Chapter 3

Assessment of Resilience against Liquefied Natural Gas Import Disruptions in Thailand

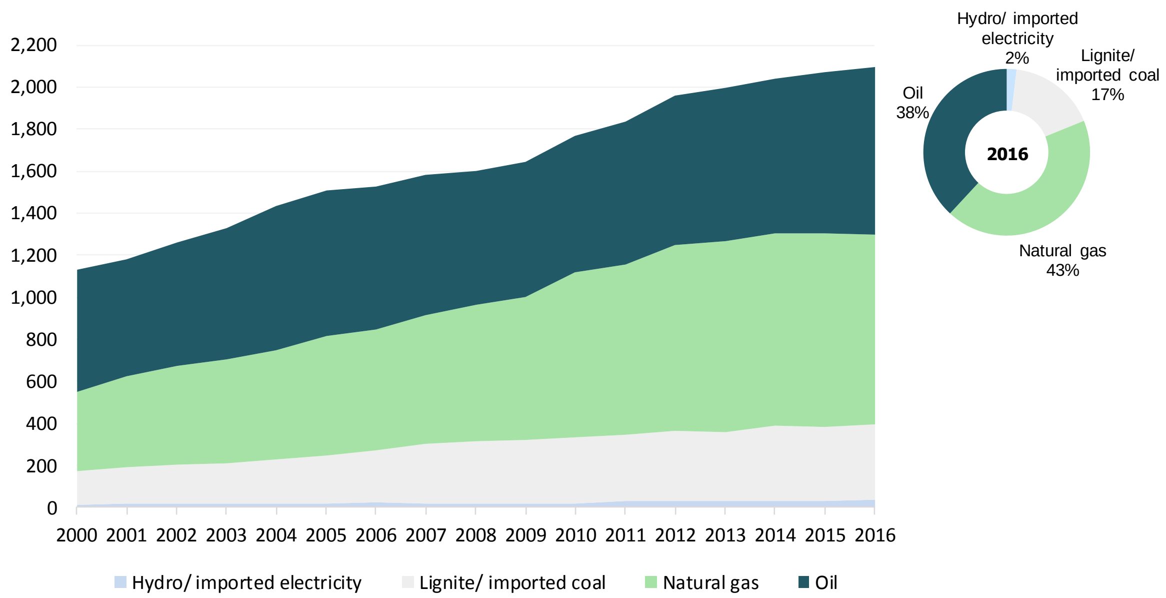
As a case study to apply the assessment procedure developed in the Chapter 2, the study assessed the resilience against LNG import disruptions in Thailand.[2] Prior to the assessment, the Petroleum Institute of Thailand (PTIT) was provided with scenarios of LNG import disruption and possible countermeasures presented in the previous section. PTIT, with using its varied and in-depth information and expertise on the energy supply system in Thailand, assessed the country's resilience to the LNG import disruption scenarios. This chapter presents the results of the PTIT assessment study.

3.1. Background on Natural Gas Market and Infrastructure in Thailand

Thailand's energy use reflects its expanding economic activities, which generally trend with the world's economy. Non-renewable fossil fuels constitute most of the energy use in the country; and although Thailand can produce some of its energy, indigenous supply is rather limited. The country has to rely on energy imports. In addition, Thailand relies only on several sources of energy – with natural gas being the most heavily consumed. In 2016, natural gas consumption averaged 901 kboed (thousand barrels of crude oil equivalent per day) and made up 43% of the country's total commercial primary energy consumption of 2,093 kboed – followed by oil at 798 kboed (38%), lignite/imported coal at 355 kboed (17%), and hydro/imported electricity at 40 kboed (2%).

[2] This part of the study was conducted by the Petroleum Institute of Thailand (PTIT).

Figure 3.1. Commercial Primary Energy Consumption in Thailand



Source: Energy Policy and Planning Office Ministry of Energy; data collected and summarised by the Petroleum Institute of Thailand.

3.1.1 Natural gas market in Thailand

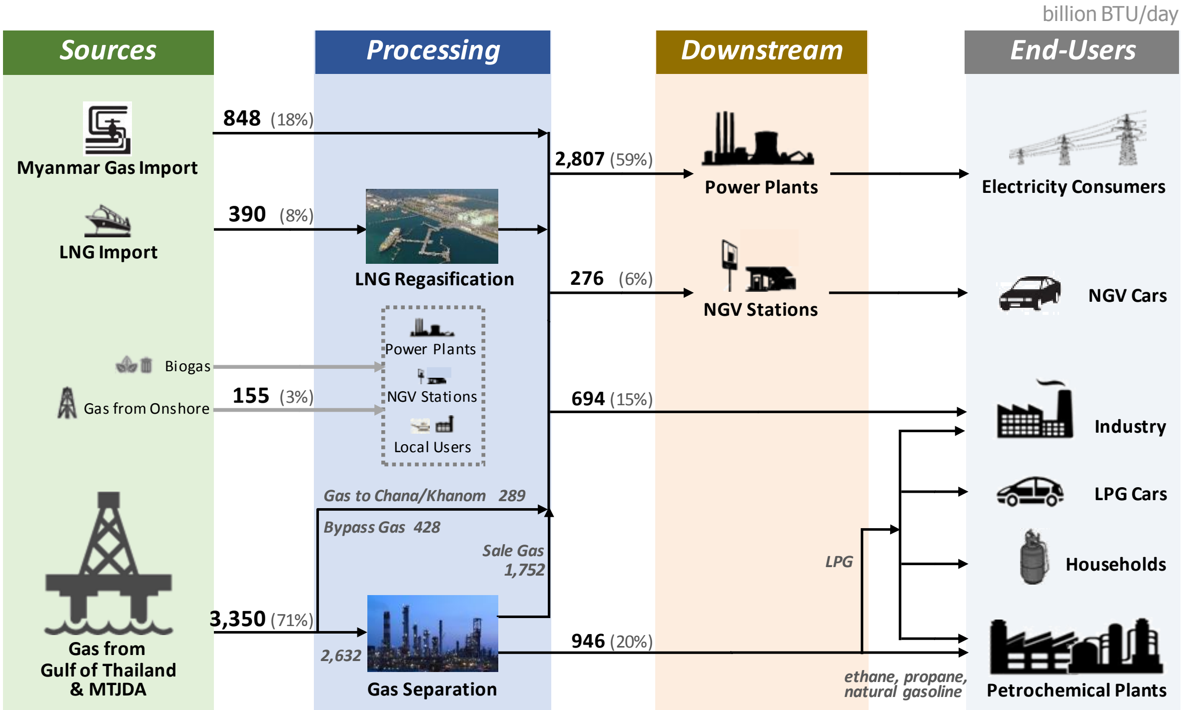
Thailand is both a producer and an importer of natural gas. The country produces natural gas from offshore fields in the Gulf of Thailand and the Malaysia–Thailand Joint Development Area (MTJDA) and from onshore fields in the north and northeast. Indigenous gas, however, does not suffice for the country's demand; thus necessitating piped gas imports from Myanmar and LNG imports.

Figure 3.2 summarises the natural gas supply chain in Thailand. In 2016, Thailand consumed altogether 4,723 billion British thermal units per day (billion BTU/day)[3] of natural gas, consisting of 2,807 billion BTU/day for electricity generation (equivalent to 59% of total natural gas demand), 276 billion BTU/day as natural gas for vehicles (NGV) (6%), 694 billion BTU/day for industrial use (15%), and 946 billion BTU/day by gas separation plants to extract ethane, propane, liquefied petroleum gas (LPG), and other hydrocarbons[4] (20%).

[3] In this report, natural gas demand and supply figures are expressed in terms of heating value – that is, in billion BTU/day and 1,000 BTU/scf (standard cubic foot of gas).

[4] Natural gas produced from the Gulf of Thailand is generally 'wet' gas. That is, it is made up of other hydrocarbons (ethane, propane, butane, etc.) besides methane. It is fed into gas separation plants (GSPs) to extract these hydrocarbons for other applications besides simply burning as fuel.

Figure 3.2. Natural Gas Supply Chain in Thailand



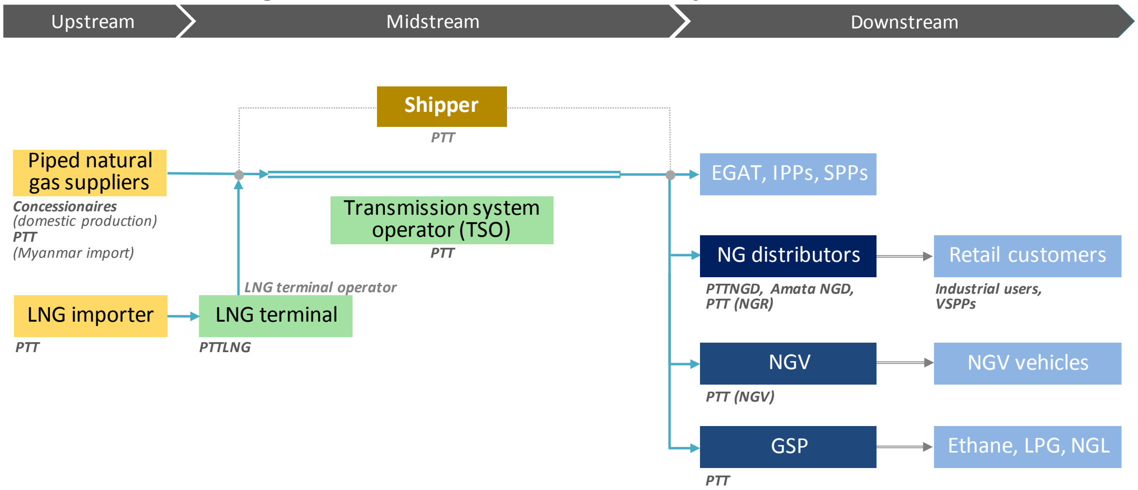
BTU = British thermal unit, LNG = liquefied natural gas, LPG = liquefied petroleum gas, MTJDA = Malaysia–Thailand Joint Development Area, NGV = natural gas for vehicles, scf = standard cubic foot.
Note: Based on 2016 statistics and natural gas supply and demand volumes at 1,000 BTU/scf.
1) Onshore natural gas is stranded; that is, transmission pipelines are not interconnected to the main trunk lines. Hence, it is consumed only by local/nearby power plants, NGV stations and community enterprises. Similarly, there is biogas, which is mainly produced and consumed in nearby small-scale power and industrial plants.
2) Offshore natural gas constituted 2,853 billion BTU/day from the Gulf of Thailand and 497 billion BTU/day from MTJDA.
3) Calculation is subject to rounding off.
Source: Department of Mineral Fuels, Energy Policy and Planning Office, Department of Energy Business, PTT, and Electricity Generating Authority of Thailand; data collected and analysed by the Petroleum Institute of Thailand.

On the supply side, in 2016, Thailand produced 3,350 billion BTU/day of natural gas from the Gulf of Thailand and MTJDA (equivalent to 71% of total natural gas supply) and 155 billion BTU/day from onshore fields (3%), while importing 848 billion BTU/day from Myanmar (18%) and 390 billion BTU/day of LNG (8%) from Qatar and Oman – adding up to 4,743 billion BTU/day.

3.1.2 Natural Gas infrastructure in Thailand

At present, the players in the Thai natural gas market are rather limited in number as shown in Figure 3.3. As energy security is of ultimate concern and natural gas infrastructure requires huge capital investments, PTT as the national oil and gas state enterprise was assigned to operate the whole natural gas industry. Over the years, PTT has become the sole natural gas shipper, the sole transmission system operator, the sole LNG importer, the sole LNG terminal operator (through PTTLNG, a 100% PTT affiliate), a gas distributor, and an NGV retailer.

Figure 3.3. Natural Gas Market Players in Thailand



GSP = gas separation plant, IPP = independent power producer, LPG = liquefied petroleum gas, NG = natural gas, NGL = natural gas liquids, NGD = natural gas distribution company, NGR = natural gas distribution, SPP = small power producer, TSO = transmission system operator, VSPP = very small power producer.

Source: PTT; data collected and analysed the Petroleum Institute of Thailand.

Having PTT, the country's oil and gas state enterprise and flagship, as the key player in the market could be both an advantage and a disadvantage during a crisis. One advantage is that the government could order PTT to promptly take action, while a disadvantage is that a single player's network could be constrained. Realising that liberalisation would improve efficiency through equitable and transparent competition, the country has been liberalising the natural gas market by encouraging more players in the business and limiting the size of the incumbent. In the second half of 2017, the Electricity Generating Authority of Thailand (EGAT) successfully applied for an LNG shipper license to become the second LNG shipper besides PTT.

- **Natural gas transmission network**

Thailand's natural gas transmission network is divided into five different zones as shown in Figure 3.4 :

- **Zone 1**

The offshore gas transmission system off Rayong coast – for transporting most of the Gulf of Thailand and MTJDA gas ashore at Map Ta Phut, Rayong province, for feeding into PTT's gas separation plants (with the volume exceeding the gas separation plants' capacities being bypassed and injected directly into the main onshore transmission network)

- **Zone 2**

The offshore gas transmission system off Khanom coast – for transporting part of the Gulf of Thailand gas ashore at Khanom, Suratthani province, for feeding into PTT's Khanom gas separation plant (GSP #4) to extract methane for the Khanom power plant and LPG

- **Zone 3**

The main onshore gas transmission system spanning over the eastern, central, and western regions – into which bypassed gas from the Gulf of Thailand and MTJDA, sales gas extracted from PTT's gas separation plants in Rayong, LNG and gas imported from Myanmar are injected for delivery to power and industrial plants and NGV stations

- **Zone 4**

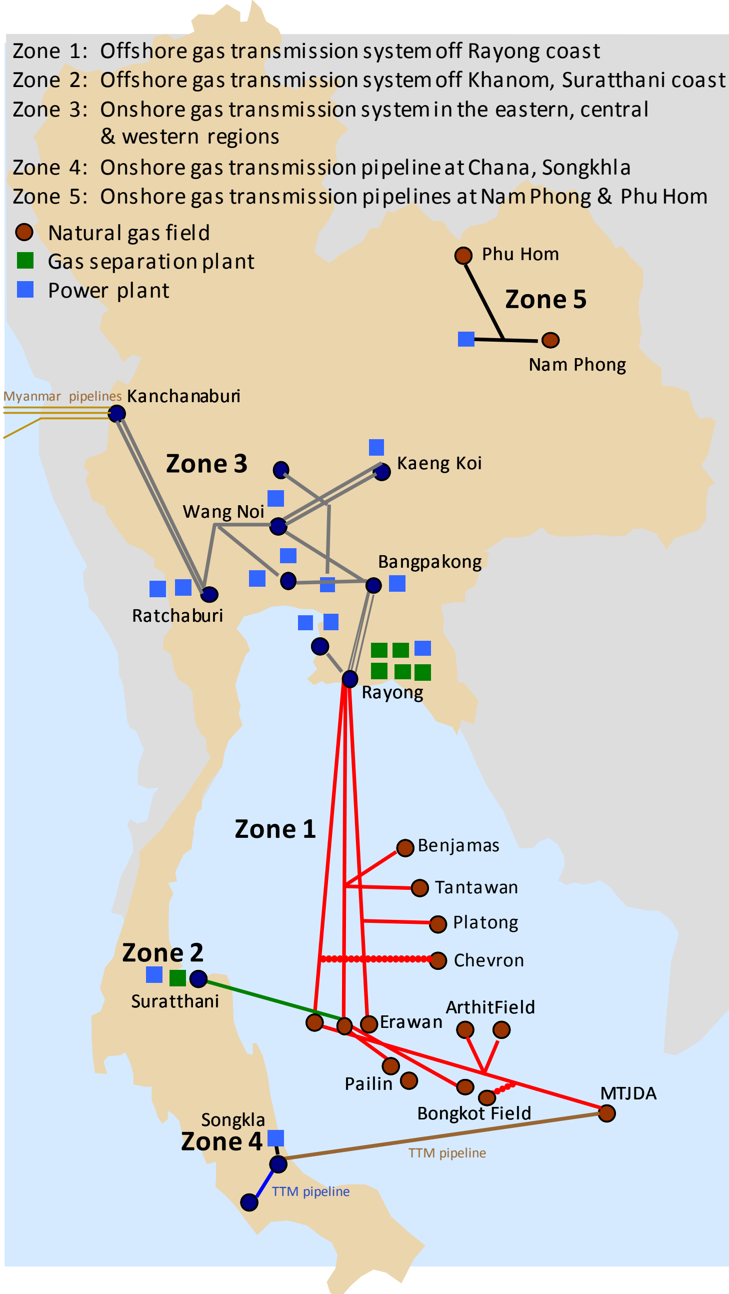
The onshore gas transmission pipeline at Chana, Songkhla – for delivering part of the MTJDA gas to Chana power plant

- **Zone 5**

The onshore gas transmission pipeline at Nam Phong and Phu Hom – for delivery of the onshore gas from Phu Hom and Nam Phong fields to Nam Phong power plant in the northeast.

The purpose of zoning the network is to calculate and collect transmission pipeline tariffs.

Figure 3.4. Natural Gas Pipeline Network in Thailand



MTJDA = Malaysia–Thailand Joint Development Area, TTM = Trans Thailand–Malaysia Gas (Pipeline).

Sources: Energy Policy and Planning Office and PTT; data collected and summarised by the Petroleum Institute of Thailand.

- **LNG terminal**

With rising demand for natural gas, depleting gas reserves in the Gulf of Thailand and MTJDA, and Myanmar's clear-cut policy of no future gas export to Thailand, importing LNG is essential. Presently, Thailand has a single LNG receiving terminal in Map Ta Phut, Rayong province. It is owned and operated by PTT LNG Company Limited (PTTLNG), a wholly-owned subsidiary of PTT.

The LNG terminal completed its first phase of construction with a regasification capacity of 5 million tonne per year and started receiving commercial LNG cargoes in 2011. In 2017, the terminal completed its second phase, expanding its regasification capacity to 10 million tonnes per year as shown in Table 3.1. However, as shown in Figure 3.5, PTTLNG's regasification terminal has not been fully utilised. Before completing the second-phase expansion, terminal utilisation only reached 56% at maximum, equivalent to approximately 390 mmscfd (million standard cubic feet per day) in 2016.

Table 3.1. Existing LNG Receiving Terminal in Map Ta Phut, Rayong, Thailand

Capacity	Phase 1	Phase 2	Total
Regasification (mmtpa / mmscfd)	5 / 700	5 / 700	10 / 1,400
Jetty (no.)	1	1	2
Vessel size (m^3) (max. mmscf)	125,000-264,000 5,720	125,000-264,000 5,720	
LNG tank (m^3 x no.) (mmscf x no.)	160,000 x 2 3,470 x 2	160,000 x 2 3,470 x 2	160,000 x 4 3,470 x 4

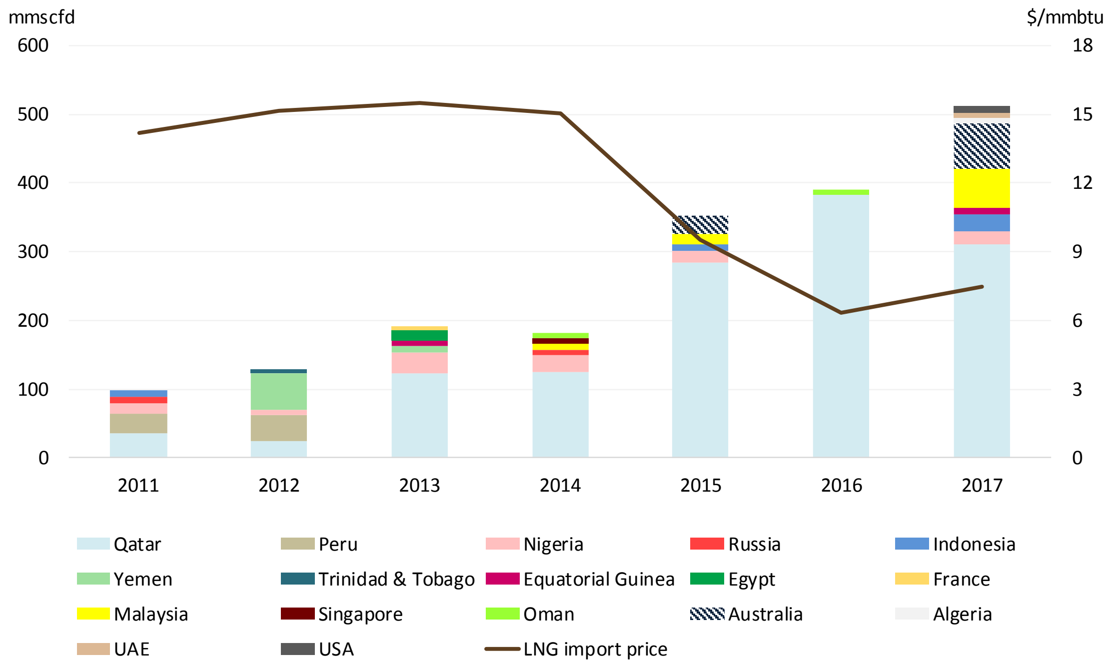
LNG = liquefied natural gas, m^3 = cubic metre, mmtpa = million metric tonne per annum, mmscfd = million standard cubic feet per day.

Note: On 17 September 2015, the National Energy Policy Council, chaired by the Prime Minister, reached a resolution to expand PTTLNG's first receiving terminal by another 1.5 million tonnes per year to 11.5 million tonnes per year. This additional capacity will be brought on stream by 2019.

Sources: PTTLNG, PTT, and Energy Policy and Planning Office; data collected and summarised by the Petroleum Institute of Thailand.

The Ministry of Energy projects LNG imports to rise to 34 million tonnes per year in 2036. It is anticipated that LNG imports will exceed PTTLNG's total regasification capacity of 11.5 million tonnes per year by 2021/22. The country is hence studying the feasibility of constructing another LNG receiving terminal with a capacity of 7.5 million tonne per year in Nong Fab, Rayong, by PTT (PTTLNG) to be operational by 2022 and a 5 million tonne per year floating storage and regasification unit (FSRU) in the upper Gulf of Thailand by EGAT by 2024.

Figure 3.5. Volume and Price of LNG Imports in Thailand



LNG = liquefied natural gas, mmbtu = million British thermal units, mmscfd = million standard cubic feet per day, UAE = United Arab Emirates, USA = United States of America.
Note: LNG import price is the weighted average import price for the year.
Source: Department of Energy Business; data collected and summarised by the Petroleum Institute of Thailand.

- **Natural gas distribution network**

Currently, there are three natural gas distribution system operators/retailers in Thailand: PTT, PTT Natural Gas Distribution Company Limited (PTTNGD), and Amata Natural Gas Distribution Company Limited (Amata NGD). The latter two have PTT as their major shareholder.

Natural gas distribution in Thailand is distinctly segregated. That is, PTTNGD and Amata NGD sell natural gas to industrial users in industrial estates only, while PTT serves customers both inside and outside industrial estates. The three operators oversee their specific service areas/customers, which are generally located in proximity to the main onshore Zone 3 transmission system in the eastern, central, and western regions.

3.1.3 Natural gas quality and flow in Thailand

Having seen the supply/demand overview, the players, and the infrastructure in the Thai gas market, the study now turns to natural gas quality and how natural gas flows in Thailand.

- **East and West Gas quality**

Natural gas from various sources have varying qualities/properties – as measured particularly by the Wobbe Index (WI)[5], which is an indicator of combustion energy output of fuel gas and has a direct impact on the gas-fuelled appliances/machinery in industrial and power plants. For Thailand, the standard WI for designing appliances and machinery to receive Gulf of Thailand and MTJDA gas (the so-called 'East Gas') is between 1,220 and 1,340 BTU/scf ($\pm$ 5%).[6] On the other hand, the standard WI for Myanmar gas is between 970 and 1,040 BTU/scf.[7]

For the East Gas, PTT manages the gas quality by mixing three different gas supplies: (1) sales gas from gas separation plants (GSPs), with carbon dioxide (CO_2) stripped off: WI = 1,330 BTU/scf; (2) bypass gas with 15–20% CO_2 & 0–3% nitrogen gas (N_2): WI = 1,050 BTU/scf; and (3) LNG: WI = 1,380–1,400 BTU/scf (see Figure 3.6). The decline in the Gulf of Thailand gas supply will foremost curb the bypass gas volume and then the sales gas from the GSPs, while the LNG volume will escalate. The shifting proportion of these gases will alter the WI, thus affecting gas users. As of 2017, PTT has already changed the standard WI three times. PTT has projected that it will likely adjust the WI range of the East Gas around 2020 to be between 1,280 and 1,420 BTU/scf – as the LNG (with high WI) import share will rise to over 30% of the total natural gas supply.

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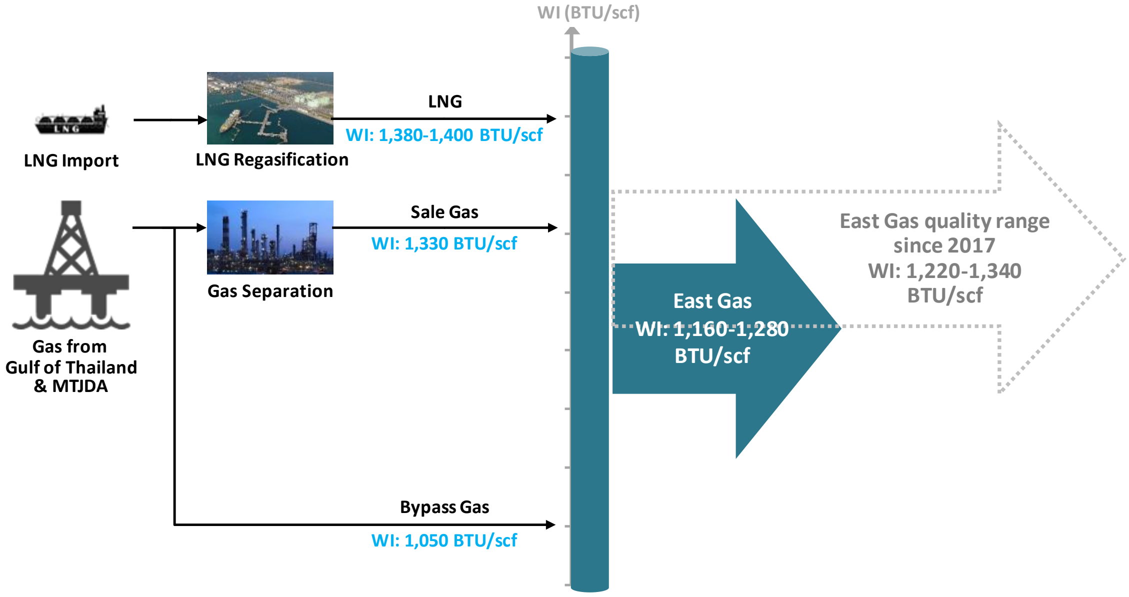
[5] Wobbe Index (WI) indicates the relationship of combustion energy output of a burner and fuel gas property (WI = HHV(dry)/SQR(SG) where HHV = high heating value, SQR(SG) = square root of specific gravity) at constant pressure. In general, the burners can receive fuel gas of $\pm$5% WI – for some up to $\pm$10-15% – with no impact on the combustion process (see PTT website).

[6] In 2017, PTT adjusted the WI range of the East Gas to between 1,220 and 1,340 BTU/scf, meaning that all the industrial and power plants using the East Gas had to adjust their gas-fuelled appliances and machinery to receive the East Gas in the WI range of 1,220–1,340 BTU/scf ($\pm$5%).

[7] Calculated by rounding off from actual HHV(dry) and WI (see PTT website, April 2016). Normally, natural gas import from Myanmar is measured based on its heating value (HV). Yadana gas is N2-rich (more than 24%) compared with Yetagun and Zawtika, resulting in a much lower HV than the other two gases. Yadana gas's HV averages around 720 BTU/scf, Yetagun around 950 BTU/scf, and Zawtika around 900 BTU/scf. When the three gases are mixed and imported to Baan I-Tong, Kanchanaburi province, for injecting into the West Gas transmission system, the average HV stands at 803–858 BTU/scf or in the WI range of 970–1,040 BTU/scf ('West Gas quality').

Figure 3.6. East Gas Quality Management



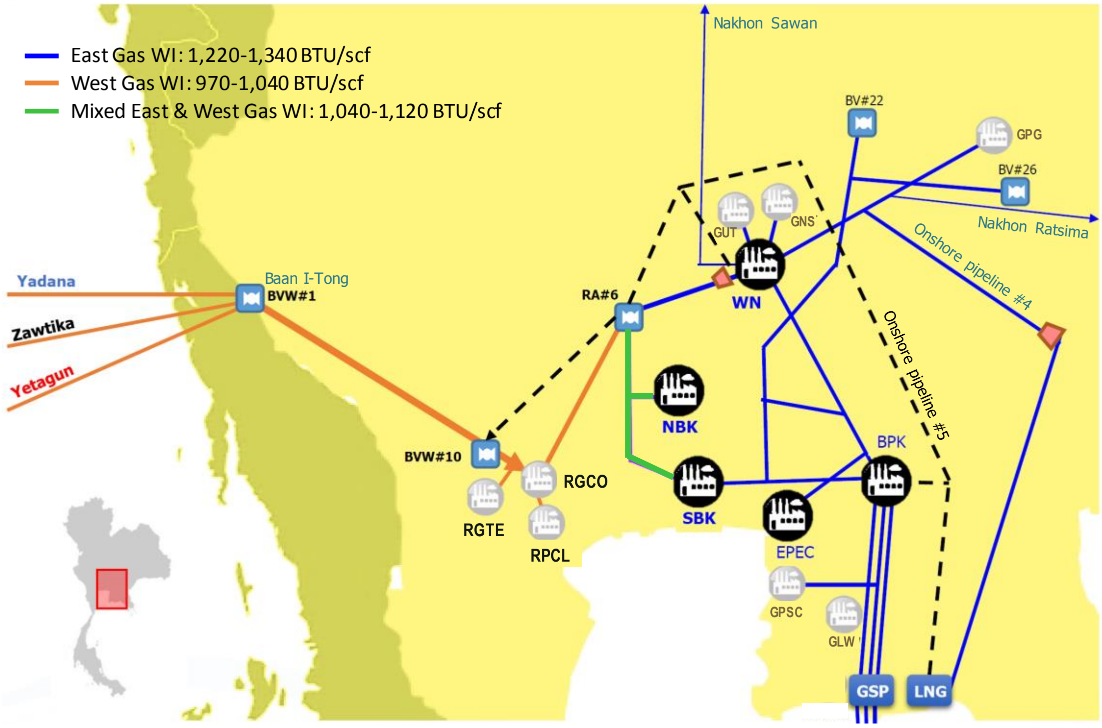
BTU = British thermal units, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, scf = standard cubic foot, WI = Wobbe Index.
Note: The East Gas WI range of 1,160–1,280 BTU/scf had been effective since July 2010. Then, in 2017, PTT adjusted the WI range of the East Gas to 1,220–1,340 BTU/scf, resulting in all the industrial and power plants using the East Gas having to adjust their gas-fuelled appliances/machinery to receive the East Gas of WI range of 1,220–1,340 BTU/scf (±5%).
Source: PTT; data collected and summarised by the Petroleum Institute of Thailand.

The West Gas quality management is more complicated and has fewer options than the East Gas due to supply constraints of the Myanmar gas (from Yadana, Yetagun and Zawtika fields) which have caused the quality to decline rapidly. Yadana gas is N_2-rich (over 24%). Its heating value is thus lower than Yetagun and Zawtika gas. The average heating values are around 720 BTU/scf for Yadana, 950 BTU/scf for Yetagun, and 900 BTU/scf for Zawtika. With Yetagun gas production and the daily contract quantity shrinking since 2014, Yetagun gas producers have been experiencing technical problems and have notified PTT of the decline in natural gas reserves and daily contract quantity. PTT must lower its call for Yadana gas (resulting in a take-or-pay) – in order to control/maintain the WI range so that it does not impact gas users' appliances/machinery. Such a decline in daily contract quantity will inevitably affect PTT's natural gas supply management both in terms of quantity and quality.

The RA#6 compression station in Sainoi, Nonthaburi province, is where the East Gas and the West Gas meet and are mixed (see Figure 3.7). The mixed gas, with WI ranging around 1,040–1,120 BTU/scf, is used by EGAT's North Bangkok and South Bangkok power plants.

It can be concluded that natural gas consumption in Thailand is rather 'supply source-specific' and is divided into three distinct areas: the East, the West, and the mixed zone. Disruption of certain supply sources, thus, does have specific regional impacts.

Figure 3.7. Natural Gas Transmission Network in Thailand by Gas Quality

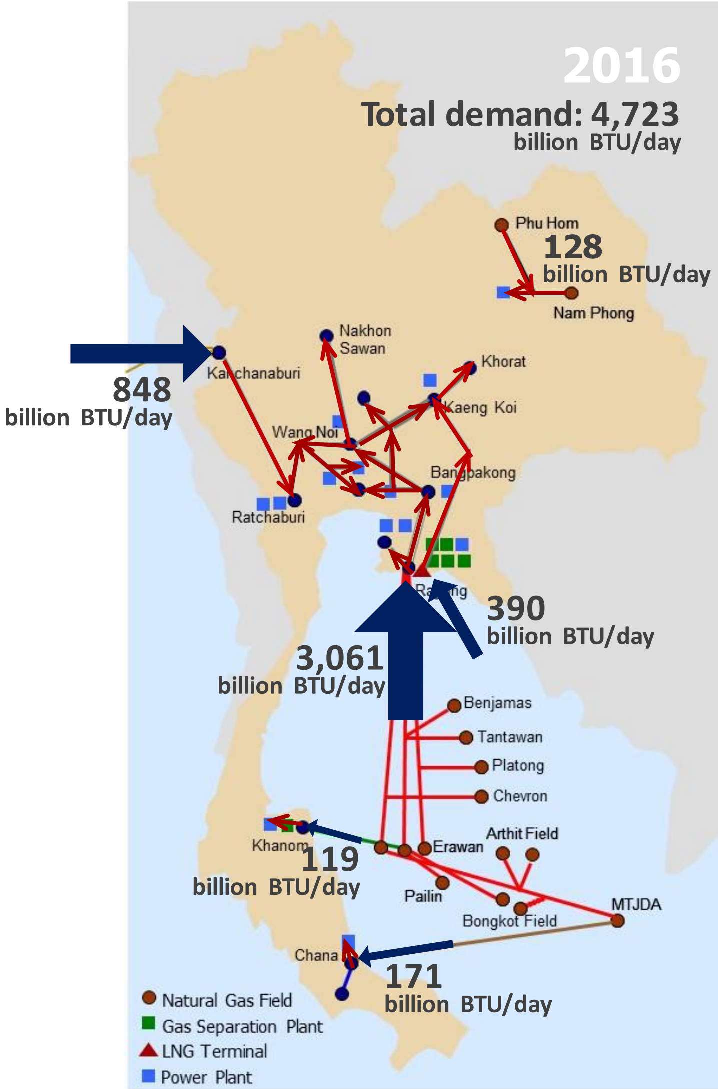


BPK = Bang Pakong power plant, BTU = British thermal units, BV#22, #26 = Block Valve #22, #26, BVW#1, #10 = Block Valve West #1, #10, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, NBK = North Bangkok power plant, RA#6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, SBK = South Bangkok power plant, scf = standard cubic foot, WI = Wobbe Index, WN = Wang Noi power plant

Source: PTT and Energy Policy and Planning Office; data collected and summarised by the Petroleum Institute of Thailand.

- **Thailand's natural gas flow**

Figure 3.8. Natural Gas Flow in Thailand



BTU = British thermal units, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area.

Notes:

1) Only onshore Phu Hom and Nam Phong gas fields are shown on the map, but there is also associated gas produced from Sirikit (26.8 billion BTU/day) and Burapa (0.5 billion BTU/day) oil fields in central-north Thailand. Such associated gas is consumed only by local community enterprises and small nearby power plants. Their pipelines are not connected to the main trunk lines.

2) The volume shown for MTJDA gas that goes ashore at Chana, Songkhla represents only Thailand's portion.

Source: Department of Mineral Fuels, Energy Policy and Planning Office, Department of Energy Business, PTT, Electricity Generating Authority of Thailand; data collected and analysed by the Petroleum Institute of Thailand.

Figure 3.8 illustrates the country's natural gas flow. In general, around 96% of the Gulf of Thailand gas and 66% of the MTJDA gas is transported via PTT's offshore transmission pipelines no. 1, 2, and 3 ashore at Map Ta Phut, Rayong, where it is fed into GSPs to extract sales gas (methane) and various hydrocarbons. The sales gas is then injected into the onshore Zone 3 transmission system along with the bypass gas and LNG for consumption by or via power and industrial plants and NGV stations situated in the eastern and central regions. The other 4% of the Gulf of Thailand gas is transported via the Khanom offshore pipeline to be fed into the Khanom gas separation plant (GSP #4) and Khanom power plant, respectively, whereby the remaining 34% of the MTJDA gas goes to Chana power plant in the south.

Imported Myanmar gas is primarily consumed by power plants, NGV stations, and industrial plants in the west, with around 27% mixed with the East Gas (2%) for use by power plants in North and South Bangkok.

As the fields (be they Nam Phong and Sin Phu Hom gas fields in the northeast and Sirikit and Burapa oil fields in the north)[8] are not interconnected with the main trunk lines, onshore natural gas is therefore consumed only within the vicinity – that is, in nearby power plants, community enterprises, and NGV stations.

3.2 Background on the power market in Thailand

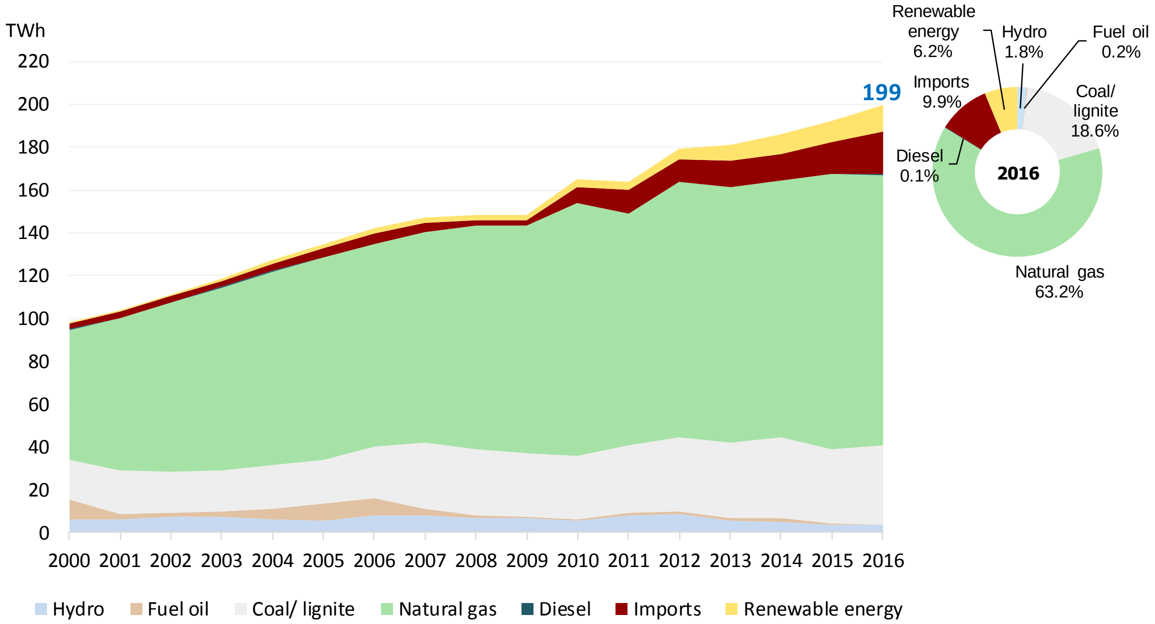
3.2.1 Power market in Thailand

Thailand largely consumes natural gas as fuel in electricity generation as shown in Figure 3.9. Out of the total electricity generated in 2016, over 63% came from natural gas as fuel – followed by coal at 18.6%, electricity imports 9.9%, renewable energy 6.2%, domestic hydroelectricity 1.8%, fuel oil 0.2%, and diesel 0.1%. Generally, power plants in Thailand rarely run on fuel oil and diesel. When a disruption occurs to the natural gas supply, however, the power plants (e.g. thermal power plants, switching between natural gas and fuel oil; or combined cycle power plants, switching between natural gas and diesel) that can also run on these fossil fuels help prevent possible brownouts and/or blackouts.

The majority of the natural gas-fired power plants in Thailand have a form of fuel-switching capability – either to fuel oil or to diesel. Under existing power purchase agreements (PPAs), power plants with fuel-switching capability must demonstrate this ability by operating under the alternative fuel for at least 3–5 consecutive days.

[8] 'Associated gas' is not shown on the map in Figure 3.8.

Figure 3.9. Power Generation by Fuel Type in Thailand



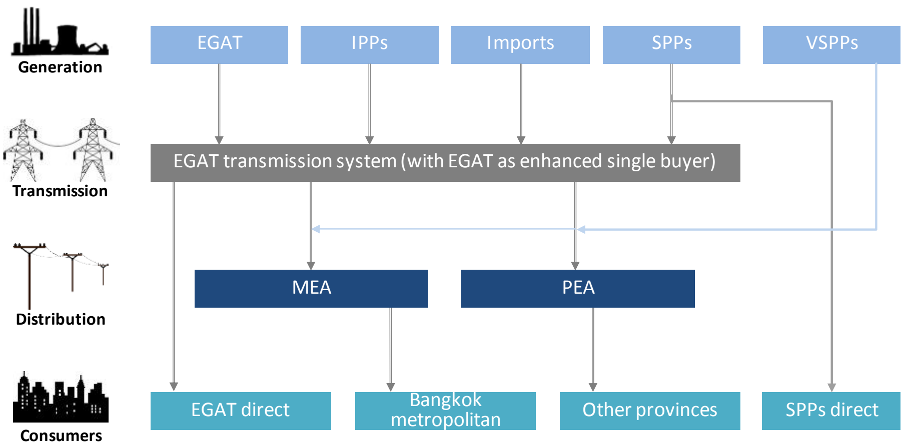
Note: Power generation on the Electricity Generating Authority of Thailand system.
Source: Energy Policy and Planning Office; data collected and analysed by the Petroleum Institute of Thailand.

Like PTT, EGAT – also a state-owned enterprise – is a vertically integrated utility and the key player in Thailand's power sector as shown in Figure 3.10. It owns and operates many power plants (approximately 38% of Thailand's total installed generation capacity). As an enhanced single buyer, EGAT has the exclusive rights to purchase electricity generated by independent power producers (IPPs) and small power producers (SPPs) and sell it to the two state distribution agencies: the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA).

EGAT is the sole owner of the transmission system nationwide. It is also responsible for system operations, including central dispatching of electricity generation.

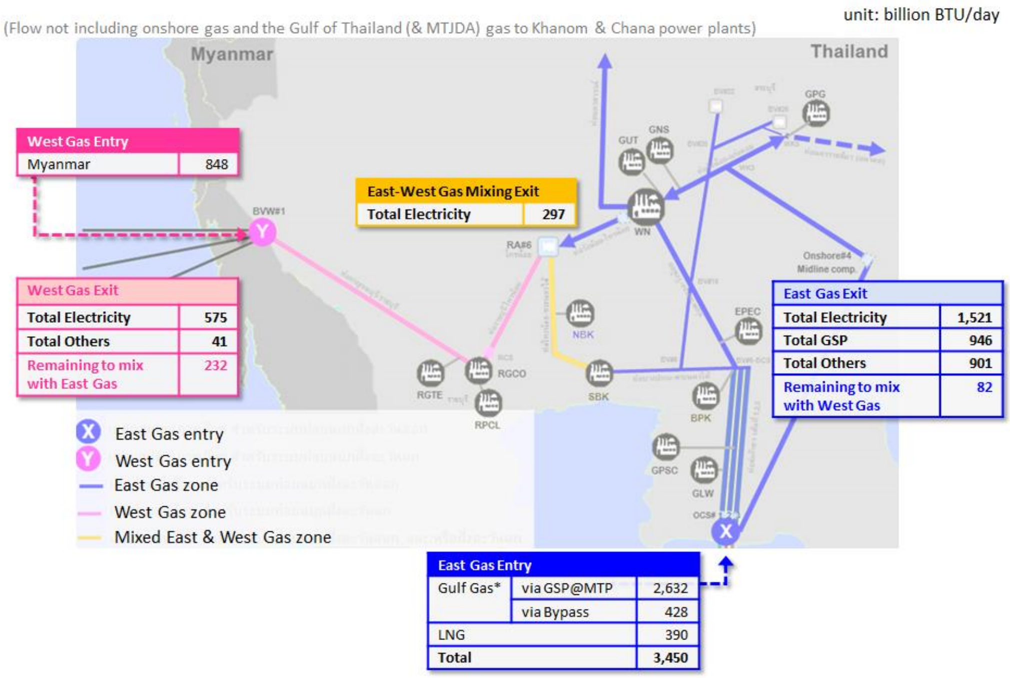
In 2016, EGAT power plants nationwide consumed a combined total of 941 billion BTU/day of natural gas, while IPPs consumed 1,014 billion BTU/day and SPPs 852 billion BTU/day. Figure 3.11 specifically shows natural gas flow to the gas-fired power plants via the main onshore Zone 3 trunk lines (i.e. excluding the onshore gas in the North, the Northeast, and the Gulf of Thailand and MTJDA gas that goes to Khanom and Chana power plants in the south). Of the total East Gas of 3,450 billion BTU/day, 1,521 billion BTU/day went to EGAT and IPP power plants in the central and eastern regions, and 852 billion BTU/day went to SPPs. Meanwhile, of the total West Gas of 848 billion BTU/day, 575 billion BTU/day went to IPP power plants in Ratchaburi province, and 232 billion BTU/day went to mix with the East Gas of 82 billion BTU/day for consumption by EGAT's North Bangkok and South Bangkok power plants in the mixed gas zone.

Figure 3.10. Power Market Players in Thailand



EGAT = Electricity Generating Authority of Thailand, IPP = independent power producers, MEA = Metropolitan Electricity Authority, PEA = Provincial Electricity Authority, SPP = small power producer, VSPP = very small power producer.
Notes: IPPs with generation sold to EGAT > 90 megawatts (MW); SPPs with generation sold to EGAT ±90 MW; VSPPs with generation sold to MEA/PEA ±10 MW.
Source: Office of the Energy Regulatory Commission; data collected and summarised by the Petroleum Institute of Thailand.

Figure 3.11 Main Natural Gas Flow to Power Plants in Central, Eastern and Western Regions in Thailand, 2016



BPK = Bang Pakong power plant, BTU = British thermal unit, BVW #1 = Block Valve West #1, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NBK = North Bangkok power plant, OCS #1,2,3 =

Onshore Compressor Station #1, 2, 3, RA #6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, SBK = South Bangkok power plant, WN = Wang Noi power plant
Note: Including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants.
Source: Department of Mineral Fuels, Department of Energy Business, Electricity Generating Authority of Thailand, PTT; original map from PTT; data collected and analysed by the Petroleum Institute of Thailand.

One critical point that must be mentioned is that Thailand has a high power reserve margin. Tables 3.2 and 3.3 show the country's total installed power generation capacity in mid-September 2017 of 42,013.2 megawatts (MW), while generation capacity was 26,089 MW. Electricity demand typically peaks during the hottest months of April and May. In 2016, peak demand reached a record high of 29,619 MW in May (Figure 3.12).

Table 3.2. Installed Power Generation Capacity vs Actual Generation in Thailand, by Player

Installed capacity	MW	% share	Generation	MW	% share
EGAT	16,071.1	38.3%	EGAT	8,212	31.5%
IPPs	14,948.5	35.6%	IPPs	8,776	33.6%
SPPs	7,116.0	16.9%	SPPs	5,365	20.6%
Foreign	3,877.6	9.2%	Foreign	3,736	14.3%
Total	**42,013.2**	**100%**	**Total**	**26,089**	**100%**

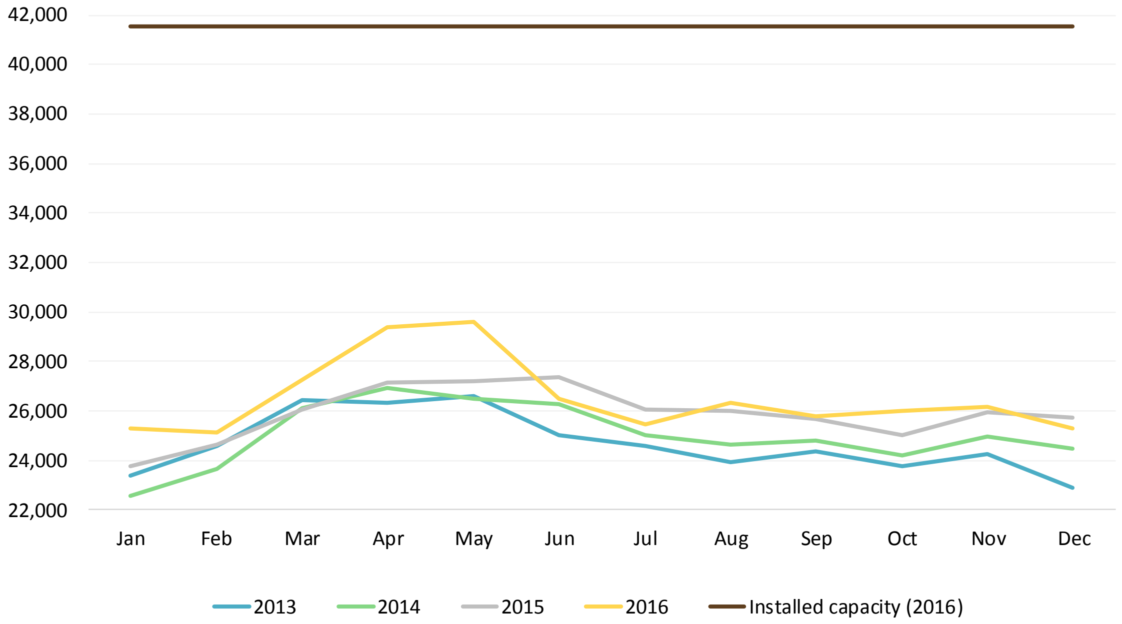
EGAT = Electricity Generating Authority of Thailand, IPP = independent power producers, MW = megawatt, SPP = small power producer.
Note: Data in mid-September 2017; calculation is subject to rounding off.
Source: EGAT; data collected and summarised by the Petroleum Institute of Thailand.

Table 3.3. Installed Power Generation Capacity vs Actual Generation in Thailand by Fuel Type

Installed capacity	MW	% share	Generation	MW	% share
Natural gas	27,957.0	66.5%	Natural gas	17,167	65.8%
Renewables	6,869.4	16.4%	Domestic hydropower	417	1.6%
Domestic coal	4,564.0	10.9%	Imported hydropower	1,904	7.3%
Imported coal	1,473.0	3.5%	Other renewables	600	2.3%
Fuel oil	319.5	0.8%	Domestic coal	3,992	15.3%
Diesel	30.4	0.1%	Imported coal	1,565	6.0%
Others	800.0	1.9%	Others	444	1.7%
Total	**42,013.3**	**100.0%**	**Total**	**26,089**	**100.0%**

MW = megawatt.
Note: Data in mid-September 2017; calculation is subject to rounding off.
Source: Electricity Generating Authority of Thailand; data collected and summarised by the Petroleum Institute of Thailand.

Figure 3.12. Monthly Peak Electricity Demand vs Installed Generation Capacity in Thailand, 2013–2016



Source: Energy Policy and Planning Office; data collected and analysed by the Petroleum Institute of Thailand.

3.3 Countermeasures in the event of LNG disruption

3.3.1 Setting the scene

At present, Thailand has four long-term LNG contracts – with Qatar, Shell, BP, and Petronas. They total 5.2 million tonnes per year of LNG. Details of these long-term contracts are shown in Table 3.4.

Table 3.4. Existing Long-Term LNG Contracts in Thailand

Contract partner	Contract volume		Duration	
	mmtpa	mmscfd @1,000 BTU/scf	No. of years	Period
Qatargas	2	280	20	2013–2032
Shell	1	140	15	2017–2032
BP	1	140	20	2017–2037
Petronas	1.2	168	15	2017–2032
Total	**5.2**	**728**		

BTU = British thermal unit, mmscfd = million standard cubic feet per day, mmtpa = million metric tonnes per annum, scf = standard cubic foot.
Note: Period does not necessarily start at the beginning of that calendar year.
Source: Energy Policy and Planning Office; data collected and analysed by the Petroleum Institute of Thailand.

In order to investigate countermeasures that Thailand could take in the event of LNG disruptions, IEEJ has set out four different LNG disruption scenarios as illustrated in Table 3.5.

Table 3.5. LNG Disruption Scenarios

Disruption duration	Disruption to	
	largest long-term contract of 2 mmtpa	existing LNG terminal of 10 mmtpa capacity
30 days	A	C
180 days	B	D

LNG = liquefied natural gas, mmtpa = million metric tonnes per annum.
Source: Authors, refer to Table 2.6.

- **Scenario A: Largest long-term LNG contract of 2 mmtpa disrupted for 30 days**

This is equivalent to the disruption of 280 billion BTU/day or 8% of total natural gas supply to the country for 30 consecutive days, which amounts to 8,400 billion BTU. The impact is minimal as the total disrupted volume is much less than the available LNG stock level.

- **Scenario B: Largest long-term LNG contract of 2 mmtpa disrupted for 180 days**

This is similar to Scenario A but for a more extended period. The daily disrupted volume is also 280 billion BTU/day or 8% of the total natural gas supply. With the disruption duration of 180 days, however, the total disrupted volume amounts to 50,400 billion BTU, which well exceeds the available LNG stock level. Hence, additional countermeasure(s) must be explored.

- **Scenario C: Existing LNG terminal of 10-mmtpa capacity disrupted for 30 days**

In terms of terminal capacity, 10 mmtpa of LNG is equivalent to the disruption of 1,400 billion BTU/day of natural gas supply. However, as illustrated earlier, the LNG terminal is at present not being fully utilised. Prior to completing the second-phase expansion, PTTLNG's terminal utilisation only reached 56% at maximum in 2016, equivalent to approximately 390 billion BTU/day. In 2017, with the terminal's capacity expanded to 10 mmtpa, preliminary data show a maximum LNG import of 693 billion BTU/day and a minimum of 288 billion BTU/day, averaging out around 512 billion BTU/day. Hence, for the analyses in the event of the existing LNG terminal disruption, the resulting disrupted LNG volume is assumed to equal the total long-term contracted volume of 728 billion BTU/day at present[9].

Thus, this is equivalent to the disruption of 728 billion BTU/day or 21% of the total natural gas supply to Thailand for 30 consecutive days, which amounts to 21,840 billion BTU. The impact is clearly perceptible. It would be the equivalent of approximately six 700 MW power plants going offline for 1 month – though the country has lots of spare power generation capacity and fuel-switching capability for most of the gas-fired power plants.

- **Scenario D: Existing LNG terminal of 10-mmtpa capacity disrupted for 180 days**

Using the same logic as for Scenario C, Scenario D is more intensified as the disrupted volume of 728 billion BTU/day (21%) lasts for 180 days – totalling 131,040 billion BTU of natural gas supply shortfall. It is therefore interesting to see if Thailand's high spare power generation capacity and fuel-switching capability could still hold out, or if supplementary countermeasure(s) must be considered.

3.3.2 Investigating possible countermeasures

In the event of LNG import disruption, there are possible countermeasures that Thailand could take as indicated in Table 3.6. The viability as well as the limitations of countermeasures are explored.

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[9] This is in line with the latest Ministry of Energy Gas Plan 2015 (as of 8 December 2016) that projects LNG imports to average around 790 billion BTU/day in the next years, before climbing to over 1,400 billion BTU/day in 2020.

Table 3.6. Possible Countermeasures in the Event of LNG Import Disruption in Thailand

<table>
<tr><th>Countermeasures</th><th>Details/remarks/assumptions</th></tr>
<tr><td colspan="2">Step 0: To use existing LNG stock or storage</td></tr>
<tr><td></td><td>With four LNG tanks of 160,000 m^3 or 3,470 mmscf in size each, this amounts to a total of 13,880 mmscf or 13,880 billion BTU of natural gas supply.

If 5% is subtracted for dead stock, the available volume becomes 13,186 billion BTU.</td></tr>
<tr><td colspan="2">Step 1: To increase indigenous natural gas supply (including MTJDA)</td></tr>
<tr><td>1.1 Indigenous gas supply volumes</td><td>
<table>
<tr><th>Total supply volume in 2016:</th><th>billion BTU/day</th></tr>
<tr><td>Gulf of Thailand</td><td>2,853</td></tr>
<tr><td>MTJDA (volume delivered to Thailand)</td><td>497</td></tr>
<tr><td>Onshore</td><td>155</td></tr>
<tr><td>Gulf of Thailand + MTJDA at East Gas entry</td><td>3,060</td></tr>
</table>
This analysis will be based on the total East Gas entry volume, because it is the point where the major portion of Gulf of Thailand and MTJDA gas is mixed with LNG and transported through the main onshore transmission system. This is the so-called ‘East Gas’, which constitutes the main portion of Thailand’s natural gas consumption and flow (see Figure 3.11).

This is in line with the Ministry of Energy Gas Plan 2015 (revised 8 December 2016 version), which projects the Gulf of Thailand and MTJDA gas supply to reach a maximum volume of around 3,300 billion BTU/day in 2017/18. If subtracting the Gulf of Thailand gas that goes to Khanom (119 billion BTU/day) and the MTJDA gas that goes to Chana (171 billion BTU/day), the remaining Gulf of Thailand and MTJDA gas volume at the East Gas entry would be 3,010 billion BTU/day. Hence, for this analysis, the supply of the Gulf of Thailand and MTJDA gas for the East Gas entry is assumed to be ramped up to 3,060 billion BTU/day maximum (2016 figure).

Typically, indigenous gas supply has a $\pm$ 15% flexibility. With dwindling reserves (particularly MTJDA supply to last only until 2027), 2016 volumes are kept as the best possible case.

Remark: The onshore gas is not considered in this analysis as there are no pipelines connecting the onshore gas fields to the main onshore transmission network. The onshore gas is consumed only by local/nearby power plants, NGV stations, and community enterprises. Plus, its volume is fairly small.</td></tr>
</table>

Countermeasures		Details/remarks/assumptions
1.2	Natural gas pipeline network for Gulf of Thailand and MTJDA gas	There are three main offshore trunk lines that bring natural gas from the Gulf of Thailand and MTJDA ashore at Map Ta Phut, Rayong province, and continue on to constitute the main onshore trunk lines (as shown in Figure 3.4). These pipelines are called the 1st Pipeline, 2nd Pipeline, and 3rd Pipeline. Flow rates reported for them are as follows:

Flow (mmscfd)	max
1st Pipeline	840
2nd Pipeline	1,137
3rd Pipeline	1,900
Total	3,877

In addition, there are separate pipelines that bring a portion of the Gulf of Thailand gas to Khanom, Suratthani province, and a portion of the MTJDA gas to Chana, Songkhla province in the south. These have the following flow rates:

Flow (mmscfd)	max
Offshore Khanom Pipeline *(Gulf gas)*	250
TTM Pipeline *(MTJDA gas)*	425

Hence, the overall pipeline capacity or network for both the Gulf of Thailand and MTJDA gas should not put any limitation on this analysis.

1.3	Capacity of gas separation plants	The total capacity of PTT's gas separation plants #1–6 stands at around 2,800 mmscfd (or billion BTU/day). The main objective of the gas separation plants – particularly, GSP #1–3 and 5–6 located in Map Ta Phut, Rayong – is to maximise extraction of ethane, propane, LPG, and other hydrocarbons ('natural gas liquids' or 'C_2+'), which combines to a maximum of around 950 mmscfd (or billion BTU/day). However, when necessary (e.g. during a natural gas supply shortage), C_2+ extraction from the gas separation plants could be reduced in order to have more sales gas for power generation.
Step 2:	To increase natural gas import from Myanmar	
2.1	Myanmar gas import volume	

Total import volume in 2016:	billion BTU/day
Myanmar gas import	848
Yadana	*419*
Yetagun	*213*
Zawtika	*216*

		As already mentioned in Section 3.1.3, importing Myanmar gas is a rather complicated issue in itself due to the differing heating values of the various fields and the rapidly shrinking Yetagun gas production. Natural gas from Yadana is N_2-rich and, thus, has a much lower heating value than the gas from Yetagun and Zawtika. Therefore, there must be a 'balanced' combination of supply among the Yadana, Yetagun, and Zawtika gas fields in order for Thailand to receive the gas that can meet the country's West Gas quality range. For this analysis, the option of increasing Myanmar gas import is hence omitted.
2.2	Natural gas pipeline network for Myanmar gas import	The Yadana, Yetagun, and Zawtika gas fields are all located in the Gulf of Martaban, Myanmar. Gas from these fields is transported via distinct offshore and onshore transmission pipelines before being combined at the border and piped into Thailand's main onshore transmission network at BW#1 at Ban I-tong, Kanchanaburi province, and then distributed to various gas-fired power plants located in western and central Thailand as well as to industrial plants and NGV service stations. The main trunk line extending from BW#1 has a (maximum) flow rate of 1,100 mmscfd.
Step 3:	To increase LNG import from other suppliers	
		This is a possibility for Scenarios A and B (though for Scenario A, the disruption duration may be too short) – where the contracted LNG volume of 2 mmtpa is disrupted and the LNG terminal can still operate. With the present environment, where continuously growing LNG supply (from Qatar, the United States, Australia, etc.) has led to a supply glut, buyers have more choices for flexible contracting terms. Thailand could consider importing spot/short-term cargoes from Malaysia, Indonesia, or Qatar. This measure has been implemented from time to time.

<table>
<tr><th colspan="2">Countermeasures</th><th>Details/remarks/assumptions</th></tr>
<tr><td>Step 4:</td><td colspan="2">To increase the use of other fuel sources such as oil and/or coal for power generation</td></tr>
<tr><td>4.1</td><td>Capacity of power plants of oil and/or coal

(see Table 3.3 in Section 3.2.1)</td><td>As discussed in Section 3.2.1, Thailand has lots of spare power generation capacity, with total installed capacity of around 42,000 MW vs peak demand of 29,619 MW.

Specifically, there are 4,564 MW of coal-fired power plants in the country and (almost) all of them are being fully operated due to coal’s price competitiveness. Raising power generation by coal-fired plants as natural gas supply is disrupted is thus not an option for this analysis.</td></tr>
<tr><td>4.2</td><td>Fuel switch from natural gas to other fuels</td><td>The majority of the natural gas-fired power plants in Thailand have a form of fuel-switching capability – either to fuel oil (approx. 4,000 MW of installed capacity) or to diesel (approx. 15,500 MW). Under the existing PPAs, power plants with fuel-switching capability must demonstrate this ability by operating under the alternative fuel for at least 3–5 consecutive days.</td></tr>
<tr><td>4.3</td><td>Capacity or flexibility of power supply network in Thailand</td><td>As of January 2018, the country has a total of 33,239.53 circuit-kilometres of transmission and distribution lines at all voltage levels. Approximately 17.5% of the country’s transmission network is made up of 500 kV lines.

<table>
<tr><th>Voltage level
(kV)</th><th>Line length
(circuit-kilometre)</th><th>Number of substatio ns</th><th>Transformer capacity
(MVA)</th></tr>
<tr><td>500</td><td>5,830.84</td><td>17</td><td>32,199.78</td></tr>
<tr><td>300</td><td>23.066</td><td>–</td><td>388.02</td></tr>
<tr><td>230</td><td>14,409.59</td><td>79</td><td>59,500.01</td></tr>
<tr><td>132</td><td>8.705</td><td>–</td><td>133.4</td></tr>
<tr><td>115</td><td>12,948.54</td><td>127</td><td>14,668.16</td></tr>
<tr><td>69</td><td>18.8</td><td>–</td><td>–</td></tr>
<tr><td>Total</td><td>33,239.53</td><td>223</td><td>106,889.37</td></tr>
</table>

The power transmission and distribution network is not a concern in the central, eastern, and western regions – which are the subject of this analysis. (However, this may not be so for the south.)</td></tr>
<tr><td>4.4</td><td>Stock of oil and/or coal</td><td>The country’s combined cycle power plants that can switch to using diesel must stock diesel for fully operating the plants under their PPAs for at least 3 consecutive days. Based on this calculation, this is equivalent to around 240 million litres of diesel stock at one time.

Meanwhile, thermal power plants that can switch to using fuel oil must stock fuel oil for fully operating the plants under their PPAs for at least 5 consecutive days. Based on this calculation, this is equivalent to around 100 million litres of fuel oil stock at one time.

Presently, Thailand exports around 14 million litres per day of diesel and almost 10 million litres per day of fuel oil. Therefore,</td></tr>
</table>

Countermeasures	Details/remarks/assumptions
	fuel-switching to diesel and fuel oil by certain gas-fired power plants should not be a point of concern in terms of their availability.
	Department of Energy Business statistics for 2017:

million litres/day	Diesel	Fuel oil
Production	73.70	16.05
Import	2.23	0.16
Demand	63.73	5.76
Export	14.37	9.64

Step 5: To increase electricity import, if possible

As of December 2017, Thailand has PPAs with the Lao People's Democratic Republic and Malaysia – with a combined total of 3,877.6 MW.

Power import	MW
Lao People's Democratic Republic	3,577.6
Theun-Hin Boun hydropower	*434.0*
Houay Ho hydropower	*126.0*
Nam Theun 2 hydropower	*948.0*
Nam Ngum 2 hydropower	*596.6*
Hongsa Lignite	*1,473.0*
Malaysia	300.0
Total	3,877.6

Typically, the country receives electricity in full from both neighbours. As far as it is known, there is a reduction margin of 5%, should Thailand requests for less electricity in certain cases for Theun-Hin Boun and Houay Ho PPAs. It is therefore an unlikely option to further increase electricity import from the existing PPAs.

Countermeasures	Details/remarks/assumptions
Step 6: To reduce energy export, if possible	
	At present, Thailand does not export any natural gas. The country does, however, export some electricity to Cambodia, the Lao People's Democratic Republic, and Malaysia at the borders. The electricity export volume for the past year amounts to around 1,110 GWh, which is merely 0.6% of the country's annual generation of around 201,070 GWh.
Step 7: To reduce natural gas consumption by sector	
	The National Energy Policy Council at a meeting in July 1996 passed a resolution on natural gas rationing in the event of supply disruption and natural gas shortage. The consideration order for natural gas supply reduction by consumption share runs from item # 6 upward (i.e. item #6 would be the first to be considered for reduction): 1. Users of natural gas as raw materials in the manufacturing process and as petrochemical feedstocks 2. Users of gas in the residential (LPG), transport (NGV and LPG), industrial (methane and LPG), and commercial sectors, who can derive more economic value than just burning natural gas as fuel in power generation and who cannot readily switch to other fuels/forms of energy 3. Power plants: 3.1 EGAT's combined cycle power plants in operation 3.2 IPP power plants from the first round of bidding 4. Other combined cycle and cogeneration power plants besides those in item #3 5. Industrial and commercial gas users who can readily switch to other fuels/forms of energy 6. Steam and gas turbine power plants However, in reality, the two key stakeholders (i.e. PTT and EGAT), which happen to be both state-owned, would be in serious discussions and planning with the Ministry of Energy to allocate natural gas supply in the event of a natural gas/LNG disruption. It would be 'easier' to manage one's own businesses/affiliates – for example, EGAT to manage their own power plants to switch to other fuels or PTT to manage NGV supply to service stations. To ration gas supply for industrial users, on the other hand, would be less easy as it may result in take-or-pay problems and many users may no longer be able to switch back to fuel oil, for example after they have changed their appliances/machinery to gas-fuelled.

Countermeasures		Details/remarks/assumptions
Step 8:	To save energy consumption	
8.1	Planned outage of electricity	It is possible to devise a plan for an electricity outage (be it a brownout or a blackout), but this would be the very last resort. EGAT, MEA, and PEA would have to work closely on the plan, and public communication and understanding must be promoted.
Step 9:	To increase LNG storage/stock	
		This is a rather long-term proposition. Under the already approved plan by the National Energy Policy Council to expand PTTLNG's Map Ta Phut regasification terminal by another 1.5 mmtpa to 11.5 mmtpa by 2019, no additional LNG storage tank will be built. However, for PTTLNG's second terminal at Nong Fab (also in Rayong province) with a capacity of 7.5 million tonnes per annum to be commercially operational by 2022, two LNG storage tanks of 250,000 m3 in size each will also be constructed.

BTU = British thermal unit, C_2+ = ethane or higher molecular weight components, EGAT = Electricity Generating Authority of Thailand, GWh = gigawatt-hour, IPP = independent power producer, kV = kilovolt, LNG = liquefied natural gas, m3 = cubic meter, MEA = Metropolitan Electricity Authority, mmscf = million standard cubic feet, mmscfd = million standard cubic feet per day, mmtpa = million metric tonnes per annum, MTJDA = Malaysia–Thailand Joint Development Area, MVA = megavolt ampere, MW = megawatt. NGV = natural gas for vehicles, PEA = Provincial Electricity Authority, PPA = power purchase agreement, TTM = Trans Thailand–Malaysia Gas Pipeline.
Note: Assume security at all cost. Any increased amount of imported fuels is assumed marginal in global market.
Source: Petroleum Institute of Thailand.

3.3.3 Assessment results

From the assessment of the four scenarios in comparison with the Base Case, at most up to only four countermeasures (excluding the use of existing LNG stocks as Step 0) are taken. These countermeasures, considered to be some of the most fundamental ones, comprise:

Step 1: to increase indigenous offshore gas supply,

Step 2: to substitute for natural gas shortfall by switching to fuel oil/diesel for power generation,

Step 3: to reduce NGV supply, and

Step 4: to reduce GSP C_2+ extraction.[10]

[10] Extraction of ethane, propane, LPG, and other hydrocarbons ('natural gas liquids' or 'C2+').

Table 3.7 shows these countermeasures and their impacts, and Table 3.8 and Figures 3.13–3.19 quantify them. Please note the differing reference to the step numbers in Table 3.6 and in these tables.

Countermeasures for the four scenarios (A–D) are summarised as follows:

- **Scenario A: Largest long-term LNG contract of 2 mmtpa (equivalent to 280 billion BTU/day) disrupted for 30 days**

Step 0: Use existing LNG stock, which can last for 47 days.
(No more countermeasures needed)

- **Scenario B: Largest long-term LNG contract of 2 mmtpa (equivalent to 280 billion BTU/day) disrupted for 180 days**

Step 0: Use all existing LNG stock, which lasts until day 47.
Step 1: After day 48, increase Gulf of Thailand and MTJDA gas supply from 2,722 BTU/day to 3,002 billion BTU/day.
(No more countermeasures needed)

- **Scenario C: Existing LNG terminal of 10 mmtpa capacity (equivalent to 728 billion BTU/day as the total long-term contracted volume) disrupted for 30 days**

Step 0: Unable to use existing LNG stocks due to the terminal failure.
Step 1: Increase Gulf of Thailand and MTJDA gas supply from 2,722 BTU/day to 3,060 billion BTU/day. Still, a shortfall of 390 billion BTU/day.
Step 2: Switch to fuel oil/diesel use to substitute for the 390 billion BTU/day gas shortfall.
(No more countermeasures needed)

- **Scenario D: Existing LNG terminal of 10-mmtpa capacity (equivalent to 728 billion BTU/day as the total long-term contracted volume) disrupted for 180 days**

Day 1–30:
same as Scenario C
Day 31–180:
Step 0: Unable to use existing LNG stocks due to the terminal failure.
Step 1: Increase Gulf of Thailand and MTJDA gas supply to 3,060 billion BTU/day. Still, a shortfall of 390 billion BTU/day.
Step 2: Use of fuel oil/diesel needs to be lowered to 80% of that in the first month, equivalent to 312 billion BTU/day gas to secure supply of fuel oil/diesel. This leads to yet another gas shortfall of 78 billion BTU/day.
Step 3: Reduce gas supply to NGV by 10% equivalent to 28 billion BTU/day, by switching to gasoline.

Step 4: Reduce GSP (gas separation plant) C_2+ extraction by 5.3%, saving 50 billion BTU/day gas.
(No more countermeasures needed)

In conclusion, Thailand appears to be resilient to LNG import disruption according to this assessment. This could be a result of Thailand's high reserve margin and fuel-switching capability.

Nevertheless, it must be pointed out that LNG in the current assessment constitutes 21% of total natural gas supply at most. If the scenarios were to be evaluated again in 10 years when LNG import is projected to constitute over two-thirds of the country's natural gas supply, necessary countermeasures will prove to be exceedingly intricate. Thailand must consider and plan seriously for its future energy security now.

Table 3.7. Countermeasures Taken and Their Impacts

Countermeasures taken	Scenario A: 280 billion BTU/day disrupted for 30 days	Scenario B: 280 billion BTU/day disrupted for 180 days	Scenario C: 728 billion BTU/day disrupted for 30 days	Scenario D: 728 billion BTU/day disrupted for 180 days	
				Day 1–30	Day 31–180
Step 0: Use existing LNG stock	Yes This is more than adequate.	Yes Same as Scenario A But LNG stock lasts only for Day 1–47 Additional countermeasures necessary	No Due to terminal disruption problem	No Due to terminal disruption problem	No Due to terminal disruption problem
Step 1: Increase Gulf of Thailand (including MTJDA) natural gas supply	-	Yes For Day 48–180, have to increase Gulf of Thailand and MTJDA gas supply to 3,002 billion BTU/day	Yes Same as Scenario B But to a higher volume of 3,060 billion BTU/day Still 390 billion BTU/day short.	Yes Same as Scenario C	Yes Same as Scenario C

Countermeasures taken	**Scenario A:** 280 billion BTU/day disrupted for 30 days	**Scenario B:** 280 billion BTU/day disrupted for 180 days	**Scenario C:** 728 billion BTU/day disrupted for 30 days	**Scenario D:** 728 billion BTU/day disrupted for 180 days	
				Day 1–30	Day 31–180
Step 2: Switch to fuel oil/ diesel for some power plants	-	-	Yes Switch to use fuel oil/diesel to substitute for the 390 billion BTU/day gas shortfall. This equates to 2,256 MW of electricity. Approx. 11 million litres/day of fuel oil/diesel are needed (338 million litres total).	Yes Same as Scenario C	Yes Same as Scenario C But needs time to build up fuel oil and diesel stocks spent at power plants, thus only 80% is available after the first month. This equates to 312 billion BTU/day of gas shortfall and 1,805 MW of electricity. Approx. 9 million litres/day of fuel oil/diesel are needed (1,354 million litres total).

Countermeasures taken	**Scenario A:** 280 billion BTU/day disrupted for 30 days	**Scenario B:** 280 billion BTU/day disrupted for 180 days	**Scenario C:** 728 billion BTU/day disrupted for 30 days	**Scenario D:** 728 billion BTU/day disrupted for 180 days	
				Day 1–30	Day 31–180
Step 3: Reduce NGV supply by 10% (most NGV vehicles are dual-fuelled)	-	-	-	-	Yes NGV consumption in 2016 = 276 billion BTU/day 10% = ~28 billion BTU/day Assume this portion of NGV switches to gasoline (personal cars), 0.9 million litres/day of gasoline are needed
Step 4: Reduce GSP C_2+ extraction	-	-	-	-	Yes Natural gas consumption by GSP to extract C_2+ products in 2016 = 946 billion BTU/day Let 50 billion BTU/day or 5.3% be reduced This is equivalent to approx. 4.9 kilobarrels/ day or 419 tonnes/day of LPG supply reduction from GSP.

Countermeasures taken	**Scenario A:** 280 billion BTU/day disrupted for 30 days	**Scenario B:** 280 billion BTU/day disrupted for 180 days	**Scenario C:** 728 billion BTU/day disrupted for 30 days	**Scenario D:** 728 billion BTU/day disrupted for 180 days	
				Day 1–30	Day 31–180
Impact	No impact on gas users	No impact on gas users	No power shortage but electricity price may not be as competitive. No fuel oil/diesel supply problem as Thailand currently exports fuel oil and diesel. No impact on the West Gas and mixed gas users	No power shortage but electricity price may not be as competitive. No fuel oil/diesel supply problem as Thailand currently exports fuel oil and diesel. No impact on the West Gas and mixed gas users	Ethylene crackers in Thailand have some flexibility between LPG and naphtha. They could be asked to switch from LPG to naphtha for this amount. With local gasoline in oversupply, refineries could flex to distil the equivalent amount of naphtha for the ethylene crackers. Power plants have an extra 78 billion BTU/day of natural gas foregone by NGV and GSP for power generation. No impact on the West Gas and mixed gas users

BTU = British thermal unit, C_2+ = ethane or higher molecular weight components, GSP = gas separation plant, LNG = liquefied natural gas, LPG = liquefied petroleum gas, MTJDA = Malaysia–Thailand Joint Development Area, MW = megawatt, NGV = natural gas for vehicles

Source: the Petroleum Institute of Thailand.

Table 3.8. Natural Gas Volumes at East and West Gas Entry and Exist by Scenario

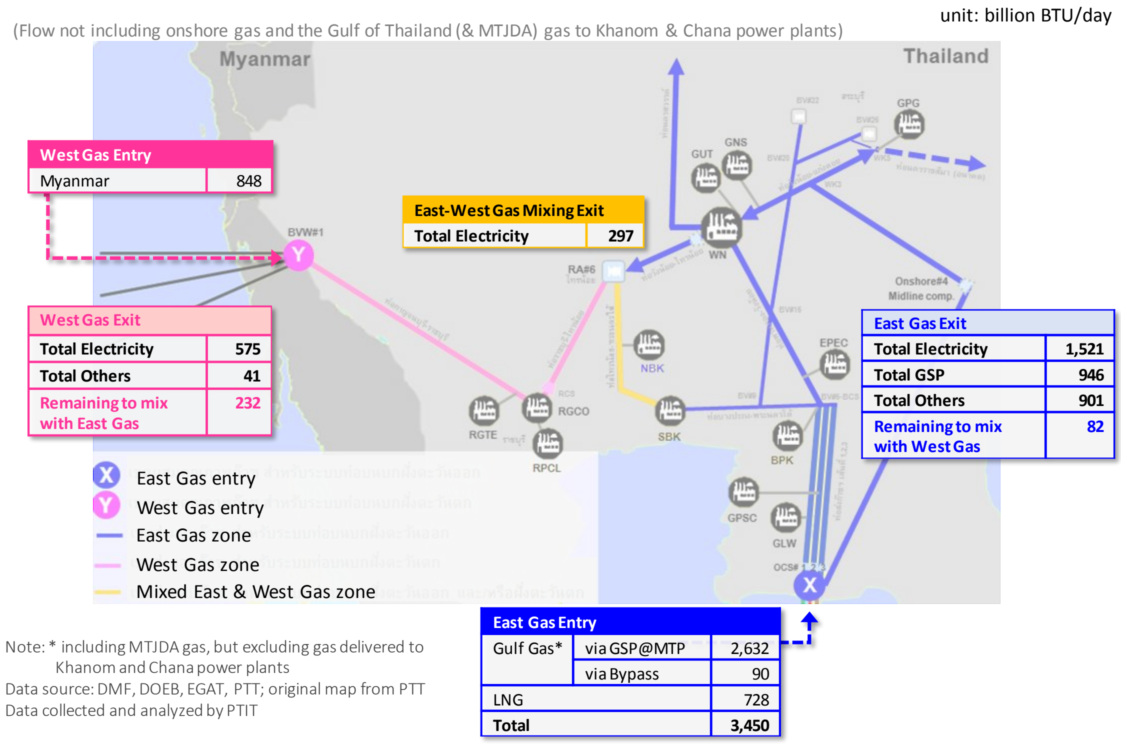
(unit: billion BTU/day)	Base Case	Case A	Case B		Case C	Case D	
East Gas Entry		Day 1–30	Day 1–47	Day 48–180	Day 1–30	Day 1–30	Day 31–180
Gulf Gas (including MTJDA)							
via GSP@MTP	2632	2632	2632				
via Bypass	90	90	90				
Total Gulf Gas (including MTJDA)	2722	2722	2722				
LNG	728	728	728	728			
LNG disrupted		−280	−280	−280	−728	−728	−728
remaining LNG available		448	448	448			
Step #0 use LNG stock		280	280		0	0	
Step #1 increase Gulf of Thailand (including MTJDA) natural gas supply to 3,060 billion BTU/day							
via GSP@MTP				2632	2632	2632	2632
via Bypass				370	428	428	428
Step #2 switch to fuel oil/diesel for some power plants					390	390	312
Step #3 reduce NGV supply by 10%							−28
Step #4 reduce GSP C_2+ extraction							−50
Additional NG for power generation provided by Steps #3 & 4							78
Total	3450	3450	3450	3450	3060	3060	3060
East Gas Exit							
Total Electricity	1521	1521	1521		1521	1521	1521
Step #2 swtich to fuel oil/diesel					390	390	312
Total Electricity East gas consumption after some plants switch to fuel oil/diesel					1131	1131	1131
Additional NG for power generation provided by Steps #3 & 4							78
GSP	946	946	946		946	946	
Step #4 reduce GSP C_2+ extraction							896
Others	901	901	901		901	901	
Step #3 reduce NGV supply by 10% (most NGV vehicles are dual-fuelled)							873
Remaining to mix with West gas	82	82	82		82	82	82
Total	3450	3450	3450		3060	3060	3060
West Gas Entry							
Myanmar	848	848	848		848	848	848
Total	848	848	848		848	848	848
West Gas Exit							
Total Electricity	575	575	575		575	575	575
Others	41	41	41		41	41	41
Remaining to mix with East gas	232	232	232		232	232	232
Total	848	848	848		848	848	848
Mixed East-West Gas Exit							
Total Electricity	297	297	297	297	297	297	297
Total	297	297	297	297	297	297	297

BTU = British thermal unit, C_2+ = ethane or higher molecular weight components, GSP = gas separation unit, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NG = natural gas, NGV = natural gas for vehicles.

Note: Assume security at all cost. Any increased amount of imported fuels is assumed marginal in global market. Natural gas supply and demand volume @ 1,000 BTU/scf.

Source: Petroleum Institute of Thailand.

Figure 3.13. Main Natural Gas Flow in Thailand: Base Case



BPK = Bang Pakong power plant, BTU = British thermal unit, BVW #1 = Block Valve West #1, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NBK = North Bangkok power plant, OCS #1,2,3 = Onshore Compressor Station #1, 2, 3, RA #6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, SBK = South Bangkok power plant, WN = Wang Noi power plant

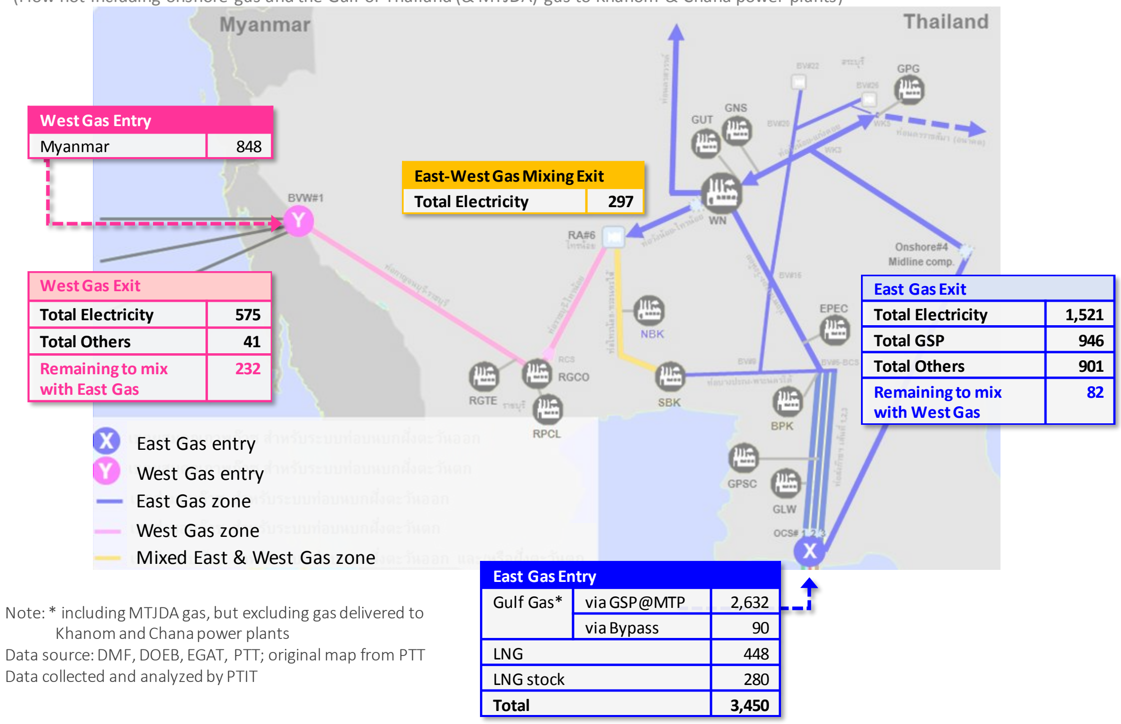
Note: Including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants.

Source: Department of Mineral Fuels, Department of Energy Business, Electricity Generating Authority of Thailand, PTT; original map from PTT; data collected and analysed by the Petroleum Institute of Thailand.

Figure 3.14. Main Natural Gas Flow in Thailand: Scenario A

unit: billion BTU/day

(Flow not including onshore gas and the Gulf of Thailand (& MTJDA) gas to Khanom & Chana power plants)



BPK = Bang Pakong power plant, BTU = British thermal unit, BVW #1 = Block Valve West #1, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NBK = North Bangkok power plant, OCS #1,2,3 = Onshore Compressor Station #1, 2, 3, RA #6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, SBK = South Bangkok power plant, WN = Wang Noi power plant

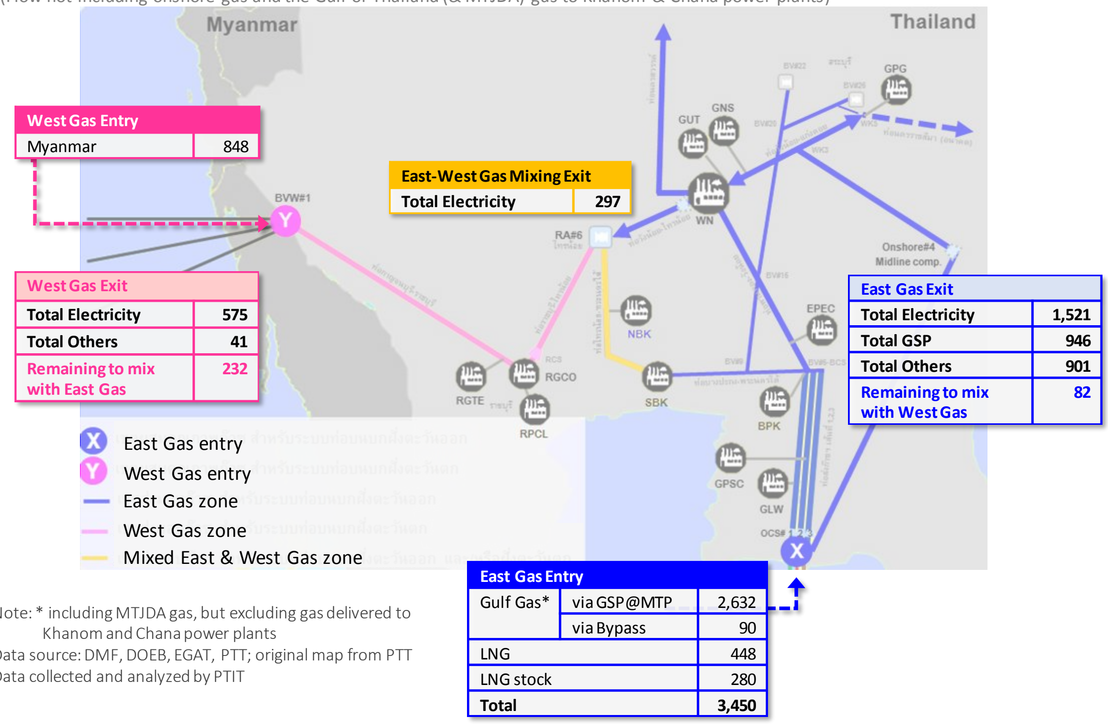
Note: Including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants.

Source: Department of Mineral Fuels, Department of Energy Business, Electricity Generating Authority of Thailand, PTT; original map from PTT; data collected and analysed by the Petroleum Institute of Thailand.

Figure 3.15. Main Natural Gas Flow in Thailand: Scenario B – Day 1–47

unit: billion BTU/day

(Flow not including onshore gas and the Gulf of Thailand (& MTJDA) gas to Khanom & Chana power plants)



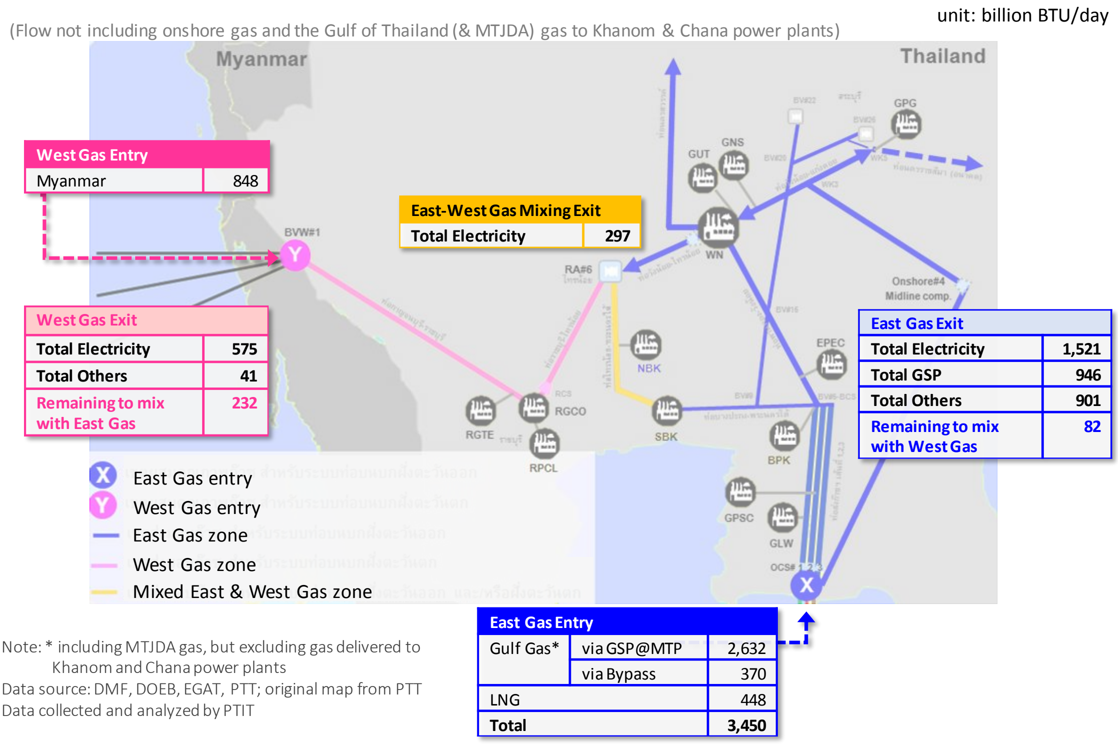
Note: * including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants
Data source: DMF, DOEB, EGAT, PTT; original map from PTT
Data collected and analyzed by PTIT

BPK = Bang Pakong power plant, BTU = British thermal unit, BVW #1 = Block Valve West #1, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NBK = North Bangkok power plant, OCS #1,2,3 = Onshore Compressor Station #1, 2, 3, RA #6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, SBK = South Bangkok power plant, WN = Wang Noi power plant

Note: Including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants.

Source: Department of Mineral Fuels, Department of Energy Business, Electricity Generating Authority of Thailand, PTT; original map from PTT; data collected and analysed by the Petroleum Institute of Thailand.

Figure 3.16. Main Natural Gas Flow in Thailand: Scenario B – Day 48–180

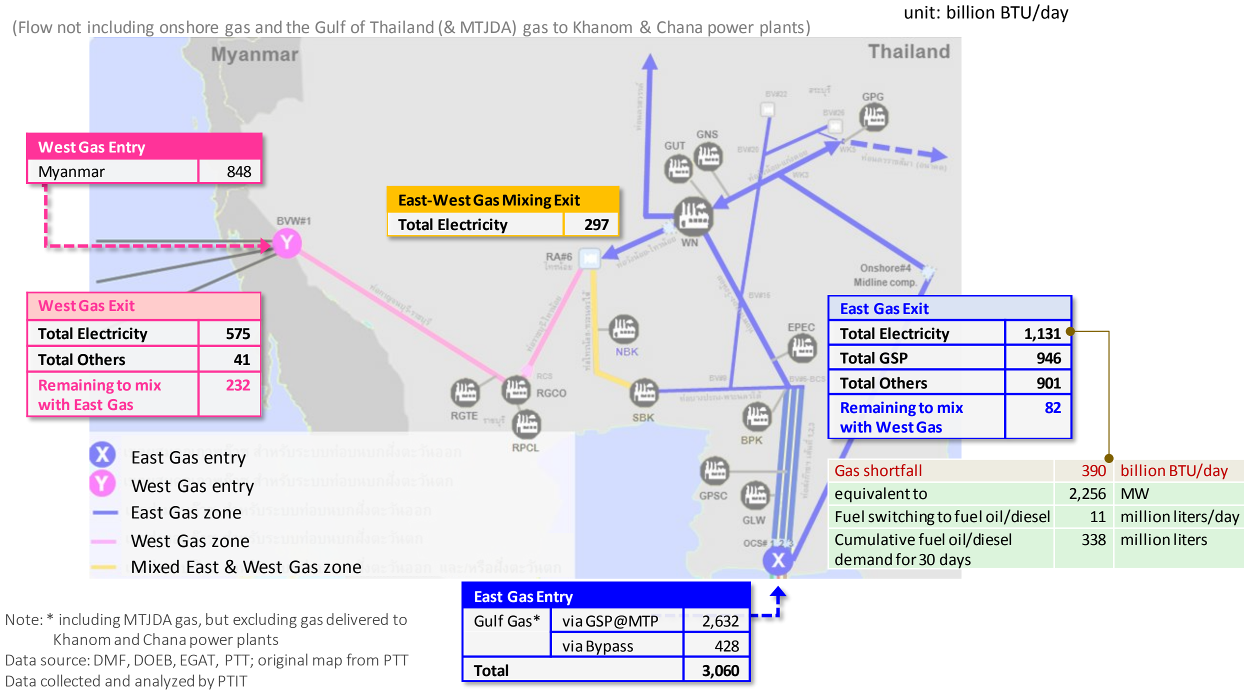


BPK = Bang Pakong power plant, BTU = British thermal unit, BVW #1 = Block Valve West #1, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NBK = North Bangkok power plant, OCS #1,2,3 = Onshore Compressor Station #1, 2, 3, RA #6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, SBK = South Bangkok power plant, WN = Wang Noi power plant

Note: Including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants.

Source: Department of Mineral Fuels, Department of Energy Business, Electricity Generating Authority of Thailand, PTT; original map from PTT; data collected and analysed by the Petroleum Institute of Thailand.

Figure 3.17. Main Natural Gas Flow in Thailand: Scenario C



BPK = Bang Pakong power plant, BTU = British thermal unit, BVW #1 = Block Valve West #1, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NBK = North Bangkok power plant, OCS #1,2,3 = Onshore Compressor Station #1, 2, 3, RA #6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, SBK = South Bangkok power plant, WN = Wang Noi power plant

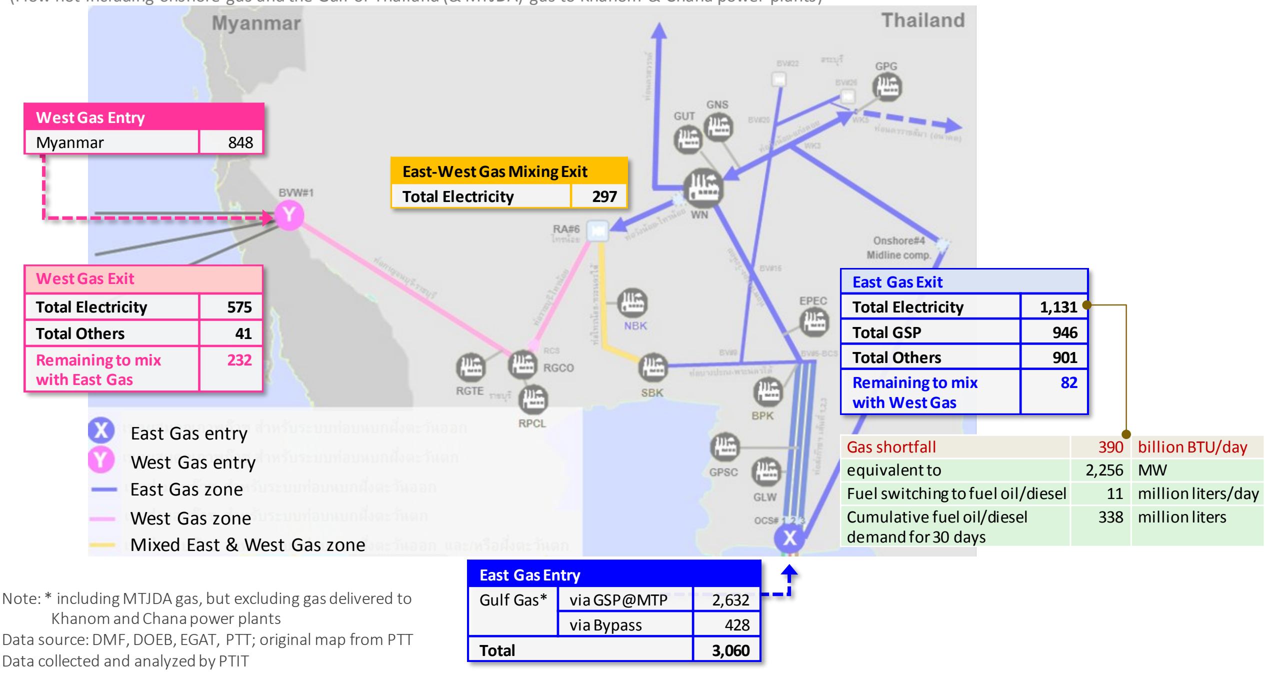
Note: Including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants.

Source: Department of Mineral Fuels, Department of Energy Business, Electricity Generating Authority of Thailand, PTT; original map from PTT; data collected and analysed by the Petroleum Institute of Thailand.

Figure 3.18. Main Natural Gas Flow in Thailand: Scenario D – Day 1–30

unit: billion BTU/day

(Flow not including onshore gas and the Gulf of Thailand (& MTJDA) gas to Khanom & Chana power plants)



BPK = Bang Pakong power plant, BTU = British thermal unit, BVW #1 = Block Valve West #1, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NBK = North Bangkok power plant, OCS #1,2,3 = Onshore Compressor Station #1, 2, 3, RA #6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, SBK = South Bangkok power plant, WN = Wang Noi power plant

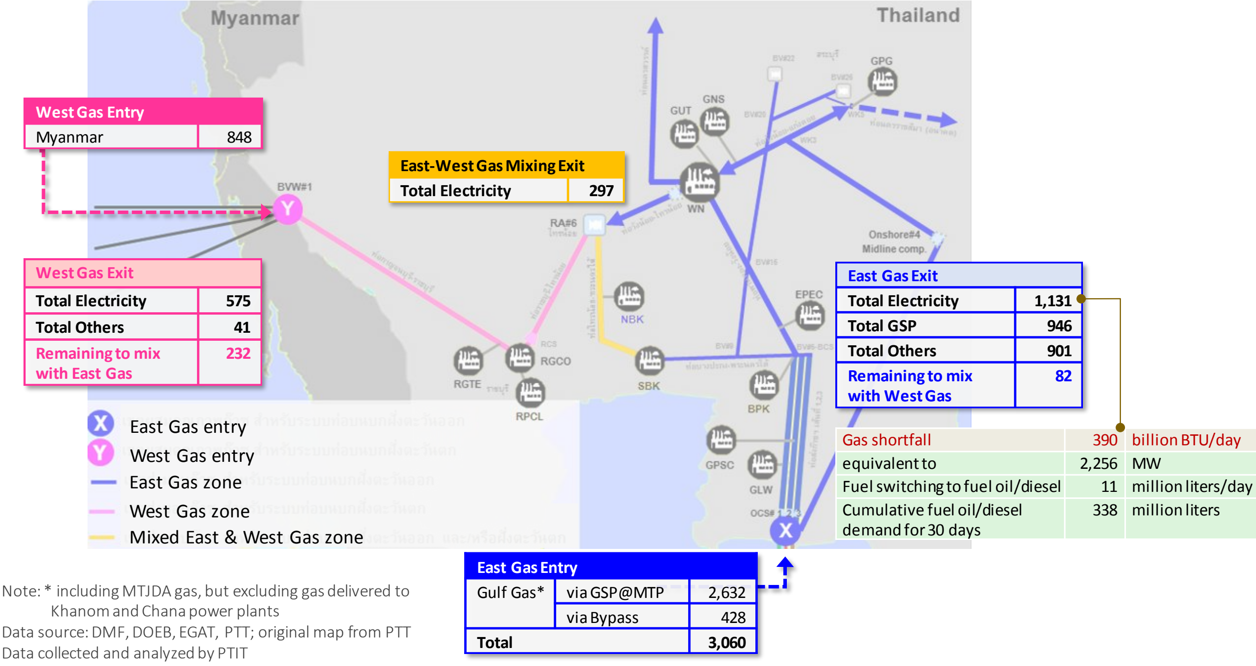
Note: Including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants.

Source: Department of Mineral Fuels, Department of Energy Business, Electricity Generating Authority of Thailand, PTT; original map from PTT; data collected and analysed by the Petroleum Institute of Thailand.

Figure 3.19. Main Natural Gas Flow in Thailand: Scenario D – Day 31–180

unit: billion BTU/day

(Flow not including onshore gas and the Gulf of Thailand (& MTJDA) gas to Khanom & Chana power plants)



BPK = Bang Pakong power plant, BTU = British thermal unit, BVW #1 = Block Valve West #1, EPEC = Eastern Power and Electric power plant, GLW = Glow IPP power plant, GNS = Gulf JP Nong Saeng district power plant, GPG = Gulf Power Generation power plant, GPSC = Global Power Synergy power plant, GSP = gas separation unit, GUT = Gulf JP Uthai district power plant, LNG = liquefied natural gas, MTJDA = Malaysia–Thailand Joint Development Area, MTP = Map Ta Phut, NBK = North Bangkok power plant, OCS #1,2,3 = Onshore Compressor Station #1, 2, 3, RA #6 = Ratchaburi-Wangnoi #6 Block Valve Station, RGCO = Ratchaburi Electricity Generating Co, Ltd power plant, RGTE = Ratchaburi Tri Energy Co, Ltd power plant, RPCL = Ratchaburi Power Co, Ltd power plant, SBK = South Bangkok power plant, WN = Wang Noi power plant

Note: Including MTJDA gas, but excluding gas delivered to Khanom and Chana power plants.

Source: Department of Mineral Fuels, Department of Energy Business, Electricity Generating Authority of Thailand, PTT; original map from PTT; data collected and analysed by the Petroleum Institute of Thailand.

3.4 Appendix

Main Assumptions and Conversion Factors Used in Chapter 3

Natural gas supply and demand volume			@	1,000	BTU/scf
	5	mmtpa LNG	=	700	mmscfd natural gas
			=	700	billion BTU/day natural gas
To generate electricity				use	
	700	MW		121	mmscfd natural gas
				121	billion BTU/day natural gas
	100	MW		0.5	million litres/day fuel oil
	100	MW		0.5	million litres/day diesel
	158.984	litres	=	1	barrel
NGV	0.128	kg	=	1	litre
LPG	0.54	kg	=	1	litre
	1	MJ	=	0.000947817	million BTU
Heating value	NGV		=	38,500	BTU/kg
	NGV		=	5.2	MJ/litre
	gasoline		=	33.5	MJ/litre

BTU = British thermal unit, kg = kilogram, LNG = liquefied natural gas, LPG = liquefied petroleum gas, MJ = megajoule, mmscfd = million standard cubic feet per day, mmtpa = million metric tonnes per annum, MW = megawatt, NGV = natural gas for vehicles.
Source: Petroleum Institute of Thailand.