Chapter 2

Disruption Scenarios and Procedure of Assessment

2.1. Selection of a fossil fuel for the study

Table 2.1 summarises the status of fossil fuels used in the EAS region. Coal, oil, natural gas supplied by pipelines and LNG are compared along the supply chain.

Table 2.1. Status of Fossil Fuels Used in the East Asia Summit Region

	Source/ Procurement	Market flexibility	Present usage	Future usage	Transport of fuels	Stock	Supply-chain resilience
Coal	Indigenous/ Import	Medium	Electricity/ Industry	Constant	Flexible	Flexible	High
Oil	Indigenous/ Import	High	Transport/ Industry/ Chemical	Increase	Flexible	Flexible	High
PL gas	Indigenous/ Import	Very low	Electricity/ Industry	Constant	Fixed	Limited	Low
LNG	Import	Low	Electricity/ Industry	Increase	Limited	Limited	Medium

LNG= liquefied natural gas; PL= pipeline
Source: Authors.

Coal is used primarily for power generation. Some EAS countries have indigenous coal resources. The use of coal may increase to meet more demand for electricity and other process industries, but may remain at a relatively constant level due to the environmental concern linked with coal consumption.

Oil is largely used for transportation and various industries. Some EAS countries have indigenous oil resources and also have been investing in overseas upstream business. Thanks to the mature, flexible and redundant capacity and the shale gas/oil revolution originated in the United States, the procurement of oil has now become relatively easy. Oil refineries are generally located at several key locations countrywide. Oil products as well as crude oil can be imported, allowing for a more flexible and resilient oil supply structure. Many countries in the EAS region have already gained a lot of experience importing oil.

The use of natural gas is relatively new compared to coal and oil. Some EAS countries have a variety of natural gas supply sources, including LNG and/or indigenous gas resources and import via international pipelines from neighbouring countries. Supply security is considered very high for indigenous natural gas production because the government can manage it directly. There are many concerns, however, such as the depletion of indigenous natural gas resources in the region. Unlike in Europe and the United States, there is virtually no interconnected gas pipeline network available in ASEAN. The ASEAN Council of Petroleum has recently revised its natural gas security policy, recommending that, rather than solely pursuing a regional natural gas pipeline network, countries in the EAS region should establish a gas spot market and infrastructure that incorporate LNG trade.

While a number of emerging countries in the EAS region have just started or will soon start introducing LNG, careful attention should be paid to the supply security, both commercially and technically. For most countries that have just introduced LNG or virtually have limited demand for LNG in the initial stage, the amount of imported LNG is relatively small, within a few million tonnes. They need to rely on just one or two traditional long-term oil-price-linked contracts. They would need to create more LNG demand to enjoy flexible and diversified procurement. LNG in general requires more technical effort to stockpile as compared to coal and oil. The treatment of boil-off gas is essential for LNG storage, limiting the duration of storage. In the introduction phase of LNG or in the period of limited demand, typically just one LNG receiving terminal is operational, supplying regasified natural gas mainly for power generation. A single LNG terminal is responsible for a certain portion of the country's entire power generation, and its power supply is vulnerable. Thus, several LNG receiving terminals are needed, diversified geographically and connected by gas pipelines to be more resilient for natural gas supply.

A disruption of LNG imports could generate serious problems for the country's total energy supply, particularly when the LNG infrastructure is not yet mature. An unexpected disruption of LNG imports may occur at any process in the LNG supply chain, such as gas production, liquefaction, LNG transport, and LNG receiving and regasifying, either due to political, commercial, technical, or environmental reasons. These should be carefully examined.

2.2. Selection of a country for case study

Among emerging EAS countries, one country is selected as suitable for the case study to assess resilience against LNG import disruption. Comprehensive insights and policy recommendations are generated. Finally, a generalised assessment procedure is established, which should be applicable to many other countries in the EAS region.

Thailand is believed to be the most suitable candidate for the case study of LNG import disruption as described below.

Myanmar, the Philippines, Thailand, and Viet Nam are regarded typical 'LNG introducing emerging countries'. They either have just introduced or will soon introduce LNG import. They are somewhat similar in terms of natural gas supply and utilisation. While they all have indigenous gas resources, they require LNG import to meet increasing demand for economic growth. A major part of indigenous natural gas is used for power generation, and LNG import is expected to supplement the shortage of indigenous natural gas. Table 2.2 summarises natural gas utilisation in Myanmar, the Philippines, Thailand, and Viet Nam.

Table 2.2. Natural Gas Utilisation in Myanmar, the Philippines, Thailand, and Viet Nam

As of 2015		Myanmar	Philippines	Thailand	Viet Nam
Natural gas in total primary energy supply[a]		15%	6%	28%	13%
Natural gas in power generation[a]		39%	23%	71%	33%
Natural gas sources (bcm / %)[b]	Indigenous	3.48 / 100% (total 17.5 bcm)	3.47 / 100%	33.0 / 68%	11.3 / 100%
	PL import	–	–	11.7 / 24%	–
	LNG	–	–	3.6 / 7%	–
	Total	3.48 /100%	3.47 /100%	48.3 /100%	11.3 /100%
Natural gas for power gen. (bcm / % in total natural gas consumption)[b]		2.29 / 66%	3.28 / 96%	29.6 / 61%	9.50 / 83%
Power generated in 2015		16 TWh	82 TWh	178 TWh	153 TWh
LNG receiving terminals		Under planning	Under planning	In operation: 1, under construction: 1	Under planning
LNG or PL import in power generation	2015 (actual)	0	0	5% PL import: 17%	0
	2020-2025 (estimated)	1–5%	1–5%	15–25% PL import: 5%	5–10%
	After 2030 (estimated)	5–10%	5–10%	approx. 30% PL import: 0%	10–20%

bcm = billion cubic metres; LNG = liquefied natural gas; PL = pipeline; TWh = terawatt-hour
Sources: [a] Institute of Energy Economics, Japan, [b] International Energy Agency natural gas information; data collected and summarised by authors.

Myanmar, which self-supplies as much as 400% of the country's natural gas, is planning to import LNG to meet increasing demand for electricity in the near future. Two thirds of natural gas consumed in Myanmar was used for power generation in 2015.

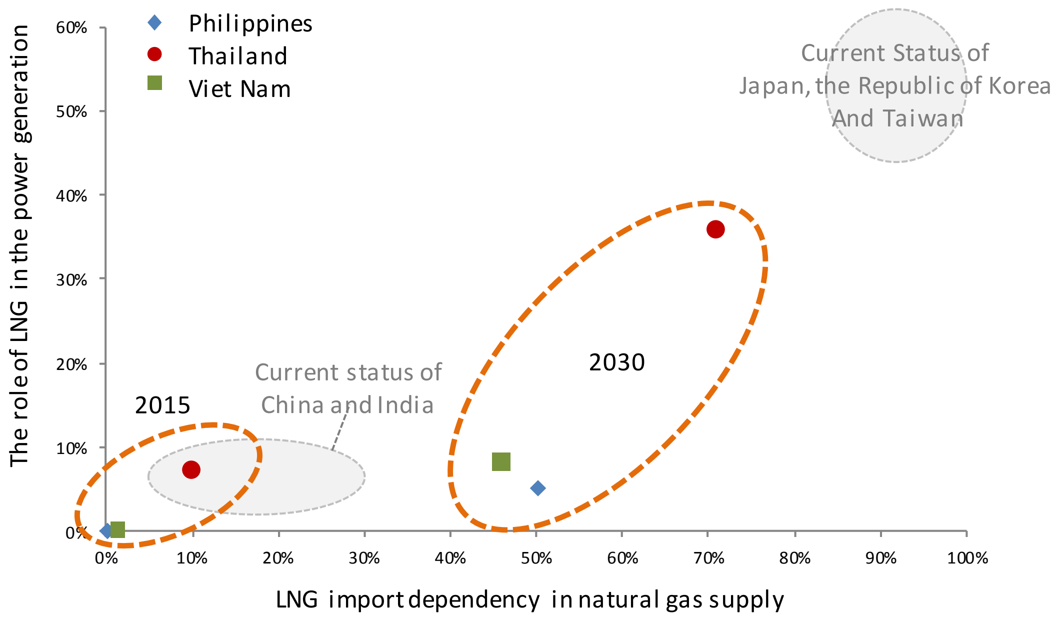
The Philippines and Viet Nam are currently self-sufficient in terms of natural gas supply with indigenous gas production. In 2015, most indigenous natural gas was used for power generation (83% in Viet Nam and 96% in the Philippines). Both countries, however, have been planning to introduce LNG imports to meet increasing demand for electricity. They initially plan to use most imported LNG for power generation, expanding gradually to use in industry.

Thailand has reasonably diversified natural gas supply sources. The country has indigenous natural gas resources and has been importing natural gas from Myanmar via pipeline as well. Furthermore, Thailand has a leading role in LNG imports in the region. In 2015, Thailand relied on natural gas for 71% of its power generation and 31% of natural gas was imported (24% via pipelines and 7% as LNG). This means Thailand relied on imported natural gas for 22% of its power supply, consisting of 17% via pipeline and the remaining 5% as LNG. It should be noted that since approximately 80% of the total LNG was imported from Qatar, Qatari LNG alone was responsible for 6% of the total natural gas supply and 4% of the total power supply to Thailand. Of the total natural gas supplied, 61% was used for power generation.

Figure 2.1 shows LNG import dependence in total natural gas supply and the role of LNG in power generation. Current (2015) and estimated (2030) status of LNG dependence for the Philippines, Thailand and Viet Nam are shown. The current status of LNG dependence for Japan, the Republic of Korea and Taiwan (as matured LNG importing countries) and those for China and India (as other emerging LNG importing countries) are also shown for reference. Dependence on LNG is estimated to increase substantially from 2015 to 2030. Thailand, in particular, is expected to depend heavily on LNG in 2030, approaching current levels for Japan, the Republic of Korea and Taiwan. The Philippines and Viet Nam are expected to follow a similar trend.

Thailand has a full set of natural gas supply sources: indigenous gas resources and gas imports via pipelines and LNG. Thailand will be increasingly dependent on LNG for power generation. It has just entered the expansion phase of LNG projects with viable diversification of LNG sources. Thailand has been leading EAS emerging countries regarding experience in LNG import.

Figure 2.1. LNG Import Dependence in Total Natural Gas Supply and the Role of LNG in Power Generation

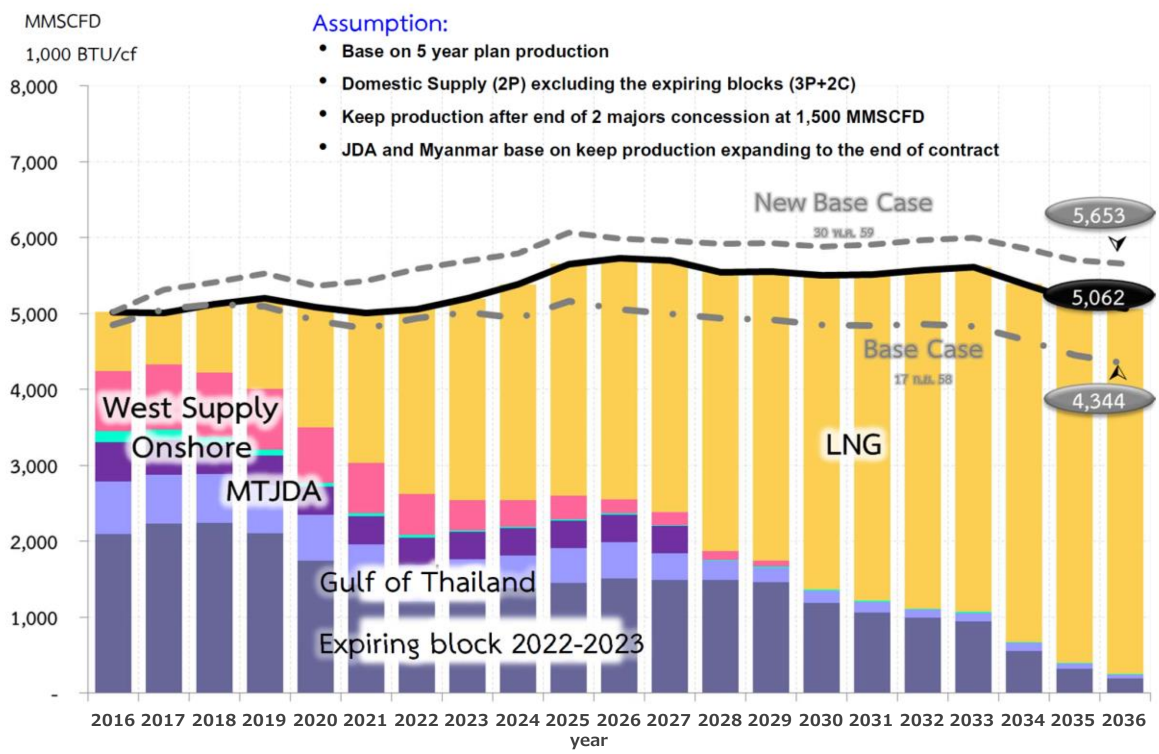


LNG = liquefied natural gas.
Source: International Group of Liquefied Natural Gas Importers (GIIGNL) 2017, BP Statistical Review 2017, Asian LNG Demand-Key Drivers and Outlook (Oxford institute for energy studies, Apr 2016), Philippines LNG-Developing New Import Markets (The Latau Group Nov. 2014), and Thailand's Gas Plan (Ministry of Energy, June 2017); data collected and summarised by authors.

2.3. Overview of natural gas status in Thailand

Figure 2.2 shows gas supply plan in Thailand. After 2020, a substantial decrease in Thai indigenous natural gas production is expected from onshore, Malaysia Thailand Joint Development Area (MTJDA), and Gulf of Thailand supply. Natural gas imports from Myanmar via pipelines (shown as 'West Supply') are also expected to decrease sharply. A substantial increase in LNG imports is essential to compensate for the decrease in indigenous gas production and pipeline gas imported from Myanmar. On top of this, more LNG will be needed to meet increasing demand for natural gas. Dependence on imported natural gas was 31% in 2015, which will jump up to 50% in 2020. In 2030 when the pipeline import is supposedly terminated, LNG will be responsible for 70% of the total natural gas supply. Indigenous natural gas production will be depleted after 2030, suggesting that eventually Thailand's natural gas supply will become almost 100% dependent on LNG import.

Figure 2.2. Gas Supply Plan in Thailand



BTU = British thermal unit, LNG = liquefied natural gas, MMSCFD = million standard cubic feet per day, MTJDA = Malaysia Thailand Joint Development Area, JDA =Joint Development Area (Malaysia-Thailand), 2P = proved plus probable reserves, 3P = proved plus probable plus possible reserves, 2C = contingent proved plus probable resources

Note: 'West Supply' refers to natural gas import via pipeline from Myanmar. In the original figure the timeline was expressed in the Buddhist calendar. It has been rewritten using the AD by the authors.

Source: Thailand's Gas Plan 2015 (2015–2036) (revised in 2016), Dr Sarawut Kaewtathip, Department of Mineral Fuels, Ministry of Energy, 26 June 2017.

Table 2.3 summarises Thailand's LNG procurement. Qatar has been the major LNG supplier in the last several years. It is the first long-term supplier to Thailand with 2 mmtpa (million metric tonnes per annum) of LNG for 20 years. With additional spot LNG supply, Thailand depended heavily on Qatar for more than two thirds of the imported LNG in 2015 and 2016. In 2017, Map Ta Phut LNG receiving terminal, the first and only terminal in Thailand, will be expanded to double its receiving capacity from 5 mmtpa (one train) to 10 mmtpa (two trains). Thailand will be able to diversify LNG sources, with three more independent long-term contracts of approximately 1 mmtpa each. The country is entering into an expansion phase of LNG import, after several years in the introduction phase with only one long-term contract.

Table 2.3. Thailand's LNG Procurement (bcm/yr)

Year	Total	Country of origin
2016	4.2	Qatar 4.1, Oman 0.1 – long term + spot basis
2015	3.6	Qatar 2.9, Australia 0.3, Nigeria 0.2 – long term + spot basis
2014	1.9	Qatar 1.3, Nigeria 0.2, Malaysia 0.1, Yemen 0.1, Oman 0.1, Russian Federation 0.1 – spot
2013	2.0	Qatar 1.4, Nigeria 0.3, Yemen 0.1, E. Guinea 0.1, European Union 0.1 – spot basis
2012	1.4	Yemen 0.5, Peru 0.4, Qatar 0.3, Trinidad and Tobago 0.1, Nigeria 0.1 – spot basis
2011	1.0	Qatar 0.3, Peru 0.3, Russian Federation 0.2, Nigeria 0.2 – spot basis
Long term contracts		
・ Qatar LNG		: 2.0 mmtpa (2.76 bcm/yr) (2013–2032, 20 yrs)
・ BP portfolio		: 1.0 mmtpa (1.38 bcm/yr) (2017–2031, 15 yrs)
・ Shell portfolio		: 1.0 mmtpa (1.38 bcm/yr) (2017–2031, 15 yrs)
・ Petronas portfolio		: 1.2 mmtpa (1.66 bcm/yr) (2017–2031, 15 yrs, ramp-up basis)

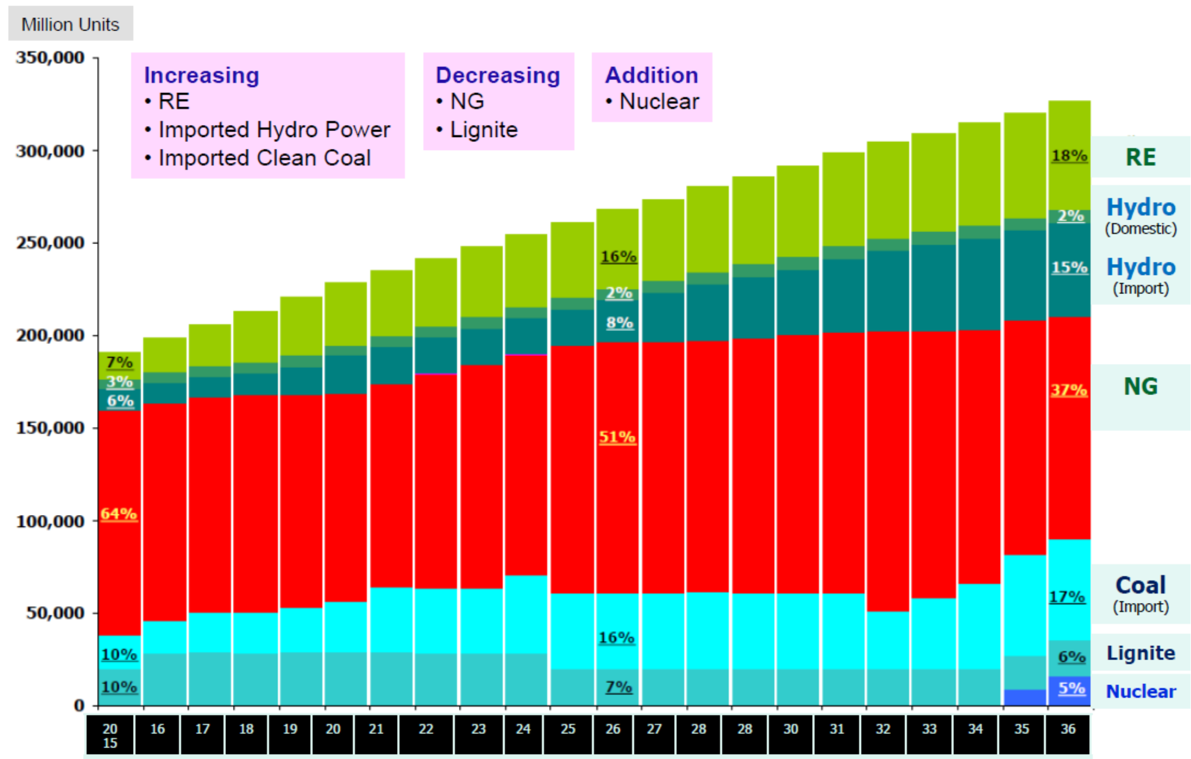
bcm = billion cubic meters, LNG = liquefied natural gas, mmtpa = million metric tonnes per annum, yr = year.

Source: BP Statistical Review-2016; data collected and summarised by authors.

Figure 2.3 shows power generation by fuel type in Thailand. While the total demand is expected to increase steadily, the capacity of natural-gas-powered generation will be maintained virtually unchanged until 2030. The share of natural gas in power generation decreases gradually from approximately 60% in 2015-2016 to 50% in 2020-2025 and less than 40% after 2030. While the share of natural gas is gradually decreasing, a sharp increase in LNG import is planned as was shown in Figure 2.2. This will eventually result in more dependence on LNG in the total power generation. The share of LNG in power generation, which used to be just 5% in 2015, is expected to jump up to 15% in 2020, 25% in 2025, and 30% in 2030. LNG will be increasingly and inevitably crucial for energy supply security in Thailand.

It should be noted again that Myanmar, the Philippines and Viet Nam are expected to follow a similar trend as shown in Table 2.2. These three countries will soon start importing LNG. In the coming decade up to 2030, Myanmar and the Philippines are estimated to rely on LNG import for approximately 5% of total power generation. Viet Nam is somewhere between these two countries, and Thailand will rely on LNG import for approximately 10% of total power generation.

Figure 2.3. Power Generation by Fuel Type in Thailand



NG = natural gas, RE = renewable energy.
Source: Dawan Wiwattanadate, Thailand's Integrated Energy Blueprint (2015–2036).

2.4. General idea on the risk assessment for LNG disruption

A variety of risk assessment methods have been proposed and utilised. In general, risk sources are identified and categorised first. Then risk sources are viewed both quantitatively and qualitatively. Basic categorisation is classifies risk sources as 'Intentional' and 'Non-intentional', which are also called as 'Threads' and 'Hazards' respectively. Another categorisation is according to the origins of risk such as 'Political', 'Economic', 'Technical' and 'Environmental'. Table 2.4 shows a list of example of risk sources, which has been taken as reference from a study on gas risk assessment in European Union. The categorisation of risk sources in the table is applicable to a variety of energy disruptions as well.

Table 2.4. Example of Risk Sources

Intent	Failure/Accident	Nature	Cascade
Acts of terrorism	Negligence	Extreme weather conditions	Loss of power supply/utilities/services
Acts of vandalism	Mistake	Pandemic (flu/etc.)	Loss of telecoms
Theft (copper/metals)	Impact (e.g. vehicle against pylon/pole)	Geological	Loss of energy supply to the electricity transmission network (interconnector / generated supply)
Theft (equipment)	Ingress of water	Fire	Loss of 'black start' capability
Industrial action	Explosion	Flood	Loss of pumped storage capacity
Targeted cyberattack	Disclosure of information (theft/leakage)	Solar activity	
Virus/trojans	Equipment malfunction or failure		
Electromagnetic pulse	Chemical (spillage)		
Act of war	Loss, unavailability, or turnover of personnel		
Diplomatic incident	Outdated and unmaintainable technology		

Source: Table 2 of Categorisation of sources of risk according to EURACOM project; EURACOM, Del. 2.3 in Ricardo Bolado, Francesco Gracceva, Peter Zeniewski, Pavel Zastera, Lenhard Vanhoorn, and Anna Mengolini (2012), *Best practices and methodological guidelines for conducting gas risk assessments*, JRC Scientific and Technical Reports. Luxembourg: Publications Office of the European Union.

Referring to the examples above, Table 2.5 summarises risk sources for LNG disruption and its estimated amount and duration of disruption. The LNG supply chain is divided into five phases: LNG exporting countries, upstream gas field, LNG liquefaction and loading, LNG transport, and LNG receiving. In each phase of the LNG supply chain, risk sources have been divided into either political or technical. Environmental aspects such as bad weather and natural disaster have been included in the 'technical' category. The amount and duration of LNG disruption are estimated, which are based on experiences by a number of LNG experts in the Republic of Korea and Japan. Note that 'several weeks' in the table is defined as durations longer than 1 week and shorter than 4 month, and 'several months' is longer than 1 month and shorter than half a year or 6 months.

Table 2.5. Risk Sources of LNG Disruption and Its Amount and Duration

		Risk sources for disruption	Estimated amount and period of disruption
LNG exporting countries	Political	・ Default by civil unrest, war, or deteriorated diplomatic relationship ・ Default due to policy change (e.g. prioritising domestic consumption)	・ Years of disruption with either part or entire amount of contracted LNG export ・ A few months of disruption before procuring either part or entire amount of substitute LNG from short-term market
Upstream gas field	Political	・ War or terrorist attack on gas fields or gas pipeline ・ Change in regulation (environment or safety) ・ Labour strikes	・ A few months to one year disruption with either part or entire amount of LNG ・ A few weeks to one month of disruption before procuring substitute LNG from short-term market
	Technical	・ Gas resource depletion ・ Technical or operational failures ・ Natural disaster ・ Utility disruption	・ Depletion predictable ・ A few weeks of disruption due to technical or operational failure ・ Up to a month disruption before procuring substitute LNG from short-term market
LNG liquefaction and loading	Political	・ War or terrorist attack ・ Change in regulation ・ Labour strikes	(same as 'Upstream gas field' above)
	Technical	・ Technical or operational failure ・ Natural disaster ・ Utility disruption	・ A few weeks of disruption from respective LNG project ・ Up to a month disruption before procuring substitute LNG from short-term market
LNG transport	Political	・ Strait blockade by war or deteriorated diplomatic relationship ・ Terrorist or pirates ・ Change in regulation ・ Labour strikes	・ Malacca Strait: One-week disruption for detour/Strait of Hormuz: same as disruption from exporting countries ・ Terrorist or pirates: loss of an LNG carrier, up to a month to charter a substitute. ・ A few weeks for regulation / labour issues
	Technical	・ Stranding/collision ・ Technical failure of an LNG carrier ・ Delay by natural disaster	・ Disruption by loss of an LNG carrier ・ Up to a month to charter a substitute LNG carrier ・ A week delay of delivery by bad weather
LNG receiving	Political	・ Terrorist attack, etc. ・ Change in regulation (environment or safety) ・ Labour strikes	・ A few months to years of disruption depending on the damage to the terminal ・ A few weeks to month for regulation/labour issues
	Technical	・ Natural disaster ・ Technical failure ・ Utility disruption ・ Unable to dock due to serious troubles in a port	・ A few months to years of disruption due to a big disaster, such as a huge tsunami ・ A few days to weeks of disruption due to technical or operational failure and trouble in a port

LNG = liquefied natural gas.
Note: one week < 'a few weeks' < 1 month, 1 month < 'a few months' < half a year.
Source: Authors.

2.4.1 LNG exporting countries

All or part of LNG export could be disrupted by either civil war or a war between countries, in which an exporting country is involved. The Middle East oil crisis in the 1970s and several wars in the region are typical examples. Deterioration of diplomatic relations could also cause disruption. Various disputes between the Russian Federation and Ukraine over the last decade have led the Russian Federation to disrupt natural gas supply to Ukraine, which eventually had enormous impacts on the rest of Europe. Political risks include changes in policy in favour of domestic gas supply. Unless it causes global-scale disturbances, however, the effect of a war is rather limited to respective countries or a region.

The net contracted amount of LNG between the exporting and importing countries could be disrupted, usually in the order of several million tonnes per annum (mmtpa). Substitute LNG could be procured from the international LNG spot market. If the disruption is expected to be long, then LNG importing countries could look for another long-term purchase contract with third-party countries. Depending on the demand-supply status in the global LNG market, substitute LNG could be delivered within several weeks to months if the LNG supply is disrupted from a single exporting country. The duration of disruption could be as long as several months.

The recent dispute between Qatar and its neighbouring countries suggests a possible worst-case scenario. Qatar exported 78 mmtpa of LNG in 2015, which amounted to approximately 31.8% of global LNG exports of 245 mmtpa. There was approximately 66 mmtpa of short-term LNG trade in 2015, which was not enough to cover the potential loss by Qatari LNG disruption. Nevertheless, the global LNG market has been a buyer's market, with approximately 50–100 mmtpa of additional production capacity reportedly available from LNG producing countries. In the current LNG global market, substitute LNG could be procured at most in a few months even if Qatari LNG, the largest supply source, were to be disrupted. It should be recalled also that it took just a few months for Japanese utilities to procure additional 20 mmtpa of LNG to make up for the energy shortage caused by the disaster in 2011.

2.4.2 Upstream gas field and liquefaction

LNG export could be disrupted for months to years if an upstream gas field or a liquefaction facility were to be totally destroyed by a terrorist attack or huge natural disaster. The maximum amount of disruption could be the production capacity of the respective LNG project, from approximately 5 mmtpa for a single standard LNG project to approximately 20 mmtpa for a large-scale project such as in Bintulu, Malaysia. Unless caused by a global-scale disaster or terrorism, the disruption should be limited to the respective projects. Substitute LNG could be procured within several months from the global LNG market. Disruption due to a technical failure or bad weather condition is not uncommon, with its duration ranging from a few days to at most several months. Several hurricanes have caused a lot of damage to various oil/gas infrastructure in the southern states of the United States in recent years, but it took only a few months to resume operations. Every several years, LNG liquefaction facilities require major maintenance lasting a few months, during which their LNG export is temporarily halted. Arrangements are made between exporting and importing countries as to how to deal with such temporary disruptions. Generally speaking, unless the damage is totally devastating, LNG export is believed to resume within a month.

2.4.3 LNG transport

LNG transport could be disrupted by a war, terrorist attack, or pirating. Stranding and/or collisions sometimes occur also under deteriorated weather conditions. If an LNG carrier is severely damaged, the delivery of one cargo of LNG could be suspended. The loss of LNG could amount to 60,000–130,000 tonnes, depending on the ship's cargo capacity. The damaged LNG carrier could be out of service for a certain period, and it could take several weeks to charter an alternative LNG carrier if needed. Delay in delivery, or disruption duration, is estimated to be several weeks. In 2016, there were approximately 360 LNG carriers operational in the world, with 46 ready for short-term charter (International Gas Union 2017 report). It should be noted that several hundred thousand tonnes of LNG could be procured from the international spot market within a short period of time.

The Malacca Strait and Strait of Hormuz are strategically important for the supply of LNG to the EAS region. The Malacca Strait could become blocked due to various accidents such as a collision or stranding of ships, whether or not involving an LNG carrier. LNG carriers could make a detour through the Lombok Strait, which would cause several days of delay in delivery. A blockade of the Strait of Hormuz, either due to political or technical reasons, could result in the total disruption of Qatari LNG, not to mention oil from the Persian Gulf area. It could have a similar impact as the export embargo of Qatari LNG. If a blockade were to last long, it might become necessary to procure substitute LNG from the spot market, which could take several weeks to months. Additional LNG carriers might need to be chartered if Qatari LNG carriers were trapped in the Persian Gulf.

In 1974, a fully loaded oil tanker collided with another ship at the mouth of Tokyo Bay. The collision caused a huge fire and the oil tanker was stranded. Tokyo Bay was closed for 10 days, during which nearly all marine transports into and out of Tokyo Bay were suspended. Since then, several LNG receiving terminals have been built inside Tokyo Bay. It is widely believed that this accident has led to the efforts to maintain the LNG stock at around 20 days of total demand, twice the suspended duration of 10 days. Marine accidents occurring at bottlenecks of sea lanes might cause serious disruption of LNG as well.

2.4.4 LNG receiving

The longest disruption of LNG could occur if LNG receiving terminals are totally destroyed by, for example, a terrorist attack or huge natural disaster. If major facilities such as LNG tanks and a berth/jetty are destroyed, it could take months or even years to restore the terminal. The tsunami caused by the Great East Japan Earthquake on 11 March 2011 is well-known to have totally devastated the Fukushima No. 1 nuclear power plant. It also struck Minato LNG receiving terminal in the city of Sendai, 300 kilometres north of Tokyo. Although no serious damage was identified for the LNG tank, it took 9 months to repair the entire receiving terminal before it was operational again. (For reference, Figure 2.4 shows a photo taken as the tsunami struck Minato LNG receiving terminal in Sendai on 11 March 2011.)

Figure 2.4. Tsunami at Minato LNG Receiving Terminal in Sendai, Japan

Source: Gas Bureau, City of Sendai, http://www.gas.city.sendai.jp/top/info/2013/05/001936.php

LNG receiving terminals have an LNG storage capacity of up to 10–20 days, allowing them to manage delays of several days up to 2–3 weeks. A delay of several days is not uncommon, for example due to unexpected outage of liquefaction facilities or bad weather conditions en route. Generally, if delivery is delayed for a month, LNG receiving terminals can no longer maintain their planned or rated supply of regasified natural gas.

A global LNG market is being established, where exporting countries and regions are gradually diversified. Hundreds of LNG carriers are in operation to secure the flexibility and redundancy in LNG transportation. However, if a country has just started importing LNG with merely one receiving terminal, this terminal itself could be the most crucial bottleneck in the entire LNG supply chain. To be more specific, a berth/jetty of a receiving terminal is believed to be one of the most crucial facilities of an LNG receiving terminal that determine the supply security of LNG.

A standard-sized, economically preferable LNG receiving terminal with a single berth/jetty has a capacity of approximately 5 mmtpa, which could generate 30–40 terawatt-hours of electricity annually. Referring to Table 2.2, a single standard-sized LNG terminal, if fully operational for power generation alone, could provide potentially more than 20% of the total power generated in Thailand or Viet Nam, 40% in the Philippines, and virtually 200% in Myanmar. For emerging EAS countries, the first LNG project alone could have a substantial impact on the country's power generation portfolio. The impact of a single LNG project is rather small for the developed LNG importers such as Japan, the Republic of Korea, and Taiwan, which already have several LNG terminals in operation to meet much larger demand for power.

2.5. LNG disruption scenarios for Thailand

Based on the consideration above, risk scenarios of LNG disruption for Thailand are formulated and shown in Table 2.6. Four disruption scenarios (A–D) are assumed, consisting of interactions between two different amounts (2 mmtpa and 10 mmtpa) and durations (30 days and 180 days). One of the two cases for disrupted amount is associated with LNG production/export and the other with LNG receiving.

Thailand's largest long-term contract is for Qatari LNG (2 mmtpa), which is considered the most serious risk source in the LNG production/export phase. Thailand has only one LNG receiving terminal whose receiving capacity was recently expanded to 10 mmtpa. The worst disruption scenario in the receiving phase is assumed to be the shutdown of the entire terminal.

A disruption of 30 days represents relatively serious but not fatal disruption scenarios. It generally takes a month to procure additional LNG from the spot market, the same time that it takes to repair a relatively serious failure of a receiving terminal. A disruption of 180 days represents fatal scenarios, in which the delivery of LNG is halted due to global-scale political uncertainty or a large-scale technical failure of a receiving terminal.

Table 2.6. LNG Disruption Scenarios: Amount and Duration for Thailand

		Disrupted amount (annualised amount)	
		Largest long-term contract amount 2 mmtpa	**Capacity of the largest LNG terminal 10 mmtpa***
Disrupted duration	30 days	A	C
	180 days	B	D

LNG = liquefied natural gas, mmtpa = million metric tonnes per annum.
* There is only one terminal in Thailand, thus it is the largest.
Source: Authors.

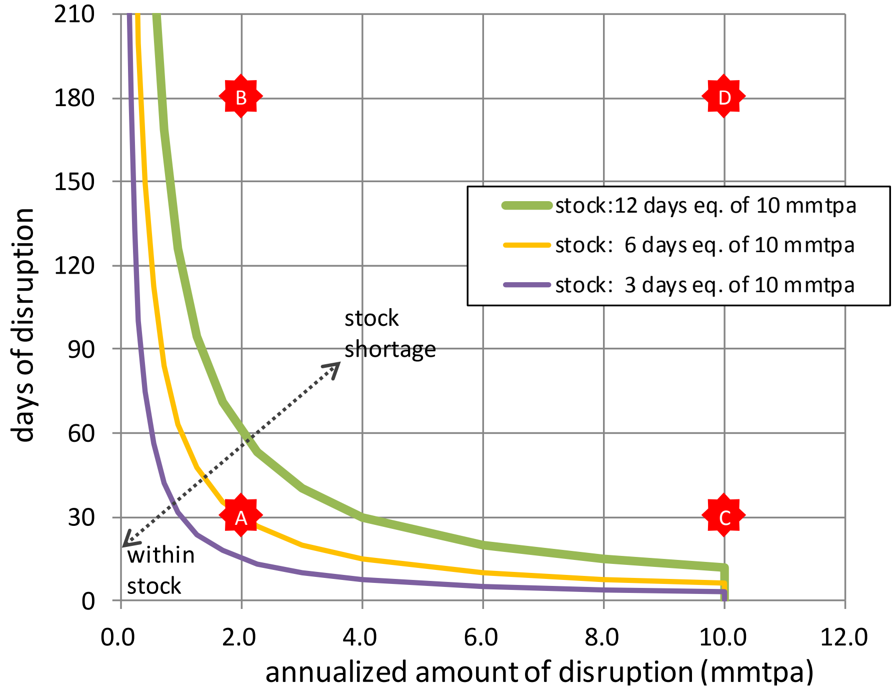
The selection criterion for the two cases of disrupted amount is similar to the 'N–1 principle', which has been widely applied when assessing gas supply security in European Union countries.[1] The N–1 principle is a realistic scenario that describes the technical capacity of the gas infrastructure to satisfy total gas demand in the calculated area in the event of a disruption of the single largest gas infrastructure.

Figure 2.5 illustrates the disruption scenarios and the effect of LNG stock. Each of the four scenarios (A–D) in Table 2.6 is plotted in terms of annualised amount of disruption and days of disruption. Note that the amount of disruption is represented as 'annualised' on an equivalent basis. In the years up to 2020, Map Ta Phut LNG receiving terminal, the only receiving terminal in Thailand, will have a receiving capacity of 10 mmtpa. The LNG stock is reported to be in the order of 10 days at maximum. The three lines in the figure represent the relationship between allowable days of disruption and amount of disruption under three different levels of LNG stock, equivalent to 3, 6, and 12 days of 10 mmtpa LNG receiving.

Under a fixed amount of stock, allowable days of disruption bear an inverse relation to the amount of disruption theoretically. For example, LNG stock equivalent to 6 days of 10 mmtpa (orange line) allows maximum 30 days of the rated supply when LNG disruption is equivalent to 2 mmtpa LNG. This example coincides with disruption scenario A, suggesting that the amount of stock is crucial as to whether or not the disruption is tolerable. Disruption scenario A is therefore in a kind of grey zone, suggesting that countermeasure to LNG disruption should be studied in case of a relatively low level of stock. Under scenarios B, C, and D, due to the shortage of stock, the receiving terminal is no longer able to maintain its rated supply of gasified natural gas over the days of disruption.

[1] Regulation (EU) No. 994/2010 of the European Parliament and of the Council of 20 October 2010, concerning measures to safeguard security of gas supply and repealing Council Directive 2004/67/EC.

Figure 2.5. Disruption Scenarios and the Effect of LNG Stock



LNG = liquefied natural gas, mmtpa = million metric tonnes per annum.
Source: authors

Countries such as the Republic of Korea and Japan have sufficiently diversified LNG exporting countries and regions. Also, a large number of LNG receiving terminals have been built. Thus, LNG disruption from a single export project could have relatively limited impact on the country's total LNG procurement. An unexpected long-term shutdown of an LNG receiving terminal could be compensated by several other existing LNG terminals. A high degree of LNG supply security has been already achieved. In contrast, LNG supply security is rather vulnerable for the EAS countries that are in the introduction phase of LNG import. Like the Thailand case, a single exporting country or project is often dominant in the total LNG procurement. Only one LNG receiving terminal is in operation, and a single serious failure of the terminal could affect the country's entire supply of natural gas.

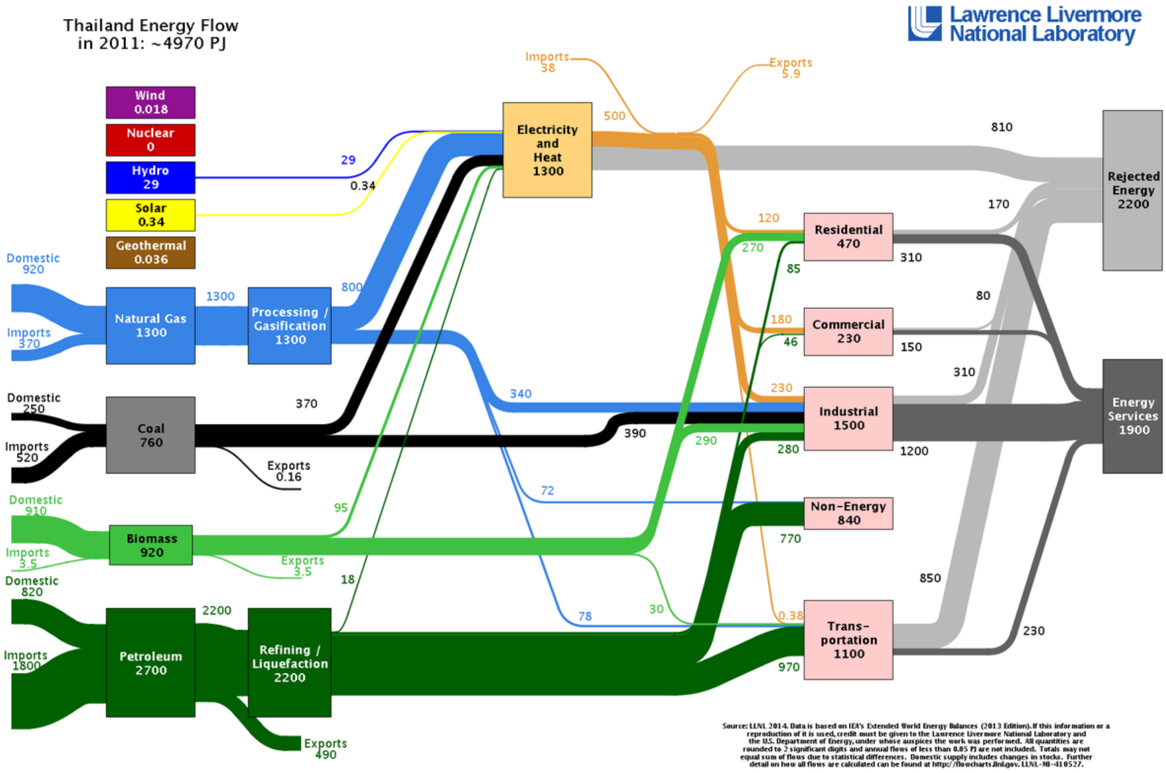
2.6. Assessment procedure of LNG disruption

The major objective of this study is to investigate how to secure the total supply of energy as a whole, and electricity in particular, in the event of an LNG disruption. In this subsection, typical scenarios of LNG import disruption have been identified. The easiest shortcut would be to build LNG tanks to increase the stockpile up to, for example, 90 days as mandated by IEA for oil stock. This could automatically solve most of the disruption scenarios assumed here.

There are many other viable countermeasures, however, by managing the energy supply system totally. As a reference, Figure 2.6 shows the energy flow in Thailand in 2011. Part of the disrupted

LNG could be supplemented by increasing indigenous gas production or gas import via pipelines; part of natural gas could be replaced by other fuels such as oil, coal, and biomass. Some power plants are reportedly ready to deal with dual fuels, allowing oil to replace natural gas. The procurement of substituting fuels should be carefully assessed economically as well as technically. Flexibility and redundancy of the domestic energy supply network play a key role in changing energy sources. Particular considerations should be given to power generation and supply, for which the flexibility and redundancy of power grids should be examined. Detailed knowledge and understanding are essential regarding the energy supply system. Quantitative assessment of the energy supply system is needed to identify potential bottlenecks that constrain the flexibility of the energy supply chain.

Figure 2.6. Energy Flow in Thailand in 2011



Source: Lawrence Livermore National Laboratory

The following generalised countermeasures are proposed. The viability of each countermeasure should be analysed step by step:

0) To use existing LNG stock
1) To increase indigenous natural gas production
2) To increase natural gas import via pipelines
3) To increase the use of other energy sources such as oil, coal, and renewables
5) To increase electricity import
6) To reduce energy export

7) To save energy consumption by means of planned outage of electricity and/or gas
8) To increase LNG storage/stock capacity
9) Other measures

2.6.1 Countermeasures in the event of LNG disruption in Thailand

More specifically for Thailand, these countermeasures can be rewritten as follows:

Step 0: To use existing LNG stock or storage

Step 1: To increase indigenous natural gas production
- Production volume of indigenous gas – e.g. average/max production volume, flexibility, etc.
- Capacity or flexibility of natural gas pipeline network in Thailand – e.g. max flow of natural gas pipeline network, different zones, etc.
- Capacity of gas separation processes, if needed

Step 2: To increase natural gas import from Myanmar
- Import volume of Myanmar gas
- Procurement contracts
- Capacity of the import transmission pipeline
- Capacity or flexibility of natural gas pipeline network in Thailand

Step 3: To increase natural gas from MTJDA
- Production volume of MTJDA gas delivered to Thailand
- Procurement contracts
- Capacity of the MTJDA transmission pipelines
- Capacity or flexibility of natural gas pipeline network in Thailand

Step 4: To increase the use of other fuel sources such as oil and/or coal for power generation and/or industry gas supply
- Capacity of power plants of oil and/or coal
- Fuel switch from natural gas to other fuels
- Capacity or flexibility of power supply network in Thailand
- Stock of oil and/or coal
  (Note: Increased amount of imported oil and/or coal is assumed marginal in the global market)

Step 5: To increase electricity import, if possible

Step 6: To reduce energy export, if possible and substantial

Step 7: To save energy consumption
- Planned outage of electricity and/or city gas supply

Step 8: To increase LNG storage/stock

Step 9: Other measures