017	India	United Arab Emirates	Mangalore	5.86
2018	India	United Arab Emirates	Padur	9.2

Source: Indian, Korean and Japanese government administrations.

Stockholding situations of non-IEA countries in ASEAN+6

As their share of global oil demand rises, non-IEA countries in ASEAN+6 will play an increasingly critical role in ensuring global energy security when oil supply is disrupted. Although these countries are at differing stages of developing oil stockholding systems, they recognise the necessity of oil stockpiling and are planning to develop government and commercial oil storage. Most of the ASEAN countries currently rely on industry stockholding obligations to mitigate the impact of oil supply disruptions.

China

China has been steadily building an oil stock reserve system since 2001. In 2003, the government announced the construction of four stockpiling facilities as the first phase of its SPR plan. The second phase of construction is now under way. The country expects to boost its SPR capacity to 500 mb by 2020. While building the SPR, the government has also encouraged domestic oil companies to increase their commercial reserves to enhance resilience. In January 2015, the National Development and Reform Commission (NDRC) started to oblige refineries to hold at least 15 days of crude oil reserves based on daily processing capacity. An energy reserve mechanism would be further developed with equal priority on governmental reserves and corporate reserves, with complementarity between central and local governments, resource and technological reserves, strategic reserves and emergency-response stocks as well as domestic and international reserves. China's National Bureau of Statistics reported that the SPR stood at 274 mb at the end of June 2017, up 33 mb (90 kb/d) from a year earlier. The IEA estimates that China's SPR reached 287 mb at the end of 2017, some of which was stored at commercial facilities on behalf of the government.

India

India officially decided to establish an SPR in January 2004. In June 2004, the Indian Strategic Petroleum Reserves Limited (ISPRL), a wholly owned subsidiary of the Oil Industry

Development Board under the Ministry of Petroleum and Natural Gas, was formed to implement and manage proposed SPR projects. The entire SPR volumes are expected to be in the form of crude oil. In 2006, India's Integrated Energy Policy recommended creating emergency oil stocks equivalent to 90 days of oil imports. In 2008, the government approved the construction of rock caverns in three locations – Vishkhapatnam, Mangalore and Padur – as Phase I of India's SPR scheme, with a total capacity of 5.33 Mt (40 mb). The construction of all three sites was completed by 2018 and the caverns are now filling. In October 2018, after a detailed feasibility study conducted by ISPRL, the government selected Chandikhol and Padur-II as the optimum locations for the Phase II SPR projects, designed to expand the stockpile significantly. India's Union Cabinet approved this project in principle, which involves the creation of an additional 6.5 Mt of storage capacity (around 50 mb) in rock caverns and associated facilities. The government is also exploring a public-private partnership business model for building caverns. India does not place an obligation on its industry to hold a certain amount of stock.

ASEAN

Brunei

Brunei Darussalam's Energy Contingency Plan for Refined Petroleum Product Imports sets an obligatory level of stockholding at 31 days within the industry. The emergency stock is called Country Wide Stock (CWS). In times of emergency, the government has a mandatory right to purchase and control all crude and oil product stocks held by the industry.

Cambodia

Cambodia has a stockholding obligation on industry to hold at least 30 days of domestic oil consumption. As there is no refinery in Cambodia, these obligated stocks are in the form of oil products held at supply terminals. In mid-2019, however, the new Cambodian Petrochemical Co. refinery is expected to come on-line with an initial processing capacity of 2 million tons of oil per year. In future, emergency stocks could be held at the refinery, including crude oil stocks. In 2015, the government announced that it will study the possibility of developing an oil stockpile while the oil price is low. Japan, at Cambodia's request, has conducted a needs assessment in providing policy options and legal framework for setting up an oil stockpile.

Indonesia

Indonesia relies upon operational stocks held by the national oil company, Pertamina, amounting to 21-24 days of consumption. The Ministry of Energy and Mineral Resources is preparing a new regulation to increase to 30 days the operational stocks that commercial entities are obliged to hold. The government also aims to create a national emergency reserve system. The National Energy Council is preparing a roadmap for the provision of 30 days of Energy Buffer Stocks (EBS), to be used only for emergency purposes and to be held by the government. Indonesia has no bilateral stockholding agreement with other countries. However, given its lack of sufficient domestic storage capacity, it is reported that a certain amount of product storage in Singapore is used for Indonesia.

Lao PDR

Lao PDR aims to establish public emergency stocks of 60 million litres, equivalent to 30 days of consumption, by 2020 (Prime Minister's Decree No. 76/2014). The oil industry is obligated to hold at least 15 days of oil imports.

Malaysia

Malaysia, on the verge of becoming a net oil importer, does not have mandatory requirements for government or industry oil stockpiling, but legislation gives the prime minister authority over the national oil company Petronas in the case of emergency – including full control over the company's stocks. Oil storage projects with a capacity of 34 mb are being built, which could be used for public storage. Most of Malaysia's oil product and crude oil terminals are on the eastern coast of Peninsular Malaysia, and offshore as floating storage and production facilities, which have a strategic potential to become a regional oil storage and trading hub in the Asia-Pacific region.

Myanmar

Myanmar holds a certain amount of government stocks in its state-owned oil company's storage tanks as an operational inventory. The Energy Security Plan of the Ministry of Electricity and Energy draws a roadmap of oil stockpiling in days of net imports that aims to achieve 30 days by 2020, 45 days by 2030 and 90 days by 2050. Private companies also have plans to expand storage capacity, although it is not clear how these will feed into the stockpiling roadmap.

The Philippines

The Philippines maintains a Minimum Inventory Requirement (MIR) on the oil industry because the downstream oil industry sector faces risks such as geopolitical instability and supply delivery problems to areas affected by calamities (e.g. typhoons, floods and earthquakes). The current MIR for refiners is in-country stocks equivalent to 30 days of crude oil and refined products, while an equivalent of 15 days of refined product stocks is required for oil product importers and 7 days for the LPG importers. According to the Department of Energy data, the average inventory level for crude and products for the first half of 2017 was the equivalent of 47 days of supply (38 days of in-country stocks and 9 days in-transit).

Singapore

Singapore abolished obligatory crude oil stockpiling in 1983. Power-generating companies are obliged to hold 90 days of fuel oil stocks as backup fuels. Operational stocks in refineries are estimated at around 50 days.

Thailand

The Fuel Trade Act (2000) places mandatory stockholding obligations on all Thai refiners, retailers and importers in the private sector that have operations greater than 100 Kt per year. These operators have to stockpile 6% of their yearly sales of crude oil and 1% of oil products (reduced from 6% in May 2015), which should be at least equivalent to 25 days of consumption (reduced from 43 days in May 2015). Thailand is also considering establishing a government SPR and is studying details such as target volume of the stocks (in days of net-imports/consumption) and type of stocks (crude/products). Thailand conducts an annual domestic emergency response exercise involving all oil, gas and electricity stakeholders to test administrative procedures and communication protocols.

Viet Nam

In July 2017, Viet Nam announced a target plan to build up oil stocks to the equivalent of at least 90 days of net imports by 2020. It aims to increase commercial stocks up to 30-35 days, by requiring refineries to maintain crude stockpiles equivalent to 15 days of their processing capacity and 10 days of oil products output. The government also plans to build strategic petroleum reserves of up to 13.8 mb for crude oil (equivalent to six days of net imports) and 11.3 mb of oil products (14 days of net-imports). However, it is not clear how the remaining days are to be achieved. The Ministry of Industry and Trade and other state-owned oil companies are carrying out a feasibility study.

3. Gas Security in ASEAN+6

Gas market outlook

Natural gas is the cleanest and least carbon-intensive fossil fuel, giving it an important role in the transition to a cleaner and more flexible energy system, especially in emerging economies in the Asia-Pacific region. LNG is making headway in several countries that have recently become gas importers, reshaping the global gas market into a more fragmented and but more interconnected constellation, with greater needs for flexibility. Increasing import dependence will bring challenges for security of supply. At the same time, gas demand is expected to become more flexible, especially for power generation, where gas will be used to accommodate the integration of a growing share of intermittent renewable production sources like wind and solar.

Global gas supply has outpaced demand in recent years. The availability of ample, competitively priced supply is now paving the way for growing gas demand in Asia-Pacific, notably led by **China**. In the *WEO 2018* New Policies Scenario, it is forecast that China's gas demand will rise by nearly 5% per year between now and 2040, reaching 708 bcm, making it the second-largest market in the world behind the United States. China will represent nearly 30% of global demand growth from 2017 to 2040, and the share of gas in China's primary energy mix will increase from 7% to 14%, assisted by a policy drive to improve air quality. China's 13th Five-Year Plan (2016-2020) provides strong policy support for gas, helping it to counter tough competition from coal in almost every sector. Replacing coal in power generation, household heating and industrial applications, such as textiles, food and footwear, could substantially boost the use of gas in China. Gas production in China itself is also growing, underpinned by output of unconventional gas (such as shale gas), and will reach 343 bcm by 2040. Despite this rapid output increase, domestic supply falls well short of demand and China will become a major gas importer. Its total net gas imports are expected to reach around 370 bcm by 2040, both from pipelines and LNG.

India leads growth in the rest of Asia-Pacific, as its gas demand is expected to triple from 2017 to 2040, surpassing Japan's in the next decade. The demand growth is driven by an improvement in economic prospects and the restart of some idle gas-based power plants, taking advantage of cheap LNG supplies. The increased use in industry is led by the fertiliser sector. Despite robust growth in recent years, the share of gas in the power mix is still small, at 5% in 2017, down from 13% in 2009, when massive installation of coal-fired power plants started, supported by the government's strong push to increase domestic coal production to meet growing electricity demand. Although the increase in gas-fired electricity is mainly an instrument to reduce power shortages rather than to replace coal use, the rising concerns about air quality in India's major cities may increase the role of gas in the energy system. As India faces a widening gap between indigenous gas production and demand, its import needs will rise. These are likely to be met entirely by LNG, as India has made no concrete progress in international pipeline projects.

Southeast Asia will also experience significant growth in demand for natural gas, led by the industry sector, which will account for 60% of incremental gas demand in the period to 2040.

Further demand growth is limited in the power sector, primarily due to competition from abundant and cheaper coal. The share of natural gas in Southeast Asia's power mix is projected to drop from around 41% today to around 29% in 2040. Nevertheless, natural gas demand is growing faster than its production in the region as a whole, which will become a net importer of gas by the mid-2020s. In **Indonesia,** domestic production has been discouraged by the government's introduction of lower regulated gas prices to improve the competitiveness of gas-using domestic industry. As a consequence, increased domestic demand has to be balanced by increasing imports. In both **Thailand** and **Malaysia,** production is likely to decline and imports to increase. Interconnectivity is crucial to secure gas supply in the region, as inter-country and intra-regional trade is also expected to grow. LNG infrastructure such as regasification terminals – onshore or floating – is growing rapidly as there is limited intra-regional pipeline infrastructure. There is an ambitious plan to develop the Trans-ASEAN Gas Pipeline, which could bring important energy security benefits and increase liquidity of gas trade, but various commercial, technical and regulatory challenges remain.

In **Japan** and **Korea**, the world's largest LNG importers, gas demand is expected to decline as consumption falls in the power sectors. Gas demand trajectories in both countries are uncertain, however, because their nuclear policies are in flux. In Japan, the use of gas in the power sector increased from 28% in 2010 to a peak of 42% in 2014 after all nuclear power plants, which used to account for 25% of power generation, were shut down in the wake of the Fukushima Daiichi nuclear accident. Future gas demand in Japan will be determined by decisions about restarting Japan's nuclear reactor fleet. In Korea, the new government has announced a nuclear phase-out and curtailment of coal-fired power generation, which would lead to an increase in gas use.

Role of LNG in the gas security of Asia-Pacific

The move towards a more diverse, flexible and liquid global gas market, facilitated by the increasing share of LNG in gas trade, has important implications for investments and offers significant benefits for energy security. While geography limits interconnectivity with pipelines between countries in the Asia-Pacific region, especially for Japan and Southeast Asia, there is considerable scope within countries to improve links between demand centres and LNG terminals. Access to LNG becomes even more important as a way of providing flexibility where there is little gas storage. Due to geology, underground storage is unlikely to play the role in some parts of Asia that it does in Europe and North America.

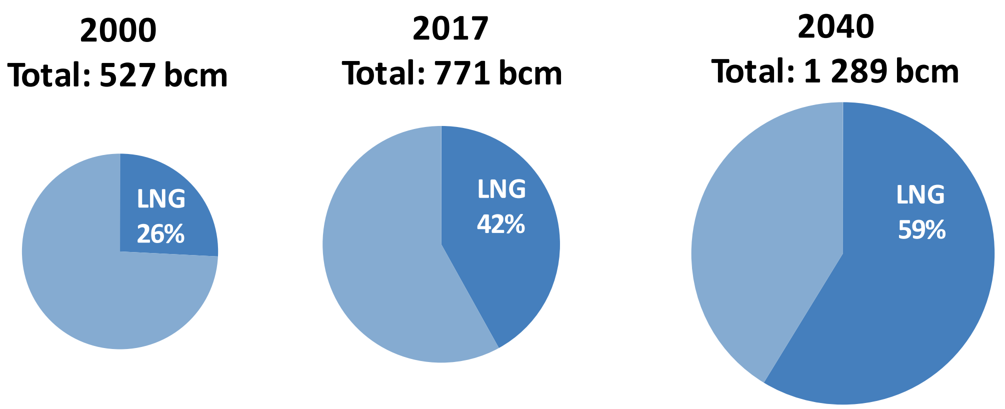
Increasing role of LNG in gas trade

Japan and Korea already rely heavily on LNG imports to supply domestic markets. The region's dependence on LNG is expected to expand, with China, India and the countries of Southeast Asia set to become major forces in international LNG trade in the period to 2040. The Asia-Pacific region is expected to account for around 80% of global LNG imports by 2040.

China will play a major role in rebalancing and shaping the LNG market. It became the largest contributor to global LNG consumption growth in 2017, surpassing Korea as the world's second-largest LNG importer. China's LNG imports are expected to quadruple from 2017 to 2040, making it the world's largest LNG importer. India's LNG imports are forecast to increase to the level of Korea's, or slightly higher, making it the third-largest LNG importer. Although there are major LNG exporters in Southeast Asia, such as Brunei, Indonesia and Malaysia, the region is becoming increasingly dependent on LNG imports; its growth in LNG imports will be much higher than India's over the same period. The rise of LNG has changed the regional gas landscape, pushing countries to evaluate their market structure and consider the case for market liberalisation. With imports on the rise, it is in the region's interest to initiate co-operation on the LNG front.

The importance of LNG in inter-regional trade is expected to grow remarkably. LNG will make up nearly 90% of the incremental volumes traded over long distances, and its share of global gas trade will increase from 42% today to almost 60% by 2040 (Figure 10). The flexibility offered by LNG is one of the factors underpinning its growth. There is growing diversity on the supply side as well, with the main additions expected to come from the United States and Australia, followed by Russia, Qatar, Mozambique and Canada. The concentration of import growth in the Asia-Pacific region and the rise in LNG trade will increase the inter-connectivity of global gas trade, which will shift fundamentally from the Atlantic basin to the Asia-Pacific region.

Figure 9. Share of LNG in global long-distance gas trade



Source: IEA (2018a), *World Energy Outlook 2018*.

The rise in LNG trade underpins increasing diversification and interconnectivity of the global gas market; Asia-Pacific is the primary destination of rising LNG imports.

Removing destination clauses

Traditionally, large Asian importers have bought LNG under long-term contracts tied to crude oil prices. Due to lack of competition, gas has been systematically more expensive in East Asia than in Europe or North America – a so-called "Asian premium" has been a key feature of global gas markets for decades. Destination clauses (restricting the right to re-sell gas) have also prevented buyers from seeking arbitrage opportunities and have enabled price discrimination. However, the boost in LNG trade is altering pricing and trade mechanisms. The slump in gas prices and the growing volumes of uncontracted LNG have shifted bargaining power to the demand side. Large Asian LNG importers – with Japanese stakeholders at the forefront – have started to seize this opportunity to revisit some of the contract terms that restrict the flexibility of LNG trade. In June 2017, Japan's Fair Trade Commission concluded that destination clauses are potentially at odds with the country's Antimonopoly Act and suggested that contracts should not contain resale restrictions. Korea's Fair Trade Commission began researching the legality of destination clauses in LNG contracts in August 2017. Other importing countries could follow suit, boosting the flexibility and liquidity of the LNG trade. Various Indian and Chinese buyers are reported to have secured destination flexibility in recent contracts.

From the suppliers' side, the biggest push towards a more competitive gas market comes from the large and rapid increase of LNG supply from the United States, which has many of the characteristics – flexibility, hub-based pricing or spot availability – that are transforming the wider gas market. More and more gas is being priced on the basis of benchmarks that reflect the supply-demand balance for gas, rather than the price of alternative fuels. Between now and 2025, over 150 bcm of supply agreements will expire (representing 35% of the contracts in place in 2015). Of the expiring contracts, 80 bcm have Asia-Pacific as a final destination. The direction of this new contracting cycle in the region will be an important pointer for the long-term evolution of the LNG market.

Creation of LNG trading hubs

The transformation of the gas market underscores the need for transparent and reliable regional LNG pricing indexes and trading hubs, particularly in Asia-Pacific, where the global demand growth is concentrated. Although Asia-Pacific is a major natural gas-consuming region, the region lacks a liquid and transparent LNG pricing benchmark similar to the Henry Hub in the United States or the National Balancing Point in the United Kingdom. China (Shanghai and Chongqing), Japan and Singapore are now developing regional trading hubs in Asia-Pacific markets. They have launched benchmark LNG pricing indexes and announced various financial instruments to be traded on domestic exchanges to encourage LNG price discovery and transparency. The formation of functional natural gas market hubs will take time, however, as it did in the United States (15 years) and in Europe (10 years).

Each of the proposed LNG market hubs in China, Japan and Singapore faces considerable regulatory and infrastructure challenges, including lack of third-party access to infrastructure and limited pipeline connectivity within and between countries. To promote transparent LNG pricing, further market liberalisation will be necessary, including a regulatory environment that assures equal third-party access that can attract new infrastructure investment – for example in pipelines and regasification terminals – to ensure cost recovery and prevent conflicts of interest. Japan recently started a comprehensive reform of its gas and electricity sectors to move from the existing regional monopolies to a more competitive model. China is also pursuing full liberalisation and gas companies are encouraged to split sales and pipeline businesses in a step by step manner to promote a market-based pricing mechanism. In Singapore, a spot market for local use of gas is being created, including secondary markets for gas consumers, and third-party access to facilities such as gas storage is under development.

Successful implementation of these market reforms over the coming years would enable the demand side to react to supply shocks and boost the number of buyers that can purchase competitively priced LNG on the short-term market, and undercut the position of those whose gas is procured at higher oil-linked prices.

Floating technologies

The growth in global LNG trade will also benefit from increasing deployment of floating storage and regasification unit (FSRU) technology. FSRUs are vessels that can be moored at sea or docked in a port to regasify LNG and feed it into a transmission or distribution network (or deliver it directly to an end-user). They are an affordable, fast and flexible way to provide natural gas supplies to help create pockets of growth in developing countries that lack existing infrastructure and were not in the focus of LNG exporters until recently.

For countries in Southeast Asia such as Indonesia, the Philippines and Viet Nam, where demand is scattered over numerous islands, LNG-to-power projects using FSRUs or smaller LNG ships would be an efficient way to deliver gas to places struggling with inadequate power, displacing costly and polluting diesel generators. Japan, the world's top LNG importer with over 30% of worldwide LNG movement, has experience of using many small-scale LNG ships particularly in the 1990s. They were used to feed satellite terminals across the coastal network, as domestic pipeline deliveries were not feasible because of the mountainous terrain and the remoteness and small-scale needs of some customers. Such experience and a similar business model could be replicated in other island countries in Southeast Asia.

Need for investments

The global gas market is currently awash with gas, largely as a result of the rapid growth of LNG supplies. A period of ample availability of LNG, driven largely by new liquefaction capacity in Australia and the United States, is deepening market liquidity and the ability to procure gas on a short-term basis. However, well-supplied markets will also keep prices down and discourage new investments in LNG liquefaction facilities. In general, a new investment approval for a capital-intensive LNG project requires a decision with a lead time that can range between three and six years. In 2016-17, investment in LNG declined; only two new final investment decisions (FIDs) were taken to expand existing or build new LNG liquefaction facilities in 2016 and only one in 2017. Although there are signs of a pick-up in new project approvals in 2019, the lack of investments in recent years means a new period of tightness can be expected after 2020.

Construction of LNG import infrastructure is booming, however, particularly in Asia-Pacific. Over 100 bcm/y of new regasification capacity is under construction, nearly three-quarters of which is in Asia-Pacific. By mid-2018, in China alone, 18 LNG regasification terminals were in operation with a combined capacity of 77 bcm/year, and another five facilities totalling over 18 bcm were under construction (IEA 2018d). Regasification capacity in India is also increasing rapidly. By the end of 2018, India had four operating LNG terminals with a total capacity of 36 bcm. Several projects are under development, including three FSRUs. India has a strategic target to build additional 11 LNG terminals over the next seven years to expand its import capacity.

There are various proposals to build new regasification terminals across the countries of Southeast Asia. Not all of these projects will materialise, due to diverse challenges such as bankability, demand uncertainty, pricing and affordability issues. One cost-efficient way to help resolve some of these issues is to share facilities within the region. For instance, Singapore's Keppel and Pavilion Energy has entered into an agreement with Indonesia's state-owned electricity company PLN to explore developing small-scale LNG distribution in west Indonesia. The agreement aims to take advantage of the collective expertise of the companies in the small-scale LNG value chain, to distribute LNG economically to remote areas in west Indonesia. Pavilion Gas, Pavilion Energy's LNG trading unit, has just secured two-year access rights to storage facilities at the government-owned Singapore LNG (SLNG) terminal. This could provide a model for future facility-sharing arrangements within the region and support a higher volume of LNG trading activities, small-scale LNG opportunities, and development of greater gas interconnection.

Possible emergency response measures for natural gas

In spite of the global abundance of gas supplies, security of supply of natural gas remains a concern. The sector is often exposed to unexpected events, ranging from physical shortages and supply emergencies caused by extreme weather and technical issues, to supply threats caused by political tensions. The increasing globalisation of gas through the expansion of LNG trade, and its deep interaction with the rest of the energy system, are creating a more interconnected environment, where shocks in one region can reverberate through another. Gas security challenges are evolving as the level of market globalisation evolves. Governments should always be aware that unexpected events can lead to rapid changes in energy market conditions and, thus, should continue efforts to develop robust security of supply policies, including emergency response.

Unlike in the case of oil, however, there is no framework for taking collective action in response to a natural gas disruption, and IEA countries do not have the equivalent treaty requirements to establish emergency response mechanisms for natural gas. Instead, each IEA member country has agreed to review its gas emergency response policy, to share best practices and to explore ways to reinforce gas security, individually and collectively. The mechanisms and policies of individual IEA countries for responding to gas emergencies are often assessed according to four criteria:

- gas storage capacity
- fuel switching capability
- demand restraint
- interruptible contracts.

Gas storage capacity

Gas storage is a valuable tool for responding to swings in demand and supply, and – when gas is stored close to demand centres – to mitigate technical or geopolitical risks that could occur along the transportation routes of pipelines or LNG imports. Commercial storage capacity has been developed in several IEA countries as a means of addressing both seasonal variations in demand and supply, and situations of peak demand. In some instances, specific volumes of this capacity are used to hold gas stocks for emergency purposes. This is the case in several European IEA member countries that impose gas storage obligation, in some cases requiring the transmission system operator (TSO) to book a part of the country's commercial storage capacity to meet its security standards. These storage measures provide a powerful tool for correcting acute market shortages.

While underground storage remains the most common means of holding gas stocks, the potential to develop underground storage capacity varies according to each country's geology. Some countries have resorted to developing LNG storage as an alternative. Almost all storage capacity in Japan and Korea is held at LNG regasification sites, forming a highly resilient basis for their gas supplies. The growing number of LNG regasification terminals, particularly in Asia-Pacific, would certainly provide both a source of stable, flexible and diversified gas supply, and a place of short-term storage at the terminal site. However, the high set-up costs and operating costs for storing gas are a critical impediment to developing sizeable gas storage facilities. Initial capital costs of building LNG storage facilities can be double the costs of underground gas storage and up to 50 times the cost of underground oil storage per tonne of oil equivalent stored. Again, sharing facilities within countries or regions could be a cost-effective measure. To enhance such measures, third-party access and market liberalisation should be further developed.

After having experienced gas shortages in a recent winter when millions of households in north China switched to gas from coal to combat air pollution, China has announced that it will expand its gas storage to ensure adequate future gas supplies. China's gas suppliers – mainly state-owned companies like China National Petroleum Corp, Sinopec Group and China National

Offshore Oil Corp – are now required to have storage facilities able to meet at least 10% of their contracted sales by 2020. Local authorities also will need to have sufficient storage to cover three days of consumption in their administrative regions, and city gas distributors must have storage equal to 5% of their annual supplies within the same time frame. China's gas storage facilities reached 10 bcm in 2017, equivalent to only 4% of annual consumption (IEA, 2018d). This is well below the IEA average of 20% and even lower than in China's import-dependent neighbours Japan (9%) and Korea (11%).

Fuel-switching capability

In case of a gas supply disruption, a very useful type of demand-side response could be fuel switching from gas-fired power generation to an alternative fuel like coal or oil. This would allow peak gas demand to be curbed and tight gas supply situations to be alleviated. China has a continental-scale energy system with a large domestic fuel-switching potential between coal and gas. In Thailand, most of the gas-fired power plants have their own oil stock, and can switch to using fuel oil and diesel. In normal times, environmental constraints can restrict the use of coal and oil, but for short-term emergencies, adequate fuel-switching capacity in power and industrial sectors in particular will serve to restore the supply/demand balance. It is crucial to have a diverse range of energy sources for power generation, to provide maximum flexibility in the event of a natural gas emergency.

Gas-fired power generation is growing, albeit more slowly than a decade ago, especially in the developing markets in Asia-Pacific. It increases the interdependence of the gas and power sectors which has implications for the security of electricity supply. Simultaneous gas and electricity demand peaks, for example, may create additional stress on both power and gas systems, increasing the supply risks for both. In the longer term, gas-fired power generation will play an increasingly important role in providing flexibility to the electricity systems with higher shares of variable renewables. Given such growing interdependence of power and gas markets, policy frameworks to ensure security of electricity supply should assess the potential impact of gas supply disruptions on electricity delivery systems.

Japan's experience in dealing with the electricity supply shortage that followed the Fukushima nuclear accident in 2011 illustrates well the importance of having flexible energy systems to address sudden disruptions. The availability of substantial fuel-switching potential – mainly in the form of oil-fired capacity – was a critical component of Japan's response to the accident. Between 2011 and 2013, gas replaced around one-third of the nuclear loss, an amount similar to the combined contribution of oil and coal over the period, highlighting the importance of a diversified demand structure in responding to the crisis. Lower gas demand in Europe, mostly caused by the financial crisis and the flexibility of a well-diversified power generation mix, freed up the incremental LNG volumes needed by Japan. Between 2010 and 2013, coal-fired generation in Europe increased by 7%, offsetting roughly one-third of the fall in gas-fired generation over the period. Strong growth in renewable sources also contributed to lower gas demand in the power sector in Europe. At the same time, Europe's ability to switch between LNG and pipeline imports made it possible to increase reliance on pipeline supplies at the expenses of LNG. In particular, Russia's production flexibility was called upon, with European imports from Russia reaching new highs in 2013 just as LNG imports were plummeting, to be re-directed to the more lucrative Asian markets. As a result of these adjustments, Europe was the main provider of flexible LNG volumes to global LNG markets in the post-Fukushima period, accounting for two-thirds of the flexible supply released via demand-side adjustments in 2013. This period illustrates the crucial importance of fuel-switching capabilities for crisis management and, more broadly, global gas security. The flexibility of the power sector has proved to be a major relief valve for gas in periods of tight markets, shortages or demand shocks.

Demand restraint

One way of allocating natural gas when supply is disrupted is to ration its use through demand restraint, whereby natural gas consumption is restricted. Such a policy goes beyond the voluntary limitation that occurs when customers decide to modify their consumption because of the price of gas in the market. In some cases, there is often a time lag before wholesale price changes filter through to certain classes of consumer, for instance those in the residential sector. This time lag might justify government action to make domestic gas consumers aware of a supply disruption. Governments could impose strict limitations on gas consumption in specific sectors (e.g. industry) to assure supplies to predetermined priority customers (e.g. households or vital services such as hospitals). Identifying such priority customers should be a key part of preparing procedures for activating demand restraint measures. Given the increasing use of gas in power generation, similar measures could be used to stimulate demand-side reactions in the electricity sector.

Interruptible contracts

Interruptible customers are industrial customers that consume large volumes of gas per year and agree to have their gas supply interrupted for a maximum number of days in a year in order to obtain a reduction in gas price. On average, customers with these contracts agree to a maximum of 10 to 20 days of zero supply (if necessary) in a year. Generally, large gas consumers on interruptible contracts receive volume-related discounts on wholesale gas costs, in addition to a reduction in transportation costs designed to offset the potential loss of supply. While interruptible customers are certain to have their gas supplies cut in a supply disruption, the volume saved will not always be sufficient to completely mitigate a large-scale disruption. Nonetheless, this option can be useful as part of a suite of tools for dealing with such interruptions.

China has recently announced that natural gas producers should sign annual supply contracts with major users that include details of any supply cuts during the peak winter heating season, which runs from mid-November to mid-March, stipulating the duration of such cuts and the volume to be reduced. During periods of emergency situations, the additional cost of gas supply would be borne by either the buyer whose demand is above the contracted amount or the supplier who provides less than the contracted volumes.

Case studies from recent events

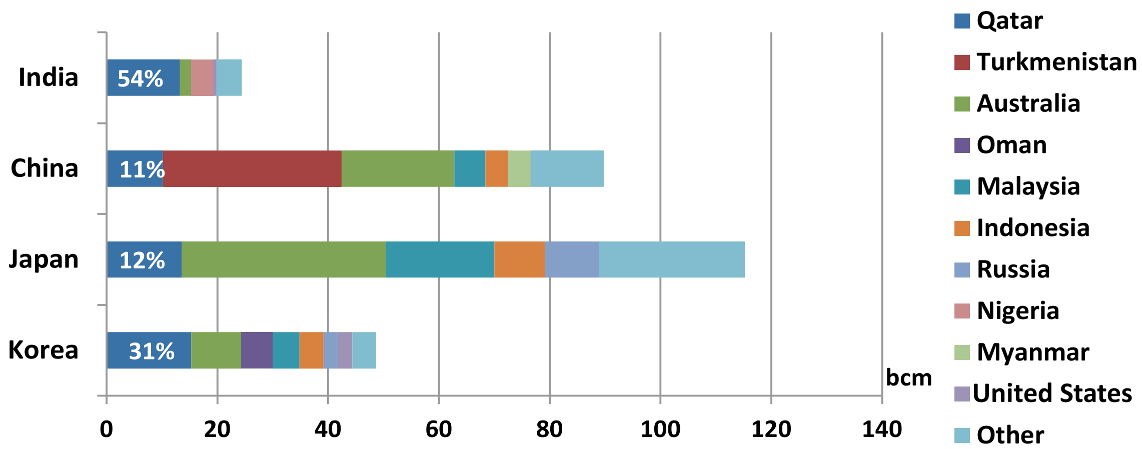
Implications of the Qatari crisis for gas security in Asia-Pacific

Qatar still is the world's largest producer and exporter of LNG, producing 105 bcm in 2017, although its historical position as the dominant LNG player is being increasingly challenged by the development of new export sources notably from the United States and Australia. As Qatar represents roughly a third of global LNG trade, any supply disruption from Qatar would significantly affect many countries in Asia-Pacific, who are dependent on LNG imports for their natural gas demand.

At the beginning of June 2017, several neighbouring Arab countries broke off diplomatic relations with Qatar, including Bahrain, Egypt, Saudi Arabia and the United Arab Emirates. To isolate Qatar economically, these countries banned Qatari vessels from their ports. After these diplomatic tensions started, the IEA observed the impact of Qatar's isolation on the global LNG market. Qatar continued to export its LNG at volumes within the past five-year range of monthly LNG export volumes and LNG flows to the Asian market were not substantially affected. Most of the Qatari LNG cargoes for Europe pass through the Suez Canal in Egypt, but the passage of Qatari-flagged or Qatari-owned vessels through the canal were not affected since Egypt is bound by international maritime law to allow free passage of seaborne vessels.

There have been no real supply issues so far, and the incident has not affected Qatar's LNG output level. There were few signs of panic in the market; LNG prices and freight rates changed little or not at all. Nevertheless, for countries in Asia-Pacific, especially those with higher dependence on Qatar for their LNG imports, such incidents are a reminder that the security of supply cannot be taken for granted. In 2017, India had the highest dependence on Qatar, which accounted for 54% of its total imports (Figure 11). The shares of Qatari imports were smaller for Japan (12%) and Korea (31%), but the consequences could be high as their import dependence for gas demand is over 98%.

Figure 10. Top four importers of Qatar's LNG in Asia, 2017



Source: IEA (2018e), *World Energy Statistics and Balances 2018* (database).

India has the highest share of Qatar's LNG in its import portfolio, but Japan and Korea could also have high consequences as their import dependence on gas demand marks over 98%.

Australia's local disruption

Australia's natural gas production is rising quickly, making the country a global leader in LNG exports. Such ample resources should ideally provide the Australian domestic gas market with a high level of supply security. Owing primarily to market conditions and lack of interconnectivity, however, Australia is increasingly challenged by domestic gas security issues. The largest gas reserves are in the west, north and east of the country, while the major demand centres are in the south-east. Although gas production in the east is almost three times higher than domestic demand in that region, most of this gas is earmarked for contracted LNG exports – which could leave the south-east with a tight market.

Gas prices in Australia's major south-eastern market, traditionally low, rose sharply in 2016 because new export projects created a price link with international markets. Higher end-user prices have led to concerns about affordability for households and the impact on industrial competitiveness.

At the same time, the Australian electricity system is undergoing unprecedented change. Thermal capacity is ageing and renewable energy – including wind and distributed solar photovoltaic (PV) systems – is increasing rapidly. Gas-fired "peaking" plants are required to balance the electricity grid in certain situations, and new gas-fired plants will probably be required to replace parts of the aging coal-fired power fleet in the coming decade. The increasing uncertainty about costs and gas availability may deter the necessary investments, resulting in a constrained electricity market.

In February 2017, Australia experienced electricity load shedding – or rolling blackouts – during a heatwave in South Australia and New South Wales partly due to the unavailability of gas-fired electricity generation capacity. In its 2017 Gas Statement of Opportunities, the Australia Energy Market Operator (AEMO) projected that declining gas supplies could result in electricity supply shortfalls between 2019 and 2021 of 80-363 GWh across South Australia, New South Wales and Victoria (AEMO, 2017a).

To address this issue, the Australian government introduced the Australia Domestic Gas Security Mechanism, which would – if activated – ensure availability of supply for domestic users by placing requirements on LNG exporters to serve the domestic market with priority. In October 2017, an agreement was announced between the Australian government and the LNG exporters to ensure that sufficient gas would be available through 2019, leading the government to defer triggering the mechanism for 2018.

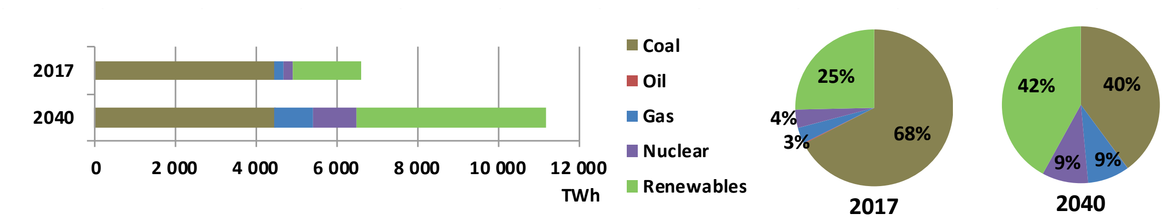
4. Electricity security in ASEAN+6

Electricity market outlook

Electricity is the fastest-growing energy source consumed. The reliability of oil and gas supply is the traditional focus of assessment of energy security. But the focus is shifting increasingly to electricity security, as electricity takes a higher share of final energy consumption. The vast majority of electricity demand growth between now and 2040 is expected to occur in developing economies, thanks in part to the success of energy access policies. Together, China and India will account for half of global electricity demand growth worldwide in the same period. Demand for energy services in households, especially air conditioning, is set to expand as incomes rise. Decarbonisation objectives are also driving electricity demand growth, and with increased occurrences of natural disasters and related impacts on energy systems, electricity security becomes more prominent. High shares of variable renewable generation like wind and solar power have a twofold impact on energy security: they temper import dependence yet create new challenges for power system operation.

China already is the world's largest market for electricity, producing over 6 500 TWh in 2017), and will lead the way over the next two decades. However, the average annual growth rate of demand will slow significantly to 2.3% from around 10% in the period 2000-17. This slowdown will come about partly because of China's continued efforts in energy efficiency and partly because of the growing role of the service sector relative to the industry sector, which in China is ten times more energy intensive. Electricity demand in the buildings sector accounts for more than 40% of China's total electricity demand growth. The demand increase for space cooling will represent around 600 TWh by 2040, which will require installed generating capacity to more than double from 2017 to 2040. Coal-fired power plants will continue to account for the largest proportion of installed capacity, but the rate of additions will slow significantly. Total coal-fired capacity will plateau around 2025 at about 1 000 GW. Gas-fired capacity will increase rapidly in the near term because of efforts to reduce air pollution, and total gas-fired capacity will triple to over 200 GW by 2040. Net additions of renewables will outpace additions from all other sources, accounting for almost 60% of total installed capacity additions by 2040. Technology cost reductions will help fuel this growth, with solar PV becoming the cheapest source of power generation in China by the mid-2030s. By 2040, the share of coal-fired production will drop from today's 68% to 40% as renewables-based generation grows to 42% (Figure 12).

Figure 11. China's electricity generation mix and share by source, 2017 and 2040

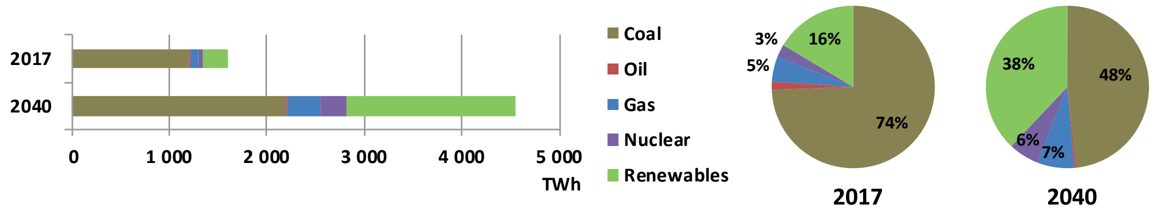


Sources: IEA (2018a), *World Energy Outlook 2018* (New Policies Scenario).

Renewables will take over from coal as the top source of electricity supply in China by 2040.

India is the fastest-growing market, with electricity demand increasing by over 5% per year, as it strives to achieve universal electricity access by the early 2020s. The total electricity generation growth to 2040 in India is similar to the size of the European Union market today. Electricity demand for space cooling will expand rapidly to reach over 15% of electricity demand in 2040. Power generation capacity needs to be increased to serve rapidly growing power demand and to overcome the shortages that cause regular load shedding. India will account for nearly 50% of the increase in global coal-fired power plant capacity and will rely on a growing share of internationally traded coal to fuel these plants; before 2020 India will become the largest coal importer in the world. India will also become a key player in terms of utility-scale solar PV, accounting for one-sixth of newly installed PV capacity in the world to 2040. The Indian government has made solar PV an energy policy priority, setting an ambitious target of 100 GW of solar PV by 2022. With deployment levels rising, costs have fallen at an impressive rate. Renewables are expected to provide about 40% of the overall increase in output from new power plants in India between now and 2040 (Figure 13).

Figure 12. India's electricity generation mix and share by source, 2017 and 2040

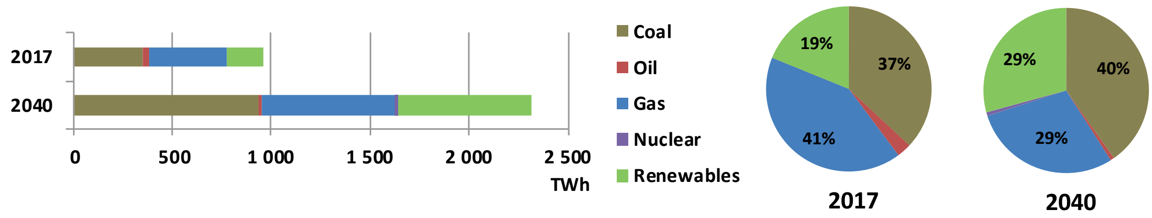


Sources: IEA (2018a), *World Energy Outlook 2018* (New Policies Scenario).

Coal will remain the primary source of electricity generation in India, but the share of renewables will expand from 16% today to 38% in 2040.

Electricity demand in **Southeast Asia** is expected to more than double over the period to 2040In Indonesia, electricity demand will triple, reaching one-third of total electricity demand in the region by 2040. The largest contribution to electricity demand growth will come from the buildings sector, underpinned by increased appliance ownership and demand for space cooling in residential buildings. As countries prioritise availability and affordability, coal will become the primary fuel for power generation in the region, overtaking natural gas. The share of coal-fired power generation will rise from 37% in 2017 to 40% by 2040 (Figure 14). Gas generation will drop from 41% to 29% as the region runs out of cost-competitive domestic gas surpluses. Renewable energy sources are abundant in Southeast Asia. They will remain an important and, in some countries and sub-regions, dominant source of energy supply. The share of renewables in power generation mix will increase to around 30%, driven by hydro, whose generation will almost triple by 2040. The four countries in the Lower Mekong Basin – Cambodia, Lao PDR, Myanmar and Thailand – have significant hydropower potential of more than 110 GW. Solar PV and wind power generation will also grow rapidly. The Philippines has the greatest potential for wind power generation, with an estimated technical potential of around 70 GW. Viet Nam's wind resources are also notable, particularly along its 3 000 km of coastline, with technical potential of around 27 GW.

Figure 13. ASEAN's electricity generation mix and share by source, 2017 and 2040



Source: IEA (2018a), *World Energy Outlook 2018* (New Policies Scenario).

Coal will overtake natural gas as the primary source of electricity generation in Southeast Asia.

Japan's electricity system was seriously affected by the 2011 Great Earthquake and the Fukushima nuclear accident, after which all nuclear power generation was shut down. While nuclear power is slowly coming back online, in line with the government's plan to reintroduce around 20-22% nuclear generation by 2030, it still represented only around 1-2% of generation in early 2018. Currently, the most important fuel for electricity generation is natural gas, providing 37%. Coal is the second most important with a 33% share. Oil plays a more important role than in most OECD countries, with 7%. Mothballed oil-powered facilities played a crucial back-up role as a temporary measure to balance the electricity system in the immediate aftermath of the 2011 earthquake, and hit a peak at 18% in the power generation mix in 2012. However, 90% of these oil-fired plants are expected to be decommissioned by 2030 as they will exceed 40 years of age.

Korea's electricity demand has increased rapidly in the last two decades and nuclear power has played a big role in meeting it. However, the government formed in May 2017 is looking more to renewables than to nuclear power to reduce carbon emissions. Korea's electricity mix is still dominated by fossil fuels and the share of renewables is one of the lowest in the OECD: 3% compared with the IEA average of 24%. According to the newly adopted Basic Plan for long-term electricity policy in December 2017, the government aims to generate 20% of its total power from renewable energy by 2030. The installed capacity of renewables is envisaged to increase from 11.3 GW to 58.5 GW in 2030, mainly of solar PV and wind.

Australia's electricity system is undergoing significant changes. Coal is the main source of electricity generation capacity, at 63% in 2017, but its capacity is ageing and old plants are closing sooner than expected. Renewable energy – including distributed solar PV systems – is increasing rapidly but is concentrated in a few regions. South Australia currently hosts 40% of Australian wind power and around 15% of rooftop solar. There are growing concerns about the availability of affordable natural gas for the power sector over the coming years. System integration and grid security has received considerable attention in Australia since a state-wide blackout in South Australia on 28 September 2016.

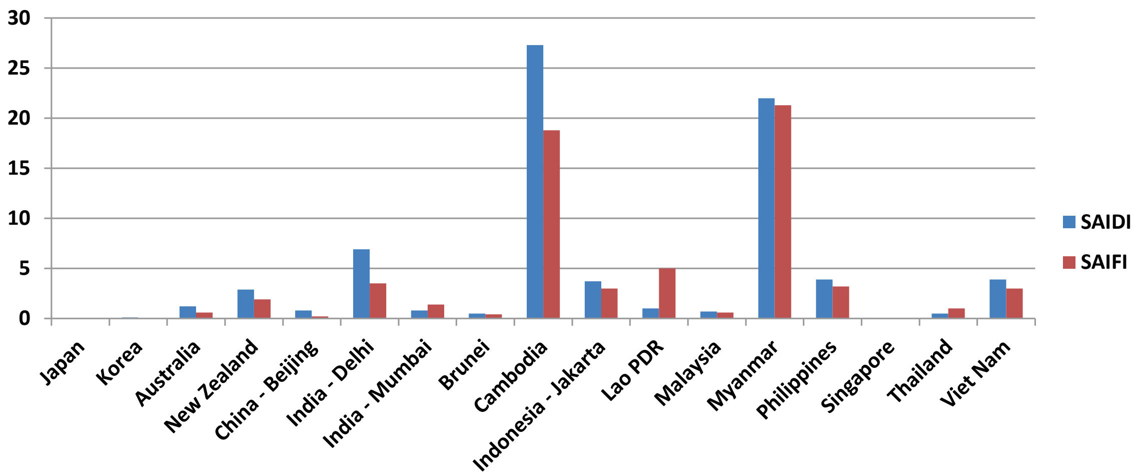
New Zealand has the second largest share of renewables in power generation among IEA member countries (after Norway) with 81% in 2017, mostly comprised of hydro (57%). New Zealand is endowed with renewable resource advantages such as cost-competitive geothermal, hydro and land-based wind energy. New Zealand's market design and operation of an energy-constrained system offer a high degree of operational variability. The state-owned transmission system operator is experienced and adept at managing supply and demand adequacy, and the power system demonstrates considerable flexibility and resilience. In recent years, the market has been able to ensure security of supply and avoid major price spikes even during years of lower hydro storage levels.

Emergency management for electricity security: Lessons from power outages

Although electricity security has many dimensions, in its most basic interpretation it is the ability of the power system to avoid supply disruptions while delivering electricity at affordable prices. Short-term security issues can result from unexpected generator outages, unpredicted fluctuations in production by variable renewables like wind and solar, damaged transmission infrastructure, or rapid and unanticipated changes in demand. As economies develop, the economic and social impacts of unplanned outages increase because digital technologies, communications infrastructure and industrial operations all depend on a reliable and efficient supply of electricity. In many emerging economies of ASEAN+6, electricity systems are coming under pressure as household incomes increase rapidly, urbanisation accelerates and access to electric appliances becomes easier. The prevention and management of large-scale blackouts is the ultimate focus of electricity security, but short-term interruptions at the distribution level can be just as annoying for consumers. To avoid system-wide blackouts, network operators sometimes use intentional rolling blackouts, or load shedding, as a last resort.

Electricity interruptions vary significantly among the countries in the ASEAN+6, as can be seen from the wide divergence of indices such as SAIDI (system average interruption duration index, the average total duration of outages in a year) and SAIFI (system average interruption frequency index, the average number of service interruptions in a year) (Figure 15). However, even countries with very few supply interruptions face constant electricity security challenges. Asia-Pacific is one of the world's most disaster-prone regions. Frequent natural disasters, including earthquakes, tsunamis, flooding, and landslides, affect millions of people every year. The region is also becoming increasingly prone to extreme weather events such as typhoons and heatwaves. These vulnerabilities raise concerns over energy security, in particular how to secure electricity supply and how to restore capacity when blackouts are unavoidable.

Figure 14. Interruption duration (SAIDI) and frequency (SAIFI) indices of ASEAN+6 countries, 2018



Source: World Bank (2018), *Getting Electricity* (database).

It is not easy to draw simple conclusions or policy recommendations from one country's experience. But lessons that have been learned in Australia, Japan and Korea after major power outages could be useful for other ASEAN+6 countries, especially emerging economies that are even more vulnerable.

Japan: Enhancing cross-regional electricity supply

After the Great East Japan Earthquake in 2011, Japan faced severe electricity supply shortages due to the closure of all nuclear power plants. Rolling blackouts were implemented in the Kanto region soon after the earthquake and power demand reduction measures were promoted by the government especially during the peak summer seasons from 2011 to 2015. The incidents revealed several weaknesses, including the regional monopoly system (vertically integrated TSOs) and the lack of transmission capacity across regions. As a crucial step to improve co-ordination and security of electricity supply, the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) was established in April 2015. Each of Japan's 10 regional TSOs is responsible for grid management and system security in its territory according to the Electricity Business Act. Now the 10 TSOs can effectively co-operate in an emergency following OCCTO's instructions. For instance, OCCTO monitors companies to make sure that each local area maintains a sufficient generation reserve margin of at least 3%. If a large power plant stops by accident and an area is faced with a supply shortage, OCCTO enhances cross-regional electricity use and gives orders for electric utilities – including power producers, TSOs and retail electric operators – to supply more electricity to that area to avoid blackouts and maintain stable electricity supply. OCCTO has also developed a cross-regional Operation System within which real-time supply-demand balance and generator outputs are monitored and supply-demand plans from generators and retail companies are reviewed. The Operation System also serves as an information hub for imbalance settlement. If supply-side measures are not sufficient, the government can ask large individual customers to cut their consumption for a certain period of time. To enhance cross-regional electricity supply, the OCCTO also plays a central role in formulating a Long-term Development Plan of Cross-regional Network for interconnection lines between different areas. For historical reasons, two systems developed independently in Japan, running on different frequencies: 50 Hertz (Hz) in the east and 60 Hz in the west. Only three frequency converter facilities connect the two areas, with a total capacity of 1.2 GW. There are plans to increase this interconnection capacity to 2.1 GW by 2020 and 3 GW by 2027.

Electricity supply security faced a big challenge in the summer of 2018 when Japan recorded its highest temperature ever in July. The spot electricity price for the Kansai region rose to just above JPY 100 (USD 0.90) per kilowatt hour for the week of July 30, the highest since 2005. In addition to fully utilising its power generators, including old oil-fired units, Kansai Electric Power (KEPCO) received 1 GW of power from five other utilities through OCCTO's co-ordination, in anticipation of the system's capacity exceeding 98% at the evening peak of demand when solar power dissipates. As a result, no demand restraint policies were issued by the government as the demand/supply balance was kept under control through energy efficiencies and well-functioning power co-ordination by OCCTO.

Korea: Efforts to increase reserve margins

In Korea, unprecedented rolling blackouts on 15 September 2011 affected 7.5 million customers for five hours. Unusually high autumn temperatures had boosted power consumption, while some power generators had been taken down for post-summer maintenance.

At the time of rolling blackouts, while forecasted demand was 64 GW, demand on the day peaked at 67.2 GW (after load shedding), and there was inadequate reserve capacity available to meet the sudden surge in demand. The reserve margin was 6.6%, even though the target reserve margin rate had been set at 15% by the Basic Plan for Long-term Electricity Supply. The low reserve margin was partly the result of low electricity prices, which provided consumers with little incentive to amend their behaviour. Prices were low because the retail tariff mechanism did not reflect the costs of producing electricity or the profile of electricity usage in Korea.

While the government has taken steps to strengthen short-term demand management measures and the Korea Power Exchange (KPX) is improving its load forecasting, in the absence of tariff restructuring, problems continued into 2012. Electricity reserves fell to dangerously low levels in early August 2012, prompting KPX to issue a shortage warning. Since 2014, the reserve ratio has increased to more than 11% as more natural gas-fired, coal-fired, and renewable capacity has come online and nuclear facilities affected by the safety problems in 2012 have returned to service. In its latest electricity plan, Korea projects that reserve margins will reach 22% by 2031.

Australia: Investments on emergency generation and battery storages

South Australia experienced a state-wide blackout after being hit by severe storm on 28 September 2016, disrupting power supply to around 850 000 customers (AEMO, 2017b). A strong heatwave in February 2017 also provoked load-shedding measures in several states. A week after the blackout in 2016, the Australian Energy Market Operator (AEMO) published a preliminary incident report providing initial observations about the pre-event situation, the event and restoration, and an outline for the next steps. Six months later, AEMO published its final incident report, which includes not only the incident investigation and analysis but also recommendations for actions to avoid future blackouts. These rapid responses by the administration, providing transparent information and data, should improve the country's ability to respond to electricity security issues in the short and longer term.

The South Australian blackout of 2016 prompted a range of reviews to identify measures that can promote power sector resilience, and several immediate remedial actions were taken to prevent a similar event from recurring. In addition, this event was the catalyst for the commissioning of the Independent Review into Australia's Energy Security (the Finkel Review) by the Energy Council of Australian Governments (COAG). In light of the increased severity of extreme weather events, the Finkel Review recommended that the COAG develop a strategy to improve the integrity of the energy infrastructure and the accuracy of supply and demand forecasting. One subsequent development was a range of public security investments in emergency generation and large battery storage to provide additional flexibility. Following the South Australian blackout and capacity shortages during a countrywide heatwave in early 2017, several storage projects and plans were announced by state governments and the federal government, including pumped storage hydropower (PSH) and large-scale batteries. South Australia's government is building the largest grid-connected battery in the country with up to 100 megawatts (MW)/129 megawatt hours (MWh) of battery storage. In addition, South Australia has considered providing system services by battery storage, in particular fast frequency response (FFR). The Australian Energy Market Commission made a rule change to align operational dispatch and financial settlement from 30 to five minutes. This will have major implications for the adoption of battery storage. The Finkel Review also outlined the importance of storage requirements for wind and solar projects by recommending that these projects should be paired with storage capacity (or dispatchable generation) to manage variability. For pumped storage hydro (PSH), the federal government announced a plan to expand the existing scheme, which consists of seven power stations and two pumping stations, doubling its capacity from 2 GW to 4 GW. In December 2017, the world's largest lithium-ion battery went on stream in South Australia when Tesla completed its challenge to build the battery in 100 days. The battery can provide power to 30 000 homes.

Medium- to long-term approach for electricity security and its challenges

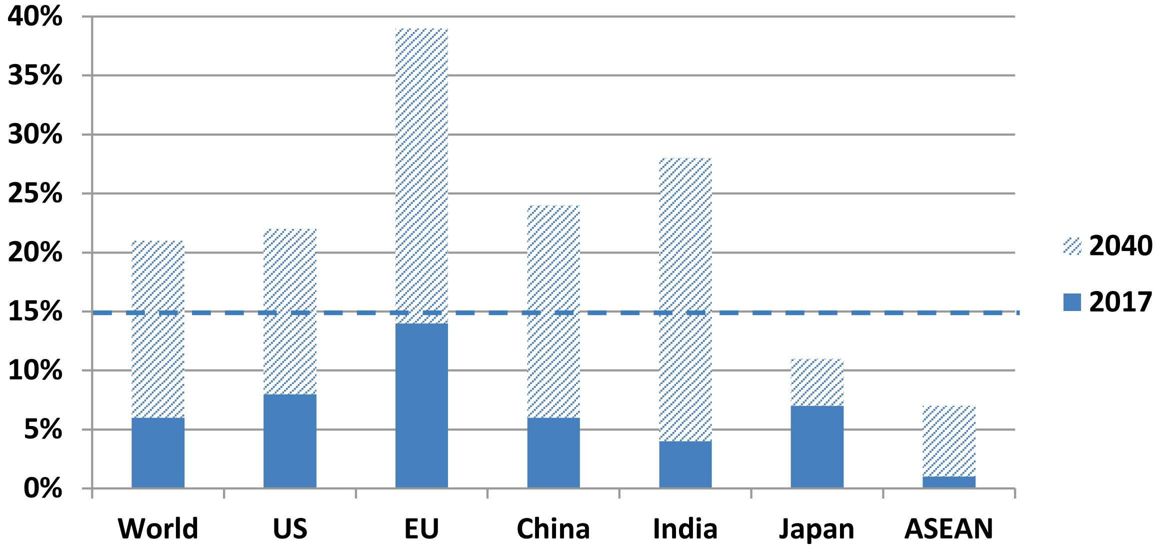
In the medium to long term, enabling the system integration of variable renewable electricity generation and establishing regional power grid projects are key considerations for achieving more secured and balanced electricity supply, especially in ASEAN+6 countries. Integrating significant shares of renewable resources is a key way to satisfy increasing electricity demand, reduce CO_2 emissions, diversify the electricity generation mix and decrease import dependencies on conventional fuels. Although each country is at a different stage of development in power sector integration, common challenges and corresponding measures can be assessed and shared. A regional power system can be established through co-ordination between neighbouring balancing areas. Such an initiative is under way in ASEAN with the creation of a regional power grid that integrates system operations. Optimising power system operations across borders can result in significant cost savings and reduce the flexibility requirements of integrating larger shares of variable renewable energy.

System integration of variable renewable electricity generation

A comprehensive approach is increasingly required to integrate variable renewable energy, given its growing share in power generation. To design the necessary policies and adaptation measures, it is important to determine whether the system as a whole can cope with high peaks of intermittent supply and demand.

Based on the experience of countries that have led the way with wind and solar investments, significant integration challenges can start to appear when the share of variable renewables in total generation reaches 15%. Then it becomes vital that the power system has generation adequacy and sufficient transmission capacity so that it can respond quickly and efficiently to uncertainty and variability in the supply-demand balance. Dispatchable power plants that supply power on demand, such as natural gas plants, can play a critical role in providing flexible mid-load or baseload generation, supporting the integration of variable renewables by providing balancing capacity. Flexibility can also come from potentially dispatchable low-carbon power sources, including hydropower and pumped-hydro storage, from a strong grid with good interconnections, or from demand-side management. Among the ASEAN+6 countries, China and India are expected to exceed a 15% threshold of renewable generation by 2040 (Figure 16).

Figure 15. Share of variable renewables in power generation, 2017 and 2040



Source: IEA (2018a), *World Energy Outlook 2018* (New Policies Scenario).

A rising share of wind and solar in power generation requires a range of policy responses to enhance the flexibility of the power system.

In **China**, the rapid growth of variable renewables in recent years has exposed difficulties in integrating them, such as the curtailment of wind and solar PV due to both market structures and technical network and dispatching constraints. Successful implementation of power sector reforms will be critical to unlock the full potential of wind and solar facilities. The trade of electricity between provinces through ultra-high-voltage (UHV) transmission lines is already an important element in China's power system. The ultra-high-voltage network has been developed mainly in the past ten years, and includes five UHV direct current (DC) lines bringing predominantly excess hydropower from northern and southwestern provinces to the load centres in the east. China aims to nearly double this transmission ability through UHV lines by 2020 to improve cross-provincial allocation of power surpluses. By 2040, the Northwest region is expected to export one-third of its annual generation, helping to meet around 10% of demand in both the East and Central regions, providing cleaner energy to densely populated areas. This will help reduce the reliance on coal-fired generation, lowering primary pollutant emissions in the region and improving health. The Central region also plays an important role in the balancing of electricity across China, taking advantage of the flexibility of hydropower to import large amounts of power from the Northwest region while exporting power to the East.

China will also continue developing flexible new power plants, including gas-fired power plants and pumped hydropower facilities, and increasing the flexibility of the existing fleet of coal-fired power plants, which are critical to the successful integration of variable renewables. Currently, limited flexibility is provided by recently build coal-fired power plants, but this is set to change through the encouragement of competition in electricity markets and a large programme to retrofit coal capacity to facilitate its flexibility. In its 13th Five-Year Plan, China commits to retrofit 133 GW of combined heat and power and 86 GW of condensing coal-fired plants to enhance their operational flexibility and environmental performance by 2020. This represents about one-fifth of the installed coal-fired capacity of China. Demand-side response potential is also enormous in China. More than 60% of the world's smart meters are in China. The potential of demand-side response in the buildings sector is expected to grow as demand for appliances, electric heating and cooling expands in developing Asia.

In India, the share of variable renewables in electricity generation is expected to increase from 4% in 2017 to 28% in 2040. This leap will increase flexibility needs, including power plant flexibility, better interconnections between the five sub-regions, demand-side response and energy storage. By 2040, India will account for 60GW out of almost 220 GW of global battery storage capacity. Although India has made progress in recent years in interconnecting its five network zones to establish a nationwide grid, the transmission grid and the interconnections remain too weak to handle the large-scale build-up of variable renewables. Further action is needed to strengthen India's transmission and distribution network, along with a boost in distributed generation to help reduce the strain on the transmission grid. Deployment of system-friendly renewables, e.g. low-speed wind turbines or plans to couple solar PV with air conditioning, will make an increasingly important contribution to the integration of these technologies.

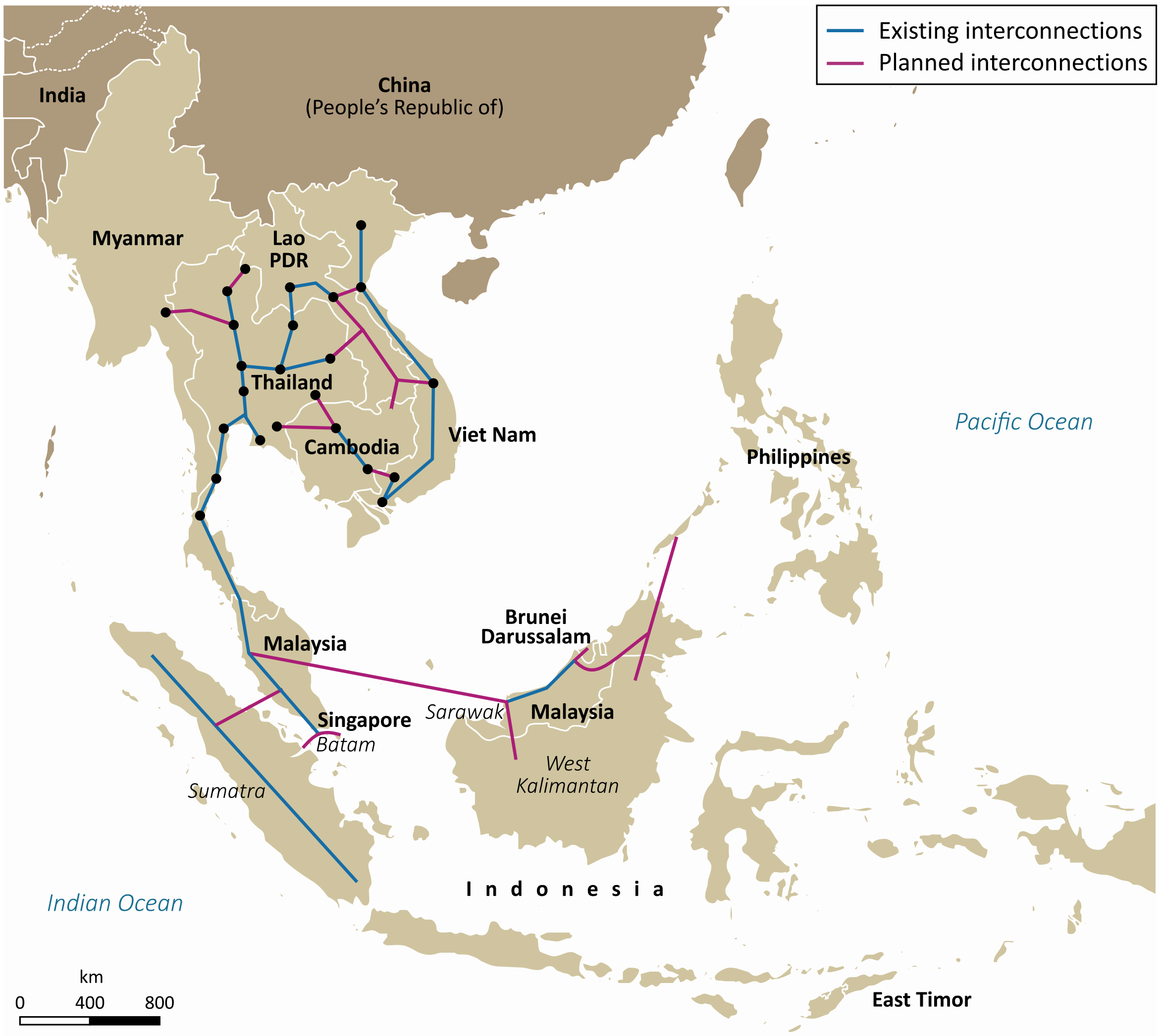
In **Southeast Asia**, variable renewables, especially wind and solar PV, are expected to be the fastest-growing technology in terms of installed generation capacity between now and 2040. From 2017 to 2040, solar PV capacity will expand from 4 GW to 80 GW and wind power capacity from 1 GW to around 21 GW. This penetration level requires not just large-scale grid expansion and the deployment of flexible electricity supply technologies, but also additional integration measures such as storage and demand-side management options (through load shifting or load shedding). Realisation of a long-planned regional grid would make large-scale renewables-based projects more viable and would also help manage variability issues in the region's power system. For example, Viet Nam, with its significant wind potential, could benefit by using hydro resources in Lao PDR to balance the variability of wind generation.

Challenges for regional power integration

Co-ordination between neighbouring balancing areas to optimise power system operations across borders can result in significant cost savings and improve security of supply. Especially with an increasing share of variable renewable generation deployment, expanding the size of balancing areas can improve flexibility by diversifying resources across different geographical regions. Globally, many neighbouring TSOs have started to co-ordinate power system planning to optimise the use of resources and benefit from increased flexibility. Inter-regional co-ordination is evident in the European Union and the United States, and is making inroads in Southeast Asia.

Increasing energy connectivity among the Southeast Asian countries has been a fundamental goal for decades. While these long-standing objectives cover several areas, key among the infrastructure aims is to increase the level of electricity interconnection. To this end, in 1997, the ASEAN heads of states first agreed to develop the ASEAN Power Grid (APG) to ensure energy security in the region through investment in regional power interconnections (Figure 17). The APG aims to ensure mutually beneficial regional electricity security and sustainability, connecting those countries with surplus power generation capacity to those who face a deficit. A regional grid could help all ASEAN countries meet rising energy demands, improve access to energy services, and minimise the costs of developing energy infrastructure. In several low-income countries that have large, untapped renewable energy resources, particularly large hydropower, there is insufficient demand in the proximity to justify development; interconnection could expand the service area sufficiently to underpin development.

Figure 16. ASEAN Power Grid status and its plan, 2017



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Note: These maps are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: IEA (2017b), WEO-2017 Special Report: Southeast Asia Energy Outlook; adapted from Ibrahim (2016).

Most of regional interconnections are developing in the northern region.

The APG is moving forward as ASEAN countries plan to gradually expand interconnections beyond solely bilateral connections – first on a sub-regional basis and eventually into an integrated ASEAN system. As of November 2017, cross-border interconnections with a combined capacity of 5 500 MW had been developed, of which the majority of were between Thailand and Lao PDR. A project for APG power trade is outlined in an agreement announced in 2017 between Lao PDR, Malaysia and Thailand, with plans for Malaysia to import 100 MW of power from Lao PDR, wheeled through existing interconnections in Thailand to minimise costs. Singapore is expected to join at a later date. The implementation of the first phase of this Lao PDR-Thailand-Malaysia-Singapore (LTMS) Power Integration Project (PIP) started in January 2018 as the first multilateral electricity trade initiative in the region. Another example of a regional multilateral power exchange in the region is the Greater Mekong Sub-region (GMS). The GMS regional power integration programme began in 1992 and includes five

ASEAN northern countries (Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam) and two southern Chinese provinces, Yunnan and Guangxi.

Since the APG was conceived in the late 1990s, its development has proceeded in a piecemeal fashion. Although several interconnections have been developed and the overall level of interconnections has increased, they have been used mostly on a bilateral basis. Little progress has been made on establishing a regional (or even sub-regional) multilateral power market. Several barriers to regional integration persist, including underdeveloped domestic transmission grids in several ASEAN countries (particularly in lower-income Cambodia, Lao PDR, Myanmar, Viet Nam and the rural eastern provinces of archipelagic Indonesia) and diverse electricity market structures. The prospects for an integrated ASEAN power sector remain promising, but achieving the full potential of a regional power grid will require significant investments and well co-ordinated governance. Even if some interconnections lack economic viability at present, they play important role in strengthening regional grid stability, and can therefore be valuable as a public good.

In Northeast Asia there is also an ambitious initiative for an international grid connection plan, known as the Asia Super Grid (AGS). Proposed in 2011 by the chairman and chief executive of the Japanese telecom company SoftBank, the grid would connect the electricity networks of China, Japan, Korea, Mongolia and Russia. The idea is to link the power grids of these countries to allow abundant renewable electricity supplies produced in China and Mongolia to be used in other countries, and thereby to bolster the region's energy security (REI, 2018). The super grid is envisaged to ultimately allow Northeast Asian countries to share energy supplies. However, further considerations are needed especially in terms of legal frameworks and political backups in order to create a feasible investment model.

On an even larger scale, China's State Grid Corporation (SGCC), the world's largest power transmission company, announced its Global Energy Interconnection (GEI) vision in 2015, which aims to spearhead the construction of a highly efficient, worldwide electricity system through ultra-high voltage (UHV) transmission lines. In March 2016, the international non-profit foundation Global Energy Interconnection Development and Cooperation Organization (GEIDCO) was established with the goal of realising this GEI concept. GEIDCO concluded a memorandum of understanding on research and planning for the promotion of the international power grid with SoftBank, State Grid Corporation of China (SGCC), KEPCO, and Rosseti (Russia's state-owned transmission company). To start such a system in Asia, GEIDCO proposes to develop six UHV grids across China, Northeast Asia, Southeast Asia, South Asia, Central Asia and the Middle East to cement a clean power system in the region. Its proposed time schedule includes reaching a consensus by 2020, formation of grids on each continent by 2030, formation of intercontinental grids by 2040, and completion of grids on a global scale by 2050.

While building interconnections requires technical expertise and finance, bringing interconnected power systems into operation requires policy co-ordination. Transparent, rules-based regulatory frameworks are crucial to facilitate and govern cross-border electricity exchanges. The establishment of an effective regional co-ordinator to work with national governments on developing rules for cross-border infrastructure development and power trade is vital to support the harmonisation of national power markets, regardless of market structure.

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General annex

Abbreviations and acronyms

ADCOP	Abu Dhabi crude oil pipeline
ADNOC	Abu Dhabi National Oil Company
APEC	Asia-Pacific Economic Cooperation
APG	ASEAN Power Grid
APSA	ASEAN Petroleum Security Agreement
ASCOPE	ASEAN Council on Petroleum
ASEAN	Association of Southeast Asian Nations
CO_2	carbon dioxide
DESA	Department of Economic and Social Affairs
ERA	Emergency Response Assessment
ERE	Emergency Response Exercise
EV	electricity vehicle
FFR	fast frequency response
FSRU	floating storage and regasification unit
GB	Governing Board
GDP	gross domestic product
GEI	Global Energy Interconnection
GEIDCO	Global Energy Interconnection Development and Cooperation Organization
GMS	Greater Mekong Sub-region
IEP	International Energy Programme
IPSA	Iraqi pipeline in Saudi Arabia
ISPRL	Indian Strategic Petroleum Reserves Limited
JS	joint stockpiling

KEPCO	Kansai Electric Power Company
KNOC	Korean National Oil Corporation
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MoMo	IEA Mobility Model
NDRC	National Development and Reform Commission
NESO	National Emergency Strategy Organisation
NGL	natural gas liquid
NGV	natural gas vehicle
OCCTO	Organization for Cross-regional Coordination of Transmission Operators
OECD	Organisation for Economic Co-Operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PSH	pumped storage hydropower
PV	photovoltaic
SAIDI	system average interruption duration index
SAIFI	system average interruption frequency index
SGCC	State Grid Corporation of China
SPR	strategic petroleum reserve
TSO	transmission system operator
UAE	United Arab Emirates
UHV	ultra-high voltage
UN	United Nations
USD	United States dollar
EV	electric vehicle
WEO	World Energy Outlook

Units of measure

bcm	billion cubic metres
GW	gigawatt

GWh	gigawatt hour
kb	thousand barrels
km	kilometre
mb	million barrels
mb/d	million barrels per day
Mt	million tonne
MW	megawatt
MWh	megawatt hour
t	tonne
TWh	terawatt hour

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