



Understanding the Value of Gas Infrastructure in Supporting Southeast Asia's Mid-Merit Power Demand

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How do we unlock the value in LNG flexibility?

- Paris Agreement requires a substantial shift towards low-carbon power
 - Natural Gas is less carbon intensive than coal
 - Natural Gas fits well with intermittent renewables technically (rapid ramp up/down etc)
- But LNG for power is struggling in ASEAN
 - Coal remains cheaper for base-load
 - LNG requires expensive infrastructure
 - Solar competes directly with LNG for day-time generation, reducing the volume and certainty of LNG required
 - Traditional LNG supply agreements (in Asia) have allowed very limited flexibility
 - Inflexibility undermines the value of LNG for power

We assess the economics of LNG (i.e. LNG terminal with anchored CCGTs) from the “whole-of-system” perspective

What sources of value would LNG can create?

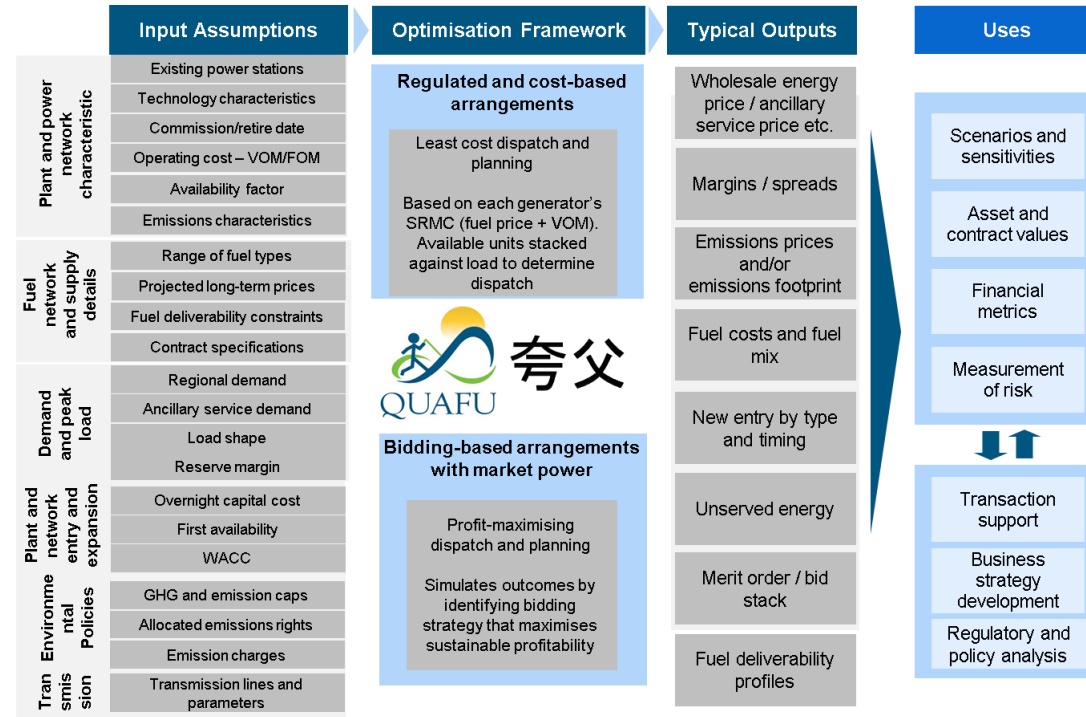
What are the associated costs of LNG?

How should these be evaluated to ensure a net beneficial decision for the system?

The Philippines is an instructive case study: a competitive electricity market with diverse fuel sources and a lot of commercial activities

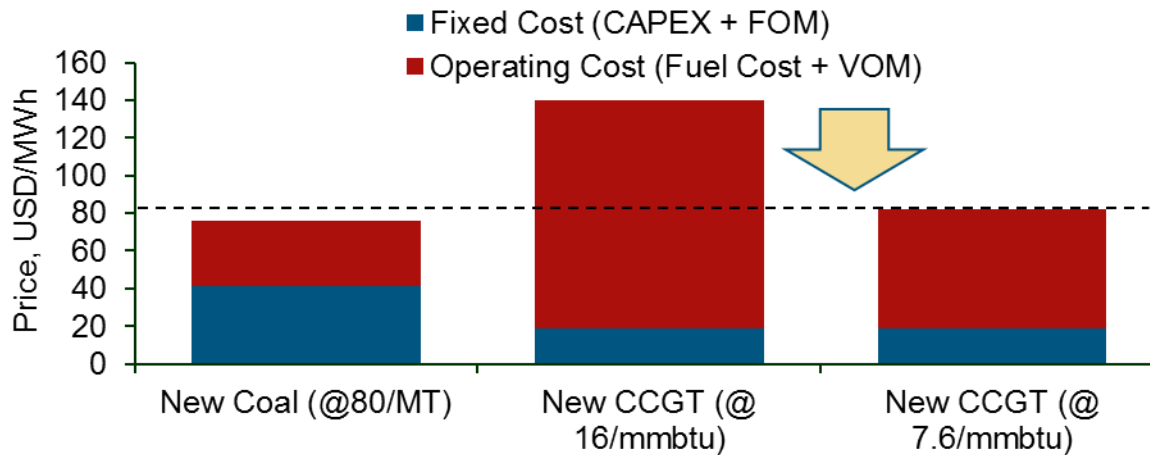
- We use the Philippines as a case study of a problem widespread across Southeast Asia
 - Philippines has an existing gas fleet of 3.2 GW, using gas from the domestic Malamapaya gas field
 - Domestic gas reserve is declining, but there are no existing operational LNG terminals
- Three stage analysis
 1. Re-examine fuel economics: gas is cheaper than many think
 2. Re-examine fuel complementarity: is solar squeezing gas or providing certainty?
 3. Re-examine value of flexibility

QUAFU power dispatch model framework



Economics of gas-fired *capacity* is fairly robust to fuel price fluctuations as long as gas is available flexibly

New coal vs new gas in ASEAN @ 75% capacity factor



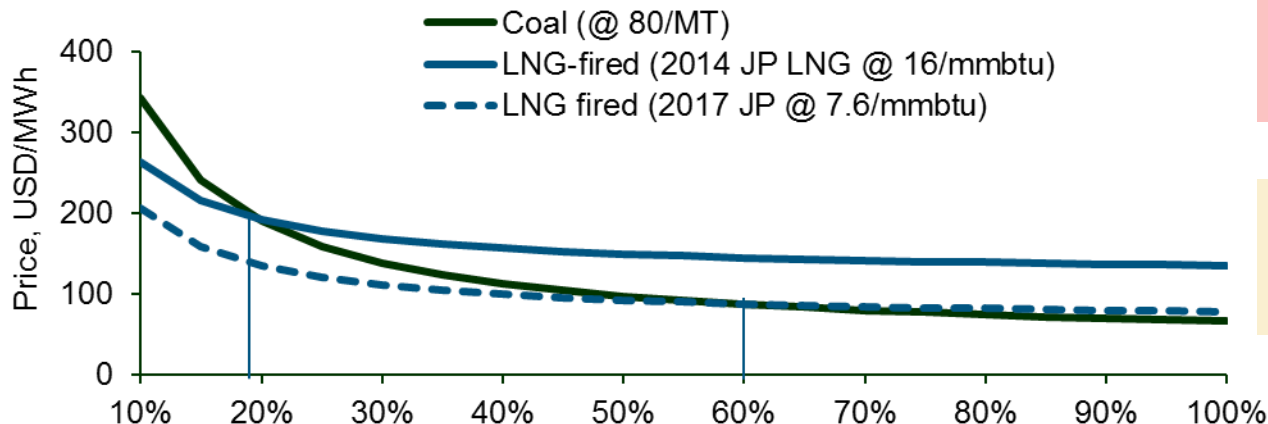
- Basic characteristics of coal vs gas
 - Coal – high CAPEX, low fuel price
 - CCGT – low CAPEX, high fuel price
- **Gas always has a role for mid-merit or peaking.**

Coal *capacity* value is **vulnerable** at lower utilisation due to higher capital costs relative to gas.

Gas *capacity* value is **robust** at lower utilisation unless *committed to take too much gas*

The amount of gas that is optimal swings wildly with changes in fuel costs. Gas is currently lower cost

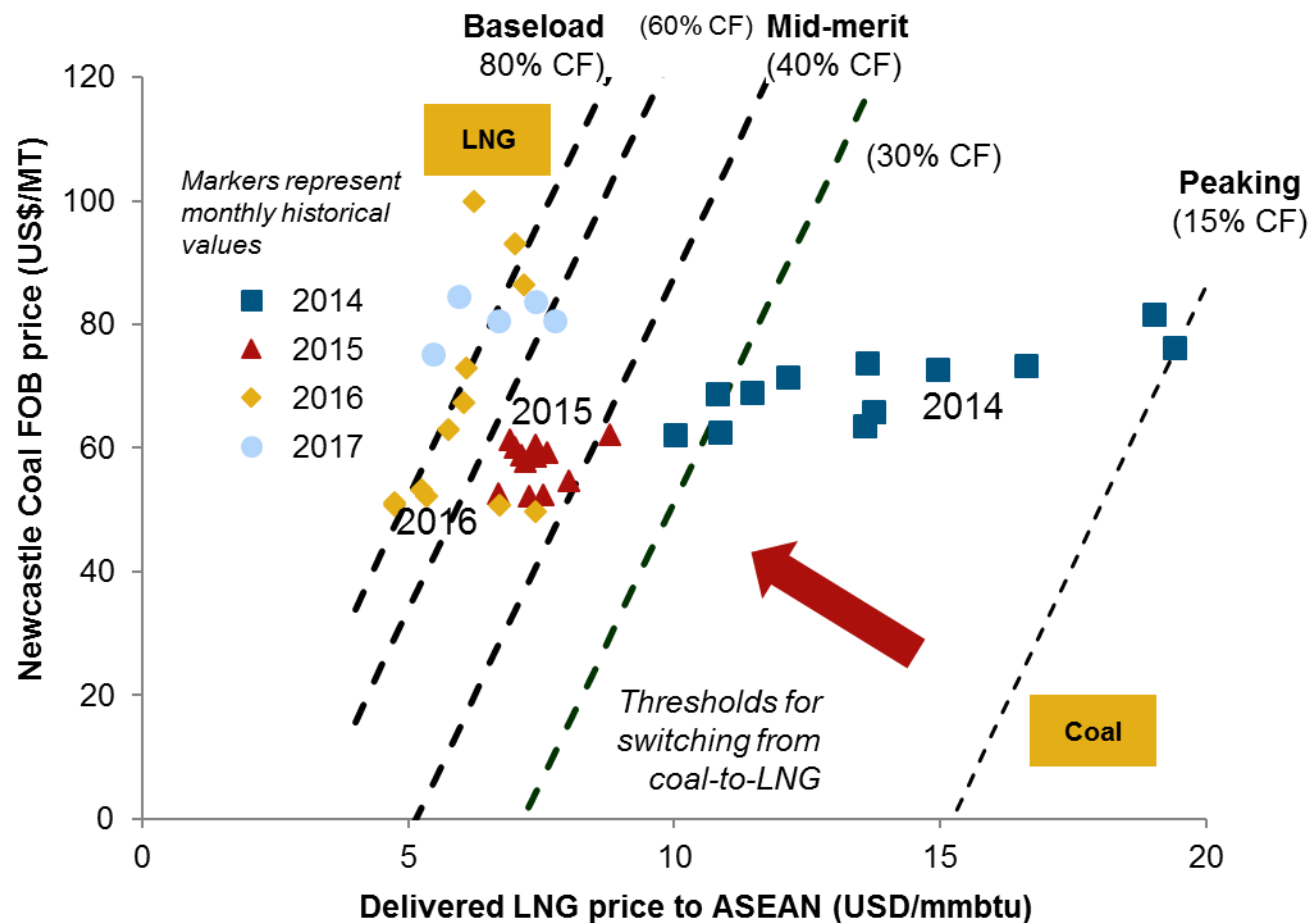
Screening Curves of coal vs gas



Note: Key assumption: LNG regas and associated pipeline tariff to the power plants is US\$1.5/mmbtu and coal transportation cost is US\$7/metric tonnes; capital cost coal US\$1,800/kW gas CCGT US\$800/kW; HHV net heat-rate coal 9.5 GJ/MWh, gas CCGT 7.2 GJ/MWh, FOM is USD 40/kw-year for coal and USD 23/kw-year for gas, VOM of coal is 2.5/MWh for coal and USD 1.0/MWh for gas. WACC is 12 percent.

Fuel economics: LNG position is always changing, and is currently attractive

Coal-to-LNG Switching in Power Sector for New Investment

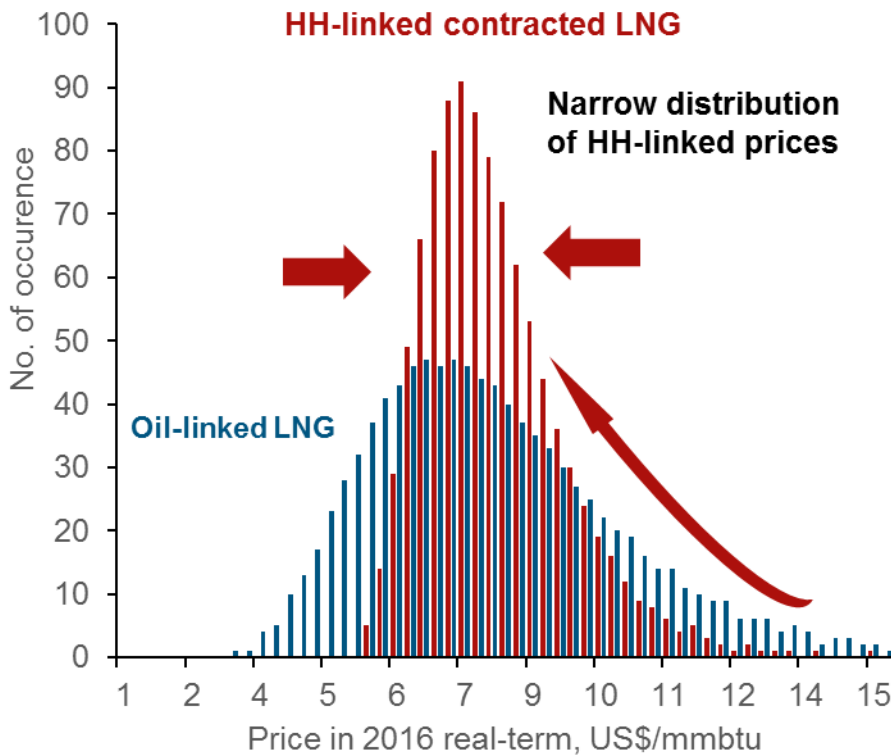


- Spot LNG prices have fallen far enough for major switching from coal-to-LNG
- Key uncertainties still exist
 - Risk that gas prices will rise again can be a deterrent, but has reduced with supply from US
 - Cheaper China coal EPC could reduce the competitiveness of gas slightly
 - But financing for greenfield coal projects is becoming more difficult

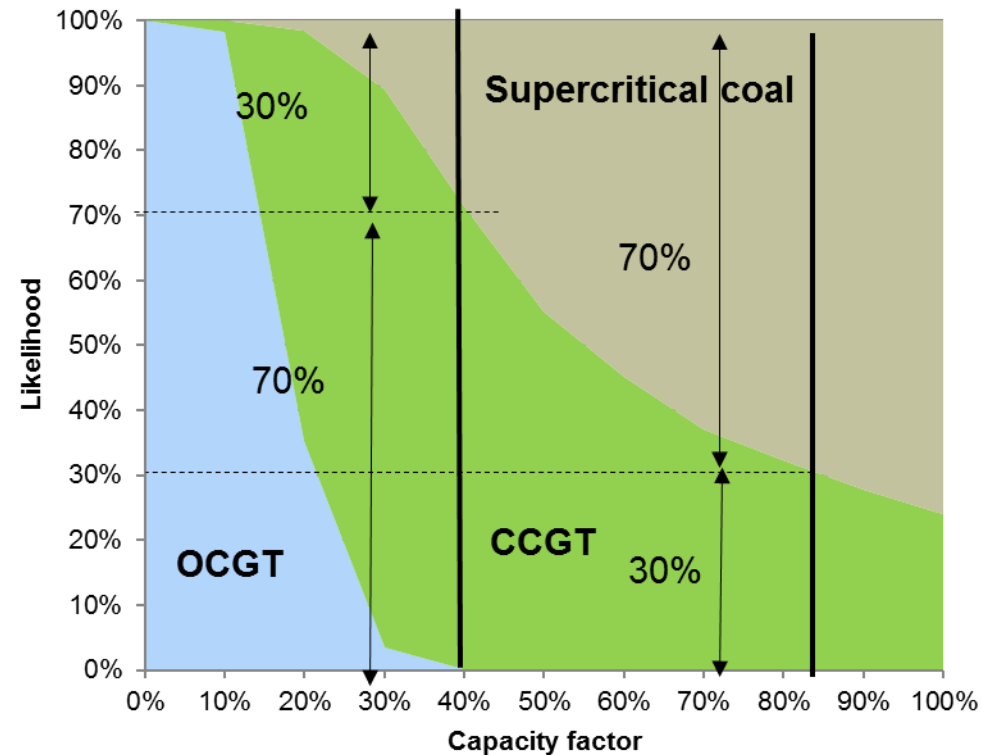
Note: Key assumption: Historical LNG prices are based on spot JKM LNG prices reported by Platts. LNG regas and associated pipeline tariff to the power plants is US\$1.5/mmbtu and coal transportation cost is US\$ 7/metric tonnes; capital cost coal US\$1,800/kW gas CCGT US\$800/kW; HHV net heat-rate coal 9.5 GJ/MWh, gas CCGT 7.2 GJ/MWh, FOM is USD 40/kw-year for coal and USD 23/kw-year for gas, VOM of coal is 2.5/MWh for coal and USD 1.0/MWh for gas, WACC is 12 percent

New gas would be competitive against new coal for mid-merit generation with a high probability, and for base-load generation with some chance

Future delivered LNG price distribution to ASEAN
(based on forward oil and gas curves and historical volatility)



Simulation: likelihood of each technology being lowest LRMV at different capacity factors

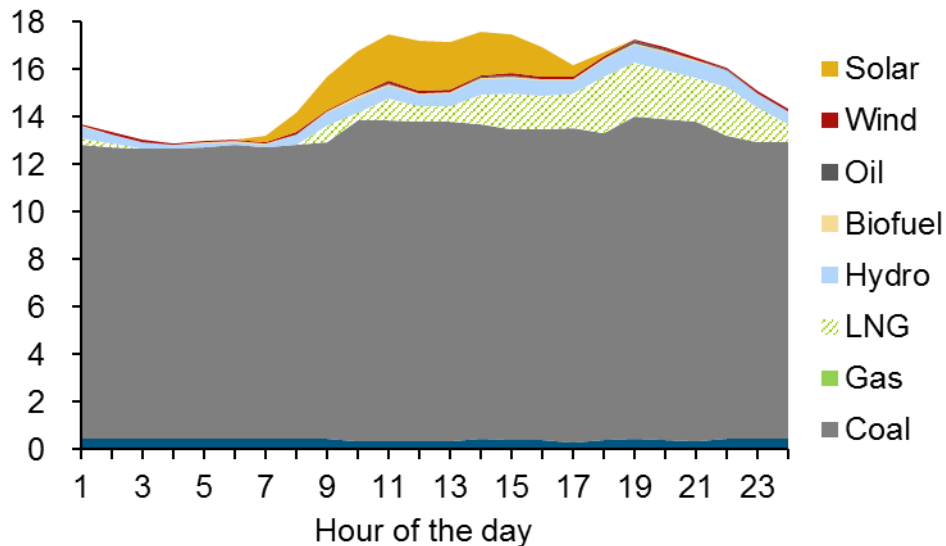


Note: Oil-index contract DES LNG formula is $0.13 \times \text{Brent} + 0.8$, HH-linked contracted LNG formula is $1.15 \times \text{HH} + 3$ (liquefaction cost) + 1.5 (shipping). Based on daily forward curves of Brent and Henry Hub prices, the short-term volatility of Brent and Henry Hub gas prices is 7 percent and 10 percent and their long-term volatility is 5.5 percent and 5.1 percent respectively.

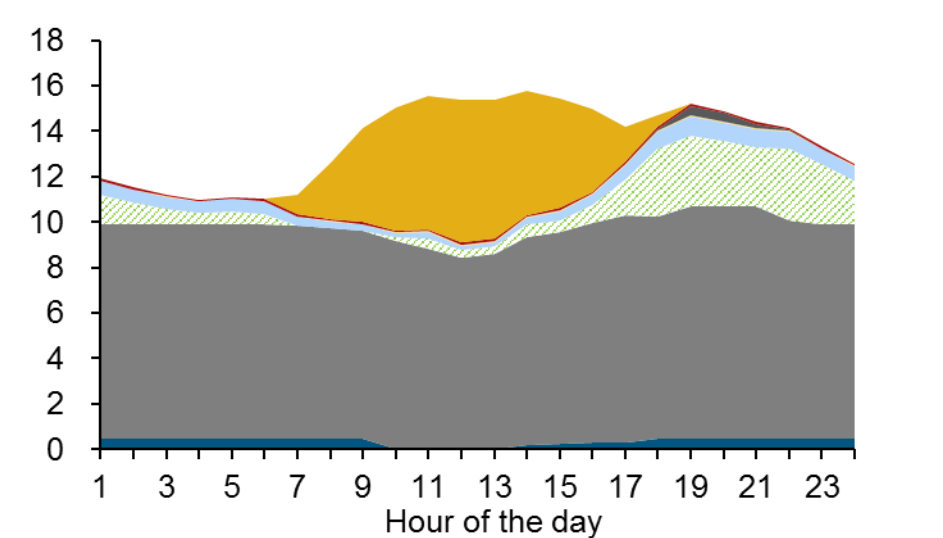
Source: ICE, NYMEX and TLG research and analysis

Fuel complementarity: gas fits well with large amount of solar for both economical and technical reasons

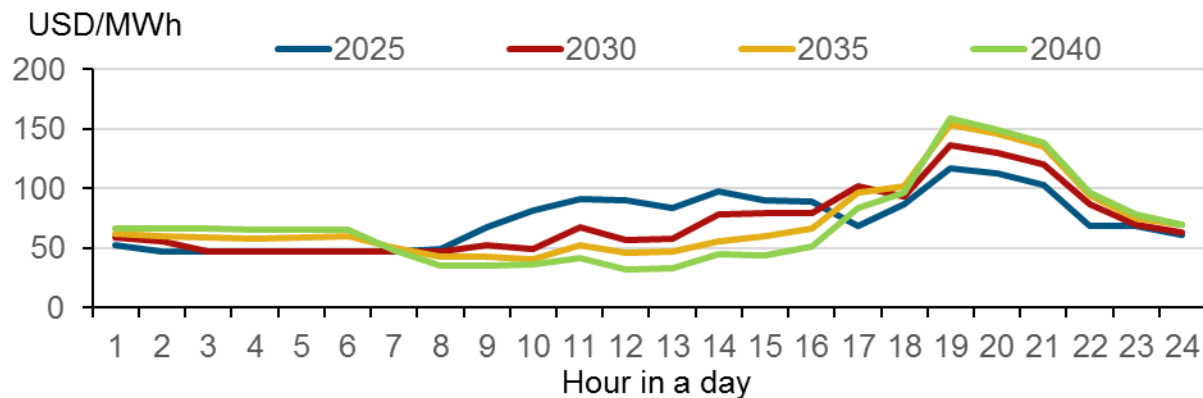
Slow annual solar cost declining Case (1.8%) – Generation fuel mix in Luzon Philippines (2040)



High annual solar cost declining case (4.5%) – Generation fuel mix in Luzon Philippines (2040)



High annual solar entry case – average hourly prices (2040)

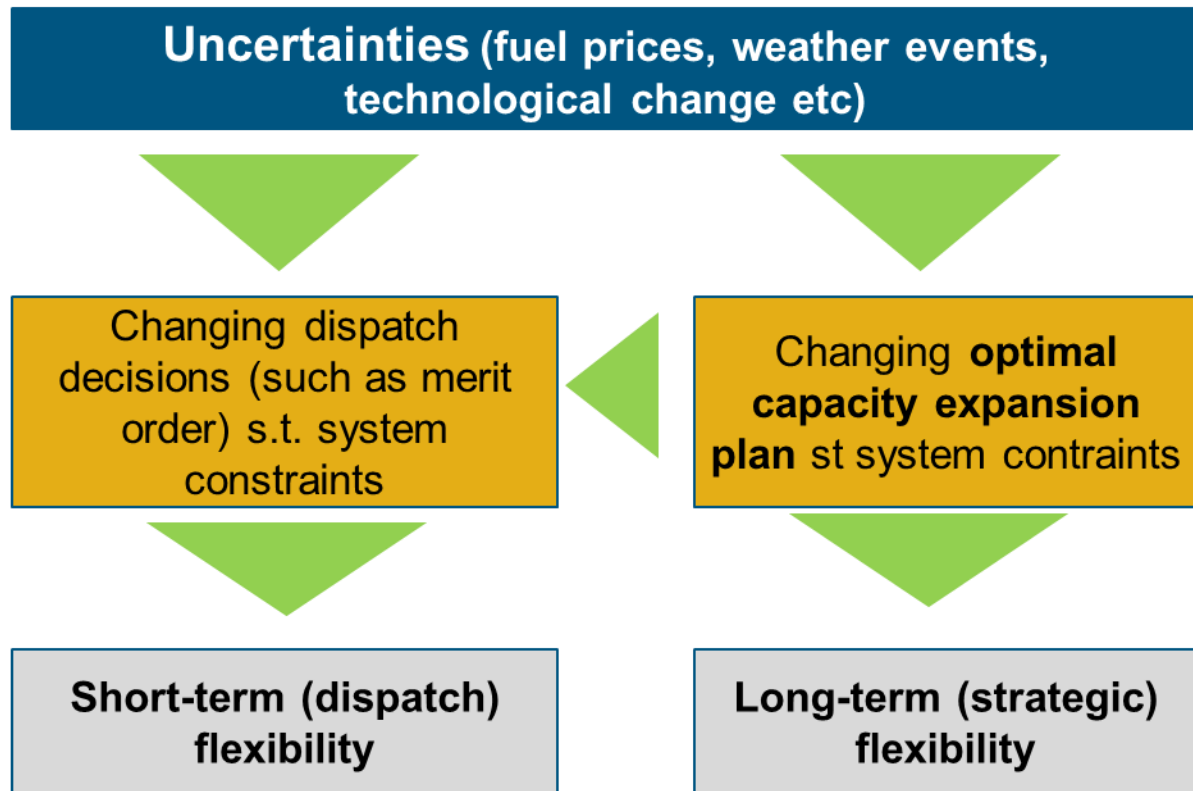


- In the near term, increasing solar can compete with gas generation during day-time.
- In the long-term, gas fits well with large solar entry for both economical and technical reasons.

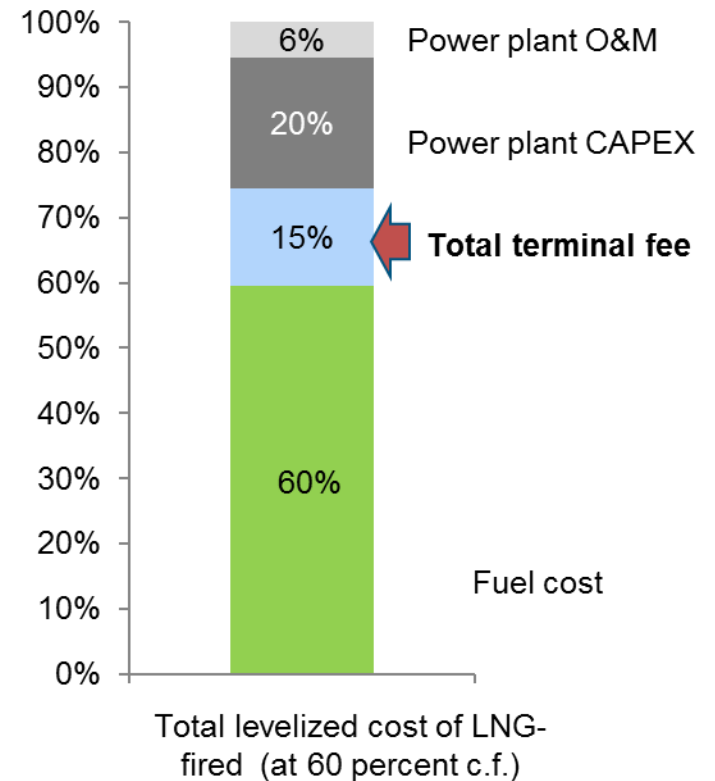
6 Note: Key assumption: Long term LNG price delivered to the power plants is USD 10/mmbtu in 2016 real-term, coal price is USD 3.3/mmbtu, solar cost is declining from USD 1400/kW in 2016 to USD 907/kW in 2040 for the slow solar cost declining case, from USD 1400/kW to USD 460/kW under the aggressive solar cost declining case

The LNG terminal is a key source of flexibility – and its contribution to total cost is comparatively small – yet without it, nothing else happens

Short-term and long-term flexibility



Total levelized cost of LNG-fired CCGT

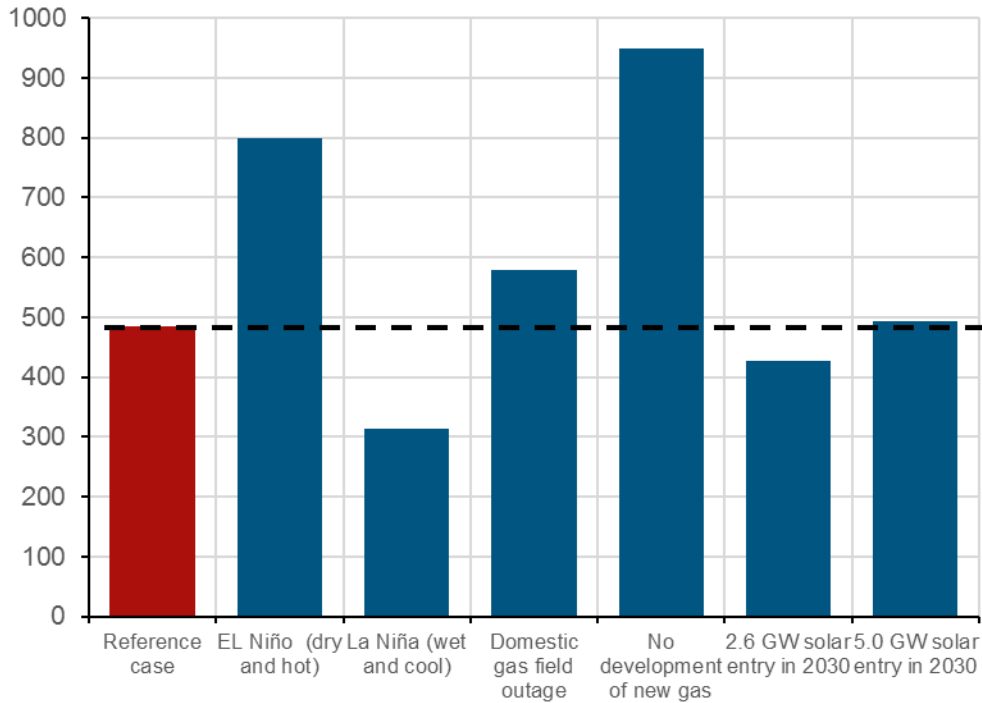


The terminal has significant option value as long as it is available to support flexible utilisation of gas over time

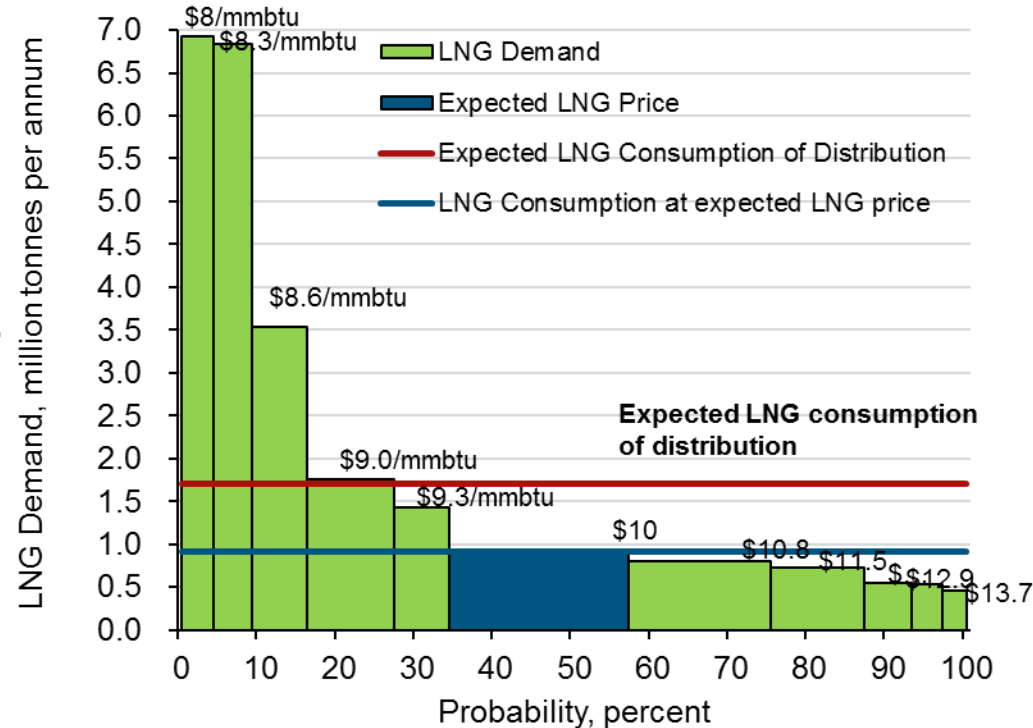
Flexibility around the LNG contracts and LNG terminal charging mechanism is key to underpin the various sources of option value of the LNG terminal

Annual economic LNG consumption in 2030

Thousand tonnes per annual, ktpa



Probability distribution of economic quantities of LNG in 2035

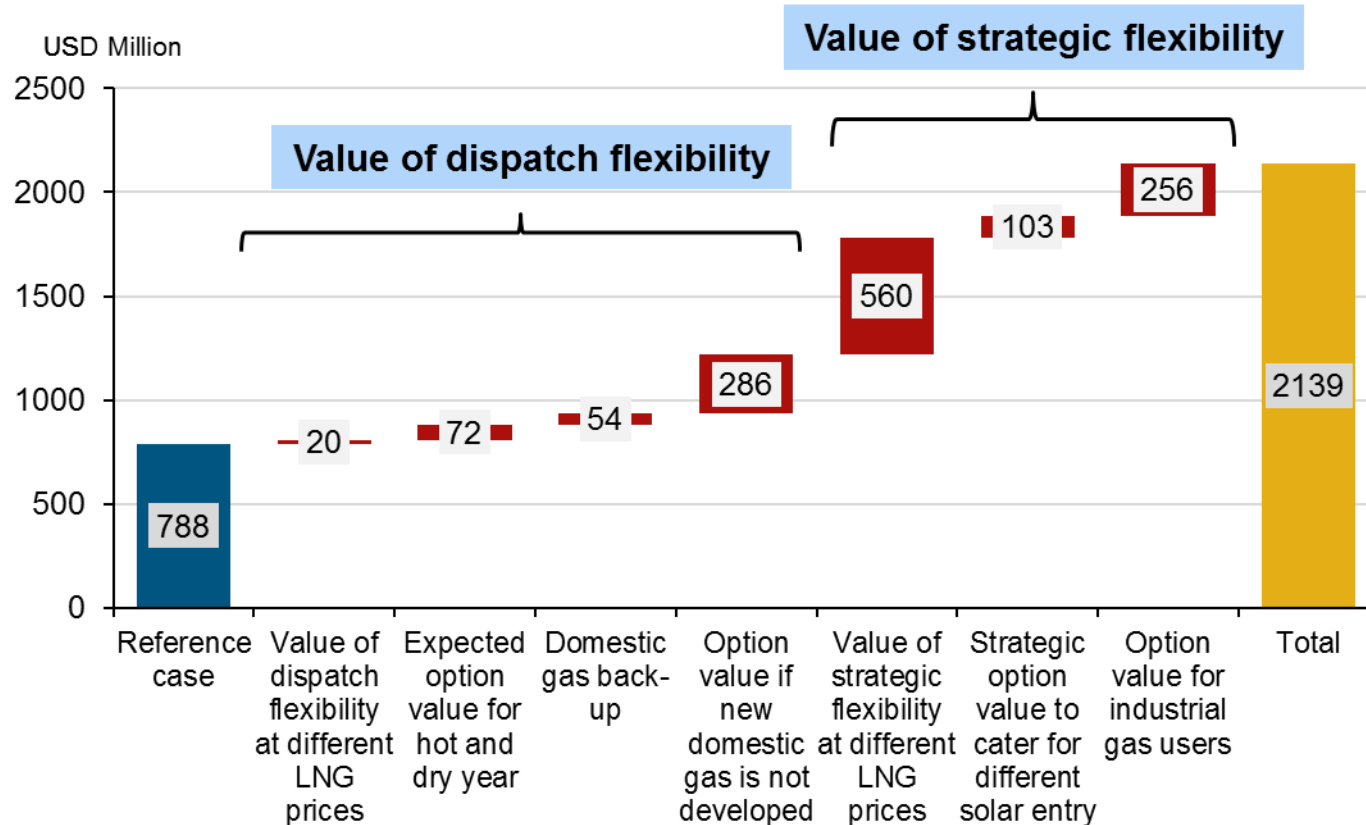


- Annual economic LNG consumption varies widely
- Rigid LNG contracts with high take-or-pay can be costly

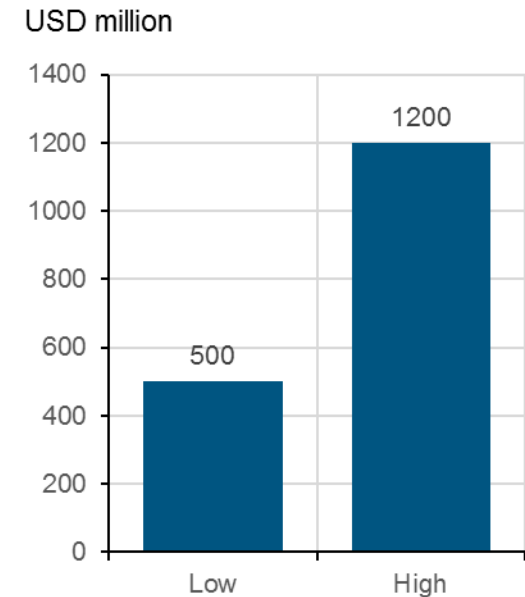
- Asymmetrical LNG demand shape around the expected LNG price, which can give rise to significant value for strategic flexibility

The full value of LNG terminals in the Philippines can support more than two LNG terminals in the long term

Present value of the revenue to the LNG terminal owner from “whole-of-system” perspective in the Philippines



Range of proposed cost of planned LNG terminals

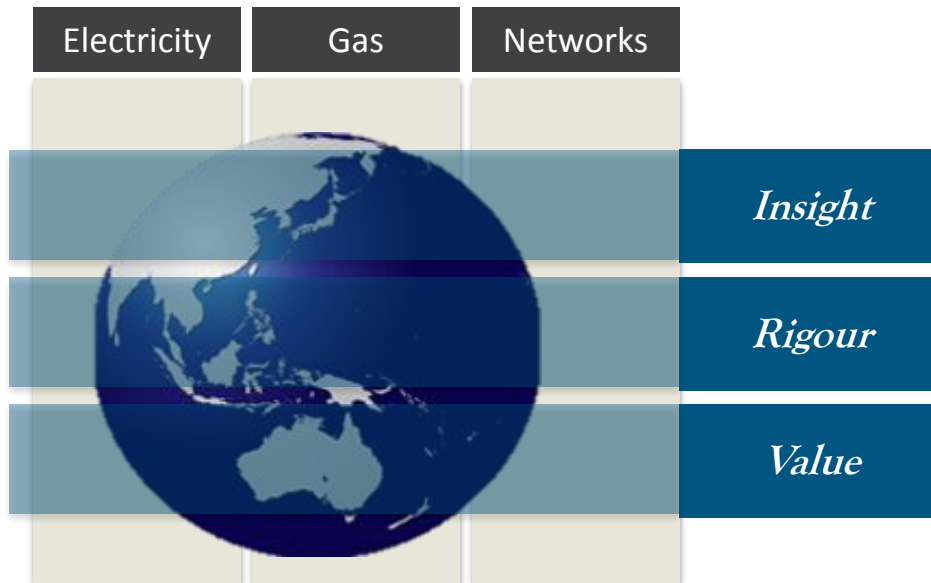


Note: other sources of values of the LNG terminals, such as lowering carbon emissions, increasing energy security and increasing optionality to do break-bulking and regional LNG trading, are not quantified here.

Flexible LNG supply has value, but only if a terminal exists that can be used flexible (and is not tied up in a long-term, take-or-pay arrangement)

- Fuel margins matter and vary widely over time
- The drop of LNG price and evolving contracting environment have improved the economics of LNG against coal
 - Near the tipping point where LNG-fired can even compete with coal-fired to meet base-load requirement
- LNG is compatible to solar both technically and economically in the long term
- LNG-fired generation will be subject to daily load variation, price fluctuation, weather conditions, domestic gas production swings and solar entry uncertainty
 - Costly to be constrained by inflexible and high take-or-pay commitments
 - LNG terminals in ASEAN provides substantial optionality value to the system
 - LNG contracts and terminal charging design need to be sufficiently flexible to underpin those option values
 - LNG contracts: avoid rigid arrangement with high take-or-pay gas
 - Tolling mechanism: recover its cost primarily based on capacity reservation charges, rather than throughput charges. Sizing of terminal storage capability will be also the key design variable
- Needed: a new set of commercial and regulatory arrangements to enable decoupling of capacity and usage....in Asia

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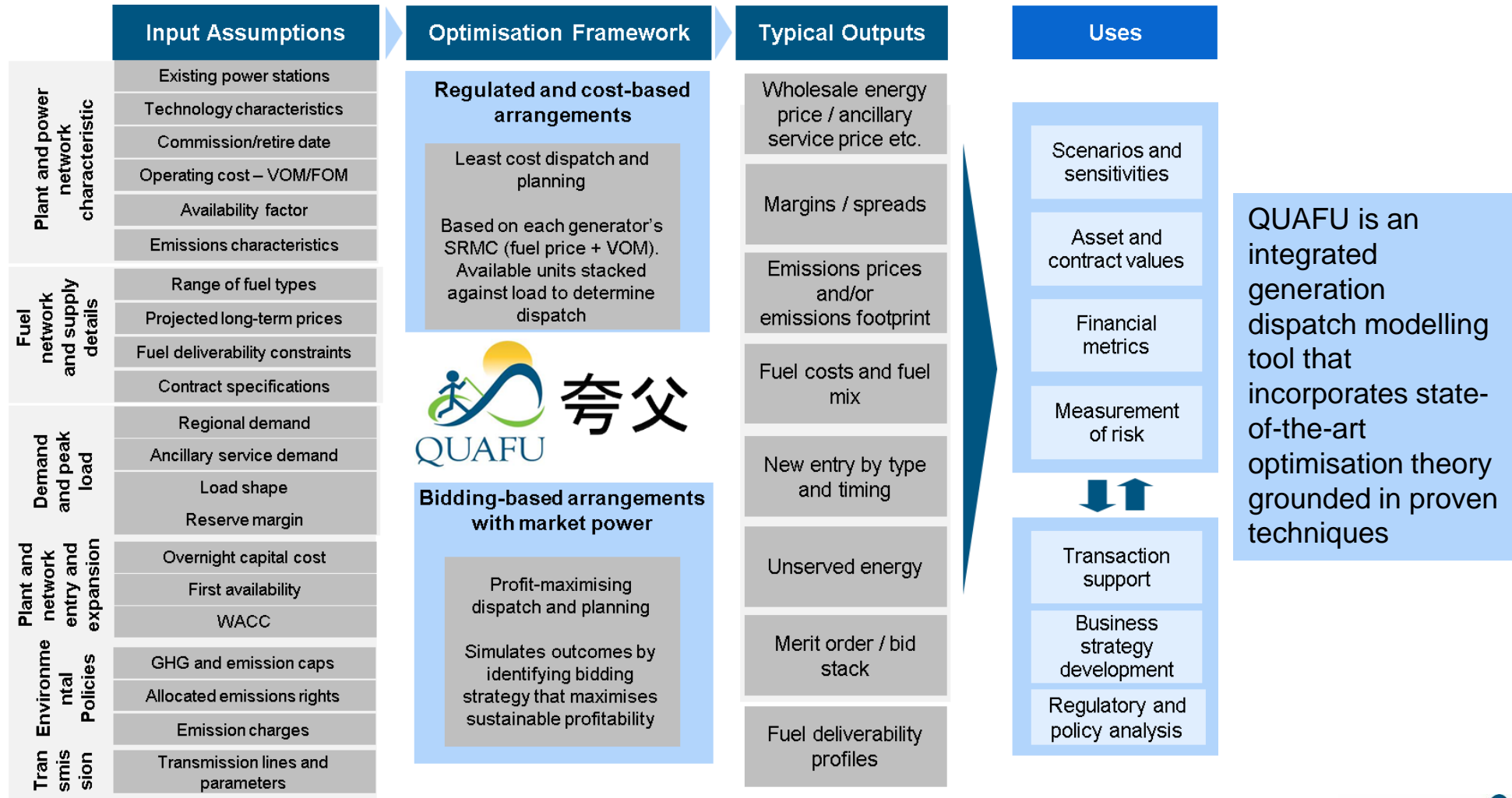
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TLG's power dispatch model - QUAFU

QUAFU model framework

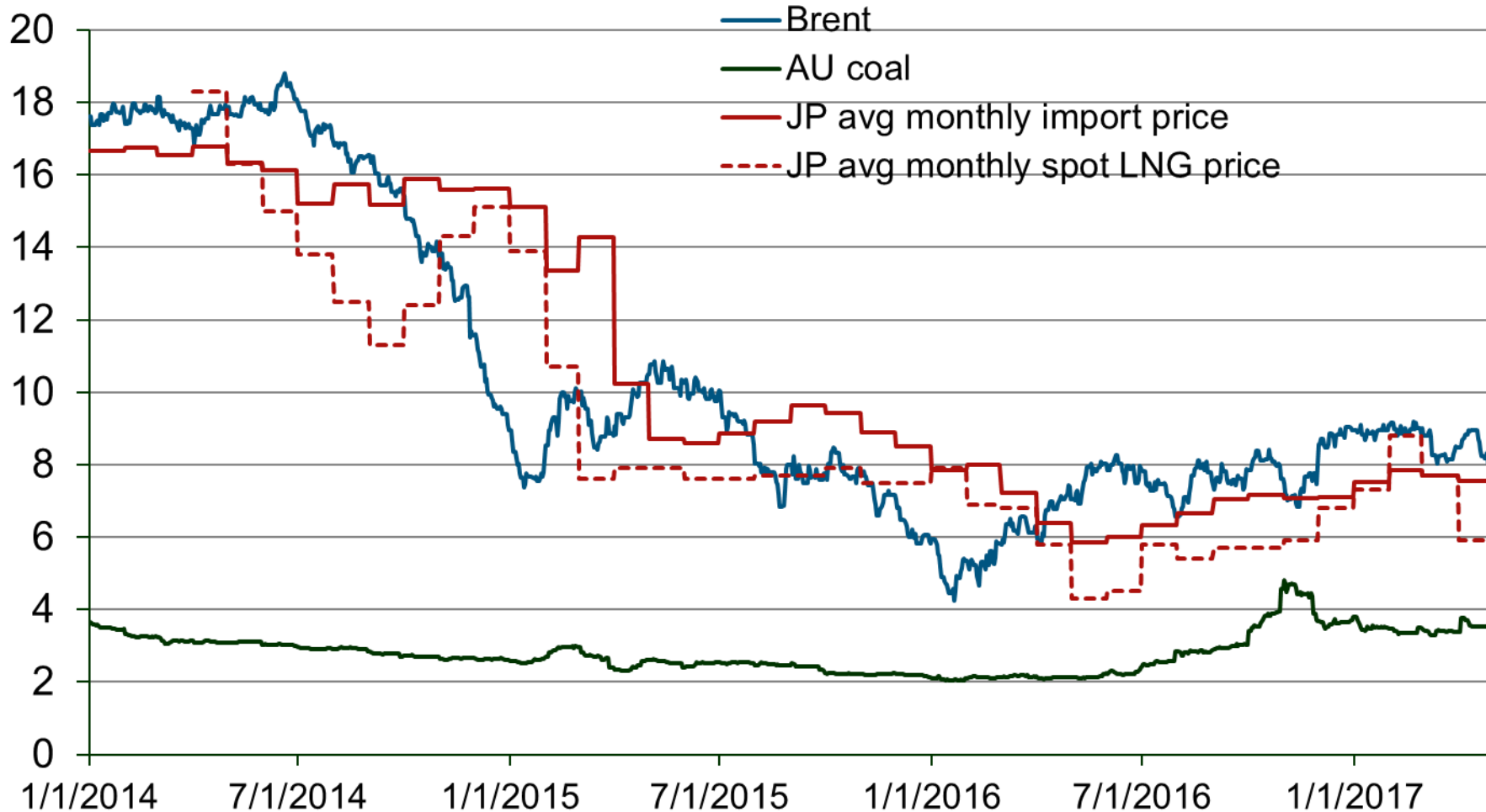


QUAFU is an integrated generation dispatch modelling tool that incorporates state-of-the-art optimisation theory grounded in proven techniques

Coal gas price spread has narrowed in 2016 as LNG price drops and coal price increases

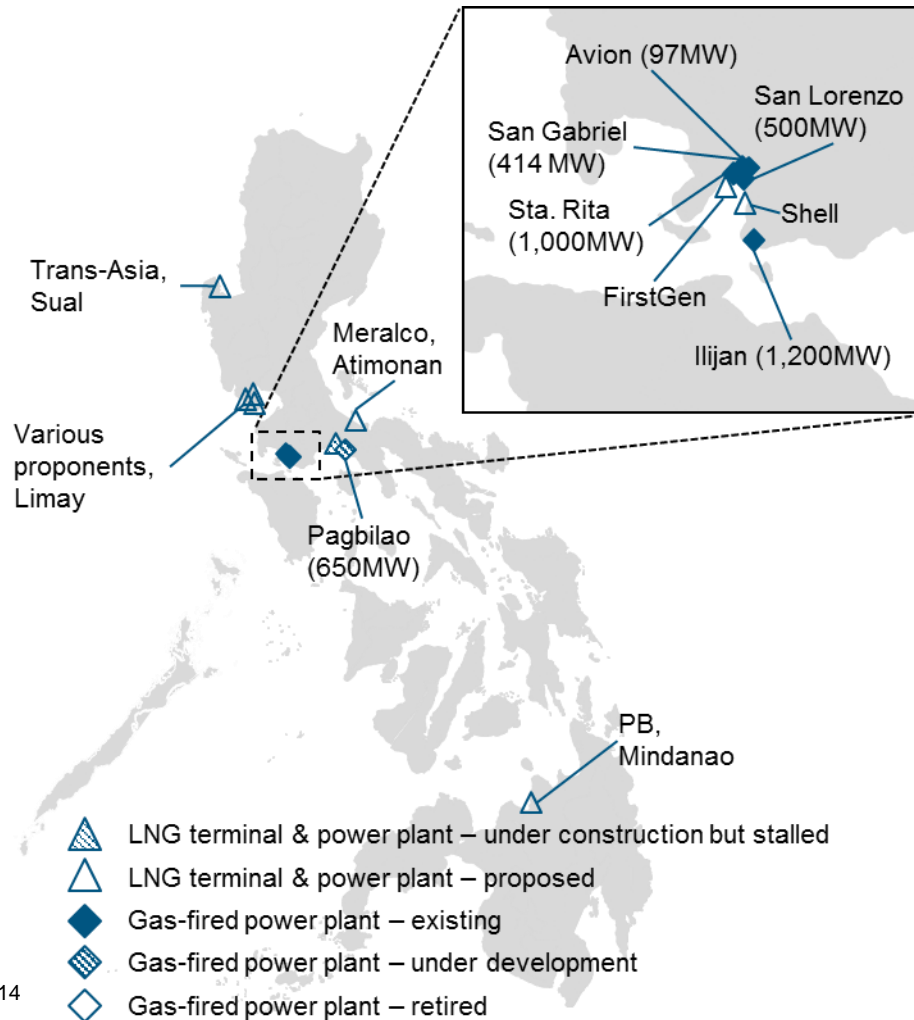
Daily Asian Fuel Prices

USD/mmbtu

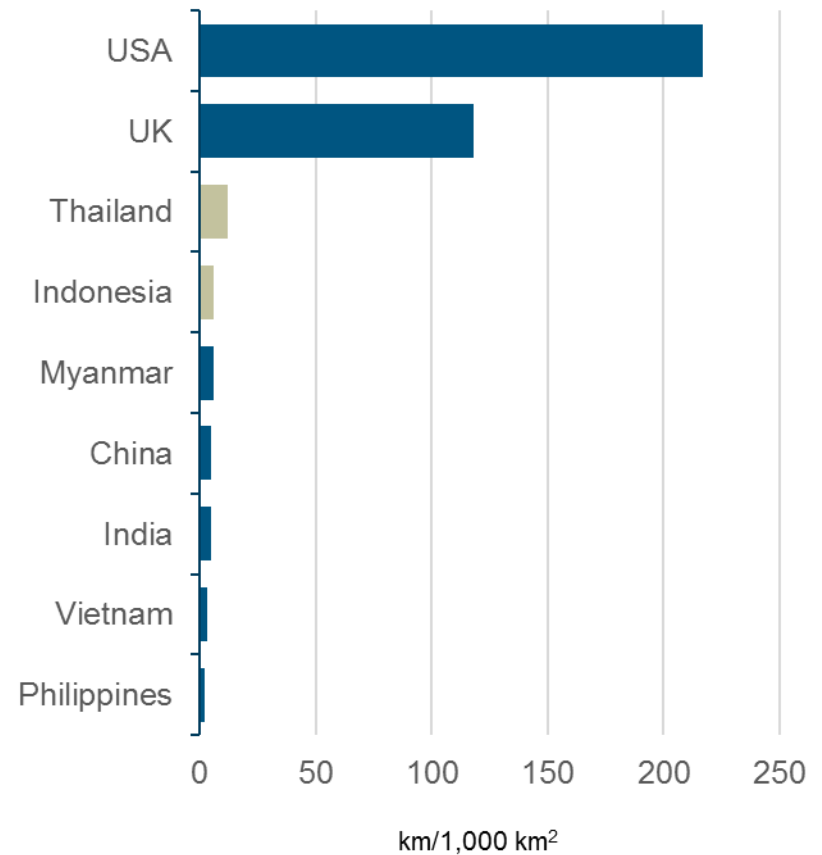


LNG infrastructure development is still in a nascent state in ASEAN – a lot of talks but few actions

Philippines example: a lot of talks on building LNG terminal since 2012

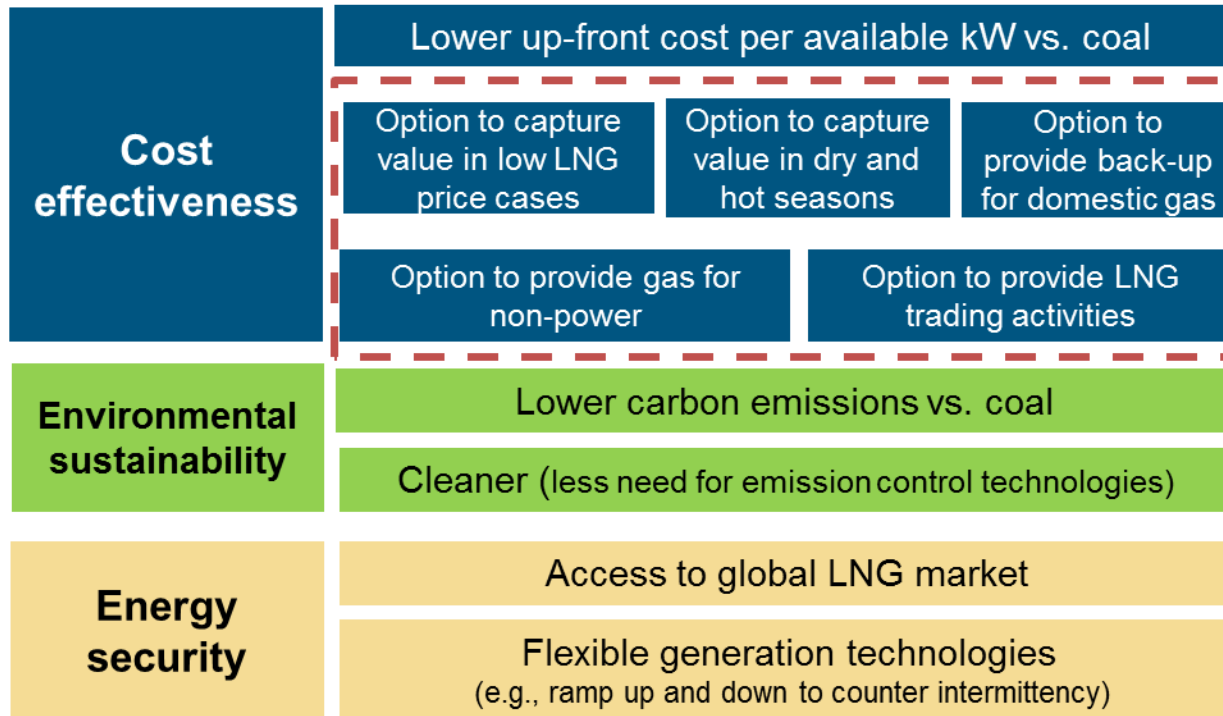


Pipeline length per land area (2013)

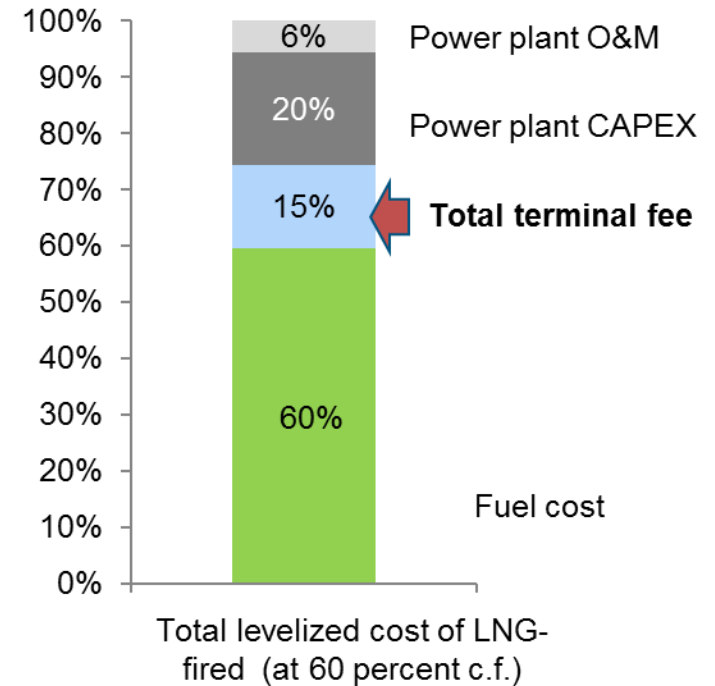


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Sources of value of LNG-fired CCGT with LNG terminal

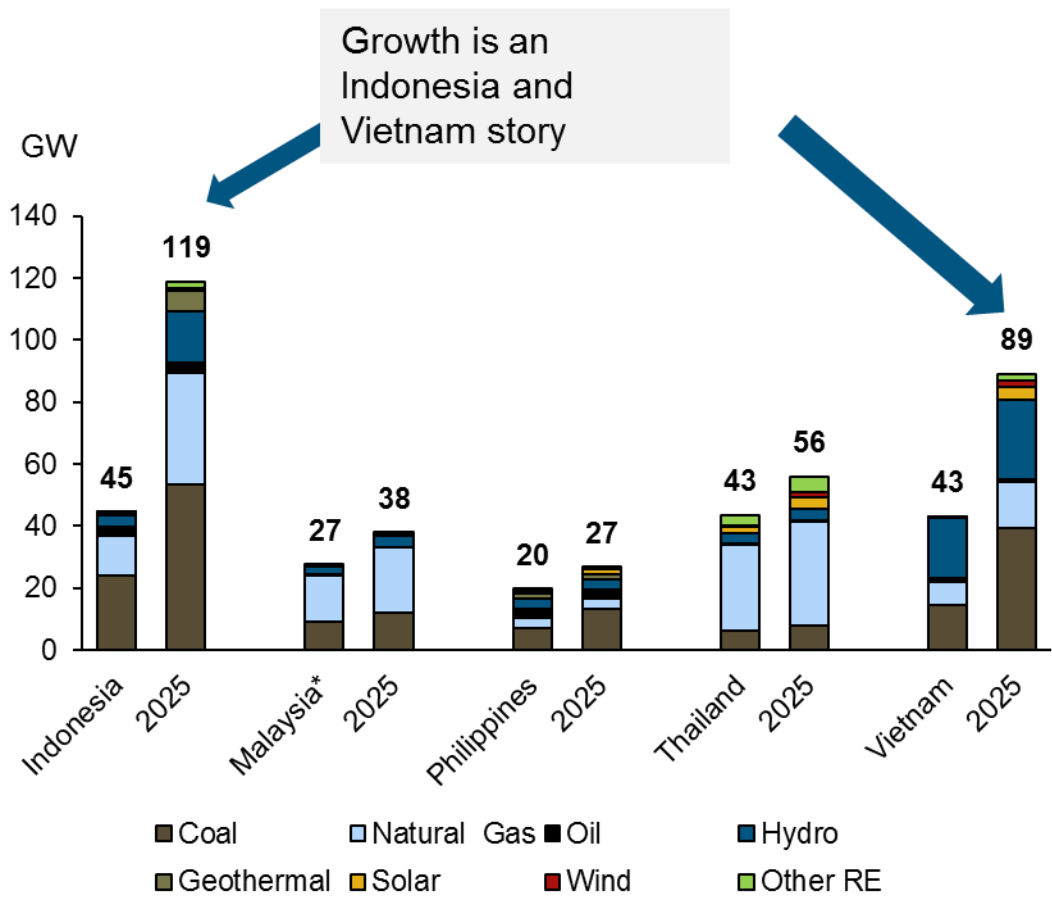


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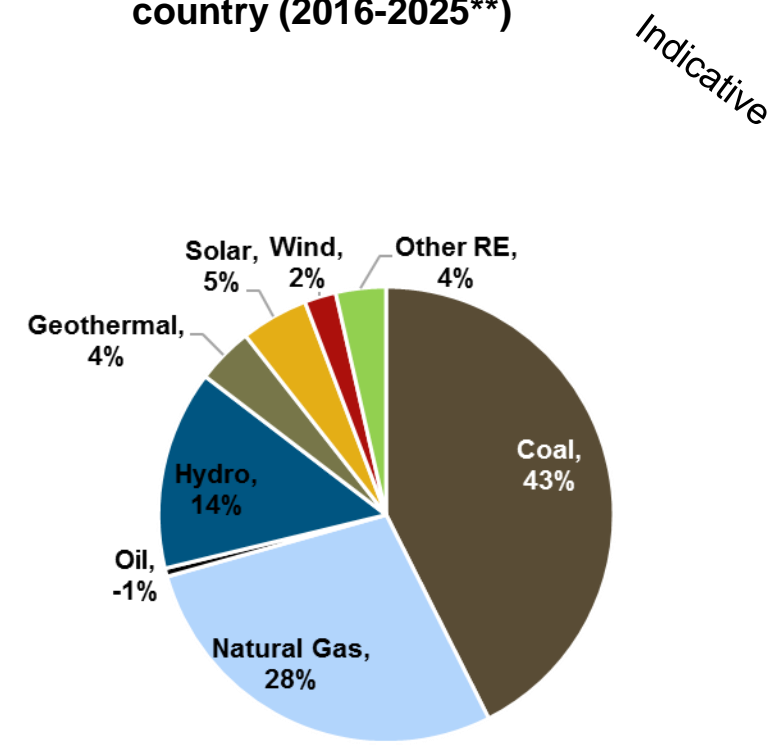


Where is the growth?

Installed capacity in Selected Asia: 2015 vs. 2025



Capacity addition of the selected country (2016-2025**)



Source: Data reflects Power Development Plans and other official planning, except Philippines where forecasted capacity additions have been modeled using TLG market models.

Vietnam has plans to develop LNG infrastructure and gas-fired power plants to meet a rapid demand growth and depleting gas fields

Robust Demand Growth

GDP and power consumption in Vietnam increased by 6.2% and 11.9% respectively in 2016.

Depleting Fields

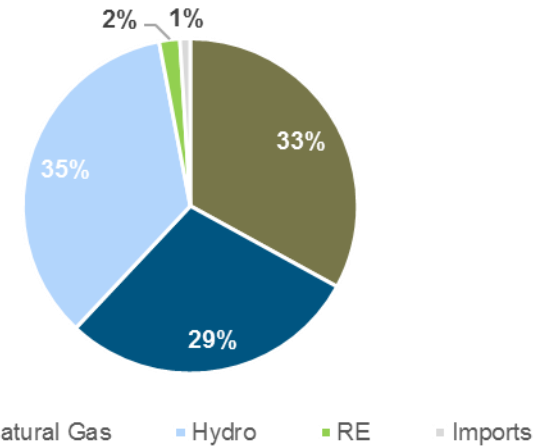
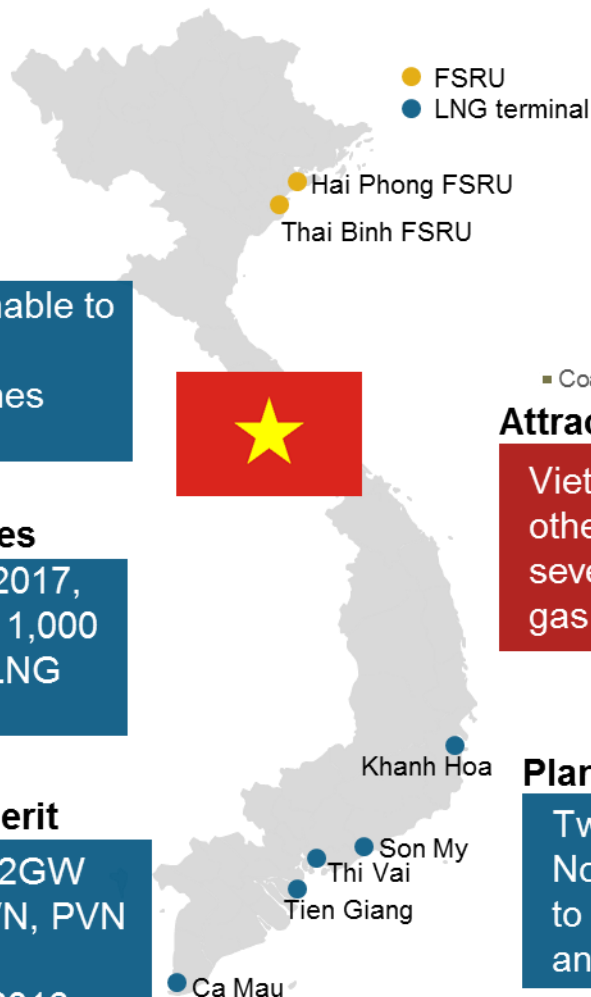
Existing gas fields are depleting and unable to support existing and planned gas-fired capacity. There is also a lack of pipelines connecting the South to other regions.

Ambitious plan to develop LNG facilities

Latest Gas Master Plan, released Jan 2017, forecasts that imported LNG will rise to 1,000 mmscfd by 2030 and proposes seven LNG terminals (incl. two FSRUs) by 2035.

Demand for gas-fired plants for mid-merit

16 CGGT power plants with a total of 12GW capacity are proposed to be built by EVN, PVN and BOT according to revised Power Development Plan 7 (PDP7) in March 2016.



Attractive market for foreign investors

Vietnam attracts high levels of FDI relative to other SE Asian countries. The country offers several incentives to foreign investors in the gas and power sectors.

Planned unallocated FSRUs in the North

Two planned unallocated FSRUs in the Northern region are expected by 2030 due to the need to replace depleting gas fields and the lack of pipelines.

Indonesia is ambitious to expand its LNG infrastructure, especially for small scale LNG solution due to its archipelagic nature with many remote areas

Robust Demand Growth

Large Demand Potential due to a large population, low rural electrification, high economic growth, and shortage of power

Experience with LNG and FSRUs

Indonesia, home to two existing FSRUs and a small FRU, plans to have nine additional FSRUs by 2020 based on GoI's infrastructure development plan.

Experience with Floating Power Plants

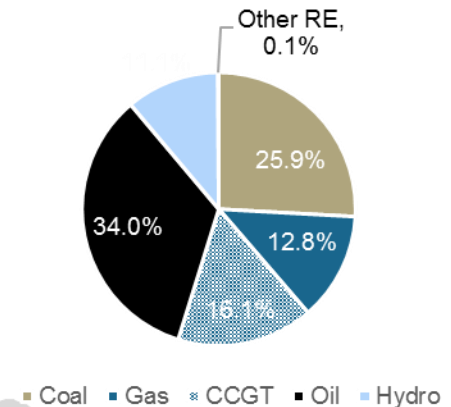
PLN awarded a 540MW contract to Karpowership to supply electricity in 5 regions using powerships. The first ship, the 125MW Zeynep Sultan, was inaugurated in Dec 2016 to start supplying to North Sulawesi

Quick Deployment Advantage

Implementation challenges and high demand growth mean significant unmet demand. Thus, there is a premium on the ability to rapidly deploy new capacity.

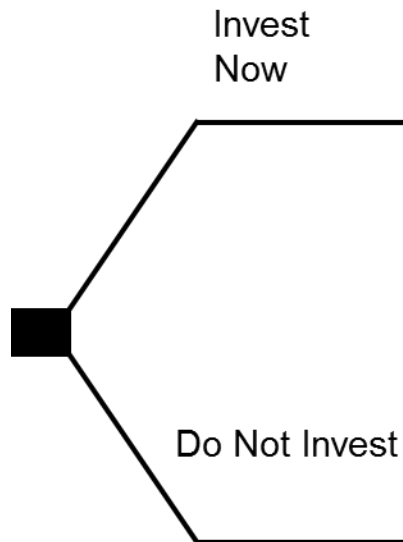
Remote Archipelagic nature ideal for FGPPs

Fragmented pipelines, archipelagic nature, and under-utilized natural gas reserves in remote locations mean small scale LNG based on a milk-run model could be well placed to supply power.

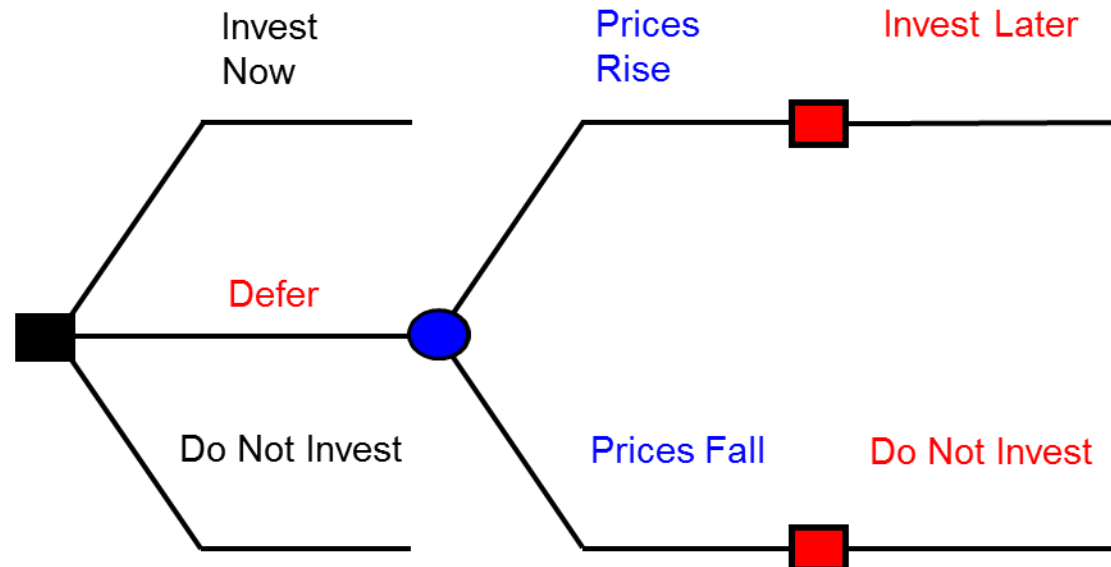


Evaluation methodologies can affect investment outcomes

Static Decision



Dynamic Decision



The ability to avoid an unfavourable outcome next year increases the value of deferral today

Third party access to LNG terminals, gas transmission and distribution is still not commonly adopted in Asia

	Terminals	Transmission	Distribution
Thailand	Third Party Access (TPA) on paper but all capacity in current and expansion booked by PTT and on-sold to EGAT.	TPA on paper for onshore pipelines and might be expanded offshore.	Bundled service offered by PTT NGD.
Indonesia	Owner controls access and procures LNG.	Allowed for some transmission lines but not enforced by regulator.	It is mostly a bundled service.
Pakistan	Tolling fee charged to users.	No. Two majority state-owned companies offer bundled service.	No. Two majority state-owned companies offer bundled service.
Philippines	Gas circular 2002 requires TPA on T&D but did not mention terminals. TPA at a terminal would depend on the condition of its permit.	Batman pipeline still hampered by lack of rights of way. Would have TPA if ever built.	Unlikely to develop as there is no meaningful residential demand.
Vietnam	None started construction yet. Not clear if an equity partner would get some capacity allocation.	Monopoly of PVGas	Monopoly of PVGas

Lack of third party access for gas infrastructures constraining options for all possible business models to build new lines and ways to monetize the gas infrastructures