Asia-Pacific
Economic Cooperation

Advancing Free Trade
for Asia-Pacific **Prosperity**

Study on Optimal Use of Small-scale Shallow-draft LNG Carriers and FSRUs in the APEC Region

APEC Energy Working Group

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Executive Summary

The twenty-one economies of the Asia-Pacific Economic Cooperation (APEC) are as diverse economically and culturally as can be found. Despite that fact, these economies all share in the common goal of sustained economic growth, particularly to foster the economic improvement of the lives of the populations in the underdeveloped APEC economies. In order to accomplish this, the underdeveloped economies will need to increase their energy use significantly. At the same time, the APEC economies need to recognize the need to foster economic growth in an environmentally acceptable manner. One of the more efficient and environmentally acceptable ways to foster this economic growth, at least until the transition to a zero-carbon economy, is through the use of natural gas.

Those economies that do not have sufficient natural gas resources to meet their growing demand will have to rely on imports. In most cases, those imports will need to be in the form of liquefied natural gas (LNG) because of the lack of pipeline infrastructure economically available from economies with gas production. For a subset of the APEC economies, their energy requirements and/or their physical geography dictates the use of small-scale and/or shallow draft LNG infrastructure.

As a result, APEC has commissioned this study to evaluate the potential application of small-scale shallow-draft LNG carriers and FSRUs (floating storage regasification units) in the APEC region. The objective of the study is to assess the practicality of these solutions focused on regional island-to-island, shallow coastal and/or river LNG transport. This report provides recommendations for the introduction of such LNG infrastructure.

SSLNG (small-scale LNG) is suitable for markets that experience any of the following traits or combinations of traits: demand of less than 1 MTPA (million tons per annum) or approximately 130 MMbtu/d (million British thermal units per day), scattered demand centers, lack of delivery infrastructure, variable demand, short timeline for implementation, and/or financial constraints. The infrastructure requirements for a SSLNG project can be fulfilled in onshore and/or offshore options, such as FSUs (floating storage units) with small onshore regasification equipment, FSRUs, LNGCs (LNG carriers), and ISO (International Organization for Standardization Intermodal) containers, either on ships or barges. Floating solutions are often more economical than their onshore counterparts, making them attractive to cash restricted economies. However, storage capacity may be a constraint when implementing these options as they are limited either by ship size or deck space.

Commercially, there are two basic models for these applications: merchant model and service/tolling model. In the merchant model, the project developer owns both the commodity and the infrastructure. In the service or tolling-model the developer or owner/operator receives a service fee for processing a third party's commodity through the facilities. A commercial variation on these models is the milk-run model where LNG is delivered to more than one terminal via one LNG carrier, including potentially utilizing one facility to "break-bulk" the LNG. This model has been studied for application in Southeast Asia (particularly in Indonesia) without being successfully implemented.

In this study, five APEC economies were shortlisted as potential candidates for the implementation of SSLNG solutions: Papua New Guinea, Viet Nam, the Philippines, Indonesia, and Thailand. These economies were selected considering their GDP per capita based on purchasing power parity, total primary energy supply per capita, and their coastal locations. SSLNG potential in Papua New Guinea is primarily driven by its efforts to increase electrification rates in its economy and the opportunity to have that be gas based. For the Philippines and Thailand, the incentive for SSLNG infrastructure is to move the economy away from coal and the potential for shallow water river transportation. In Viet Nam, the potential driver for the implementation of an SSLNG solution is to replace biomass (wood burning) for household energy supply. A potential segment for SSLNG would be bunkering. For Indonesia, the opportunity is driven by the fact that the economy is made up of seventeen thousand islands, all of which need more electricity and need to reduce use of biomass as an energy source.

In order to address one of the objectives of APEC regarding improving the lives of women in these economies, these shortlisted economies have been ranked according to the impact that the implementation of an SSLNG solution would have on women in the economy. Based on our analysis, the implementation of an SSLNG solution would have the greatest impact in Papua New Guinea, followed by the Philippines, Indonesia, Viet Nam, and Thailand.

Table of Contents

Glossary

Aggregator	A firm that acts on behalf of different smaller customers to combine them into one large customer to try to achieve the lowest possible price.
Baseload demand	Minimum amount of demand over a given period of time.
Charter	Reservation of a vessel for private use.
Delivery Ex Ship (DES)	Is a trade term by which the seller is required to deliver the goods to the buyer at an agreed port or arrival, aboard the ship, not yet cleared by Customs. Buyers are responsible for unloading the goods, clearance through Customs, and the associated costs.
Floating LNG	Water-based production, liquefaction, storage, and transfer facility.
Freight on Board (FOB)	Is a trade term by which the buyer is responsible for the transportation of the LNG from the liquefaction plant to the receiving terminal.
IMO 2020 sulfur cap rule	New 0.5% global sulfur cap on fuel content starting on January 1, 2020 enforced by the IMO.
LNG Bunkering	Providing liquefied natural gas fuel to a ship for its consumption.
Metocean	Meteorology and oceanography conditions.
Upside	Potential increase in value; appreciation.

Abbreviations

APEC	Asia-Pacific Economic Cooperation
ATB	Across-the-Berth
BCM	Billion Cubic Meters
BOE	Barrels of Oil Equivalent
BOG	Boil-Off Gas
BOT	Build, Operate, and Transfer
BTU	British Thermal Units
CAPEX	Capital Expenditure
CNG	Compressed Natural Gas
CNOOC	China National Offshore Oil Corporation
DES	Delivered Ex-Ship
E & P	Exploration and Production
FID	Final Investment Decision
FLNG	Floating LNG
FOB	Freight-on-Board
FPSO	Floating Production, Storage, and Offloading units
FRU	Floating Regasification Unit
FSRU	Floating Storage Regasification Unit
FSU	Floating Storage Unit
GID	Gross Inland Deliveries
GIIGNL	International Group of Liquefied Natural Gas Importers
GSA	Gas Sales Agreement
GSPA	Gas Sale and Purchase Agreement
GW	Gigawatt
HFO	Heavy Fuel Oil
IFV	Intermediate Fluid Vaporization
IGC	International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGU	International Gas Union
IMO	International Maritime Organization
ISO	International Organization for Standardization Intermodal Carriers

LNG	Liquefied Natural Gas
LNGC	LNG Carrier
LPQ	Liquefied Petroleum Gas
LTA	Liquefied Terminal Agreement
MMBtu	Million British Thermal Units
MMCFD	Million Cubic Feet per Day
Mtoe	Million Tons of Oil Equivalent
MTPA	Million Tons per Annum
MW	Megawatt
NDRC	National Development and Reform Commission
NM	Nautical Miles
OLT	Offshore LNG Toscana
OPEX	Operating Expenditure
ORV	Open Rack Vaporizers
PCEP	Philippines Conventional Energy Contracting Program
PEL	PT Pelindo Energy Logistik
PNG	Papua New Guinea
RUPTL	Indonesia’s Electricity Supply Business Plan
SPA	LNG Sale and Purchase Agreement
SSGC	Sui Southern Gas Company Limited
SSLNG	Small-Scale LNG
SSLNGC	Small-Scale LNG Carrier
STL	Submerged Turret Loading
STS	Ship-to-Ship
TCF	Trillion Cubic Feet
TCP	Time Charter Party
TOE	Tons of Oil Equivalent
TPES	Total Primary Energy Supply
TUA	Terminal User Agreement
US	United States of America

List of Figures

List of Tables

1 Introduction

The Asia-Pacific Economic Cooperation (APEC) is a regional economic forum established in 1989 to leverage the growing interdependence of the Asia-Pacific region, primarily concerned with trade and economic issues amongst its members. Twenty-one-member economies have joined in this initiative to create greater prosperity for the people of the region by promoting balanced, inclusive, sustainable, innovative, and secure growth and by accelerating regional economic integration.

As part of its goals, APEC promotes energy-related trade as well as the enhancement of access to reliable, efficient, and clean energy sources within its member economies, mandating "[the evaluation of] the potential of unconventional resources and to recommend cooperative actions which could…boost natural gas trade and use" with a priority "to evaluate the production, trade potential and environmental impact of shale gas and other unconventional natural gas resources, as well as promote steady investment in natural gas infrastructure, including liquefaction facilities, for increasing energy security and economic growth in the APEC region."

With continued projected energy demand growth in the Asia-Pacific region, the development and trade of natural gas resources is key to APEC's regional energy security agenda. Many APEC economies have plans to expand their energy matrices by importing liquefied natural gas (LNG). However, existing infrastructure in many of these economies is insufficient to accommodate the planned LNG imports. Among APEC economies, especially in South-East Asia, there is a growing list of Floating Storage Regasification Units (FSRU) proposals, which, if they came to fruition, could substantially boost APEC economies' use of LNG.

Small-scale shallow-draft LNG carriers could be used to serve FSRUs located in shallow water coastal areas, in harbors, and in rivers. In areas with no onshore regasification or storage facilities, FSRUs could be part of a virtual pipeline linked to onshore vehicles transporting gas to residential, commercial, and industrial end-users. The FSRUs would facilitate energy access through island-to-island, shallow coastal, and river LNG transport for areas in the APEC region that lack expansive LNG infrastructure for large LNG imports.

With this in mind, the APEC Secretariat has requested the preparation of a report to study the optimal use of small-scale shallow-draft LNG carriers and FSRUs in the APEC region. The primary objectives of the report are:

- to assess the practicality of small-scale shallow-draft LNG carriers and FSRUs in the APEC region and demonstrate their efficiency for regional island-to-island, shallow coastal, and river LNG transport.
- to develop considerations and recommendations for decision-makers in individual APEC economies so they can tactfully introduce this LNG infrastructure into their markets.

This report's explanatory information about the benefits of shallow-draft carriers and FSRUs as well as practical considerations will enhance the knowledge of key decision-makers in further developing their LNG markets.

The report is divided into seven chapters. Chapter 2 provides a baseline overview of the LNG value chain and its segmentation. Chapter 3 explains the SSLNG value chain, including market characteristics, technical specifications and value propositions, limitations of SSLNG, deployment status of vessels, proposed projects, and SSLNG in the context of APEC economies. Chapter 4 provides an overview of FSRUs. This chapter discusses the FSRU market characteristics, technical specifications, value proposition, limitations, global deployment, proposed projects, and FSRUs in the context of APEC economies.

Chapter 5 provides specific information on commercial aspects and strategy development focused on small-scale shallow-draft LNG development, such as business models and case studies. Chapter 6 identifies parameters to consider when planning the development of an SSLNG project, provides an economic comparison of various elements of the SSLNG value chain, and provides a Tool to be used as guidance by decision-makers when evaluating the suitability of developing a SSLNG solution. Chapter 7 studies the short-listed APEC economies which are the most suitable for implementing an SSLNG solution. The short-listed economies are ranked and prioritized based on the impact that implementing SSLNG solutions would have on women's lives. This chapter also provides recommendations on how to incentivize the development of SSLNG and FSRU solutions in these economies.

2 LNG Value Chain

With a global effort towards lower carbon emissions, countries are increasingly considering natural gas as the fuel for today and the future. Natural gas is primarily methane, which when burned results in less carbon dioxide (CO_2) emissions per British thermal unit (Btu) in comparison to hydrocarbon-based fuels (See Figure 1). According to BP's Energy Outlook 2019[1], renewables and natural gas will be the fastest growing fuel segments over the next two decades, and gas will comprise almost 25% of primary energy share globally. The demand for gas this decade is further supported by abundant reserves and low prices due to increased supply competition through pipeline trade and LNG.

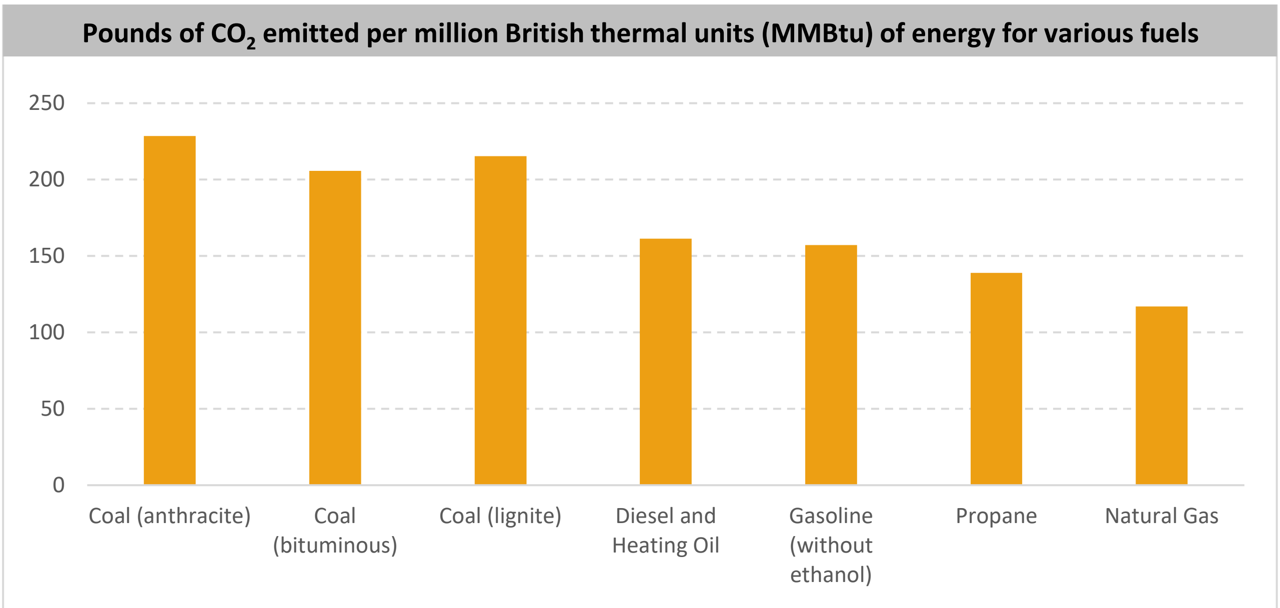

Figure 1: Carbon Dioxide Emissions by Fuel Type[2]

Natural gas is produced from organic matter trapped underground millions of years ago being subjected to high temperatures and pressure. Sources of natural gas can be broadly categorized into conventional and unconventional reserves. Conventional resources refer to natural gas that migrated into cracks and/or layers of impermeable rocks and can be extracted using conventional drilling methods. Unconventional natural gas refers to the occurrence of the hydrocarbon in tiny pores in shale, sandstone, or other types of rock formations and often is the source for the conventional resource.[3]

Global reserves of natural gas from conventional and unconventional resources amount to nearly 6,686 trillion cubic feet (Tcf) (enough to support global gas consumption for nearly 50 years at the current consumption rate). Most natural gas reserves are located in Russia, Iran, Qatar, the United States, Saudi Arabia, China, Australia, and Mozambique. [4] Figure 2 shows the natural gas reserves from some of the major markets around the world.

[1] (BP 2019)
[2] (U.S. Energy Information Administration 2019)
[3] (US Energy Information Administration (EIA) 2019)
[4] (World Energy Council 2019)(BP, EIA, FERC, Reuters)

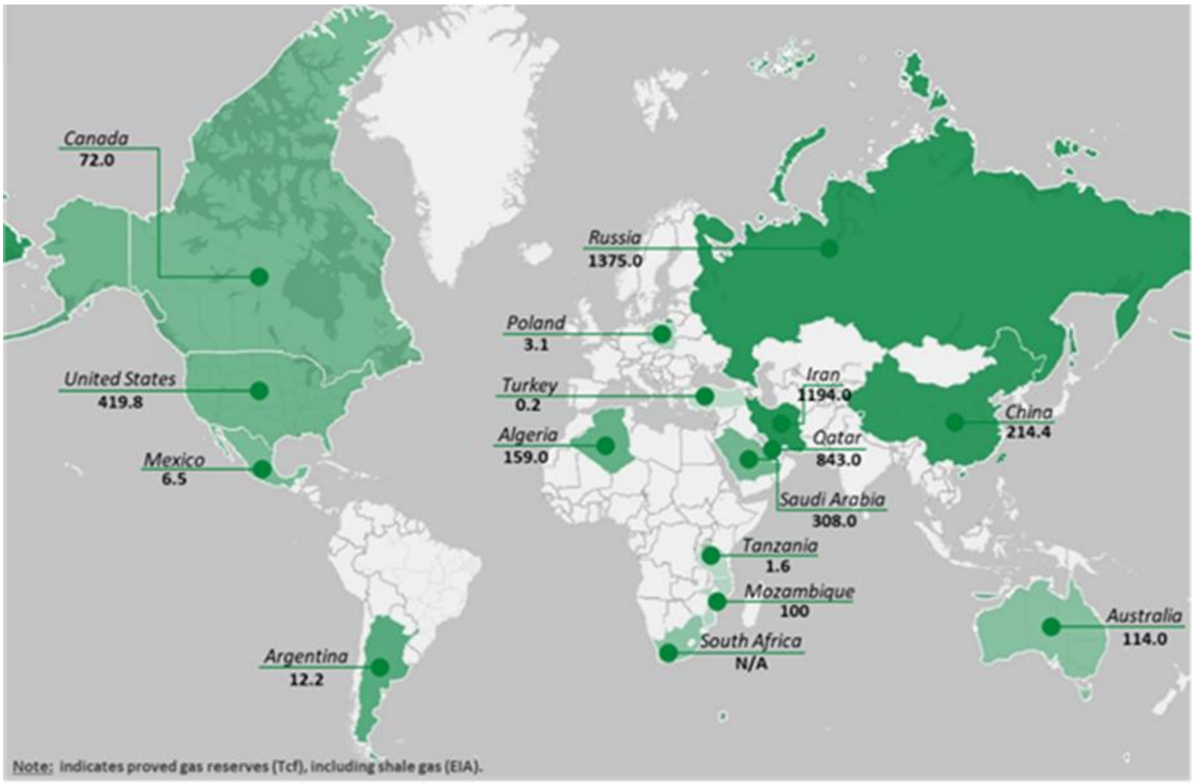

Figure 2: Global Reserves of Natural Gas[5]

Historically, natural gas was principally consumed regionally (via local production and/or pipeline imports) because of the limitation of economical inter-continental modes of transportation for the fuel. This challenge was eventually tackled by converting natural gas from gaseous to liquid form – LNG.

2.1 Value Chain and Segmentation

Figure 3 provides a simplified overview of the LNG value chain. In order to obtain LNG, natural gas is first extracted from upstream wells, then processed to remove impurities. After impurities have been removed, the gas is passed through various processes to prepare liquefaction-ready gas. These processes include acid gas removal, mercury removal, and dehydration. Finally, the liquefaction-ready gas is cooled to nearly -260 °F (approximately -161 °C), to reach a liquid state. Once liquid, the gas is stored in tanks at close to atmospheric pressure.

[5] (US Energy Information Administration (EIA) 2019)

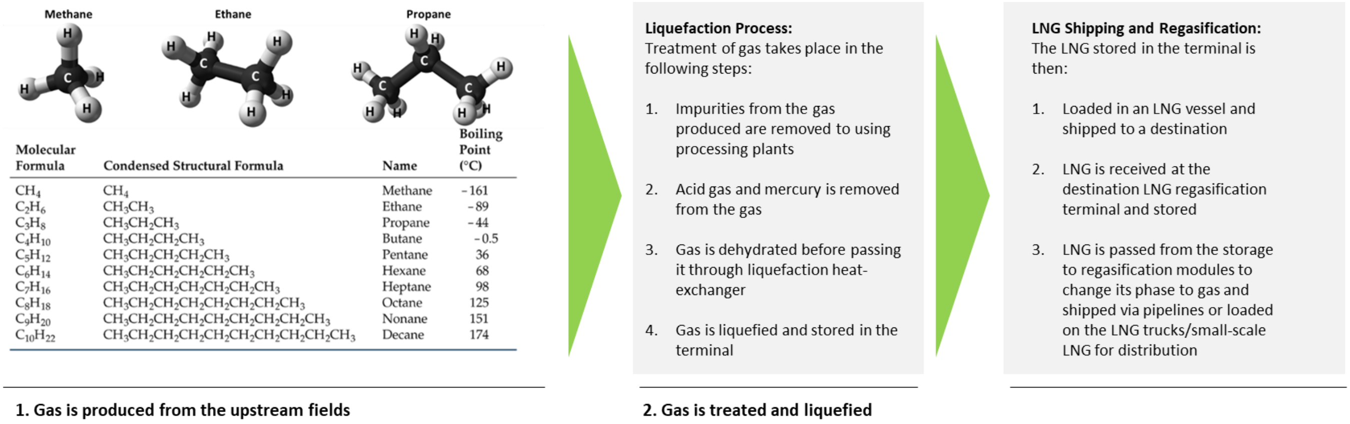

Figure 3: A Simplified LNG Value Chain [6]

The purpose of liquefying natural gas is to obtain a reduction of its volume by a factor of nearly 600 (under atmospheric pressure). This facilitates in the shipping of greater quantities of natural gas across long distances. Figure 4 compares transportation cost of natural gas using different modes. It shows that pipelines are a cost-effective method for transportation of gas over short distances yet, as distance increases, they become economically infeasible. This is particularly evident for offshore pipelines, represented by the red line on the left of the graph. At around 2,500 miles the cost increases to approximately US$4/106 Btu. Meanwhile onshore pipelines for the same distance are approximately between US$1.50 /106 Btu- US$2/106 Btu for low pressure pipelines and between US$1/106 Btu to US$1.50/106 Btu for high pressure pipelines. On the other hand, the LNG transportation cost curve is relatively flat compared to other modes of transportation thus providing lower unit cost of transportation per unit of energy as distance increases.

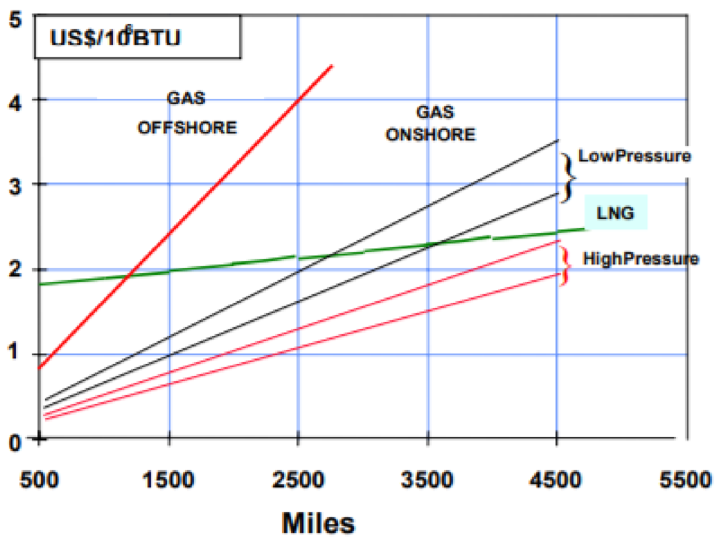

Figure 4: A Comparison of Transportation Costs [7]

Another factor for the selection of LNG over its gaseous form is the constructability of pipeline infrastructure. The construction of a physical pipeline may be challenging for technical, operational, social, commercial, and regulatory reasons. LNG provides the alternative of

[6] (Galway Group 2016)
[7] (Toscano, et al. 2016)

developing a virtual pipeline, which replicates the continuous flow of gas but using less static modes of transportation, including shipping, rails and roads.

As shown in Figure 4, the cost of LNG comes with a qualifier: large-scale baseload demand. As shown in the figure, the cost of delivering LNG is significantly impacted by the scale and nature of demand, the distance to be covered for the trade and the investment required. For example, for a demand of 50 million cubic feet per day (MMcfd) of gas delivered (equivalent to ~0.35 million tons per annum (MTPA) of LNG), using a long-term chartered vessel for a small distance (e.g. 100 nautical miles (nm)), the shipping cost could be as high as US$1.35 per million Btus (MMBtu,) whereas for a demand of 100 MMcfd, the cost is cut down to half of that. The high unit cost associated with a small volume of LNG to be shipped can be attributed to using a standard size LNG vessel (which costs nearly US$200 million[8]).

Infrastructure required to unload and store LNG is expensive. Some of the infrastructure requirements for an LNG terminal include a sizable amount of land, at least one large storage tank, a jetty and expensive cryogenic pipeline (either on-trestle or subsea), and dredging for vessel navigation, amongst others, which add further to the capital investment burden. Moreover, terminal utilization could vary significantly if the demand is seasonal in nature, for example high demand for gas in summer for power generation when demand for electricity increases for cooling, but low demand for gas for the rest of the year, causing the unit cost of infrastructure to increase.

To address these challenges of variable demand, size of investment, and supply chain economics, the LNG industry has moved away from one-size-fits-all solutions to bespoke solutions which address each individual application. Within the last 10 years, LNG liquefaction and regasification facilities – traditionally considered onshore projects – have been adapted for offshore applications utilizing various sizes and configurations on LNG vessels such as floating LNG (FLNG) and FSRUs. Distribution of gas is increasingly being considered most practical through the utilization of virtual pipelines in comparison to the previous method of using gas pipelines. Demand centers that were considered too small to be served with LNG are being catered to using small-scale bulk LNG and International Organization for Standardization Intermodal Carriers (ISO) containerized LNG. Figure 5 provides a visualization of the various components of the LNG value chain and their interactions.

The LNG industry has made an effort to standardize various elements of small-scale, mid-scale, and large baseload LNG value chain solutions. Some of these elements and their standardizations are further described in Table 1. This effort has improved the competitiveness of the industry and has increased the awareness of the availability of various configurations while helping to reduce associated costs.

Today, the scale of the development of a particular LNG project is mostly derived from the economic fit of the individual project. In the last decade, the LNG industry has explored multiple onshore and floating LNG value-chain concepts. As this report seeks to identify the optimal use for small-scale LNG Carriers (SSLNGCs) and FSRUs, most of the report will focus primarily on these two components of the small-scale LNG (SSLNG) value chain.

[8] (Galway Group 2017)

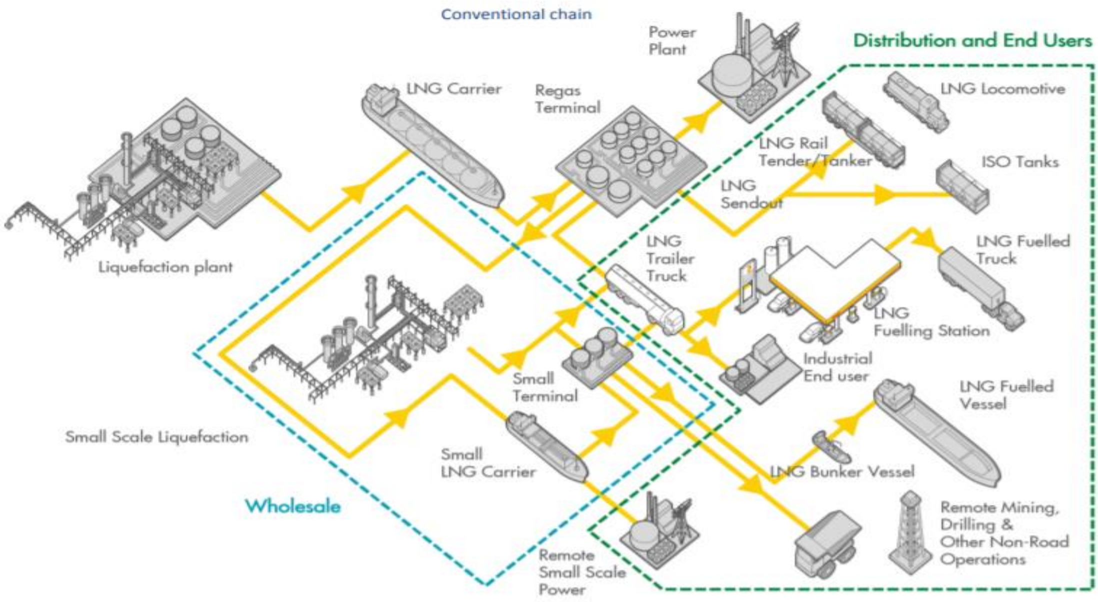

Figure 5: LNG Value Chain [9]

Elements	Small-Scale	Mid-Scale	Large Baseload
LNG Demand (MTPA)	0.1-1.0	1 – 3	> 3.0
LNG Shipping Vessel Capacity (m^3)	<30,000	30,000 – 138,000	138,000 – 267,000
LNG Regasification (MTPA)	0.1-1.0	1 – 3	> 3.0
Value chain elements (onshore)	Small-scale jetty, SSLNGC (Type C storage), bullet tanks or flat bottom storages, ISO containers, and LNG trucks	Small and medium size jetties (to support standard and small-scale operations), usually single, double or full containment tanks	Jetty (with ability to support large LNGCs), onshore tanks (>150,000 m^3), large regasification modules
Value chain elements (floating regasification)	Floating barges and small-scale FSRUs	FSRUs and Floating Storage Units (FSUs) with regasification on jetty	FSRUs and FSUs (limited examples)
Key Markets	LNG bunkering, diesel replacement in power and industrial, remote and stranded supply, remote demand	Small demand from diesel replacement in power/industrial, balancing fluctuation in demand	Large power utilities, industrial customers, traders

Table 1: Comparison of Technical Features of Small/Mid/Large-Scale LNG [10]

[9] (International Gas Union 2019)
[10] Galway Group

3 Small-Scale Value Chain

SSLNG is, essentially, the same as a standard-scale operation, but reduced in size and optimized for demand needs. The SSLNG value chain involves the use of SSLNGCs to carry LNG from a source (either an onshore or an offshore liquefaction terminal or regasification terminal with a reloading facility) to a destination. SSLNGCs are considered small-scale because they typically have a storage capacity smaller than 30,000 m^3 and have a shallow-draft capability between 5 - 8 meters, while a standard size LNGC usually requires between 12 – 14 meters. These vessels could be propelled using tugs or be self-propelled.

Once at the destination, SSLNGCs unload LNG into a small-scale tank, with a size less than 40,000 m^3. The LNG received at the terminal is then either regasified and injected into a pipeline network or transported to demand centers via LNG trucks and/or ISO containers. Figure 6 shows how an SSLNG fits into the overall LNG value chain.

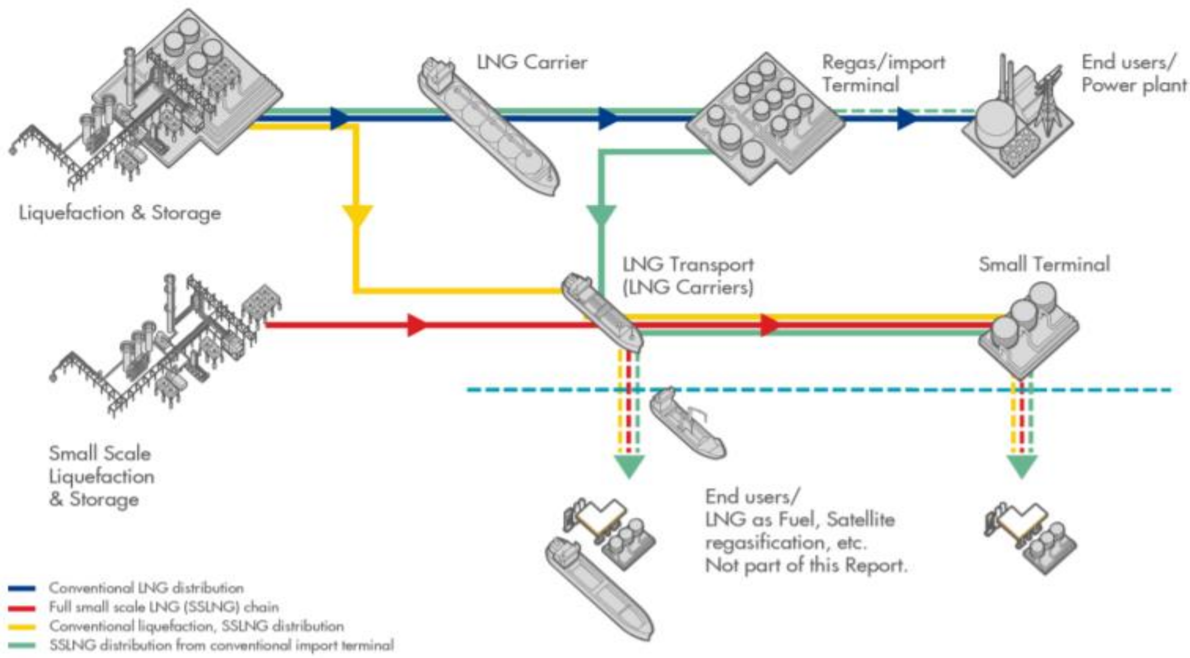

Figure 6: Small-Scale Value Chain Logistics[11]

3.1 Market Characteristics

The SSLNG market is expanding rapidly, with the following factors being consistent market characteristics:

- Small market demand pockets (usually power plant and/or industrial customers with less than 1 MTPA of aggregate demand)
- Substantial potential for LNG bunkering
- Shallow water draft access to the shore (usually less than 8 meters)
- Countries with developed inland waterways
- Archipelagos where development of pipeline infrastructure is infeasible

[11] (International Gas Union 2018)

- Substitute fuels are expensive when compared to LNG
- Mandated regulations on emissions
- Downstream gas demand is either low or has seasonal characteristics
- Economy is small to mid-size and lacks domestic natural gas transport infrastructure

3.2 Technical Specifications of SSLNGCs

As shown in Table 2, SSLNGCs are designed to carry less than 30,000 m^3 of LNG. The vessels' dimensions range from 100 to 200 meters in length and 15 to 30 meters in width and their operating speed remains in the range of 13 to 16 knots. Their fuel consumption usually less than 30 tons/day of LNG and the LNG boil-off in these vessels can be used as fuel.

Vessel Particulars	7,500 m^3	20,000 m^3	30,000 m^3
Vessel Dimensions (meters)	115 meters (length) x 18.6 meters (width)	147 meters (length) x 25.3 meters (width)	170 meters (length) x 29.5 meters (width)
Storage Capacity (m^3 LNG)	7,500 m^3	20,000 m^3	30,000 m^3
Draft Requirement (meters)	5.5 to 6 meters	7.8 meters	7.5 to 8 meters
Speed (knots)	13.5 to 15.7	15	16
Power Installed	Dual Fuel Main Engine 1 x 3,000 kW; Generating sets 2 x 1,065 kW	Dual Fuel Main Engine 1 x 5,950 kW; Generating sets 3 x 1,065 kW	Dual Fuel Main Engine 1 x 8,015 kW; Generating sets 2 x 1,065 kW
Fuel Consumption (LNG)	8 to 10 tons/day	18.1 tons/day	25 to 28 tons/day

Table 2: Comparison of Technical Features of SSLNGCs [12]

As per the International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC) codes, pressure designs for LNG storage on these ships occur in three categories: Type A for standard tank design; Type C for pressure vessel design; and Type B which falls in between the other two designs. From an LNG carrier perspective, all the large-scale vessels fall into the Type B category and have to follow the design specification necessary for Type B vessels. But unlike large-scale LNG ships, SSLNGCs are often designed using the Type C category of pressure vessels. Type C storage usually has thicker walls and thus higher steel costs; however, it is easier to fabricate. As a result of high wall thickness, the vessels can handle higher pressure from boil-off gas (BOG).

3.3 Value Proposition

Small-scale shallow-draft LNG carriers offer unique value to LNG markets (See Figure 7). These values include low draft accessibility, demand optimization, low capital outlay, flexibility, and shorter lead time.

[12] (Galway Group 2016)

Who has Small-Scale LNGCs?

Small-scale LNGCs (SSLNGCs) have been deployed in:

- Economies where the source of gas **supply is in close proximity to the small-scale demand centre**, making the logistics costs economically viable:
  - i.e. trade between Malaysia/Indonesia and Japan
- Economies with **scattered small downstream gas demand and infrastructure constraints** (i.e. accessibility – shallow draft, no pipeline network)
  - Northwest Europe, Indonesia
- Economies with significant **small-scale liquefaction/regasification terminal networks and expanding demand**:
  - China

Key Drivers	SSLNG Characteristics
Project Lead Time	– Slightly shorter than for Large-Scale LNGCs.
Capital Cost	– Smaller capital cost on absolute levels. (However, less economical in terms of cost/m³). – I.e. LNGC of 170,000 m³ costs ~ 1,200 $/m³, as compared to LNGC of 50,000 m³ which costs 4,200 $/m³.
Flexibility	– SSLNGCs are able to service the expanding and/or seasonal demand requirements. – Where supply contracts allow it, an SSLNGC can also accommodate re-balancing of demand, moving product from one terminal to a more needed destination.
Accessibility	– Having smaller draft requirements, the key advantage of SSLNGCs is accessibility to shallow water areas.

Suppliers/project developers are increasingly comfortable with SSLNGC solutions

- Successful decades of operational history of LNGCs, dating back to 1974 when the first SSLNG was constructed (Seagas in Sweden).
- As of July 2019, there were 54 SSLNGCs on the market with an additional 8 on order.

Figure 7: Value Proposition for SSLNGCs[13]

(a) **Low draft accessibility:** One of the most important value propositions of SSLNGCs is that they allow LNG to be easily distributed to shallow-draft locations. In contrast, a standard-scale LNG vessel requires a water draft greater than 12 meters and such a water depth may be available farther from the shore, which, in turn, would require a long jetty and potentially significant dredging, requiring heavy capital outlays.

(b) **Capital expenditure (CAPEX) needs and demand matching:** Conventional LNGCs require an upfront capital investment of nearly US$200 million (170,000 m^3), as compared to SSLNGCs' US$65 million (20,000 m^3). Although the per unit cost is higher for an SSLNGC than for a conventionally sized ship, savings can be gained by the berthing closer to shore, by the use of a smaller onshore storage tank, and by matching demand. The integration of these elements develops a comparably competitive small-scale value chain.

(c) **Flexible operations:** SSLNGCs add flexibility to the supply chain for seasonal demand (increasing the number of vessels or re-distributing the commodity). Additionally, the vessels can be used in other operations including break-bulk and LNG bunkering, a market which is beginning to show tremendous growth potential.

3.4 Limitations of SSLNG

There are several limitations attributable to SSLNG supply chains, mostly concerning the economics of the entire supply chain. Some of these limitations include distance from source, limited market for re-deployment, and diseconomies of scale.

(a) **Distance from source:** One of the primary disadvantages of using SSLNGCs is the cost to transport volumes of LNG over a long distance as compared to utilization of standard

[13] (Galway Group 2016)

sized ships. As the distance between the source of LNG and the small demand center increases, a greater number of SSLNGCs need to be deployed and, as this number increases, the economics of SSLNG rapidly deteriorates (the per unit cost of LNG carried can be two to three times as expensive).

(b) **Limited market for re-deployment:** Unlike standard-scale LNGCs, SSLNGCs are usually deployed regionally and are tied to specific projects. In some cases, however, these vessels can be used to transport liquefied petroleum gas (LPG)/ethylene, but such opportunities are limited. The reasons for this limitation include uneconomic shipping over long distances, undeveloped markets for small LNG volumes, and limited compatibility across the globe. As a result of the limited potential for redeployment, SSLNGC operation carries more market risk than that of conventional ships.

(c) **Diseconomy of scale:** As mentioned previously, SSLNGCs generally are constructed using type C tanks for storage. These tanks are constructed using pressure vessel standards and are relatively costlier than standard-scale LNGC storage tanks. Additionally, the cost of constructing SSLNGCs does not fall proportionately with size. For example, a 5,000 m^3 SSLNGC can cost between US$28 million and US$34 million or nearly US$6,000/$m^3$, whereas a 30,000 m^3 vessel can cost in the range of US$80 million to US$90 million (nearly US$3,000/$m^3$] while a conventional sized ship would cost less than $1,200/m3.

3.5 Current SSLNGC deployment status

Although some of the first LNGCs deployed were SSLNGCs (Methane Princess and Methane Progress - 35,000 $m^{3,}$ in 1964, which transported LNG from Arzew, Algeria to Canvey Island, UK), SSLNG saw limited potential prior to 2010 as the LNG value chain requires heavy investments and significant contractual commitments. During this time SSLNGCs were used in Japan where the Aman Bintulu (18,900 m^3), Aman Sendai (18,900 m^3), and Aman Hakata (18,800 m^3) transported LNG from Malaysia, whereas the Surya Aki (19,400 m^3) and the Surya Satsuma (23,000 m^3) transported LNG from Indonesia.

Demand for SSLNGCs has seen rapid growth during the 2010s due, in part, to increased environmental awareness, regulations for cleaner fuel (e.g. the International Maritime Organization restrictions), plentiful availability of LNG together with its low price (subject to demand and infrastructure constraints, which changes from time to time), and the evolution of proven LNG technologies. As a result, about 17 SSLNGCs were delivered as of 2015. The trend has continued and more than 30 SSLNGCs have been added since. Figure 8 traces the deployment of shallow-draft SSLNGCs and provides some details on the future order book for such vessels. The vessels reflected in Figure 8 include multi-gas carriers which are currently carrying either ethane or LPG, but can be used to carry LNG.

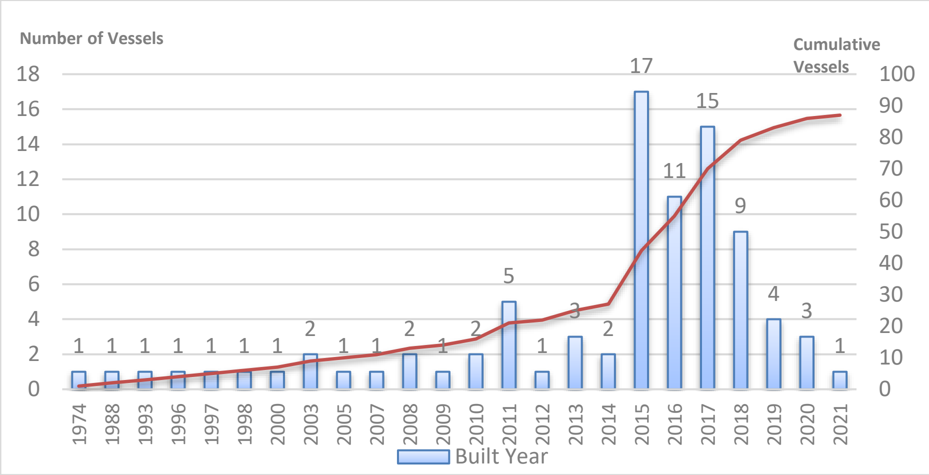

Figure 8: Evolution of SSLNGCs [14]

Approximately 65% of the existing and planned SSLNGCs vessels are under 10,000 m^3 of capacity, as can be seen in Figure 9.

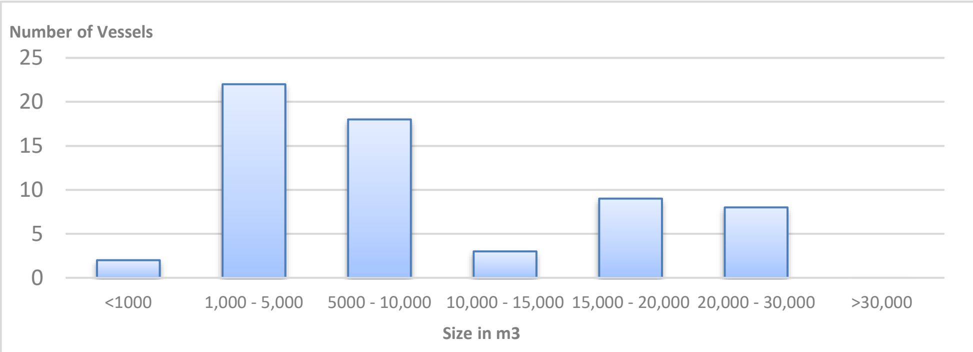

Figure 9: Split of SSLNGCs by Size [15]

Figure 10 shows that almost a quarter of SSLNGCs currently trading are located in Japan and China and about 20% are located in the United States and Northern Europe. The trade in Japan is mostly driven by a lack of domestic pipeline infrastructure due to issues with the terrain and the fact that its markets are scattered in different geographic locations, with nearly 100 satellite facilities for LNG distribution. Meanwhile China's SSLNGC needs are mostly driven by LNG bunkering and distribution of LNG to its coastal regions. Similarly, for North-West Europe, LNG distribution and bunkering are the major drivers for SSLNG.

[14] SSLNGC Database, Galway Group.
[15] SSLNGC Database, Galway Group.

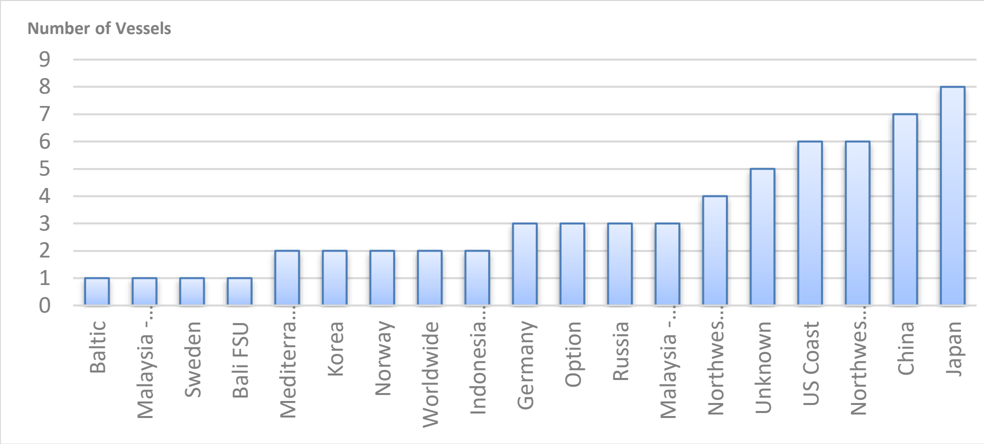

Figure 10: SSLNGCs by Region of Trade[16]

Despite that fact that there is a concentration of markets for SSLNGCs, the market participants appear to be fragmented with no clear leader (multi-gas carriers currently not trading in LNG are excluded from the list). Figure 11 shows the major SSLNGC players and the number of vessels owned.

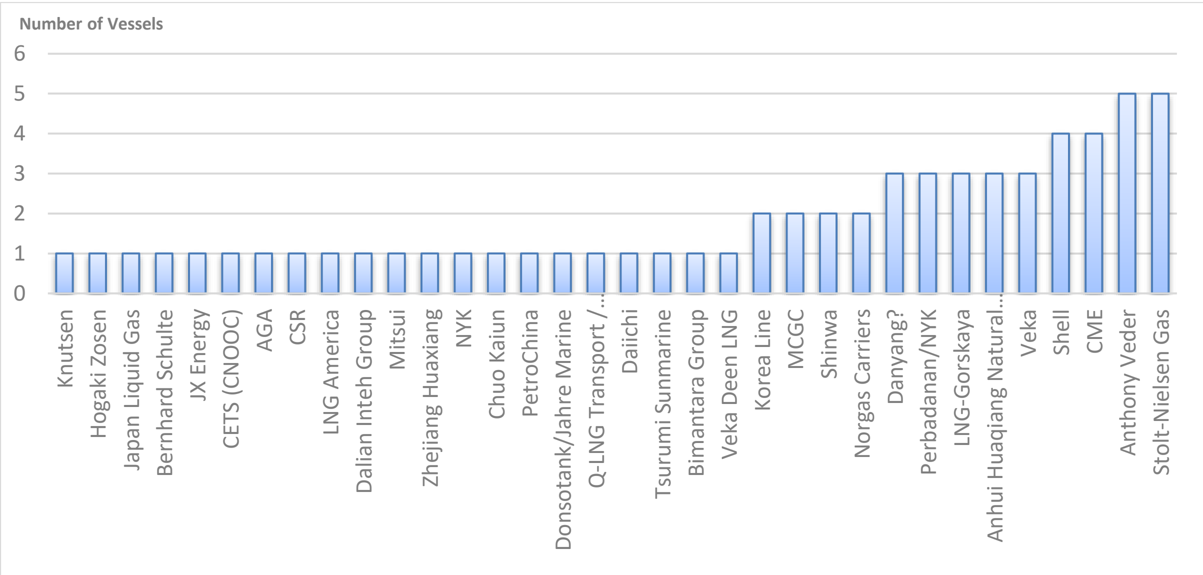

Figure 11: Ownership of SSLNGCs [17]

Stolt-Nielsen Gas and Anthony Veder each own five SSLNGCs and they all are trading LNG in North-West Europe primarily to serve conventional, but remote, markets. Shell's vessels are mainly used for LNG bunkering operations. Anhui Huaqiang Natural Gas leads LNG bunkering in China with the most LNG vessels trading there. Perbadanan/NYK retains ownership of vessels trading between Malaysia and Japan.

[16] SSLNGC Database, Galway Group.
[17] SSLNGC Database, Galway Group.

3.6 Proposed SSLNG Projects

Suitable locations for SSLNG networks include areas with shallow water drafts, scattered energy demand centers (including electricity), and emerging market economies, although certain developed economies are also pursuing SSLNG solutions for their remote or unconnected demand centers.

Another market driver to develop SSLNG projects is LNG bunkering demand, common in European ports and also deployed in other markets as a result of IMO restrictions that are coming into effect in 2020. Figure 12 shows some proposed locations for shallow water SSLNGC distribution facilities, including the Caribbean, Northern Europe, and South-East Asia.

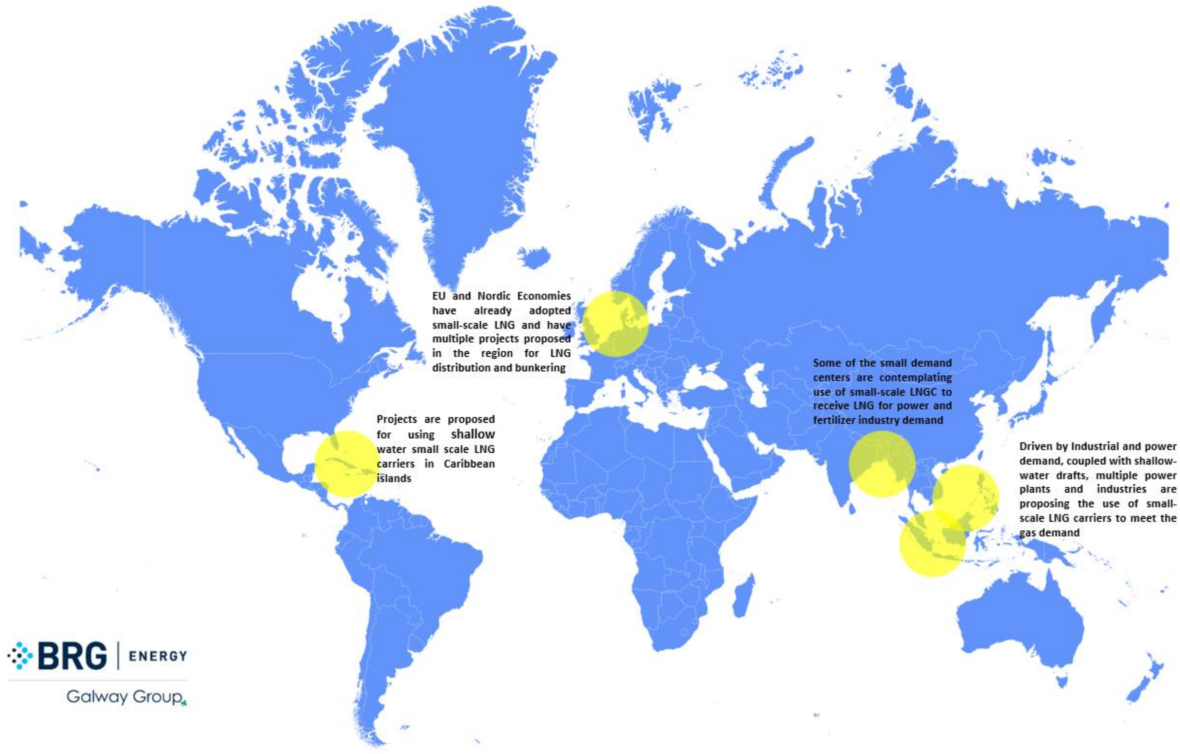

Figure 12: Proposed SSLNG Projects [18]

The proposed projects mentioned in Figure 12 cover a broad spectrum of applications. For example, there is an increasing interest in inland waterways where SSLNGCs are being considered to provide LNG to satellite stations for domestic retail distribution. In addition, there are an increasing number of applications for LNG trucking, locomotives, and LNG bunkering.

3.7 SSLNG in the Context of the APEC Economies

In the global context, the increasing demand for LNG results from (1) environmental initiatives (sometimes enforced by regulations) and (2) price competitiveness (better delivered price per unit of energy as compared to other fuels). In the SSLNG space, other drivers are infrastructure

[18] SSLNGC Database, Galway Group.

limitations and capital constraints. Some of the reasons why SSLNG and shallow-draft SSLNGC solutions are becoming increasingly popular in APEC economies are described in Table 3. Figure 13 maps the drivers for SSLNG for some APEC economies.

Economy	Drivers for adopting SSLNG and SSLNGC activities
Australia	Potential for SSLNG usage in mining operations as a replacement for diesel. Diesel utilization in mining segment in Australia has been driven by the scarcity of gas pipelines and the absence of an adequate power grid. LNG offers a cleaner alternative to diesel (emitting 25% less carbon emissions), while also being able to access remote locations (e.g. with SSLNGCs or trucks).[19] However, a potential barrier might be the fact that many mines are landlocked (SSLNGCs require a port access), therefore a combination of SSLNGCs with long distance trucking might be required, which will ultimately drive up the cost of delivery.
Brunei Darussalam	Limited, potential small demand pockets. No initiative to date.
Canada	Considering small-scale options in both its northeast and southwest; LNG trucking and ISO container modes exist for industry/power sectors as well as residential sector in remote communities. SSLNG infrastructure could be adopted by remote off-grid industries (such as mines) and remote communities that are not connected to either an electricity network or gas pipelines. These remote areas typically rely on diesel, propane, or other fuel oils for heating and other energy needs. These products are being shipped by truck, rail, or ship. LNG is preferable to those conventional fuels because of its greater cost competitiveness as well as its environmental benefits.[20]
Chile	Has opted for SSLNG distribution using trucks and has the potential for use of SSLNGCs for small demand centers in coastal areas.
People's Republic of China	In expansion mode. Small and scattered demand centers exist in the Yangtze River area and in inland water ways. There also is a potential for more LNG bunkering activities.
Hong Kong, China	Has plans for a large-scale FSRU and there is limited discussion concerning SSLNGC. However, a newly developed FSRU could drive future SSLNG activities. Also, there is the potential for bunkering operations, since Hong Kong, China is a major trading port for Asia.

[19] (Cockerill 2019)
[20] (Canadian Gas Association 2016)

Indonesia	Large potential for SSLNG applications for break-bulk distribution to scattered small demand centers. Multiple tenders have been floated for gas-to-power projects, however, there has been limited development to date. Indonesia has precedents for deployment of FSRUs, both large-scale (Lampung) and small-scale (Benoa).
Japan	The first SSLNGC user in Asia, with multiple vessels operating both along its coast and internationally and the complete LNG supply chain developed. The demand is mostly driven by power generation. Japan has limited potential for FSRU deployment due to unfavorable metocean conditions. Japan uses ISO containers loaded on rails and LNG trucks to make LNG available to remote locations not connected with its gas grid.
Korea	Environmental drivers are increasing LNG demand, the adoption of SSLNGCs, and LNG bunkering. Kogas and the Busan Port have decided to undertake feasibility studies on the use of floating LNG bunkering solutions. Kogas is also chartering two SSLNGCs (7,500 m^3 each) to transport LNG from Tongyeong LNG import terminal to a mid-scale receiving terminal on Jeju Island.
Malaysia	SSLNG is increasingly being discussed for use in Malaysia, using either SSLNGCs or ISO containers for power generation and industrial customers that are not well connected with gas pipelines and/or favor replacement of existing fuel with LNG (mostly diesel or HFO). Malaysia is expanding LNG bunkering service offerings, having completed its first LNG bunkering operation in November 2018 using a 7,500 m^3 LNG bunkering vessel (Kairos). [21] Malaysia has developed an FSU (Melaka) as well as FLNG facilities (PFLNG Satu).
Mexico	SSLNG mostly through LNG trucks for power and industrial users. Also, multiple players are interested in expanding the LNG market.
New Zealand	Limited SSLNGs activities in the economy.

[21] (LNG World News 2018)

Papua New Guinea	An exporter of LNG with upcoming expansion of LNG production. However, there are limited activities for SSLNGCs. Due to low electrification rates (12% as of 2018) and the member economy government's objective of reaching 70% electrification rates by 2030[22], there could be potential for an economy-wide SSLNG supply chain. This would maximize the distribution of Papua New Guinea's gas resource. Development of potential hydropower and other renewable energy resources may slow the development of gas resources.
Peru	LNG exporter with limited SSLNGC activities.
The Philippines	Multiple parties (e.g. First Gen, Tokyo Gas, PNOC, etc.) have shown interest in the development of an SSLNG supply chain for power and industrial customers. These concepts are largely in the proposal stage. There is potential for SSLNGCs in the region since small demand centers are scattered across the archipelago, requiring a suitable delivery method. Due to depleting gas supplies from the Malampaya field, which supplies gas to power plants in the Batangas area, several LNG import terminals are proposed which could act as break-bulking facilities for further shipment of LNG to small-scale demand centers across the archipelago.
Russia	As one of the largest LNG exporting nations, Russia has been active in deployment of both large-scale and SSLNG for both its international trade (e.g. ~19,531 m^3 SSLNGCs "Sun Arrows" deployed on a trading route between Russia, Japan, and Malaysia), as well as for supplying its coastal demand centers (e.g. 3 x 7500 m^3 Gorskaya SSLNGCs). There is potential for SSLNGC deployment in the future as part of national plans to increase accessibility of natural gas (not only by pipeline). There has been an FSRU deployed in Russia, near Kaliningrad. This facility was put into operation in January 2019 with the objective of enhancing the region's energy security. No other FSRUs are planned or are in development in Russia.
Singapore	World's biggest bunkering port spearheads LNG bunkering in Asia with multiple bunkering vessels. Small-scale loading has been performed numerous times. Singapore is an important location for LNG break-bulking utilizing SSLNG ships.
Chinese Taipei	Limited activities in SSLNGC, however, there have been discussions concerning the use of FSRUs.

[22] Papua New Guinea - 15-year National Distribution Grid Expansion Plan

Thailand	Demand centers are small and scattered along coastal regions and on islands off the mainland. There is potential to convert diesel power plants and industrial users to gas/LNG as a cleaner energy alternative. SSLNG potential has been identified for use in the natural rubber industry during the drying process and for boat taxis, compressed natural gas (CNG) stations, heating for the ceramics industry, industrial estates, and steel mills. Industrial users in southern and central Thailand have decided to build an SSLNG jetty at Map Ta Phut Terminal, which was constructed to accommodate vessels of up to ~5,000 m^3 capacity. Thailand has advanced plans for the development of LNG bunkering infrastructure ahead of the IMO 2020 sulfur cap rule.
United States (US)	LNG demand comes from marine bunkering for trans- ocean and inland vessels, peak-shaving power plants, railway locomotives, oil and gas rigs, and fueling stations. There are consistent efforts to expand the SSLNG value chain. Some multi-gas carriers from North-West Europe are currently trading ethane from both the US East and Gulf coasts. These carriers are capable of carrying LNG and could be used to trade US LNG in Europe and Canada. The demand for decentralized power is expected to further increase demand for LNG delivered via trucks and ships on inland waterways. These markets are driven by economic and environmental initiatives.
Viet Nam	Demand centers in Viet Nam are small, scattered along coastal regions, and located on islands. There is potential for diesel power plants and industrial users to convert to gas/ LNG.

Table 3: Overview of the Drivers for Adopting SSLNG and SSLNGC Activities[23]

Figure 13: Drivers of SSLNG Value Chain[24]

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[23] (Galway Group 2016)
[24] (Galway Group 2016)

4 Overview of FSRUs

FSRUs are a relatively new concept in the LNG industry. They incorporate regasification equipment on LNG vessels to provide regasification services from within the vessels themselves. The origins of the FSRU industry date back to 2005 when the United States was experiencing a shortage of domestic gas. LNG import projects were developed to supplement domestic gas supplies in both the Gulf Coast as well as the northeastern part of the United States.

After domestic gas supplies began to increase, the LNG import facilities were no longer needed. Owners of the FSRUs then marketed them to applications elsewhere. The concept was gradually adopted in various locations around the world. As of February 2019, there were 33 FSRUs available globally as well as 3 operational FSUs.[25] 22 FSRUs were deployed as regasification terminals, while 9 were being used as LNGCs and 2 were laid up/in repair.

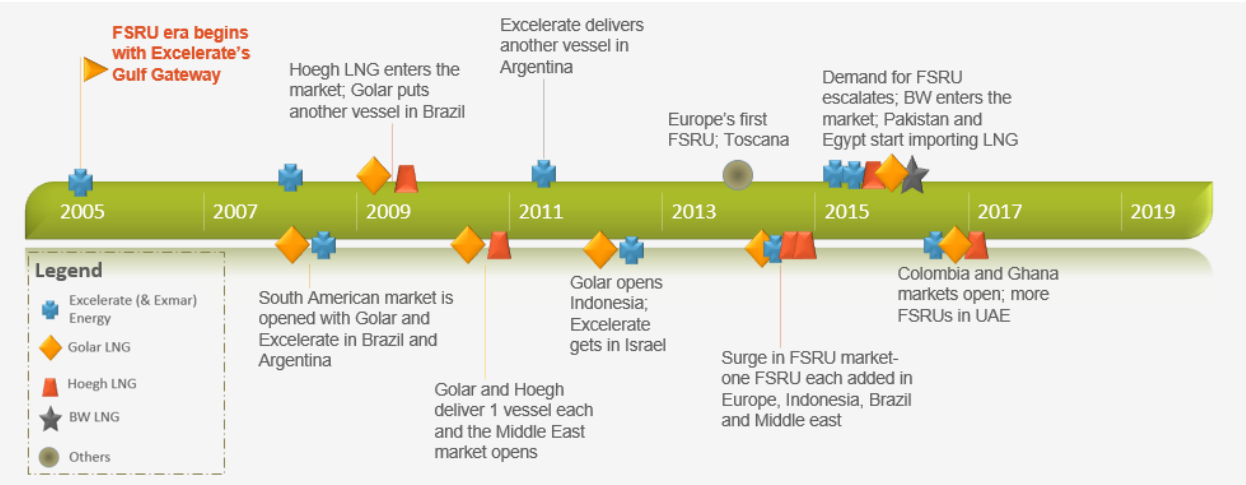

Figure 14: Evolution of FSRUs [26]

4.1 Market Characteristics

FSRUs are a flexible, cost-effective way to receive and process LNG cargos into gaseous natural gas. Floating regasification solutions are increasingly used to meet natural gas demand in locations around the globe and have the following attributes.

- Markets with limited access to significant upfront capital and those with sub-investment grade credit (low investment preference).
- Deepwater access to the shore.
- Economies where solutions have to be achieved in a short time period.
- A bridging solution is required before development of either domestic gas reserves or large-scale onshore LNG regasification terminal.
- Downstream gas demand is either low or has seasonal behavior (acute demand in some seasons and low demand in others).
- An economy is vast and lacks domestic natural gas transport infrastructure.

[25] Galway Group FSRU database, (GIIGNL- International Group of Liquefied Natural Gas Importers 2019), combined with publicly available data.
[26] Galway Group FSRU database, (GIIGNL- International Group of Liquefied Natural Gas Importers 2019), combined with publicly available data.

- An integrated solution is required to dispel any supply uncertainty.
- Site, environmental, and public safety constraints to build an onshore receiving facility.

These market characteristics are common with many emerging and developed markets.

4.2 Technical Specifications

An FSRU is similar to an LNG vessel, but with regasification modules installed on deck. Table 4 shows typical FSRU dimensions and technical specifications currently used by industry.

Vessel Particulars	Typical Values
Vessel Dimensions (meters)	300 meters (length) x 50 meters (width)
Storage Capacity (m^3 LNG)	130,000 to 180,000
Draft Requirement (meters)	12 to 15 meters
Throughput (MMSCFD)	500 to 700
Number of Regas Kits (NOS)	3-4 (Operating) + 1 (Stand by)
Fuel Consumption (% of send-out)	0.5% to 3% depending on technology

Table 4: Typical Dimensions and Technical Specifications of an FSRU[27]

A typical regasification process using an FSRU involves the following steps.

1. The LNGC arrives and moors side-by-side or across the berth, to the FSRU.
2. LNG is transferred from the LNGC to the FSRU using side-by-side flexible hoses or across a berth using hard arms.
3. LNG is then regasified in the FSRU by means of on-board regasifiers using either seawater or fired heat exchangers, and then pumped onshore via a natural gas pipeline (either subsea or over trestle).
4. The gas is received in an onshore receiving facility, metered, and sent to the end consumers.

An FSRU can assume one of multiple configuration options for water depth, mode of LNG transfer, and berthing and mooring configuration. The choice of mooring configuration impacts the floating terminal's reliability and availability because of the impact of meteorological (wind) and ocean (waves and currents) conditions by affecting:

- Availability to regasify LNG and send-out natural gas; and
- Availability to berth and unload a delivery ship.

The choice of water depth determines the type of FSRU modification and mooring structure (jetty or submerged buoy). Table 5 shows various mooring options based on asset scale. The mode of LNG transfer- Across-the-Berth (ATB) or Ship-to-Ship (STS) - determines the acceptability among the LNG suppliers. Supplier acceptability is especially important because it directly affects the competition for LNG supply to the terminal.

[27] Galway Group and publicly available data

	Standard Scale Solution	Small/Mid-Scale Solution
Near Shore Options	- FSRU with Single Berth & "STS" LNG Transfer - FSRU with Double Berth & "ATB" LNG Transfer	- Small/Mid-Scale FSRU with Single Berth & "STS" LNG Transfer - Small/Mid-Scale FSRU with Double Berth & "ATB) LNG Transfer - Regasification ATB Barge with Single Berth
Offshore Options	- FSRU with Single Submerged Mooring Buoy with STS - FSRU with Above Water Single Point Mooring (Fixed or Floating) with STS	- Small/Mid-Scale FSRU with Single Submerged Mooring Buoy with STS - Small/Mid-Scale FSRU with Above Water Single Point Mooring (Fixed or Floating) with STS - Regasification Barges with Single Submerged Mooring Buoy

Table 5: Comparison of Various Mooring Options Based on Asset Scale[28]

On-board LNG regasification is carried out by using heat exchanger systems. These systems are compact and thus suitable for the small deck space on the LNG carrier. LNG regasification can be achieved using either closed loop, open loop, or mixed loop Intermediate Fluid Vaporization (IFV) regasification systems. These processes are described below.

- Closed Loop Regasification: In a closed loop regasification, the LNG is vaporized by pumping it through a shell-and-tube heat exchanger with the heat being supplied from a water-glycol, or other intermediate fluid, mixture heated by steam from an on-board system. The natural gas is then sent to the export manifold. This process is highly fuel intensive; however, it is useful in case either the sea water temperature is lower than 14° Celsius or the use of sea water is not permitted by regulatory authorities.
- Open Loop Regasification: In an open loop regasification system, sea water is used as a medium to vaporize LNG into natural gas. The process does not require any additional heating and, thus, is less energy intensive as compared to closed loop regasification. Sea water temperature for such operation is expected to be greater than 14° Celsius so that the water does not freeze inside the heat exchanger (a 10° Celsius drop in water temperature can be expected in the process).
- Hybrid or IFV regasification system: an IFV system is similar to a closed loop regasification system, but instead of heating the intermediate fuel (propane or water-glycol mixture) with steam, sea water is used as a heating medium. This regasification system can work either on an open loop or closed loop system.

4.3 Value Proposition

FSRUs are increasingly popular with economies that have seasonal demand patterns, infrastructure and capital constraints, and immediate needs for regasification. Figure 15 describes the FSRU drivers and parameters considered during development.

[28] Galway Group and publicly available data

Who has FSRUs?

FSRU has been deployed as an option in the economies with:

- With downstream gas **demand uncertainty** (seasonal or erratic)
  - Brazil, Argentina
- Where solutions have to be achieved in a **short time,** for **bridging solution,** or where demand is low:
  - Kuwait, Jordan, Lithuania, Israel etc..
- Which are **geographically scattered** and which have gas **infrastructure constraints:**
  - Indonesia, Malaysia, Brazil and Argentina
- Where **low capital investment** is the key constraint
  - Bangladesh, Pakistan

Key Drivers	FSRU Characteristics
Project Lead Time	Significantly shorter in economies where Government permitting process is simple
Capital Cost	Medium unit capex cost compared to onshore terminal
Smaller Footprint	Easier to build with land constrained market due to smaller onshore infrastructure

Suppliers are increasingly comfortable with FSRU based import terminal solutions

- A successful decade of operational history of FSRUs with no accidents
- Reliability of operations and certain proven configurations
- Cooperation and participation in determination of best configuration to ensure smooth operations of the facility

Choice of mooring configuration impacts floating terminal's reliability and availability because of impact of meteorological (wind) and ocean (waves and currents) conditions

- Decades of FPSO operations and evolving technologies in LNG unloading increased supplier confidence about STS operations.

Figure 15: Value Proposition for FSRUs [29]

Some of the key value propositions of an FSRU terminal development are as follows.

(a) **Lower upfront capital requirement** - One of the primary drivers for selecting an FSRU option is the low upfront capital investment requirement for a standard size LNG terminal. A typical FSRU can be chartered at US$40 million/year (along with nearly US$200 to US$400 million for associated facilities) as compared to a similar-sized (gas send-out) onshore facility, which can cost in the range of US$1.0 billion to US$1.5 billion[30].

(b) **Faster development timeline:** The development timeline of an FSRU-based project can vary between 12 to 36 months. If an FSRU is already available, the delivery time is even shorter. However, if an existing vessel is converted, it could take anywhere between 12 to 18 months. In the case of a new-build FSRU, the construction and delivery time could be up to 3 years. This is considerably shorter compared to an onshore development, which requires between 48 to 56 months for development. The time advantage for an FSRU-based project can be attributed to the controlled construction environment in a shipyard and speculative FSRU availability in the market.

(c) **Asset mobility:** FSRUs provide flexibility of location, as they can be placed as close to the demand center as possible, (with lower cost for regasification capacity for delivered gas) and flexibility of use, as in the case of seasonal demand where the regasification capacity requirement is limited during off-seasons and the FSRU can be deployed as an LNGC.

4.4 Limitations of FSRUs

Although FSRUs have capital and mobility benefits, there are several limitations of an FSRU solution:

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[29] (Galway Group 2016)
[30] (Galway Group 2016)

(a) **Terminal Scalability:** FSRU terminals normally lack storage and regasification capacity on deck because of limited deck space and the size of the vessel. The cheaper and relatively flexible open rack vaporizers (ORV), used in a majority of onshore terminals, may not be appropriate for an FSRU because of space constraints. Expansion of storage capacity is not straightforward once the FSRU has been berthed, whereas onshore terminals, usually with large footprints, can be expanded easily.

(b) **Terminal Availability:** Meteorological and oceanic conditions pose some serious challenges for the FSRU industry. Depending on the severity of ocean conditions, LNG unloading could become one of the most difficult tasks in FSRU operations. For side-by-side cargo unloading, a calm to mild sea state is paramount. An LNG carrier may have to wait for the ocean to return to normal conditions before commencing safe operations.

4.5 Current FSRU deployment status globally

The FSRU solution was initially conceived as an answer to the difficulties and protracted processes of obtaining permits for building onshore LNG regasification terminals, especially along the northeastern coast of the United States. FSRUs are significantly less likely than onshore regasification facilities to face resistance from local communities due to their offshore location. This is particularly important when the intended market is a highly populated area with considerable demand for natural gas (e.g. Boston, Massachusetts in the northeastern United States). This decrease in resistance from local communities facilitates the faster implementation of the projects as compared to an onshore terminal.

Low cost and short development timelines have become the main drivers of the FSRU market. FSRU terminals can typically be completed within 2 -3 years at a significantly lower cost (20% to 50%) than traditional land-based terminals of similar capacity. After deployment in the United States, FSRUs quickly moved to South American markets such as Brazil (due to reduced power generation from hydroelectric facilities and to Argentina due to its increasing power demand growth and its declining natural gas imports from Bolivia) and have since penetrated the global gas market. Figure 16 shows existing and under-construction FSRUs as of February 2019.

Figure 16: Existing and Under-Construction FSRU Projects[31]

The FSRU market is largely dominated by three players: Golar LNG, Hoegh LNG, and Excelerate Energy. Excelerate Energy pioneered the FSRU market in 2005 by commissioning Gulf Gateway in the Gulf of Mexico and the Northeast Gateway off the U.S. northeast coast near Boston. By 2010, two new FSRU players – Golar LNG and Hoegh LNG – entered the market. No further players entered the FSRU market until 2013, when Offshore LNG Toscana (OLT) placed an FSRU in Italy. In 2015, BW gas entered the market with its first contract to provide an FSRU to Egypt, which was facing severe gas deficits. BW won its second contract for an FSRU in Pakistan in 2016. New players such as BW, MOL, Gaslog, Gazprom, and Maran Gas have FSRUs on order. Figure 17 shows the location of existing and under-construction FSRU/FSUs by location and player.

As of February 2019, there were 33 FSRUs operating either as an FSRU or LNGC (2 were laid up/in repair and 11 vessels on order). Of the operating FSRUs, nearly 75% of market share is held by Hoegh, Golar, and Excelerate. Hoegh also jointly owns two vessels with MOL and Tokyo Gas, whereas other players are mostly sole owners. Dynagas and Maran Gas Maritime are both in line for two new vessels each. (See Figure 18)[32]

[31] (Galway Group 2017) (GIIGNL- International Group of Liquefied Natural Gas Importers 2019)

[32] (Galway Group 2017) (GIIGNL- International Group of Liquefied Natural Gas Importers 2019) combined with information in public domain

Figure 17: FSRU/FSU Deployment by Players[33]

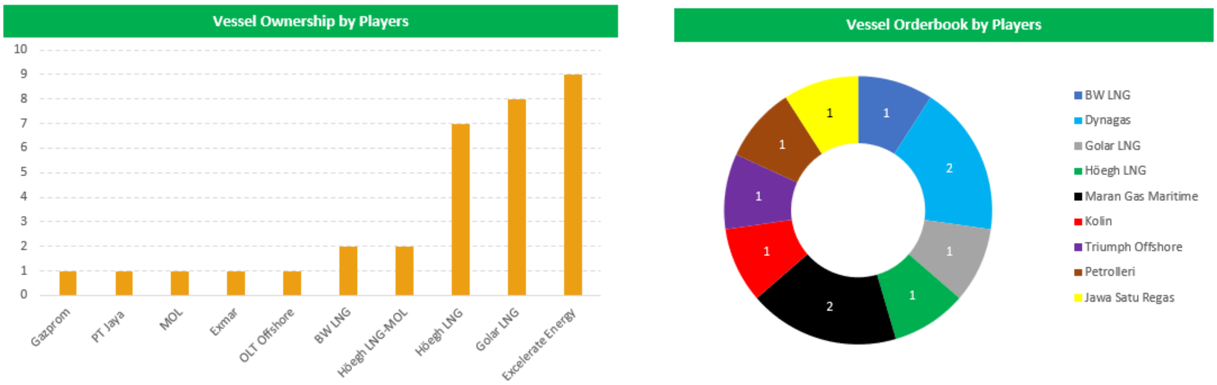

Figure 18: FSRU Market Share and Order Book by Players[34]

4.6 Proposed Projects

While most economies constructing and proposing floating solutions are typically emerging natural gas economies, often representing higher economic risk, credit risk, and regulatory issues, the FSRU market is not limited to these players. Mature gas markets with lower risk profiles are also very active in the FSRU space, driven (similarly to emerging nations) by speedy and flexible deployment, as well as lower upfront CAPEX. Almost 80 new FSRU projects are proposed globally, with most of these projects in South America and South and South-East Asia. With nearly 44 FSRUs available (including those on order), the demand for floating storage regasification

[33] (Galway Group 2017) (GIIGNL- International Group of Liquefied Natural Gas Importers 2019)
[34] (Galway Group 2017) (GIIGNL- International Group of Liquefied Natural Gas Importers 2019)

solution projects remains strong in the near future. Figure 19 maps proposed floating regasification terminals.

Figure 19: Proposed Floating Regasification Terminals[35]

4.7 FSRUs in the context of APEC economies

Among the APEC economies, the United States led in the development of FSRUs. Gulf Gateway and Northeast Gateway were the floating regasification terminals planned to supply LNG to the northeastern United States where demand for gas was high and supply was limited. The terminals never operated at full capacity and were no longer needed due to the U.S. shale gas revolution, so were successfully re-deployed to other projects.

APEC economies further led innovation in floating regasification markets: Chile pioneered the use of the FSU as a bridging vessel in 2009; Indonesia led the development of the first tower yoke mooring system for FSRUs; and Malaysia led the development of the first FSU solution with regasification on a jetty. Multiple APEC economies have shown interest in developing a floating regasification solution – either FSRU-based, FSU-based, or a combination of the two. Figure 20 shows the existing, under-construction, and proposed LNG terminals globally and delineates developments in APEC economies as compared to the rest of the world. Among the APEC economies, Chile, Mexico, Indonesia, Viet Nam, Thailand, China, Indonesia, and Australia are leading the FSRU markets.

[35] (Galway Group 2017) (GIIGNL- International Group of Liquefied Natural Gas Importers 2019)

Figure 20: Overlay of Existing, Under-Construction, and Proposed FSRU Projects in APEC Context [36]

The demand for FSRUs in Chile is driven by baseload power generation, while in South-East Australia, lack of pipeline infrastructure is contributing to natural gas shortages. Indonesia, which has deployed three FSRUs as of July 2019 (of which one is small-scale – Bali), is seeking FSRU solutions because of its scattered demand, lack of pipeline infrastructure, and power generation needs. Viet Nam and The Philippines' natural gas demand is not expected to increase much over the next decade, so therefore could use FSRUs for power generation. Hong Kong, China commenced an offshore LNG terminal and FSRU project in 2019.

Some advantages of FSRU deployment within Asian APEC economies:

- Relatively benign metocean conditions for a few economies such as Indonesia, Thailand, and Viet Nam enable higher FSRU availability for loading/unloading operations, as well as provide greater optionality for selection of mooring technology.
- The geographic characteristics of small demand centers located on the dispersed islands of Indonesia, Thailand, The Philippines, and in coastal areas of Viet Nam offer potential for small and mid-scale floating regasification concepts with milk-run or hub-and-spoke delivery options.
- The short development timeframe of an FSRU has enabled the supply of gas to economies facing acute gas shortages (e.g. Pakistan).
- The flexibility to use an FSRU as either a regasification terminal or an LNGC in markets with seasonal gas requirements (e.g. China).
- Economies with limited upfront capital or sub-investment grade (e.g. Viet Nam is classified as "BB non-investment grade" by S&P) may benefit from the greater ease of financing which an FSRU project presents.

[36] (Galway Group 2017) (GIIGNL- International Group of Liquefied Natural Gas Importers 2019)

- Supportive markets for LNG adoption (e.g. Australia, Thailand) in the form of ongoing market liberalization, the ease of permitting, and regulations which facilitate future development of LNG infrastructure, including FSRUs.

Some disadvantages which can hinder the adoption of FSRUs:

- Harsh metocean conditions may limit FSRU availability as well as the suitability of mooring technologies (e.g. frequent occurrence of cyclones in The Philippines and Japan).
- Draft availability of less than 12 meters impedes the use of standard scale LNGCs (although in such locations, small-scale infrastructure solutions are more feasible).
- Cost competitiveness of LNG as compared to other fossil fuels such as coal (e.g. The Philippines).
- Permitting and regulatory uncertainties such as potential changes in law and taxation (e.g. Papua New Guinea).
- Strict cabotage laws (e.g. Indonesia) may increase financing difficulties of an FSRU project.

5 Commercial Aspects, Strategy Development and Case Studies

The LNG supply chain is an intricate web of participants associated with each other through multiple commercial structures. These structures are in-part a result of:

- Value creation for the investors, shareholders, and value chain participants;
- Appropriate allocation of risks including business risk, commodity risk, price risk, and operational risk;
- Regulatory enforcement for a specific inter-party transaction structure and operation requirement; and,
- Other commercial structurers to ensure value chain suitability.

The LNG supply chain is the same for large and small-scale projects, with the only difference being that the elements of a SSLNG supply chain are tailored to meet small-scale demand and capacity requirements. This also holds true for the different business models that can be used in LNG projects, whether import or export projects. Like the supply chain, the business models for SSLNG are the same as those available for large-scale projects, except that they are tailored in order to meet specifics of scale projects.

5.1 Business Models for SSLNG Carriers and FSRUs/FSU

Understanding the different business models available for SSLNG and FSRUs is important in order to develop a financing and risk strategy. There are two business models prevalent in the industry: (a) merchant model and (b) service/tolling model.

Merchant Model

In a merchant model, the terminal developer (whether for import or export) owns the commodity as well as the assets- meaning the LNG supply, the LNGCs and/or FSRUs- and uses the assets to supply the commodity to the market. Figure 21 depicts a representation of this model.

Under this model, the downstream buyer(s) sign a contract with a supplier to deliver either regasified LNG or LNG downstream from the import terminal. A contract for delivery of the commodity in gaseous form is called a Gas Sales Agreement (GSA) or Gas Sale and Purchase Agreement (GSPA). Similarly, when a buyer contracts for delivery of the commodity as LNG, it is termed an LNG Sale and Purchase Agreement (SPA). The owner of the merchant terminal can either secure its LNG supplies on a Delivered Ex-Ship (DES) basis at the import terminal or on a Freight on Board (FOB) basis at the export or liquefaction terminal (or potentially onboard the LNG delivery ship when on route to the import terminal). Table 6 explains some of the pros and cons associated with a merchant model in SSLNGCs.

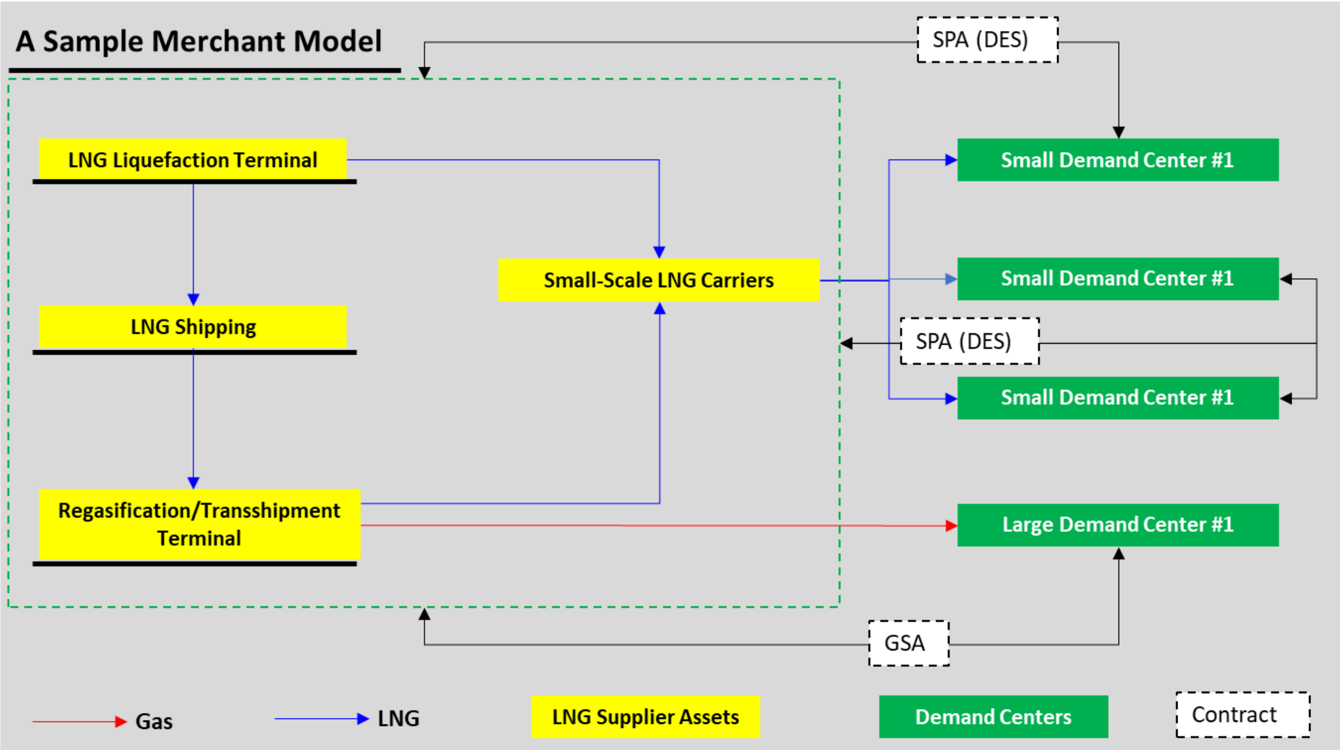

Figure 21: A Sample Merchant Model [37]

Pros	Cons
• For end customer - minimal terminal operation and supply procurement risk. • For end customer - minimal upfront capital requirements (LNGC and terminal capital investment is not required). • For end customer- likelihood that small and/or less creditworthy buyer can access LNG supplies. • For developer- captures the potential upside associated with LNG procurement and shipping efficiency/optimization. • For developer- facilities can be highly customized to meet demand profile.	• For the terminal developer- takes on potential market risk. • For terminal developer- takes on potential economic risk. • For developer- not all the locations might be suitable for terminal development (for example, metocean conditions and draft may be a factor). • For end customer- risk that the supplier carries out delivery obligation. • For end customer- likely to pay a higher price to compensate for risk taken by developer.

Table 6: Pros and Cons Associated with a Merchant Model[38]

[37] (Galway Group 2017)
[38] (Galway Group 2017)

Service/Tolling Model

In a service or tolling model, the asset owner (terminal developer) does not own the commodity (gas or LNG). In this particular model, a third party owns the commodity, whether LNG in the delivery ship and/or terminal, or gas at the inlet and/or outlet of the terminal. The third party then pays a fee to the terminal owner or operator to either liquefy or regasify the commodity. The fee can be fixed, variable or combination. Figure 22 illustrates how the service model works.

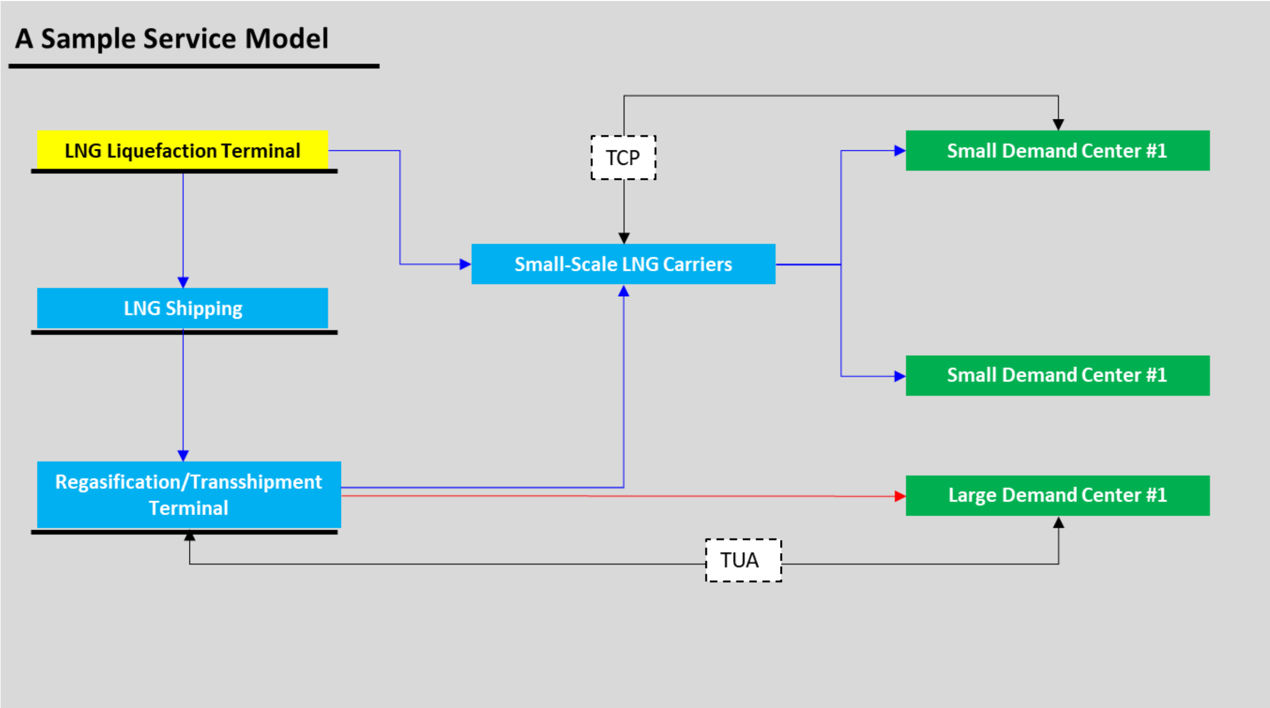

Figure 22: A Sample Tolling Model [39]

The commodity owner will enter into either a Terminal User Agreement (TUA) and/or a Liquefied Terminal Agreement (LTA) with the owner/operator of the terminal. The TUA and LTA will describe the obligations and responsibilities of the parties, including issues such as capacity, berthing scheduling, payment, and force majeure. A complimentary agreement to the TUA/LTA is the Time Charter Party Agreement (TCP), by which the commodity owner charters a vessel for receipt and delivery of LNG to the destination. This charter rate under a TCP includes a fixed rate (capital cost) and a variable rate (variable cost), indexed to an appropriate factor. Table 7 discuses some of the pros and cons of a service/tolling model.

[39] (Galway Group 2017)

Pros	Cons
• For the customer/merchant- LNG vessels are increasingly becoming commoditized and therefore can be secured competitively. • For the customer/merchant- risk of shipping operations can be clearly identified, thus increasing supply-chain reliability and bankability. • For the customer/merchant- no upfront investment or asset risk as a developer/owner takes the construction risk. • For the customer/merchant- in FSRU solution, vessel can be leased for a specific term, making the solution suitable for a bridging solution. • For all parties- terminal can be brought online in a short timeline, particularly if a speculative vessel is available.	• For all parties- commercial disputes or misalignment may result. • For all parties- LNG supplier LNG shipper, and LNG buyer (at times, aggregator) can make contractual alignment complicated. • For all parties- may not be able to control the LNGC's schedule. • For all parties- shipping market could be tight and charter rates for either a supply vessel or terminal vessel may be high. • For the owner/developer-customization of the terminal vessel reduces its redeployment possibilities and thereby increases charter rate.

Table 7: Pros and Cons Associated with a Service/Tolling Model

A developer may use a combination of FSRU/FSU and SSLNGCs to achieve an optimized LNG supply chain covering small-to-large-scale demand. Some of these strategies are discussed in the next section.

5.2 Development Strategies and Case Studies for SSLNGC and FSRUs

The evolution of SSLNGC and FSRUs has been based on the LNG industry's continued effort to provide a cost effective and timely solution to meet certain types of demand. Some of these demand categories are:

1. Small and isolated demand centers (including shallow-draft regions) that can be served using shallow-draft SSLNGCs;
2. LNG bunkering using SSLNGCs and barges;
3. Mid- to- large-scale demand centers using an FSRU when CAPEX investment and land footprint are an issue and/or there is a need to bring a terminal on-line within a very short timeframe; and,
4. Serving as a bridging solution or catering to seasonal demand with an FSRU.

In order to meet the needs of these different demand profiles, multiple strategies have evolved over the last decade. These strategies include using SSLNG for LNG distribution and bunkering; for milk run concepts; using FSU/FSRUs as a bridging solution; to manage seasonal service; and for baseload operations.

Case Study 1: SSLNGC LNG distribution and Bunkering in North-West Europe

North-West Europe was an early adopter of SSLNG solutions and bunkering operations. It is known for its well-developed and interconnected LNG/gas infrastructure. This is particularly true in Sweden and Finland, where numerous small demand centers are scattered across coastal areas. This fact combined with strong pro-environmental policies and the availability of regional gas supplies contributed to early adoption.

According to the International Group of Liquefied Natural Gas Importers' (GIIGNL), as of 2018 there were 16 LNG regasification terminals worldwide that included LNG bunkering facilities. Of these, 15 are in Europe. About two-thirds of these facilities are classified as mid-or-large-scale (more than 1 MTPA), and one-third as small-scale (less than 1 MTPA). These SSLNG terminals and LNG bunkering facilities are located in Finland (Tornio Manga - 0.4 MTPA, Pori - 0.1 MTPA), Sweden (Nynashamn - 0.4 MTPA, Lysekil - 0.2 MTPA), and the Netherlands (Fredrikstad - 0.1 MTPA).[40] Other SSLNG regasification terminals in Sweden and Norway are planning future bunkering facilities and demonstrate the growth trend associated with this sector.

In terms of a SSLNG distribution network, the Pori terminal in Finland (with nominal capacity of 0.1 MTPA and storage capacity of 28,500 m^3) receives LNG via SSLNGCs and then distributes it to end-users via trucks - having loading docks for road tankers installed on site. (See Figure 23). The terminal also has pipeline infrastructure to distribute the regasified LNG to a nearby industrial park. Since its commissioning in 2016, the terminal has received SSLNG shipments with vessels ranging from 15,600 m^3 (Coral Energy[41]) to 18,000 m^3 (Coral EnergICE). The 18,000 m^3 vessel was chartered in 2018 from Anthony Veder under a long-term time-charter. Since then, the vessel has regularly loaded at the Zeebrugge LNG import terminal (having reloading capability) which services the Pori and Tornio Manga Terminals in Finland.[42] The LNG supplies loaded at Zeebrugge are sourced globally.

In addition to having a network of SSLNGCs for distribution, Europe also leads in the use of purpose-built LNG bunkering vessels for fueling ships with LNG. LNG bunkering is gaining momentum in North-West Europe due to environmental concerns coupled with government initiatives aimed at the adoption of LNG as a marine fuel. This growth in LNG bunkering is driven by IMO2020 sulfur restrictions as well as by proclamations made by the International Association of Ports and Harbours that the safe use of LNG improves air quality. LNG bunkering is a practice of providing LNG (either from a dedicated SSLNG bunkering vessel or from a fixed facility onshore) to a ship for its own fuel consumption. See Figure 24 which illustrates an LNG bunkering ship filling a container vessel.

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[40] (GIIGNL- International Group of Liquefied Natural Gas Importers 2019)
[41] (World Maritime News 2016)
[42] (World Maritime News 2018)

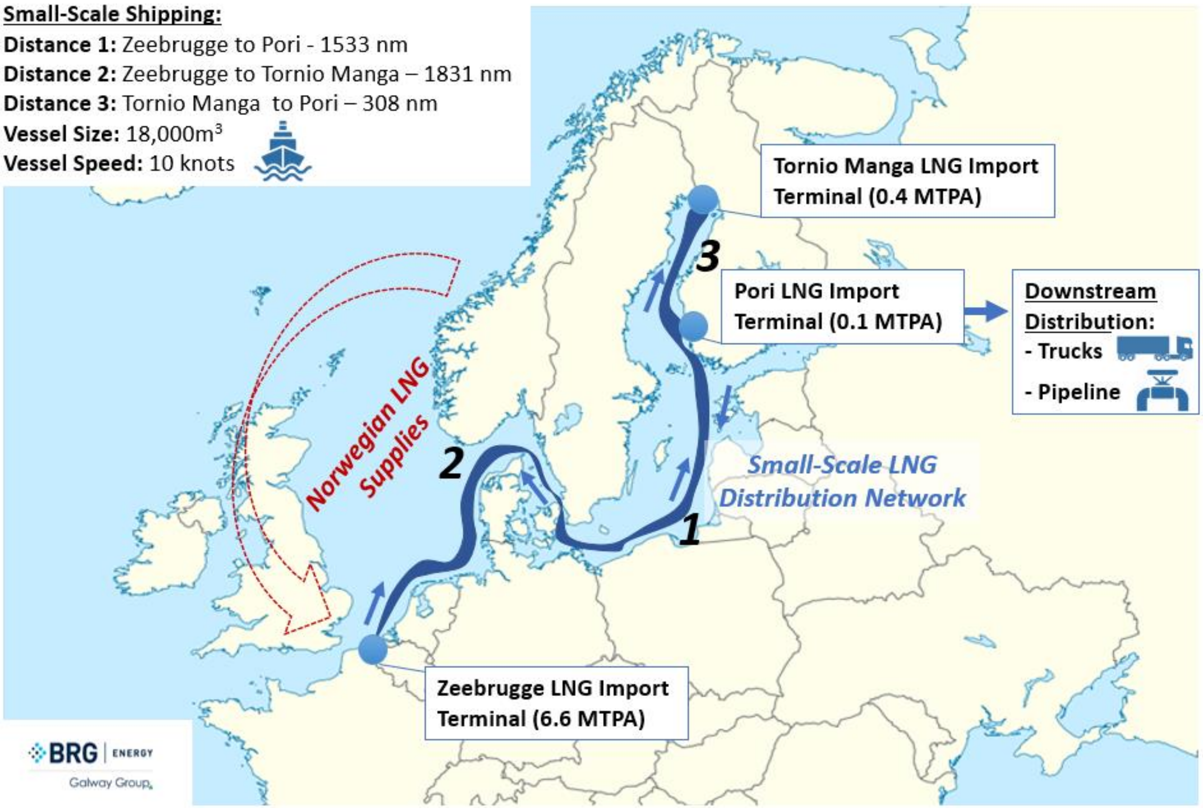

Figure 23: SSLNG Distribution at Pori Terminal in Finland (Illustration) [43]

The key advantage of using LNG as fuel is the reduction in pollutants when compared to traditional fuels such as heavy fuel oil (HFO), marine diesel oil, and marine gas oil. LNG bunkering is expected to grow significantly in the upcoming decades due to increasing international shipping activity and trade, combined with stricter environmental regulations, making it a potential market opportunity for SSLNG infrastructure adoption. As of 2018, there were two LNG bunkering vessels in the world, namely: (1) Kairos[44] – the largest LNG bunkering vessel with capacity of 7,500 m^3, and (2) Bunker Breeze – with capacity of 4,864 m^3. Both serve the European and/or Baltic market.[45] Also as of 2018 there were also approximately 7 LNG bunkering barges in operation (plus 1 under construction), with storage capacity ranging between 800 to 6,500 m^3. All the existing barges currently service the European and Chinese markets.[46]

[43] (Galway Group), Shipping distances calculated using: http://ports.com/sea-route/#/?a=2877&b=0&c=Port%20of%20Pori%20,%20Finland&d=Port%20of%20Tornio
[44] (GCaptain 2019)
[45] Galway Group internal shipping database, combined with publicly available data.
[46] Galway Group internal shipping database, combined with publicly available data.

Figure 24: LNG Bunkering Ship Filling Container Vessel [47]

More LNG bunkering vessels are proposed or are under construction in other parts of the world, such as Sembcorp Marine 12,000 m^3 vessel[48] in Singapore and the Dalian 8,500 m^3 vessel in China.[49] This trend is expected to continue in the future.

Case Study 2: Use of FSUs, FSRUs, and SSLNGCs for SSLNG Distribution

Originally, FSUs were envisaged to provide either temporary or supplemental storage capacity to a regasification facility. Over time, the suite of offerings has increased to (1) allow for flexibility of redeployment in case of a change in market, and (2) to provide a variety of LNG terminal services. An FSU could be a barge-based platform (usually small storage), an old LNGC (middle storage range), or a standard size vessel with LNG storage units and cargo handling equipment installed on board. Several small-scale FSU projects have recently been proposed or are at a concept stage. Their deployment has been limited, with only two in operation as of February 2019, (1) Indonesia's small-scale Benoa FSU and floating regasification unit (FRU), which was later replaced by an FSRU, and (2) Malta's Delimara FSU. Additionally, there is one small-scale FRU under development in Ghana's Tema Terminal.

Some small-scale FSU/FSRU projects have been proposed or are at concept stage, including:

- India: Petronet's small-scale FSRU (0.15 MTPA)[50] aimed at supplying gas to the Andaman and Nicobar Islands for city gas distribution, compressed natural gas, and piped cooking gas for households.
- Myanmar: Non-propelled small-scale FSRU barge along the Yangon River, which will service a power plant in a shallow water environment.

[47] (Ship Technology n.d.)
[48] (Rivera MM 2019)
[49] (The Maritime Executive 2019)
[50] (Business Today 2019)

- Bangladesh: Exmar's 25,000 m^3 non-propelled FSRU barge, originally intended to be chartered for provision of feed gas to a fertilizer plant. The project was shelved as other competing terminals started to import LNG in the economy.[51]

Bali, Indonesia, has an SSLNG regasification terminal with a 0.4 MTPA capacity and an FSU plus FRU configuration. See Figure 25. The FSU began service in 2015 and was replaced with a purpose built FSRU in 2018.[52] The project provides regasified LNG for a 200-megawatt (MW) gas-fired power plant at Benoa Port. The terminal is jointly owned by PT Pelindo Energy Logistik (PEL), a subsidiary of Indonesian state-owned port operator Pelindo III and PT JSK Gas. The offtake is guaranteed by PT Pelindo Energy Logistik and the LNG is sourced through an SPA with Pertamina. The terminal was awarded a 5-year build, operate, and transfer agreement (BOT) by PEL.

Figure 25: FSU and FRU Concept at Bali Benoa Terminal [53]

Another concept that is gaining momentum globally is the idea of LNG trading hubs. An LNG trading hub involves a regasification terminal with the capability of offering multiple services, such as transshipment, break-bulking, bunkering, storage, and regasification/send-out. Storage is a primary requirement for an LNG hub. This storage can either be onshore or floating. Generally, two commercial models exist for an LNG hub, (1) milk-run and (2) hub-and-spoke.

Figure 26 illustrates the milk-run and hub-and-spoke delivery methods. In a milk-run the LNG is unloaded in partial cargoes to more than one receiving terminal within the same shipping route. In a hub-and-spoke concept the LNG is delivered point-to-point, meaning the LNGC or SSLNGC delivers the full load from the source to one end-user. Hub-and-spoke is the same as traditional LNG trades, and requires various parties to agree to the use of the terminal as well as coordination of delivery schedules. Because of its nature, a hub-and-spoke concept is not economically practical for an LNG hub within an economy with dispersed demand centers, such as Indonesia. In these circumstances a milk-run concept would be better suited to meet the economy's needs.

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[51] (S & P Global Platts 2018)
[52] (Interfax 2018)
[53] (Pelindo Energy Logistik n.d.)

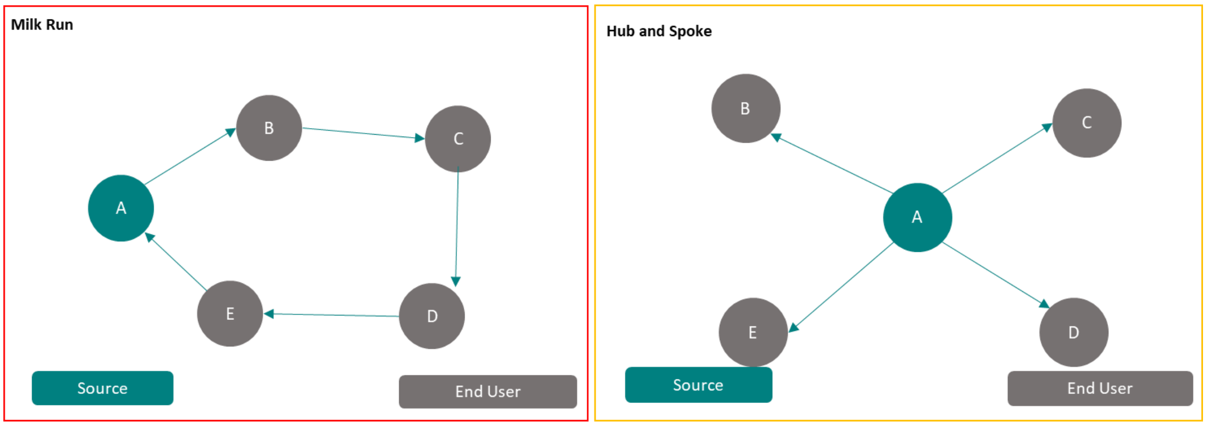

Figure 26: Illustration of Milk-Run and Hub-and-Spoke Delivery Methods[54]

Similar concepts are proposed in various APEC economies, such as The Philippines, and also in the Caribbean. The only successful application has been in Western Europe on the Baltic Sea where several small-scale LNG terminals have been developed. The Philippines concept entails a large-scale LNG import terminal (either floating or onshore) as a break bulking facility, where SSLNGCs can be loaded for distribution to potential small-scale demand centers across the archipelago. Deliveries to the ultimate market can be by either milk-run or hub-and-spoke delivery methods. However, these concepts are at an early stage and no developments have progressed to date.

The main drivers behind the adoption of a milk-run delivery option for small-scale demand centers include; (1) aggregation of very small demand centers, (2) ability to share shipping costs and vessel utilization between delivery locations, and (3) accessibility to shallow water (less than 8 meters). A typical milk-run concept uses an LNGC with capacity of less than 30,000 m^3 to deliver small cargoes.

The milk-run concept was initially proposed in Indonesia in 2010 when the government, through its electricity company PLN, launched an SSLNG campaign and commissioned a study regarding markets in eastern Indonesia. The study concluded that the archipelago and scattered islands of eastern Indonesia would be ideal for the use of SSLNG facilities. PLN then entered into a partnership with Pertamina and planned to build 8 mini-LNG terminals in Kalimantan, Sulawesi, Bali, West Nusa Tenggara, and North Maluku by 2015. However, as of 2019, no further developments have taken place for the planned 8 mini-terminals. It was anticipated that the terminals would be served by SSLNGCs, on a steady round of milk-runs, with a combined LNG-handling capacity of 0.5 - 1.5 MTPA. A range of delivery options for 3,000-4,000 km milk-runs were also studied.[55] The milk-run concept was further supported by the fact that Indonesia has numerous liquefaction assets (i.e. from Bontang in its central/north area, to Tangguh on in its east, etc.) at which SSLNGCs could be loaded. These liquefaction assets are located in relatively close proximity to demand centers throughout the archipelago, making the milk-run options economical. Figure 27 shows the routes developed in the PLN study.

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[54] Galway Group
[55] (Riviera Newsdesk 2011)

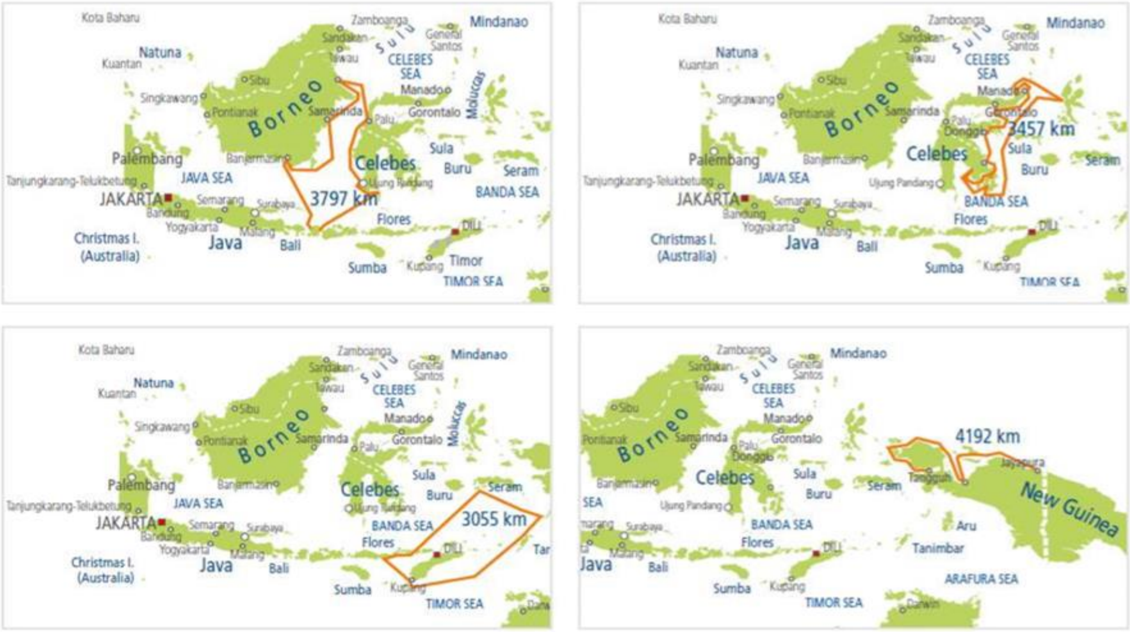


Figure 27: Indonesian Milk-Run Routes Identified in PLN Study[56]

a) FSU as a Bridging Solution

Engie employed an FSU as a bridging solution at its Mejillones LNG terminal in northern Chile while a purpose-built onshore storage tank was developed. Chile required a cost effective, fast-track solution for LNG supplies when it was affected by severe natural gas import restrictions from Argentina. Mejillones LNG terminal converted an old LNGC, the BW GDF Suez Brussels, into a 162,000 m^3 FSU, while a 175,000 m^3 anti-seismic LNG onshore tank was built. The FSU was managed and operated by BW and was designed for a maximum LNG send-out rate of 600 m^3/hour, which equals to an annual output of approximately 2.2 MTPA.

The FSU was moored to a purpose-built jetty, received LNG from shuttle tankers, and supplied LNG to a land-based regasification plant through connected loading arms, as shown in Figure 28. The LNG transfer was carried out across the jetty through a fixed piping system.[57] After the construction of the LNG tank was completed, the FSU was detached and re-deployed as an LNGC.

[56] (DNV GL 2013)
[57] (BW n.d.)

Figure 28: Chile Mejillones LNG terminal with FSU [58]

b) FSRU for Seasonal Requirements

The China National Offshore Oil Corporation (CNOOC) chartered the FSRU "GDF Suez Cape Ann" to handle high winter seasonal gas demand in Tianjin, China from 2013 until spring 2018. The vessel, with a storage capacity of 145,000m^3, was used as an FSRU in winter months and reverted to working as an LNGC in the summer months. As of mid-2018, CNOOC had replaced the "GDF Suez Cape Ann" with the FSRU "Hoegh Esperanza" with a storage capacity of 170,000m^3 and a regasification capacity of 750 MMCFD, equivalent to approximately 2.2 MTPA of LNG[59] (See Figure 29). This decision was driven by the fact that CNOOC plans to provide larger quantities of LNG to China's growing domestic gas market, therefore requiring a vessel with larger storage. Hoegh Esperanza will operate as an FSRU at the Tianjin terminal for a fixed number of months per year, with the option of being employed alternatively as an LNGC, depending on Tianjin's seasonal gas requirements.

Figure 29: Hoegh Esperanza deployed at Tianjin Terminal in China [60]

[58] (BW n.d.)
[59] (LNG World News n.d.)
[60] (LNG World News n.d.)

c) ***FSRUs in Baseload Operations***

Beyond the flexibility to serve seasonal demand, FSRUs can also be deployed to fulfill baseload LNG requirements, providing customers with a relatively large and stable quantity of natural gas. An example of an FSRU deployed for baseload operations is Pakistan's first FSRU terminal. A consortium, led by Engro Elengy, built a 4.8 MTPA FSRU (see Figure 30) to be used as a baseload facility to assist in offsetting Pakistan's gas supply deficit and ensuring the availability of natural gas for industrial, commercial, and residential customers.[61] Gas shortages in Pakistan are a result of declining domestic gas production and growing gas-fired power demand. Since the successful deployment of the first FSRU, a second FSRU has been added at Port Qasim. In terms of commercial structure, the terminal was built under a 15-year tolling arrangement with Sui Southern Gas Company Limited (SSGC). Under the agreement, Engro delivers about 400 MMCFD of regasified LNG to SSGC in exchange for a fixed capacity charge as well as a usage-based utilization charge.

Examples of FSRUs used to supply baseload requirements can be found in APEC economies as well. In Indonesia, the Lampung LNG and Nusantara Regas Satu FSRUs are deployed in West Java. These vessels, provided by Hoegh and Golar LNG, are relatively under-utilized even though they are intended to serve baseload requirements. This underutilization is due to Indonesia's geography and lack of pipeline infrastructure. As of 2019, a third FSRU terminal, Java-1, is under-construction and will provide LNG to a power plant.

Figure 30: Engro LNG Terminal in Pakistan, FSRU Exquisite [62]

[61] (Excelerate Energy n.d.)
[62] (Excelerate Energy n.d.)

6 Guidance on Utilization and Optimization of SSLNG Vessels and FSRUs

When establishing the practicality, technical, and economic feasibility of SSLNG and FSRUs, it is fundamental to define a set of parameters that shall drive the decision-makers towards selecting the right infrastructure solution for their identified demand potential.

To this end, we have defined a set of key parameters within four core areas:

1. **Demand**
2. **Infrastructure**
3. **Technical**
4. **Economy**

These key parameters will help the decision-maker to understand the required demand pattern (e.g. size and frequency of shipment), required contractual flexibility (e.g. spot or long-term procurement arrangements) and infrastructure suitability (e.g. large or small, onshore or floating terminal, large LNGCs or SSLNGCs, ISO containers or trucking, etc.).

6.1 Identification of Decision Parameters that Influence the Choice for SSLNG and FSRUs

Demand Parameters

Demand specific parameters serve as guidance for decision-makers when evaluating infrastructure options and require detailed understanding of the demand potential of the economy of interest. The following questions need to be answered by the decision-makers in order to understand the characteristics of each demand profile:

- What is the size of the demand center?
- What are the typologies of end-users?
- What is the likelihood of demand occurring?
- Is the demand seasonal or stable?
- Is there any demand upside?

A) Size of Demand Center- Has been split into the following categories:

- Mini: (> 0.05 ≤ 0.1 MTPA)
- Small: (>0.1 ≤ 1 MTPA)
- Medium: (> 1 ≤ 2 MTPA)
- Large: (> 2 MTPA)

“Mini” demand centers have been defined as end-users within a range of 0.05 to 0.1 MTPA, representing very small demand requirements in a range of 6.5 MMCFD to 13 MMCFD, such as hotels, hospitals, shopping malls or aggregated users, for example residential or other typologies of small customers where the potential demand for gas/LNG needs to be aggregated to justify even a small-scale development.

The “small” customers have been classified as those demand centers, where gas potential ranges between 0.1 and 1.0 MTPA, representing a demand between 13 MMCFD and 130 MMCFD. This demand could represent small industries (e.g. pulp and paper, metals, chemicals, petroleum refining, fertilizers, stone, glass, plastic, and food processing industries) small-scale gas-fired power plants, LNG bunkering, and CNG for regional transportation needs amongst others.

The customers with "medium" demand, between 1.0 and 2 MTPA, or 130 MMCFD to 265 MMCFD, would typically include large-scale industrial complexes (e.g. petrochemical, chemical, or fertilizer plants), or medium-sized power plants.

Large customers, with a demand above 2 MTPA, or more than 265 MMCFD, would typically include large-scale gas-fired power plants, often integrated with LNG regasification projects to achieve economies of scale. The demand centers of medium-to-large-scale would often have sufficient capital resources available for funding and/or developing the infrastructure themselves.

B) Typology of End-Users- The category of users fundamentally determines the profile of the customer in question and subsequently helps to firm up the demand pattern for LNG deliveries. Some typologies are:

- Power Generation
- Industries
- Buildings
- Transport
- Agriculture and non-specified
- Non-energy

For example, if the LNG import project will be utilized for power generation, it is key to determine if such usage will be for baseload, intermediate, or peak generation. Baseload power plants operate more or less continuously at a capacity factor of over 70% and do not shut down except for maintenance. Intermediate load power plants fill the gap between baseload and peaking plant and typically operate at capacity factor between 25 and 70%. Peaking plants, on the other hand, provide power during peak demand periods, have a capacity factor below 25%, are more responsive to changes in electrical demand and can be started up relatively quicker.[63]

The typology of industries is very diverse, generally splitting into energy intensive-sectors (e.g. iron and steel, non-metallic minerals, chemical and petrochemical, paper and pulp, aluminum, mining, and fertilizers) and non-energy intensive sectors (e.g. non-ferrous metals-except for aluminum-, equipment, machinery, glass, food processing, beverages & tobacco, wood, construction, textiles and ceramic).

Buildings refers to residential and service buildings using natural gas for space heating or cooling and cooking. Transportation encumbers the use of CNG, typically employed to power passenger cars and city buses. Agriculture and non-specified refers to the utilization of natural gas for low-temperature heat, such as in greenhouses. Non-energy employment of natural gas is associated with industrial processes.[64] Figure 31 shows that power generation, industry, and buildings are the biggest consumers of natural gas within the APEC context, both currently and forecasted.

[63] (Fuentebella 2018)

[64] The definitions of individual typologies of users have been adapted form APEC and EIA publications and are used throughout the study.

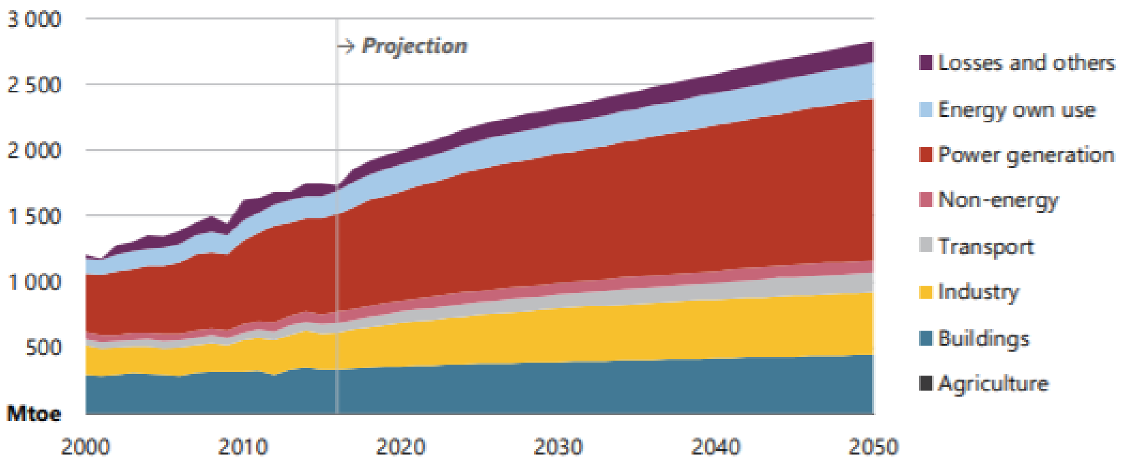


Figure 31: Total Primary Gas Supply by Typology of User [65]

C) **Likelihood of Demand Occurring:** measures the likelihood of LNG demand materializing as well as its urgency for fulfillment. It is divided in three scenarios:

- High (acute upcoming shortage of gas).
- Medium (market fundamentals for LNG exist; slowly building up)
- Low (speculative demand potential for LNG)

The high scenario reflects the demand needs of a market that faces acute shortages of gas (e.g. due to increase in electricity demand or high industrial consumption requirements) or will have an upcoming increase in demand within the next 6 to 24 months (e.g. due to new power plants coming on-line or industrial parks or similar energy intensive projects materializing) that require fast gas supply solutions. The medium demand scenario reflects markets where market fundamentals for gas/LNG supplies exist, but their occurrence is rather slow (e.g. gradual demand build up). The low demand scenario reflects markets where there is speculative demand for LNG, but it has not materialized (e.g. economies where alternative, price competitive fuels are used).

D) **Stability of Demand/Seasonality-** Gas demand can fluctuate depending on the month, the week, and even during the day. Irregular events, such as particularly extreme weather conditions, mechanical failures and political news, can also influence gas demand. This parameter will be divided in:

- Stable demand required (uninterrupted – baseload requirements)
- Irregular demand required (e.g. customers using two fuels, requiring gas only for peak-shaving, or with highly seasonal or irregular demand requirements).

Categorizing demand as stable or irregular greatly affects the asset availability and selection, the auxiliary infrastructure requirements, as well as the logistics value chain. It is essential to understand the customer's operational requirements and their tolerance if the LNG terminal is not able to supply gas. For example, Chinese natural gas storage represents only 5% of its total consumption, as compared to Europe which is 27%. Lack of storage assets has a direct impact on the seasonality requirements of the gas and is ultimately reflected in the prices that consumer pay, further impacting the affordability of gas compared to other fuels.

In order to provide examples of gas demand seasonality across the APEC region, the historical patterns for Gross Inland Deliveries (GID) were derived for each of the 21 economies, taking into

[65] (APEC Energy Working Group 2019) (EIA)

account domestic production of natural gas, minus (-) exports and plus (+) imports. The GID has been based on seasonality for the last 4 years (2015-2018), using monthly statistics. APEC economies with substantial fluctuation patterns were identified using this method. These economies, classified as seasonal, are Canada, Chinese Taipei, Hong Kong, China, Korea, Russia, Japan, the United States, and to an extent China. In the case of China, the seasonality varies greatly based on region, with the northern part being generally more seasonal due to higher heating requirements than the southern part. Figure 32 shows the historical GID patterns for these 8 economies while Figure 33 shows the historical GID pattern for APEC economies determined to be non-seasonal.

If, for example, the customer requires a large amount of gas with likely future increases on an uninterruptible basis, then an onshore solution might be preferred, since large numbers of shipments can be accommodated, and assets can be expanded with additional onshore storage. Availability guarantees for onshore import terminals range between 95 to 99.5% with some achieving 99.9% of their time online. In a floating solution, the asset availability will be closely impacted by weather conditions, thus affecting the stability of supplies. This may not be an issue if the customer has onsite storage, however, not all customers (especially small users) have such back-up infrastructure available. Most of the FSRUs in the world are located near shore (except for OLT Toscana which operates in deep and unprotected waters), since positioning of the FSRU far from shore exposes the asset to adverse metocean conditions and thus impacts the asset availability and stability of supply.

On the other hand, FSRUs provide an upside for demand centers where stability and duration of demand requires flexibility and large existing or future storage is not required. This is because the mobility of the asset allows for its redeployment to the demand center during seasonal peaks and for its use as an LNGC during low-demand months. For example, in Tianjin, China, rather than committing to a large upfront investment in baseload onshore terminal, developers opted for an FSRU which can be employed seasonally as a regasification unit and as an LNGC.

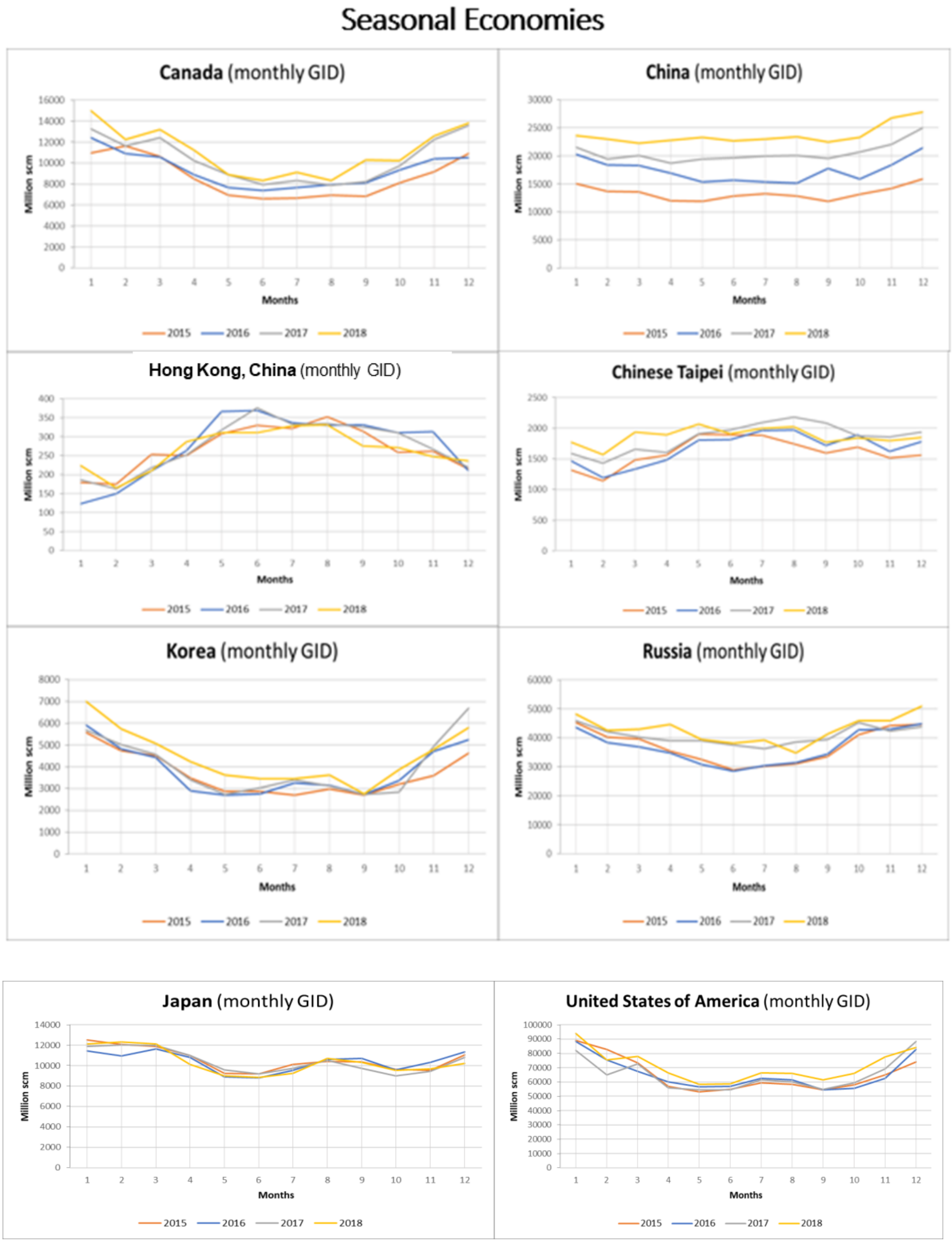


Figure 32: Overview of GID Patterns for Seasonal APEC Economies [66]

[66] Source: JODI Gas World, Galway Group

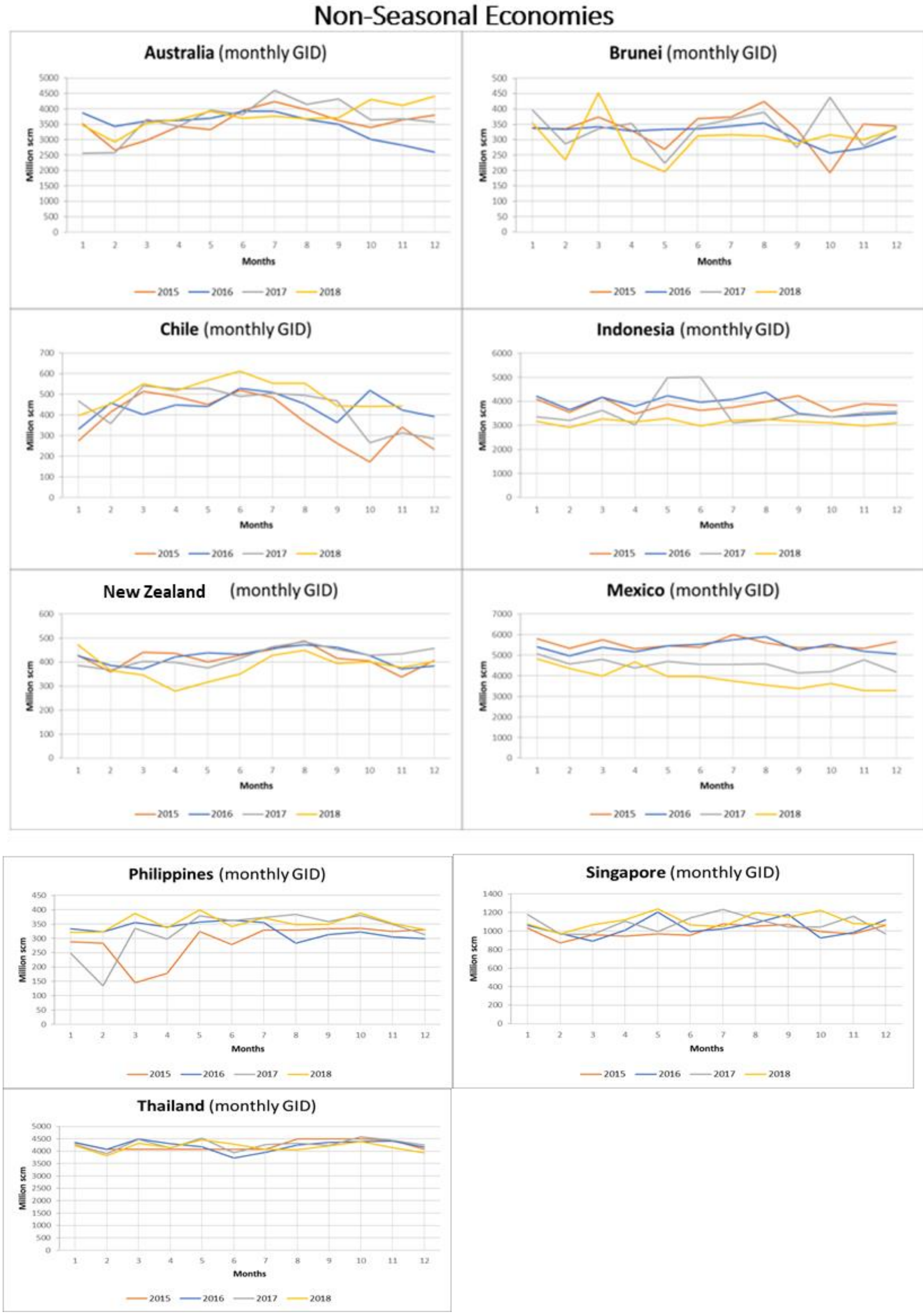


Figure 33: Overview of GID Patterns for Non-Seasonal APEC Economies [67]

E) **Potential demand upside-** Takes into consideration the possibility of demand increasing in the future. The boundaries for this parameter are:

– Yes

[67] Source: JODI Gas World, Galway Group

- No

If the size of demand is likely to increase in the future, it is important for the asset to be flexible so as to accommodate an increase. For example, onshore LNG terminals are often a preferred choice if large demand is in place and significant potential upside has been identified for future expansion. Contrary to this, floating terminals are known for their limited expansion potential, unless a new vessel is chartered or bought, or an FSU is added. The limited expansion potential is due to available deck space on the vessel. Future storage expansions would require modifications to the vessel, and might not always be possible, given the characteristics of the vessel, thus incurring an additional cost to the cost of the LNG storage tanks.

Infrastructure Parameters

The infrastructure parameters answer the following questions:

- How accessible is the identified demand center?
- How distant is the demand center from the LNG source or the supply project?
- What is the deployment urgency of the required gas/LNG supply project?

A) Accessibility:

- By sea (port access or jetty)
- By road (trucking)
- By rail
- By pipeline

Accessibility to the end-user's location is an important consideration for infrastructure selection and ultimate economic viability of a project. For example, an ideal place to locate a receiving terminal would be in an existing port or jetty, in a naturally sheltered location, with low traffic and sufficient draft to accommodate a range of vessels greater than 12m, accessible by road and rail, as well as connected to a pipeline network and in an immediate proximity to the end-user. The fewer accessibility options, the more limited the infrastructure selection will be in terms of delivery reach and flexibility.

B) Distance

1. **Sea:**

- Between 0 and 100 nm- SSLNGCs or barges with storage capacity of 2,500 m^3
- Between 100 and 700 nm- SSLNGCs with storage capacity of 15,000 m^3
- Between 700 and 2,100 nm- SSLNGCs with storage capacity between 15,000 and 30,000 m^3
- Between 2,100 and 3,000 nm- SSLNGCs with storage capacity of 30,000 m^3
- More than 3,000nm- large-scale LNGCs with capacity of 145,000 m^3

2. **Road:**

- Between 0 and 2,500 km- LNG trucking, rail and/or pipeline
- More than 2,500 km- pipeline

One of the primary advantages of using large-scale LNGCs is the ability to transport large volumes of LNG over a long distance competitively. For small demand centers, as the distance between the source of LNG and the consumer increases, a greater number of SSLNGCs need to be deployed to meet demand. With the increased number of required vessels, the economics of SSLNG can rapidly deteriorate (the per unit cost of LNG carried can be two to three times as expensive). In addition, due to smaller volumes transported, port charges, chartering of ships, and other expenses can be significantly greater on a per unit basis, ultimately driving down the competitiveness of small-scale delivery methods. Figure 34 compares the distance versus the cost per MMBtu. It shows that the cost curve for the smaller vessel, represented by the yellow line, is significantly steeper compared to the larger vessels.

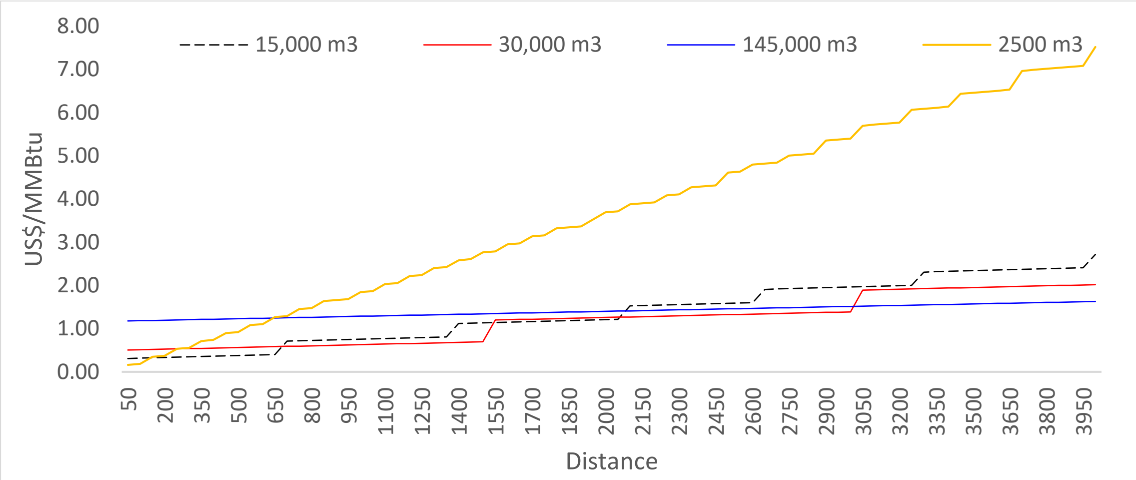


Figure 34: Economic Comparison of Vessel Sizes Considering Distance [68]

LNG trucking is commonly used up to distances of 2,500 km for road accessibility. Generally, there are two typologies of trucks used in such transportation method:

- Trucks with fitted non-removable cryogenic tank– typical size of 40 feet; and
- Trucks using removable ISO container - these can be either 20 or 40 feet and can be used not only for trucking purposes, but also in seagoing barges or vessels.

Other common methods of transportation include gas pipelines and railway, allowing for economical transportation of gas/LNG at over 2,500km. Still, availability of such infrastructure is often limited across developing economies, especially in South-East Asia.

C) Development Timeline: The urgency for the supply of natural gas/LNG is divided into the following periods.

- Immediate: between 1 and 6 months
- Short Term: between 6 and 12 months
- Medium Term: between 12 and 24 months
- Long Term: between 24 and 36 months
- Extra Long Term: more than 36 months

Determining the urgency for the supply will define the type of infrastructure which will be realistically feasible within the projected timeframe. For instance, in case of expected LNG demand of less than 0.5 MTPA, the fastest supply solution might be represented by road trucking, ISO container barge delivery, or SSLNG which are feasible in less than 6 months. For large

[68] (Galway Group)

demand, FSRUs usually require a shorter development time compared to an onshore terminal. While the FSRU requires between 6 and 36 months to build, an onshore terminal requires between 36 and 48 months. These timelines can vary based on jurisdiction and site-specific conditions.

In the case of FSRUs, the timeline further varies based on whether the asset is readily available (6 months), whether it will be converted (12 to 24 months), or a customized new-build asset will be used (24-36 months)[69]. Reasons why a development timeframe for an FSRU might be shorter include:

- Speculative investment by FSRU owners: LNG carrier owners invest in speculative FSRUs making them available on short notice, based on their experience in ship building and knowledge of construction critical path, making FSRU construction increasingly more efficient.
- Regulatory permits timeline: In economies with minimal government regulation affecting offshore oil and gas assets, the FSRU permitting process may be shorter than an onshore facility's permitting process.
- Fabrication in a controlled environment: Shipyards with resources at their disposal can construct an FSRU in a shorter time period than an onshore regasification plant can be built.

<u>Technical Parameters</u>

Technical parameters to consider are water depth, wave height, wind, current speed, and the occurrence of typhoons. Key questions include:

- Does the preferred project site have sufficient draft available to accommodate large or small LNGCs?
- What are the metocean conditions that need to be taken into account for the asset configuration and the technology selection?
- Does the preferred project site have a history of extreme natural events, such as typhoons, that can impact the availability of the asset?

A) Water Depth

- Less than 3.5m is not feasible.
- Between 3.5m and 8m is feasible for small-scale vessels or barges with capacity between 1,000 and 30,000 m^3
- Between 8m and 12m is feasible for medium-scale vessels with capacity between 35,000 and 120,000 m^3
- More than 12m is feasible for large-scale LNGCs with capacity between 125,000 and 267,000 m^3.[70]

Table 8 shows a series of draft requirements based on LNG vessel sizes.

B) Wave Height

- Less or equal to 2m (limit for berthing, LNG unloading)
- Less or equal to 2.25m (limit for dolphin/double berth jetty mooring)
- Less or equal to 3.5m (limit for navigation)
- More than 3.5m (not feasible)

[69] (International Gas Union (IGU) 2018)
[70] (GIIGNL n.d.)

C) Current Speed

- Less or equal to 0.5 m/s (Limit for LNGC mooring and loading arm connection and disconnection)
- Less or equal to 0.6 m/s (limit for berthing, LNG unloading)
- Less or equal to 0.8 m/s (limit for gas send-out, dolphin or double berth jetty mooring)
- Less or equal to 0.95 m/s (limit for FSRU turret mooring at offshore site)
- Less or equal to 1.54m/s (limit for navigation)
- More than 1.54m/s (not feasible)

D) Wind Speed

- Less or equal to 7.5 m/s (limit for LNGC mooring and loading arm connection)
- Less or equal to 12 m/s (limit for berthing)
- Less or equal to 15 m/s (limit for LNGC unmooring and loading arm disconnection)
- Less or equal to 19 m/s (limit for unloading operations)
- Less or equal to 26 m/s (limit for gas send-out, dolphin/double berth jetty mooring, navigation)
- Less or equal to 31 m/s (limit for FSRU turret mooring at offshore site)
- More than 31 m/s (not feasible)

Vessel Type	Capacity (m3)	Draft (m)	Length (m)	Beam (m)	Height/ Depth (m)	Speed (kn)
Q-Max	266,000	12.2	345	53.8	34.7	19
Q-Flex	210,000	12	315	50	27	19.5
Standard Size LNGC	175,000- 125,000	12-11.5	295-229	48-36	22.5	16.5
Mid-Scale LNGC	80,000	10-11.2	229	36	22.5	16.5
SSLNGC, type C tanks	30,000	7.5	175.15	28.60	23.70	12
SSLNGC, Ice Class (1B)	7,500	6.7	120	20	10	13
Shuttle/Bunker Barge LNGC	7,500	4	82.8	25.00	7.00	13
LNG Barge for Shallow Water Region	12,000	3.5	120	28	6.60	10

Table 8: Comparison of Draft Requirements Based on Vessel Sizes [71]

Category	Limiting Wind Speed (m/s)	Limiting Wave Height (m)	Limiting Current Speed (m/s)
Navigation	≤ 26	≤ 3.5m	≤ 1.54
Limit for FSRU turret mooring at offshore site	≤ 31	n/a	≤ 0.95
Limit for gas send-out	≤ 26	n/a	≤8
Dolphin/Double Berth Jetty Mooring	≤ 26	≤ 2.25	≤8
LNG Unloading Operations	≤ 19	≤ 2m	≤ 0.6
Limit for LNGC unmooring and loading arm disconnection	≤ 15	n/a	n/a
Berthing	≤ 12	≤ 2m	≤ 0.6
Limit for LNGC mooring and loading arm connection/disconnection	≤ 7.5	n/a	≤ 0.5

Table 9: Typical Operational Limits for FSRUs and LNGCs [72]

[71] (GIIGNL 2019) (GIIGNL n.d.) and Galway Group databases
[72] Galway Group

Table 9 shows the typical metocean limits for FSRUs and LNGCs operations, divided by various categories of activities. These limits are only indicative and, in practice, metocean conditions will be interactive, i.e. lowering wave conditions will potentially increase tolerance of other factors such as current speed.

E) Occurrence of Typhoons

- Yes
- No

Geographic vulnerabilities, such as typhoons, require careful consideration for terminal location, affecting jetty designs and operations of FSRUs. For example, if a project is to be proposed in an area with category 5 cyclone potential, the facility will need to be designed to withstand such an occurrence

Economy Parameters

Economy specific parameters include issues such as credit rating, upfront CAPEX requirements, affordability of gas, and availability of subsidies. The questions to be answered are:

- What is the economy's credit standing and does it attract sizeable investment?
- How much upfront CAPEX is required to develop the infrastructure?
- Is the delivered cost of gas affordable for the end-user?
- Are there any government subsidies available which will impact the affordability of natural gas?

A) Credit Rating:

- Greater or equal to BBB (Investment Grade)
- Less than BBB- (Not Investment Grade)

Most emerging economies have low credit ratings, and many are not investment grade. SSLNGCs and FSRUs require lower capital investment, making this option viable for economies with a low credit rating to finance. Asset mobility (the ability to move SSLNGs and FSRUs) reduces the potential for stranded assets and reduces investment risk. For example, some emerging economies in South-East Asia have seen traction from investors with whom they are partnering and developing SSLNGCs and FSRUs (e.g. Pakistan, Indonesia, and Thailand). Table 10 shows the credit ratings for individual APEC economies.

Economy	Rating	Description
Australia	AAA	Prime
Brunei Darussalam	n/a	
Canada	AAA	Prime
Chile	AA	High Grade
People's Republic of China	A+	Upper medium grade
Hong Kong, China	AA+	High Grade
Indonesia	BBB+	Lower medium grade
Japan	AA+	High Grade
Korea	AAA	Prime
Malaysia	A+	Upper medium grade
Mexico	A+	Upper medium grade
New Zealand	AAA	Prime
Papua New Guinea	B	Highly speculative
Peru	A	Upper medium grade

The Philippines	A-	Upper medium grade
Russia	BBB	Lower medium grade
Singapore	AAA	Prime
Chinese Taipei	AA-	High Grade
Thailand	A	Upper medium grade
United States	AAA	Prime
Viet Nam	BB	Non-investment grade – speculative

Table 10: Overview of Credit Rating of APEC Economies [73]

B) Upfront CAPEX requirement: This is divided into 5 categories.

- Less or equal to US$ 100 million
- Between US$ 100-200 million
- Between US$ 200-500 million
- More than US$ 500 million

Project costs are highly dependent upon site-specific conditions (i.e. availability of auxiliary infrastructure, jetty, port access, dredging requirements, resettlement requirements, environmental considerations and metocean conditions, among others) and jurisdiction (tax, permitting, regulations and staffing costs, among others). Floating terminals cost about 60% of the total cost of onshore terminals. For example, an onshore 3 MTPA terminal with one 180,000m^3 storage tank will cost between US$ 700-800 million approximately compared to US$ 400-500 million for an FSRU with similar capacity.[74] Table 11 compares CAPEX between floating and onshore terminals, assuming a 3 MTPA capacity and storage capacity of 180,000 m^3.

SSLNG infrastructure might have a higher delivered cost of LNG for the end-consumer (in US$/MMBtu) since it does not benefit from economies of scale. Small-scale infrastructure can become competitive and economically feasible if the small-scale concept is properly chosen around cost optimization, considering logistics, technologies, existing available infrastructure, and a naturally sheltered project location. In addition, further savings could be achieved because of small-scale infrastructure's ability to be located closer to the end-user.

[73] (S & P Global Ratings 2019)
[74] (Songhurst 2017)

Cost Component	Onshore (million US$)	FSRU (new-build) (million US$)
Jetty including piping	80	80
Unloading lines	100	n/a
1 Storage Tank (180,000m^3)	180	Already included in FSRU
FSRU vessel	n/a	250
Processing Units	100	Already included in FSRU
Utilities	60	Already included in FSRU
Onshore interface infrastructure	n/a	30
CAPEX	520	360
Contingency (30% onshore, 10% FSRU)	156	36
Owner's Costs	74	54
TOTAL CAPEX	750	450

Table 11: Comparison of Typical CAPEX for Onshore and Floating Terminals

Figure 35 illustrates how traditional large-scale infrastructure compares to mid-scale, small-scale and FSRU/FSU, with each cost element converted to US$/MMBtu terms.

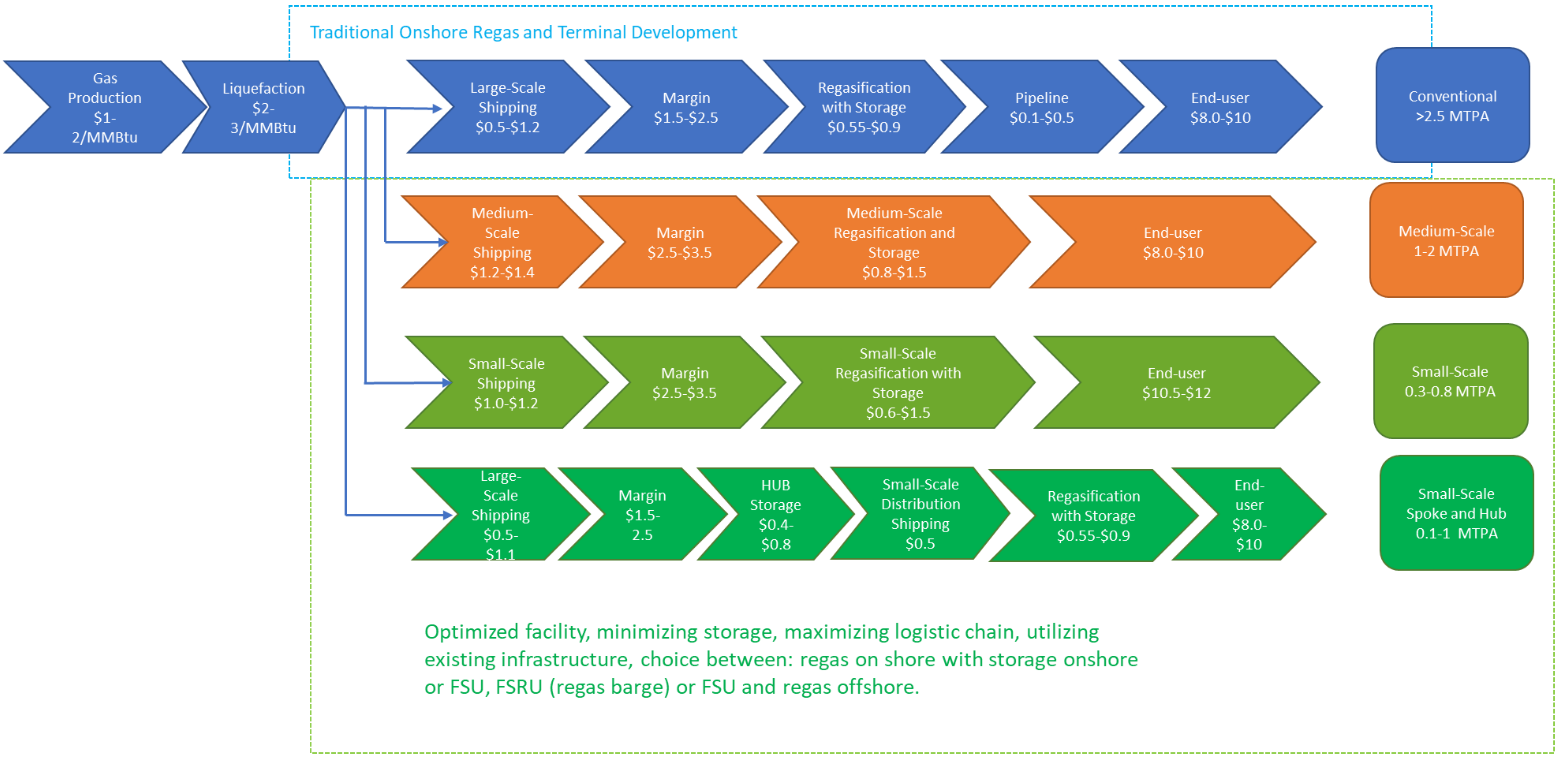


Figure 35: Comparison of Costs for Large, Medium, and Small-Scale Infrastructure [75]

SSLNGCs have smaller CAPEX requirements than large-scale LNGCs, while their per unit cost (m^3) is higher. For example, an SSLNGC with a storage capacity of 20,000 m^3, might cost approximately US$ 65 million, or 3,250 \$/m^3, compared to a large-scale LNGC with a storage capacity of 170,000 m^3, which will cost approximately US$ 200 million, or 1,176 \$/m^3. Further

[75] (Regan 2017)

savings can be achieved by using SSLNGCs because of their ability to be closer to jetties, smaller storage tank requirements onshore, and optimization from matching demand.

Figure 36 shows the costs of LNGCs based on their storage capacity.

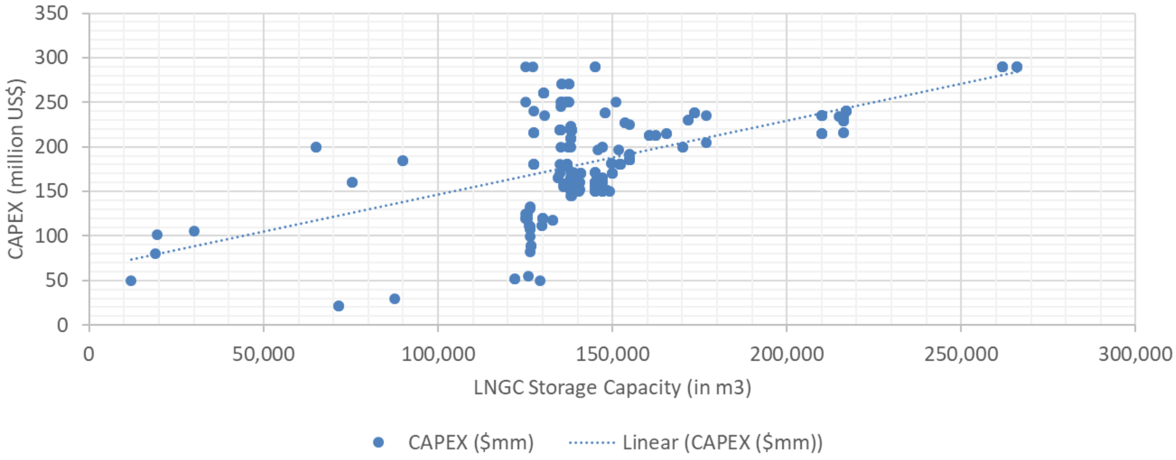


Figure 36: Comparison of LNGC Costs Based on Storage Size [76]

C) Affordability of gas: Price competitiveness of LNG is divided into 4 categories.

- US$ 2-4/MMBtu
- US$ 4-6/MMBtu
- US$ 6-8/MMBtu
- US$ 8-12/MMBtu

Affordability of gas is a major concern as it relates to gross domestic product (GDP) per capita as too low of a price to the end-consumer may not allow for the recovery of the project's CAPEX. An overview of historical wholesale prices between 2005 and 2016, as seen in Figure 37, shows that the Asia-Pacific region (e.g. Japan, Korea, Chinese Taipei, and China) had the highest wholesale prices while the Middle East and Former Soviet Union countries have the lowest. These low prices are mainly driven by the availability of domestic supplies and governmental subsidies. The wholesale prices needed to remunerate 2017 delivery costs of gas from new pipeline or LNG projects were in a range of US$ 5-8/MMBtu. Prices above this range are likely to make gas increasingly uncompetitive, potentially leading to the adoption of alternative fuels by users. [77]

[76] Galway Group
[77] IEA, World Bank, Oxford Energy Studies

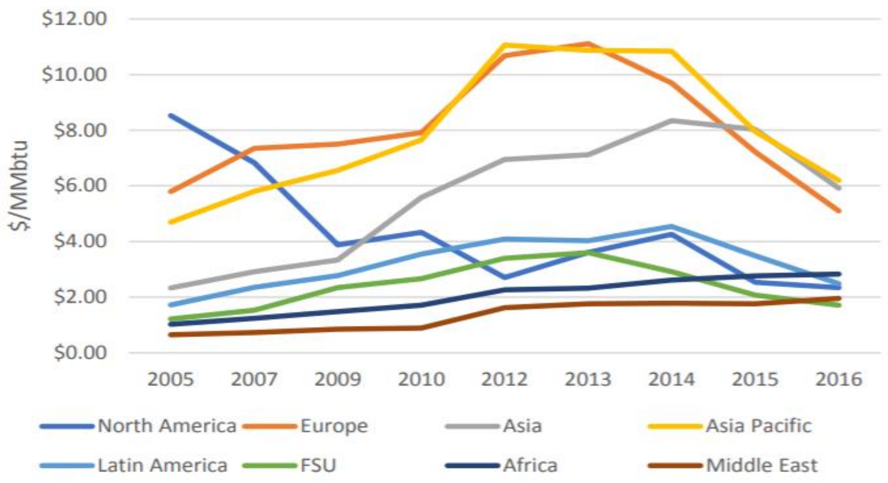


Figure 37: Overview of Historical Wholesale Gas Price by Region [78]

For gas/LNG to be competitive in low-income markets, the price should be below US$ 6/MMBtu or ideally closer to US$ 4-5/MMBtu. In higher-income markets, the delivered price should typically be in a range of US$ 6-8/MMBtu in order for LNG to be affordable and competitive, although exceptions exist – such as in case of The Philippines, Thailand, and Canada. Japan, Korea, Chinese Taipei and in recent years China had wholesale prices ranging between US$ 8-12/MMBtu, having the largest affordability among APEC economies considering their GDP. Figure 38 provides an indicative overview of wholesale prices for APEC economies. These prices may vary since the computing methodology for wholesale gas prices changes on a economy-by -economy basis. In addition to the computing methodology, government subsidies, where applicable, impact wholesale prices, as is the case in Brunei Darussalam.

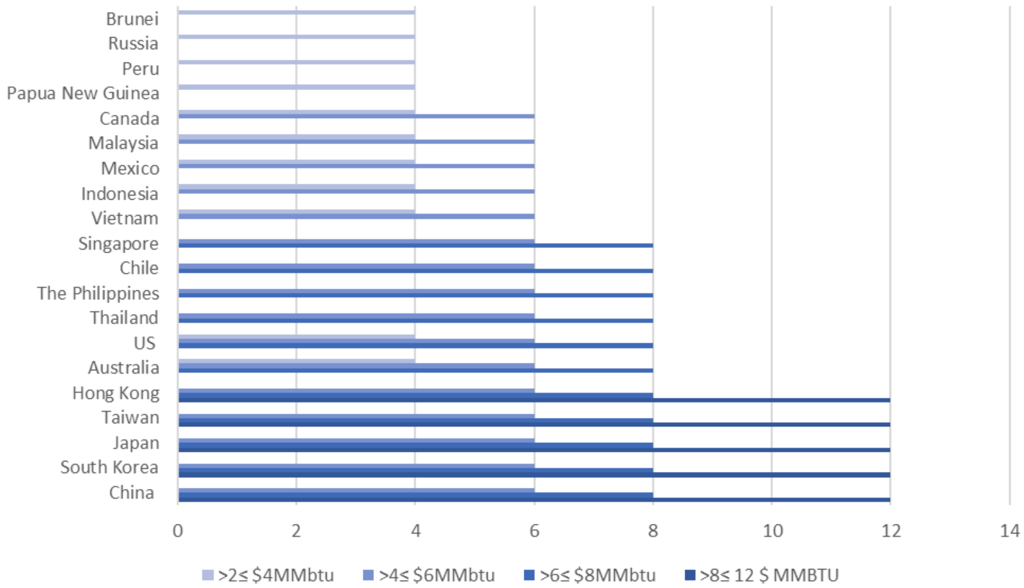


Figure 38: Overview of Affordability of Wholesale Prices by APEC Economy [79]
(Note: Prices for New Zealand were not available.)

[78] (International Gas Union 2019)
[79] (IGU) (Oxford Energy Studies) (Galway Group)

In some economies, average wholesale prices may not fully reflect affordability to end-users in individual provinces because of specific customer groups or government policies. In 2017, China's regulated city gate gas prices ranged from close to US$ 9/MMBtu in Shanghai to less than US$ 4.50/MMBtu in Xinjiang (western China). For the same period, prices in the majority of China's eastern provinces were in excess of US$ 8/MMBtu, reaching upwards to US$ 10/MMBtu, due to China's National Development and Reform Commission (NDRC) allowing for +/- 20% price fluctuations.[80] The purpose of this price fluctuation is to incentivize domestic natural gas producers to continue the development of high-cost production, especially for unconventional natural gas.

D) Availability of Subsidies:

- Yes
- No

Subsidies are financial incentives provided by a government to benefit a specific business or industry. These can be awarded to either producers or consumers in different forms, including a handout of cash or a tax break. Subsidies for fossil fuels are being gradually discontinued in certain economies due to environmental drivers and the desire to boost renewables. Still, certain regions maintain natural gas subsidies which affect the affordability of natural gas/LNG for end-users.

In 2015, natural gas represented about 24% of total energy subsidies worldwide.[81] This percentage varies greatly for individual economies and can be higher in markets where gas is used for power generation since electricity subsidies might also apply. Table 12 summarizes the typologies of fossil fuel subsidies used across APEC and provides insights regarding their recent developments.

Economy	Main fossil fuels subsidized	Recent developments
Australia	Natural gas, oil, coal	Gas subsidies for the whole value chain – from upstream to downstream: statutory effective life caps, accelerated depreciation for fossil fuel assets, and deduction for capital works expenditure.[82] The subsidies are made in a form of tax expenditure and mainly cover field development.[83]
Brunei Darussalam	Oil, electricity	No published subsidies for natural gas.
Canada	Natural gas, oil, coal	Typologies of natural gas subsidies include tax deductions for development or exploration expense, relief on royalties and production taxes on field output.[84] In 2016, Canada committed to the elimination of inefficient fossil fuel subsidies by 2025.
Chile	Natural gas, oil	Subsidies on a case-by-case basis. For example, exploration and production costs in the isolated region of Magallanes have increased due to the region's reliance on unconventional gas. Because of this increase in cost the government started to subsidize gas producer ENAP to cover its losses.[85]

[80] IGU, Galway Group, Oxford Energy Study - Prices from NDRC (converted at $1 = RMB6.5)
[81] (International Energy Agency (IEA) 2019)
[82] (Robertson 2019)
[83] (Makhijani and Doukas 2015)
[84] (Touchette 2015)
[85] (IEA and Organisation for Economic Co-operation and Development (OECD) 2018)

China	Natural gas, electricity, LPG,	Typologies of natural gas subsidies include resource-tax abatements and refunds for gas extraction, the management measures of natural gas infrastructure construction and operation, exploration fee waived for shale gas, exemption of business tax on overseas operations in construction and international transportation. These are provided as tax breaks, refunds, or tax waivers for exploration, production, pipeline operation, and development.[86] Government announced that it may extend subsidies on shale and coal seam gas production for 5 more years beyond 2020 and provide aid to tight gas production.
Hong Kong, China	Natural gas	In January 2020, the Government provided subsidies to enable greater customer affordability for the increase of natural gas in the fuel mix for 5 years.
Indonesia	Natural gas, diesel, electricity	Exemption from import duty and value added tax for goods used in gas exploration and investment credit allowance. Some non-tax incentives also exist, but it is difficult to determine if they are subsidies or how to quantify them. In 2017, the government launched a "one price policy" aimed at providing fuel access to Indonesia's remote and underdeveloped areas. The regulation stipulates that prices of fuels in those regions should be the same as in the more developed regions of the economy. In 2018, Indonesia's president instructed his ministers to keep fuel and electricity prices stable over the next 2 years, preventing future adjustments of domestic fuel prices.
Japan	Natural gas, oil	Major subsidies to promote natural gas production and distribution are provided to Japanese companies overseas. The largest subsidy is the supply of capital to Japan Oil, Gas and Metals National Corporation (JOGMEC) – which supports the acquisition of natural gas rights and diversifies supplies. As of 2011, the government phased out subsidies promoting domestic natural gas exploration.[87] A tax on fossil fuels was introduced in 2012 and increased in 2016 to favor renewable sources.
Korea	Natural gas, coal	Research and development funding for resource technologies in the exploration segment. These are provided as a direct spending subsidy. In 2015, consumption taxes were reduced on a number of other fossil fuels, including LNG, fuel oil, and propane.
Malaysia	LPG, electricity	In 2014, the Malaysian government increased electricity tariffs by an average of 15% and resumed a fuel cost pass-through mechanism, based on international gas price movements. In May 2014, natural gas prices were increased by up to 26% for certain users. In 2014 subsidies for natural gas, gasoline, and diesel were terminated. Prices are now set to track international levels.

[86] (Denjean, et al. 2015)
[87] (Doukas and Makhijani, G20 subsidies to oil, gas and coal production: Japan 2015)

Mexico	Natural gas, electricity, oil LPG, coal	Mexico has reduced fiscal pressure on fossil fuel subsidies. Natural gas subsidies include: 100% deduction of exploration expenditure on income tax payments; 25% of original investments in the exploration and development of natural gas deposits is deductible from income tax payments; and 10% of the amount invested in infrastructure for storage and transport of gas is deductible from income tax payments.
New Zealand	Natural gas, oil	Fossil fuel subsidies are very low (New Zealand is one of the leading nations in climate change initiatives. The government provides only minor tax and royalty incentives for gas exploration.).
Papua New Guinea	Electricity	No specific gas subsidies. Some cross-subsidies among customer classes in the electricity sector are allowed to ensure affordability for all customer segments. This is through a uniform tariff that subsidizes cost of supply between the regions connected to the main grid, which are powered by cheap hydropower, and remote areas powered by expensive diesel-fired power generation.[88]
Peru	Electricity	Electricity subsidies have been introduced and there are no natural gas subsidies.
Philippines	Electricity	No natural gas subsidies. Most subsidies have been terminated, with only electricity lifeline rate subsidies, senior citizen subsidies, the Universal Charge and the Feed-in Tariff Allowance (mainly cross-subsidized by other users of the distribution utility) remaining. The Universal Charge is levied on grid-connected end-users and subsidizes missionary electrification activities outside of the main grid.[89]
Russia	Electricity, gas, oil	Customs duties reduction (both import and export) granted for production-sharing agreements, tax exemption from mineral extraction for newly developed onshore and offshore fields, property tax exemption for trunk oil and gas pipelines.[90]
Singapore	Electricity	No specific natural gas subsidies. There are marginal subsidies for low income customers in the form of "save rebates" on utility bills.
Chinese Taipei	Oil, electricity, coal	No published subsidies for natural gas.
Thailand	Natural gas, oil, LPG	Existing subsidies for natural gas and LPG. Subsidies for electricity ended in 2013 and for coal in 2015.
United States	Natural gas, oil, coal	Corporate tax exemption, deduction for intangible drilling for oil and gas, lost royalties on offshore drilling, excess of percentage over cost depletion. These are made in a form of tax expenditure and cover both production and extraction.[91]

[88] (Asian Development Bank (ADB) n.d.)
[89] (Asian Development Bank 2018)
[90] (Ogarenko, et al. 2015)
[91] (Doukas, G20 Subsidies to Oil, Gas and Coal Production: United States 2015)

Viet Nam	Natural gas, electricity, coal, oil	Natural gas subsidies were discontinued in 2015 and reintroduced, covering smaller volumes of gas, in 2018. In March 2015, electricity tariffs increased by 7.5%.[92]

Table 12: Overview of Natural Gas Subsidies in APEC Economies [93]

6.2 Economic Comparison of Various Small-Scale Value Chain Elements

LNGCs Cost Comparison

Distance between demand and supply centers as well as the scale of demand are essential for determining the suitability of small versus large-scale LNGCs. Assuming a demand center with a capacity of 0.5 MTPA, SSLNGCs of 2,500 m^3 are the most economic delivery method for short distances of less than 100 nm. As the distance increases, larger vessels of 15,000 m^3 upwards to 30,000 m^3 are more cost-effective, up to a 2,100 nm (for a vessel with storage capacity of 15,000 m^3) or 3,050 nm (for a vessel with storage capacity of 30,000 m^3). For distances over 3,000 nm, large-scale LNGCs with a storage capacity of 145,000 m^3 become cost-effective.

Table 13 provides benchmark CAPEX for small, medium, and large-scale vessels, together with calculated annualized costs and charter rates. This table assumes a 20-year economic life for an LNGC and an interest rate of 8%. CAPEX ranges between US$23 million (for a vessel with storage capacity of 2500 m^3) to about US$200 million (for vessels with storage capacity ranging between 145,000 and 200,000 m^3). These costs are only indicative as charter rates will fluctuate based on actual shipping market dynamics.

Category of Cost	Units	Vessel Size (m3)			
		Small		Medium	Large
		2,500 m3	15,000 m3	30,000m3	145,000 -200,000 m3
Optimal Delivery Distance	*nm*	0-100	2,100	3,050	>3,050
CAPEX	*US$ million*	23	50	85	200
Annualized CAPEX	*US$ million*	2.34	5.09	8.66	20.37
Annualized Operating Expenditure (OPEX)	*US$ million*	0.92	2.00	3.40	8.00
Total Annual Cost	*US$ Million/Year*	3.26	7.09	12.06	28.37
Total Daily Charter Cost	*US$/day*	8,939	19,432	33,034	77,727

Table 13: Cost Comparison for Various Sizes of LNGCs [94]

While SSLNGCs require lower initial CAPEX, their price is higher in terms of cost per cubic meter of storage capacity meaning that a SSLNGC with a 2,500 m^3 storage capacity costs approximately US$ 9,200/m^3, while a large-scale LNGC with a 145,000m^3 storage capacity costs about US$ 1,379/m^3. See Figure 39.

92 (Asian Development Bank 2015)
93 ADB, EIA
94 Galway Group Database

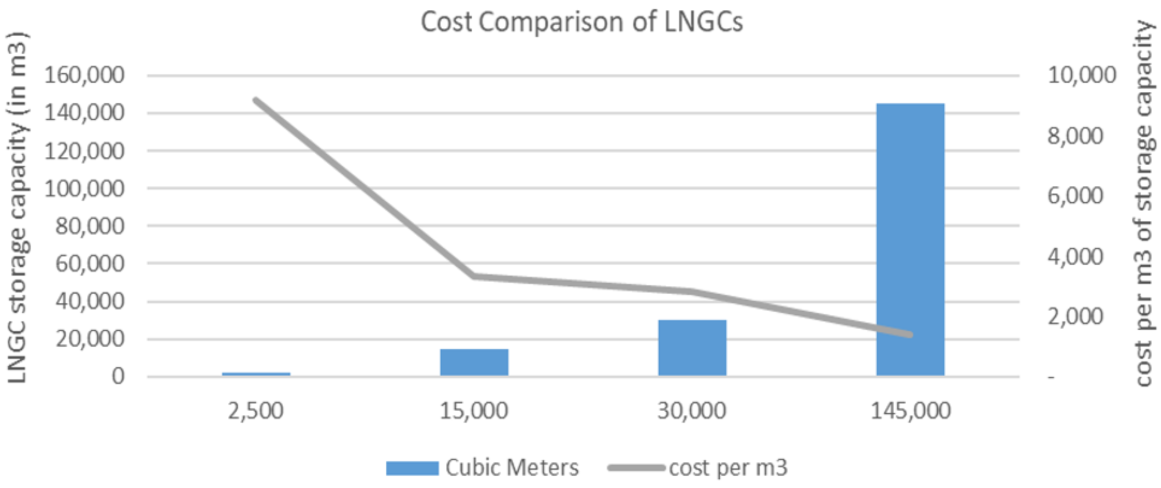


Figure 39: LNGC Cost Comparison per m^3 of Storage Size [95]

FSRUs Cost Comparison

The CAPEX of a receiving facility varies according to storage capacity, send-out capacity, send-out pressure, unloading facilities, local conditions (e.g. supply of equipment and raw material, manpower cost) and economic risk, amongst others**.** A project developer can choose between a new-build and a converted FSRU. This decision will be based on various criteria, including a development timeline as new-build vessels take longer to come online than converted vessels. New-build vessels require between 24 and 36 months (unless the vessel is readily available) while converted vessels require between 12 and 20 months. This timeline constantly changes due to fast technological advancements and increased standardization of vessels.

Converted FSRUs are usually cheaper and have less storage capacity than new-build FSRUs as shown in Table 14. This is because old LNGCs are the ones converted into FSRUs and they have storage capacity between 120,000 and 145,000m^3. The conversion cost depends on how much retrofitting is required (e.g. regasification kit, power kit, mooring system, etc.) and can range between US$ 110 -160 million (this in addition to the actual cost of the LNGC which can range between US$ 20 -40 million, depending on actual market rates).[96] The OPEX of converted FSRUs could be higher than for new-builds due to older and less efficient engines. Golar Freeze, Golar Spirit, and NR Satu are examples of converted FSRUs.

Cost Component	Units	Converted FSRU	New-build FSRU
		2.5 MTPA – 145,000m^3	3 MTPA -180,000m^3
Jetty including piping	*US$ million*	80	80
Onshore interface infrastructure	*US$ million*	30	30
FSRU vessel[97]	*US$ million*	165	250
Contingency (10%)	*US$ million*	28	36

[95] Galway Group Database
[96] Galway Group database
[97] Average cost of conversion plus the cost of the LNGC was considered for converted FSRUs; average cost was used for new-build vessels.

Owner's Costs	*US$ million*	41	54
TOTAL CAPEX	*US$ million*	344	450
Annualized CAPEX	US$ Million/Year	35.04	45.83
Annualized OPEX	US$ Million/Year	5.75	5.48
Total Annual Cost	US$ Million/Year	40.51	51.31
Total Daily Charter Cost	US$/day	110,992	140,571

Table 14: Cost Comparison for Converted and New-build FSRU [98]

SSLNG ISO Container Barge Cost Comparison

LNG ISO container barges act as a filling facility able to receive LNGCs and unload the LNG into 20- or 40-feet ISO containers for further redistribution to demand markets. From the barge, the ISO containers can be redistributed by using multi-purpose vessels or trucks. Table 15 shows that the CAPEX for an ISO container barge with a storage capacity of 8,000 m^3, which uses two buffer storage tanks and has deck capacity to accommodate approximately 136 ISO container tanks of 40 feet each, would be approximately US$35 million with an annual OPEX of approximately US$3 million. This calculation assumes an economic life of 20 years for the asset and an interest rate of 8%. Mooring systems were not included in the CAPEX overview as these vary greatly based on location.

Cost Component	Units	ISO Container Barge
Storage Size (136 x 40 feet ISO Containers on the barge)	Cubic Meters	6,206
Storage Size (2 x buffer tanks)	Cubic Meters	8,000
Material and Fabrication Costs (hull, LNG tanks, accommodation)	US$ Million	18.6
Packaged Items (RE-liquefaction unit, pumps, hoses, vaporizers, engine genset, LNG hoses, etc.)	US$ Million	6.2
Utility Systems (instrumentation, fire protection system, sea water/fuel oil/utilities package, etc.)	US$ Million	3.2
Accommodation and safety (accommodation units, HVAC system, workshop/safety equipment)	US$ Million	0.8
Contingency (10%)	US$ Million	2.9
Owner's Costs	US$ Million	3.5
TOTAL CAPEX	US$ Million	35
Interest Rate	percentage	8%
Economic Life	years	20
Annualized CAPEX	US$ Million/Year	3.58
Annualized OPEX	US$ Million/Year	3.02
Total Annual Cost	US$ Million/Year	6.60
Total Daily Charter Cost	US$/day	18,070

Table 15: Cost Breakdown for ISO Container Barges [99]

[98] Galway Group Database
[99] Galway Group Database

6.3 Tool Development to Suggest an Effective Utilization Strategy for SSLNGCs and FSRUs

A user-friendly tool was built to provide recommendations and guidance on development options. The tool utilizes inputs from the user together with listed assumptions and allocated percentage thresholds to generate a recommendation. The user selects the inputs from a drop-down menu provided for each parameter. The parameters and subdivisions that require inputs from the user are:

1. **Economy Parameters:** Credit Rating, Availability of Project Funding, Affordability of Gas

2. **Demand Parameters**: Size of Demand Center, Typology of User, Stability of Demand, Potential Demand Upside

3. **Infrastructure Parameters**: Development Timeline, Accessibility, Distance

4. **Technical Parameters** Water Depth, Wave Height, Wind Speed, Current Speed

The outputs for economy and demand parameters will be a recommendation on whether the potential project should be onshore, floating or both. (See Figure 40). It should be noted that the output is not intended to be definitive, but it is intended to act as a guidance, indicating a likely tendency towards a certain infrastructure type based on a series of defined assumptions.

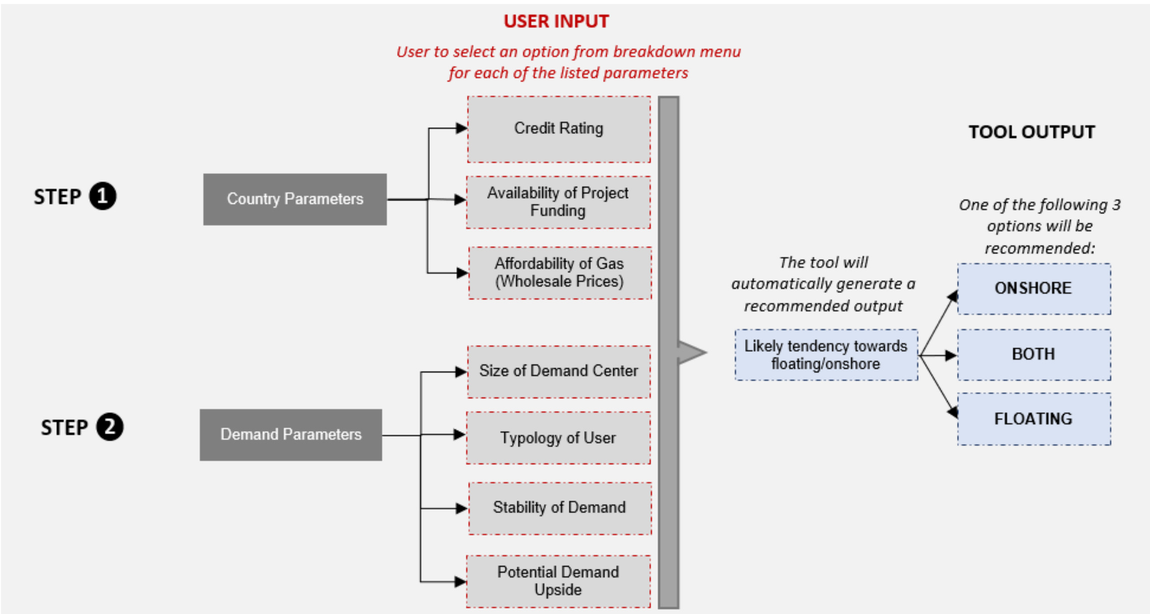


Figure 40: Overview of the Inputs and Outputs for Economy and Demand Parameters

Next, the user selects the most applicable infrastructure parameter from a drop-down menu. The output indicates the most feasible infrastructure type and the most economically feasible delivery method, as shown in Figure 41.

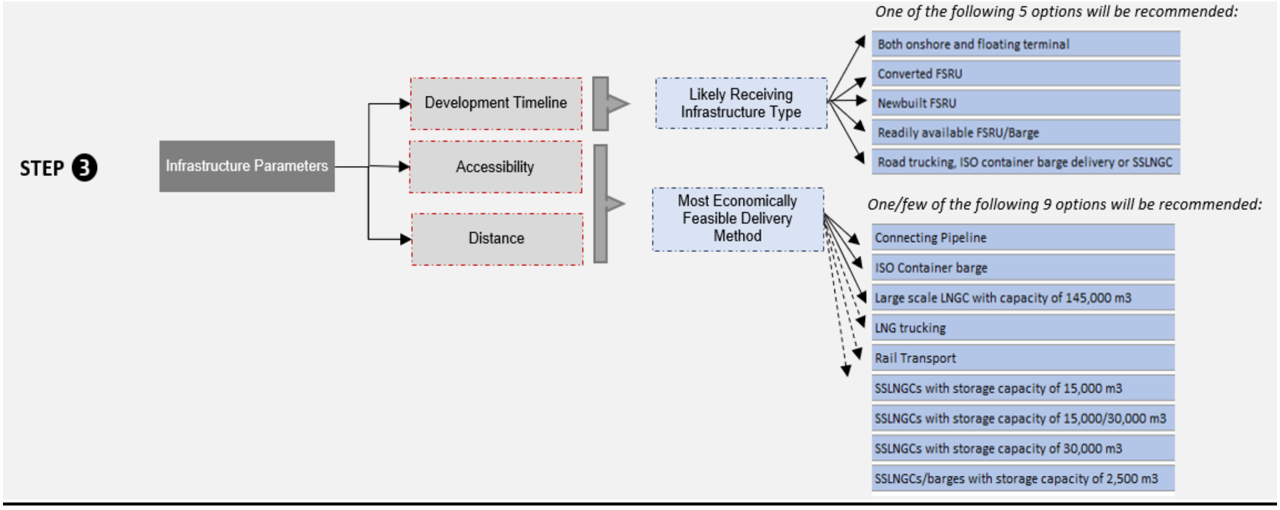


Figure 41: Overview of the Inputs and Outputs for the Infrastructure Parameter

Step number 4 requires the user to provide input for the technical parameters as shown in Figure 42. The generated output indicates the most technically feasible delivery method and marine operations limits for LNGCs/ FSRUs under specified metocean conditions. Note, however, that the technical parameters are applicable only for projects with sea access. In this selection method, the user shall reset the filter every time the new selection is to be generated.

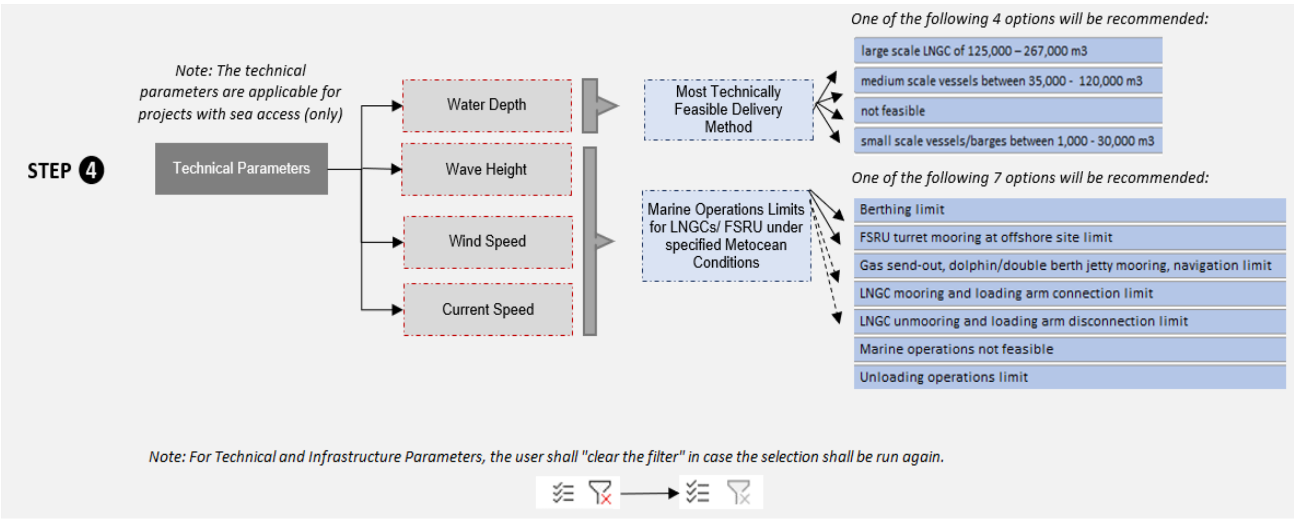


Figure 42: Overview of the Inputs and Outputs for the Technical Parameter

6.4 Case Study for the use of the tool: Indonesia

To demonstrate the functionality of the tool, Indonesia will be used as a case study for deriving recommended infrastructure typology. For this case study, the following inputs were selected for each parameter:

Economy Parameters:

- Credit Rating: ≥ BBB (Investment Grade)
- Availability of Project Funding: ≤ 100 US$ million
- Affordability of Gas (Wholesale Prices): > 4 ≤ 8 $/MMBTU

Demand Parameters:

- Size of Demand Center: Small (> 0.1 ≤ 1)
- Typology of End-user: Industries
- Stability of Demand: Stable Demand Required (uninterrupted/base load)
- Potential Demand Upside: No

Infrastructure Parameters:

- Development Timeline: Short Term (> 6 months ≤ 12 months)
- Accessibility: By sea (port access or jetty)
- Distance: > 100 ≤ 700 nm

Technical Parameters:

- Water Depth: > 3.5m ≤ 8 m
- Wave Height: ≤ 2 m
- Wind Speed: ≤ 7.5 m/s
- Current Speed: ≤ 0.5 m/s

With the selected inputs for Economy Parameters, the tool indicates a likely tendency is towards a floating facility, as shown in Figure 43.

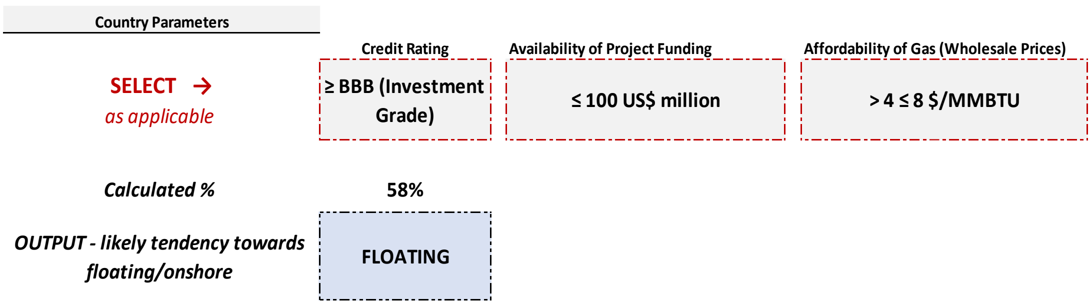


Figure 43: Step 1- User Selection of "Economy Parameters" and Generation of "Recommended Output"

With the selected inputs for Demand Parameters, the tool corroborates that the likely tendency is towards a floating facility, as shown in Figure 44.

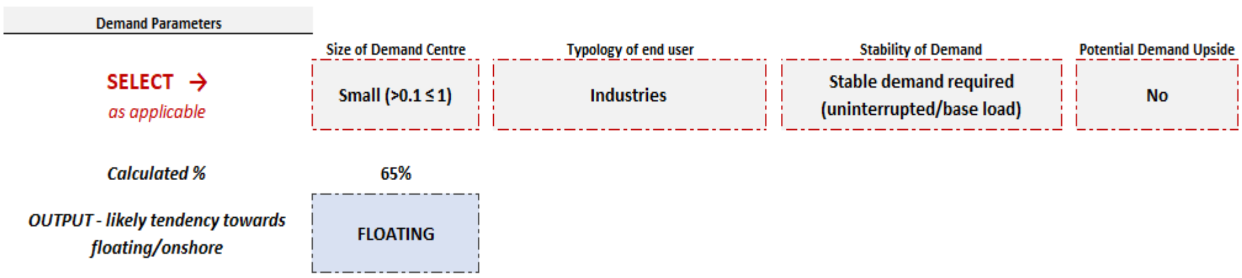


Figure 44: Step 2- User Selection of "Demand Parameters" and Generation of "Recommended Output".

With the selected inputs for Infrastructure Parameters, the tool recommends the receiving infrastructure type to be readily available FSRU/barge and the use of SSLNGCs with storage capacity of 15,000 m^3 or ISO container barges, as shown in Figure 45.

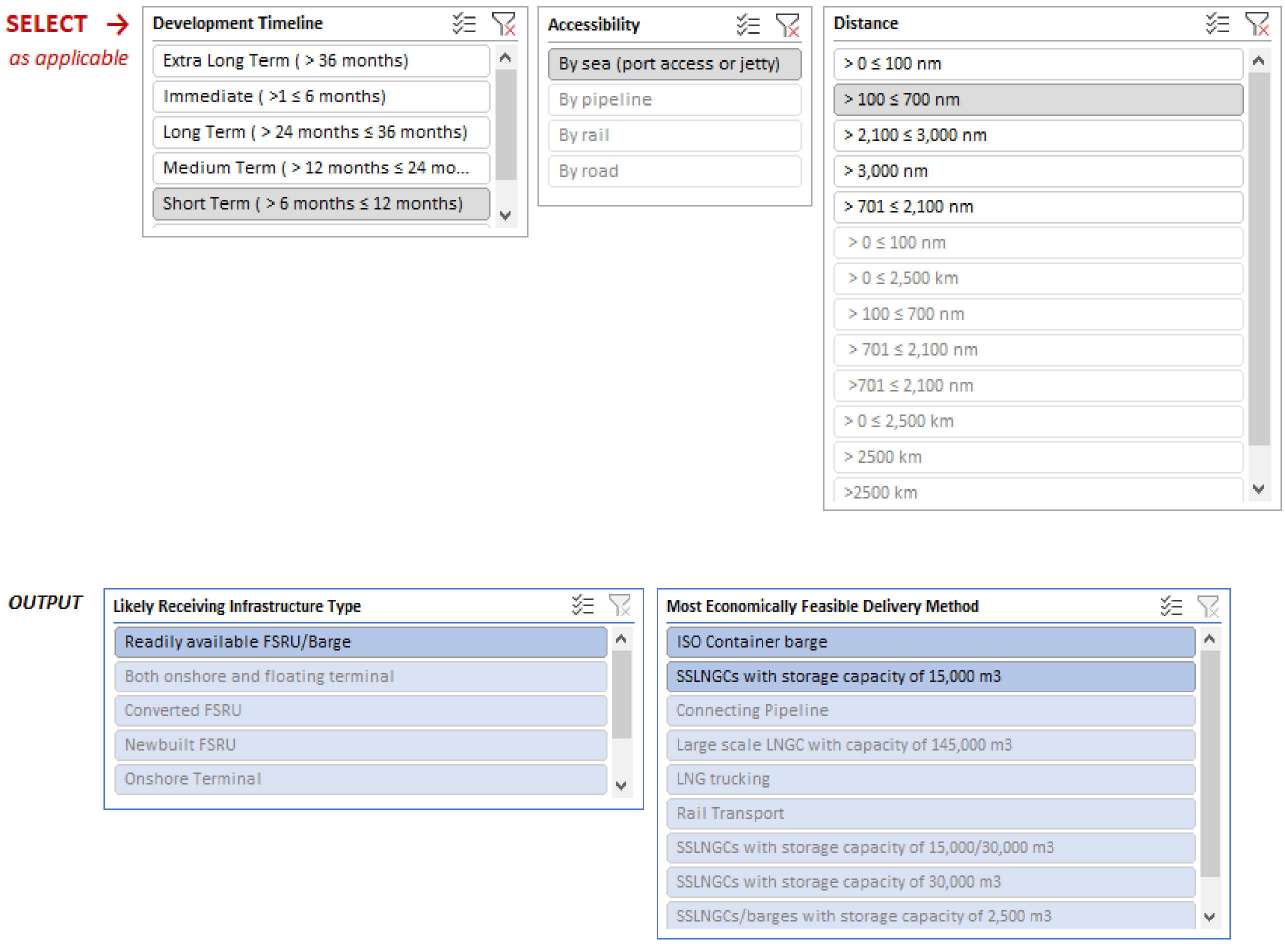
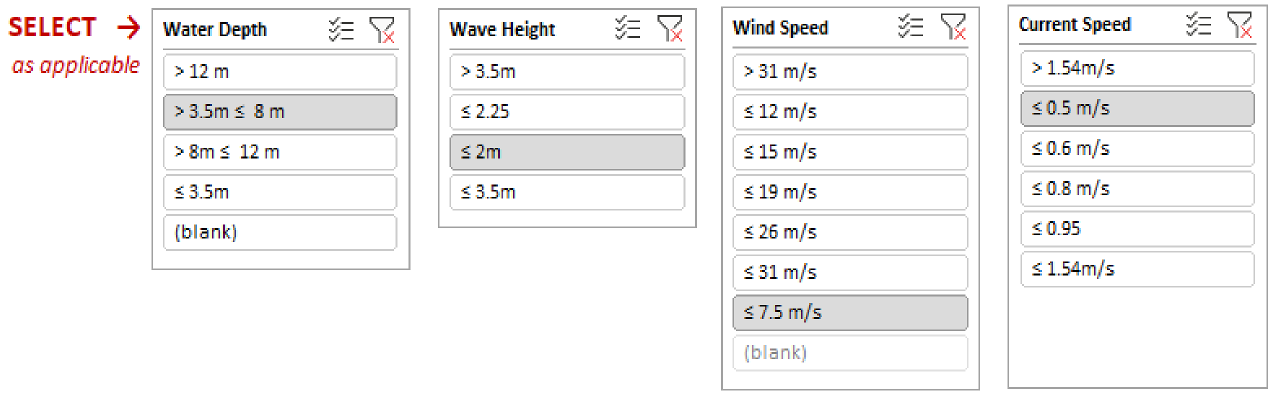


Figure 45: Step 3 -User Selection of "Infrastructure Parameters" and Generation of "Recommended Output"

With the selected inputs for Technical Parameters, the tool recommends the use of SSLNGCs/ barges between 1,000 m^3 and 30,000m^3, berthing with LNG unloading limit, and LNG mooring and loading arm connection/disconnection limit.



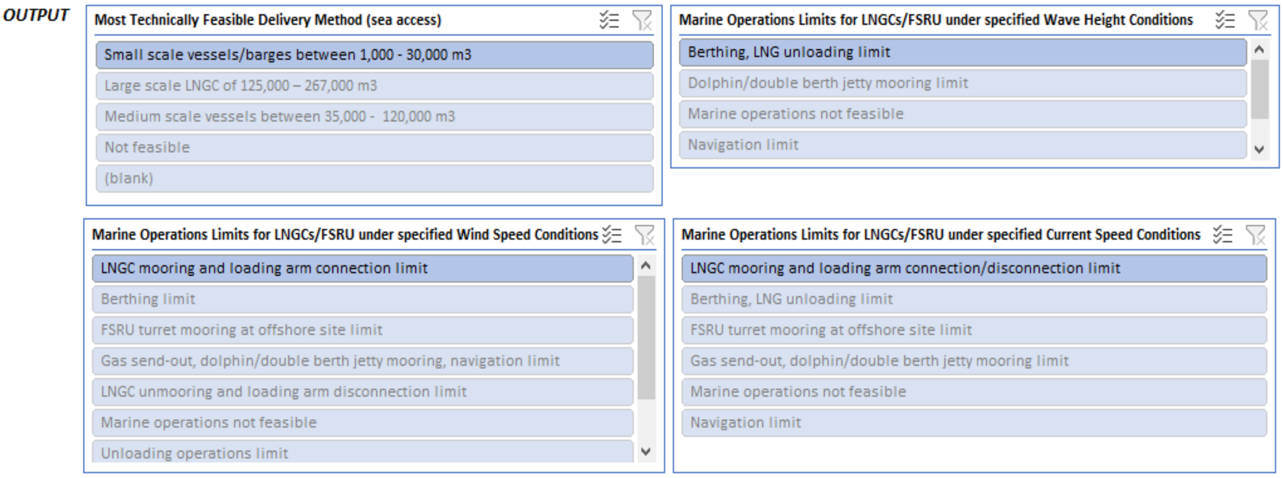


Figure 46: Step 4- User Selection of "Technical Parameters" and Generation of "Recommended Output"

7 LNG in APEC Context and Recommendations

7.1 Identification of Demand Characteristics of APEC

In order to identify the potential for SSLNGCs and FSRUs in the APEC region, the 21 APEC economies were evaluated based on three factors:

a) gross domestic product (GDP) per capita based on purchasing power parity (PPP);

b) total primary energy supply (TPES) per capita; and

c) being a South-East Asian coastal economy.

GDP per capita based on PPP:

GDP per capita based on PPP is the "sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products."[100] It is converted to international dollars using PPP rates and it is intended to indicate the standard of living of a particular economy. APEC economies with GDP per capita below US$20,000 were shortlisted for the purpose of evaluating the most suitable candidate economies for potential SSLNGCs and FSRUs deployment.[101] This provided 8 potential candidate economies: Mexico, Peru, Thailand, Indonesia, Viet Nam, China, The Philippines, and Papua New Guinea, shown in Figure 47.

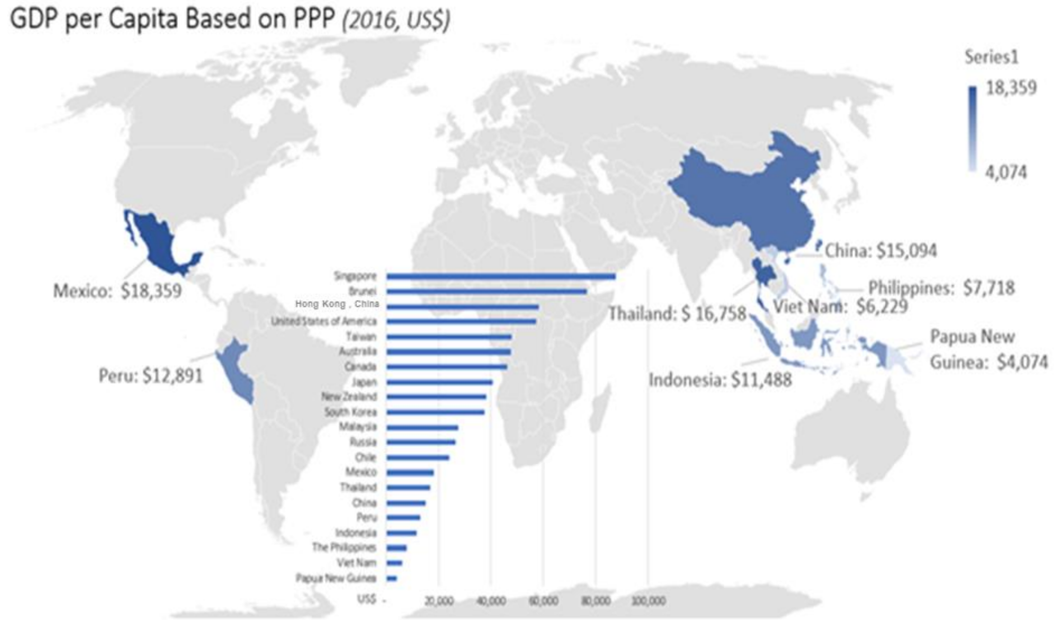


Figure 47: Shortlisted Economies [102]

(1) **TPES per capita**:

Primary energy is energy in the form found in nature (e.g. coal, oil, gas) prior to conversion through human processes (e.g. refinery process, electricity, etc.). This factor is used to measure and analyze energy consumption. [103] TPES aggregates these primary energy sources (i.e. domestic production

[100] World Bank, World Development Indicators;

[101] World Bank, World Development Indicators;

[102] Galway Group, World Bank, APEC, IEA

[103] (US Energy Information Administration n.d.)

plus imports) and subtracts exports, international marine and aviation bunkers, and stock changes. TPES per capita is used as a measure of energy efficiency in an economy.[104]

A threshold of less than 2 tons of oil equivalent (toe) of TPES per capita was used to shortlist economies based on an assumption that they have potential for improvement of their energy supplies. The eight APEC candidate economies shortlisted were: Mexico, Peru, Thailand, Viet Nam, Indonesia, Hong Kong, China, the Philippines, and Papua New Guinea (See Figure 48).

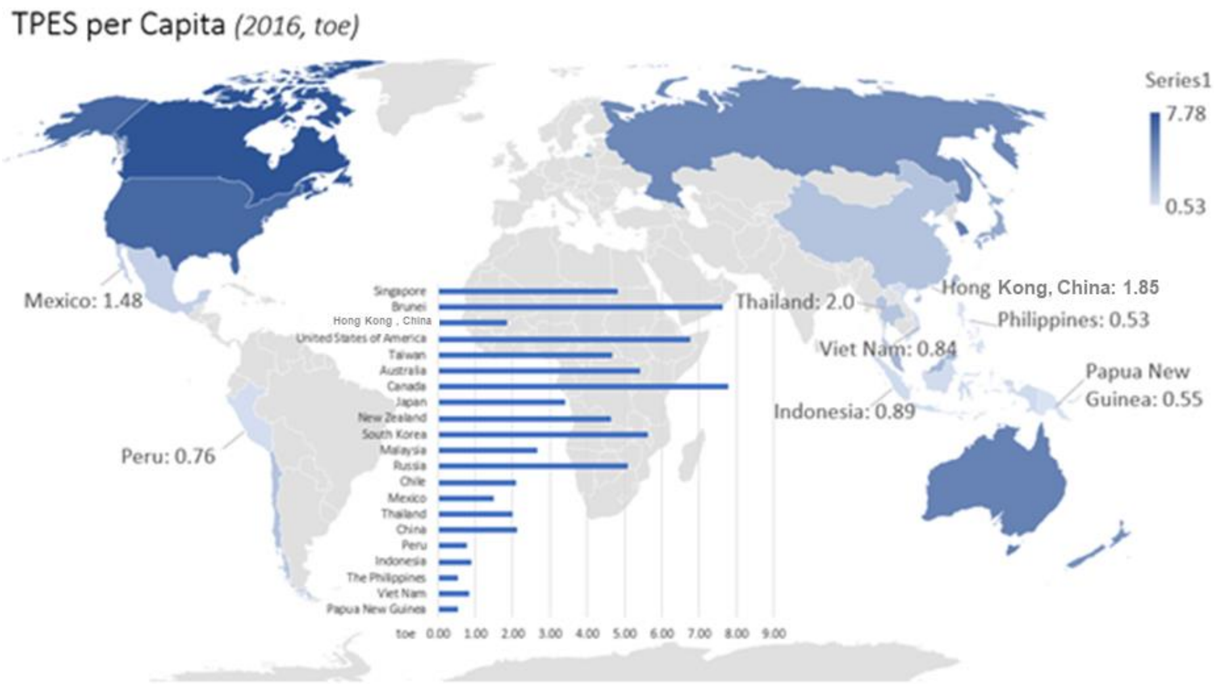


Figure 48: Shortlisted Economies with Lowest TPES Per Capita [105]

(2) **South-East Asian Coastal Economy:**

The geographical locations and coastal features of individual APEC economies were studied to determine the degree of scattered demand centers and lack of infrastructure. In this evaluation, the South-East Asian coastal region was considered optimal for economy selection because of shallow water access to market.

By combining all three criteria (1) GDP per capita based on PPP, (2) TPES per capita and (3) South-East Asian Coastal Economy, we shortlisted 5 APEC economies: Papua New Guinea, Viet Nam, The Philippines, Indonesia, and Thailand. (See Table 16)

Economy	GDP per capita PPP	TPES per capita	SE Asian Coastal
Papua New Guinea (PNG)	4,074	0.55	yes
Viet Nam	6,229	0.84	yes
The Philippines	7,718	0.53	yes
Indonesia	11,488	0.89	yes
Peru	12,891	0.76	no
China	15,094	2.13	yes
Thailand	16,758	2.00	yes
Mexico	18,359	1.48	no

[104] (International Energy Agency (IEA) n.d.)
[105] Galway Group, World Bank, APEC, IEA

Chile	24,129	2.11	no
Russia	26,543	5.08	no
Malaysia	27,389	2.66	yes
Korea	37,701	5.61	yes
New Zealand	38,437	4.65	yes
Japan	40,606	3.42	yes
Canada	46,102	7.78	no
Australia	47,643	5.42	yes
Chinese Taipei	48,093	4.68	yes
United States	57,193	6.76	no
Hong Kong, China	58,325	1.85	yes
Brunei Darussalam	76,633	7.63	yes
Singapore	87,910	4.82	yes

Table 16: Summary of Shortlisting Criteria [106]

7.2 Demand Profiling and Energy Mix Determination

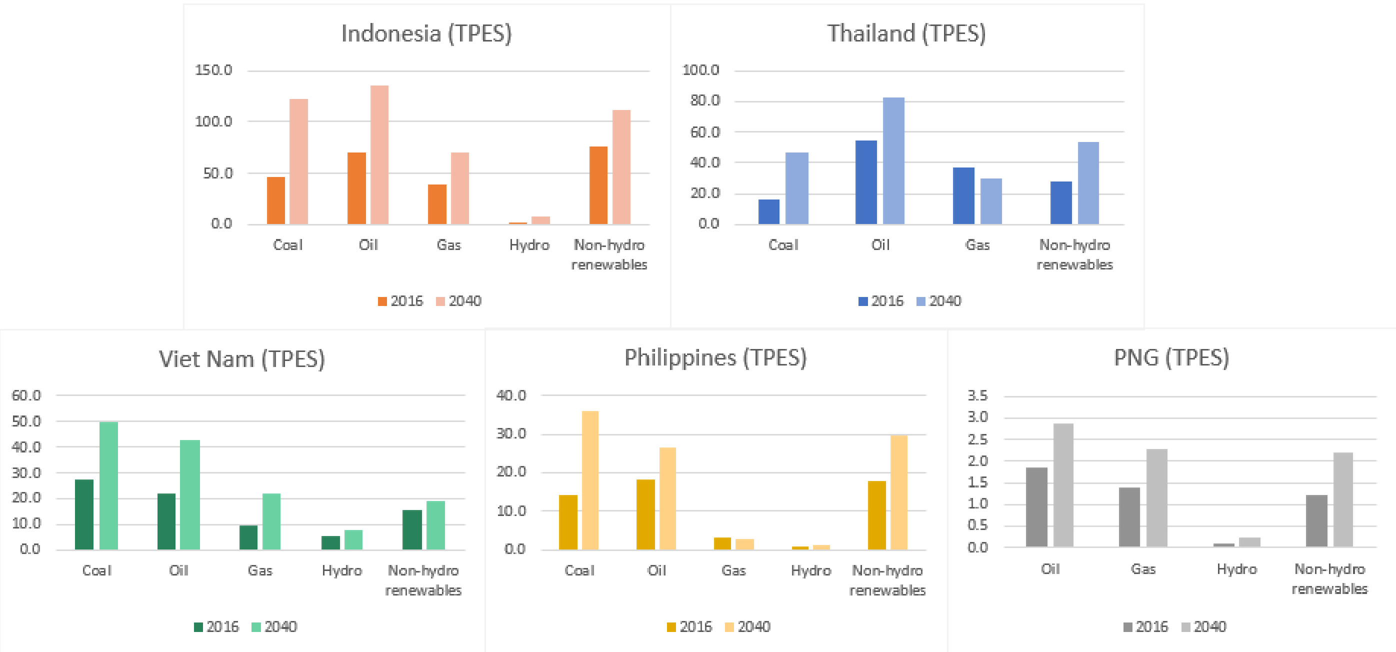


Figure 49: Overview of 2016 vs. 2040 (Forecasted) TPES for Shortlisted Economies in Million Toe (Mtoe)[107]

The greatest potential for natural gas/LNG demand, either as a stand-alone fuel or for electricity generation, is in Indonesia, Thailand, and Viet Nam. All three economies have solid and increasing demand for natural gas in their future energy mix. The Philippines and PNG markets have less infrastructure for natural gas consumption and The Philippines currently favors coal-fired power generation. However, this does not necessarily mean that there is no potential demand for SSLNG as PNG's undeveloped market (with low electrification rates), and The Philippines' power outages caused by lack of fuel supply, potentially could benefit from SSLNG infrastructure.

[106] Galway Group, World Bank, APEC, IEA
[107] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)

In the case of PNG, its government signed gas sales agreements in 2014 which allow for most of the gas it produces to be exported as LNG. These agreements also allowed the producers to recover CAPEX prior to paying royalties to the government, which has left PNG with limited financial returns from its gas. This situation is expected to change with the negotiation of new gas sales agreements for the next phase of LNG expansion projects, expected to commence in 2024, which will require that 10% of the gas produced be reserved for PNG's domestic market. [108] Figure 49 provides an overview of 2016 vs 2040 (forecasted) TPES for each assessed economy.

Table 17 identifies as potential gas-consuming target sectors for each shortlisted economy.

Economy	Potential for future gas/LNG demand and infrastructure development
Papua New Guinea	○ Gas-to-power project developments (both large and small-scale) to fulfill existing electricity generation needs due to low electrification rates (new gas-to-power projects plus potential replacement of old diesel-fired power plants). Electricity generation is expensive in PNG due to high usage of diesel-fired power plants that could be replaced by gas-fired technology. ○ Industrial sector, specifically mining, since it depends on captive power stations for operations using mainly diesel. ○ Residential segment – as a replacement for biomass usage.
Viet Nam	○ New gas-to-power projects (both large and small-scale), in order to fulfill growing electricity demand. ○ Industries, specifically fertilizers and petrochemicals. ○ Road transportation, using CNG. ○ LNG bunkering. ○ Residential segment – as a replacement for biomass usage.
The Philippines	○ Small-scale gas-to-power projects, as a potential replacement for old captive diesel-fired power plants servicing remote island locations. On the other hand, there is limited scope and incentive for new large-scale power plants, due to governmental incentives for usage of coal-fired power generation. ○ Industry, in particular planned steel mills, which could use natural gas instead of HFO or diesel. ○ Road transportation, using CNG. ○ Residential segment – as a replacement for biomass usage.
Indonesia	○ New small-scale gas-to-power projects, in order to fulfill growing electricity demand from remote island locations and new large-scale gas-to-power projects in proximity of urban or industrial areas, requiring additional capacity to avoid power black-outs. ○ Industries, primarily fertilizers and petrochemicals, with other smaller gas consuming industries including ceramics, cement, steel, and glass. ○ Road transportation, using CNG. ○ LNG bunkering. ○ Residential segment – as a replacement for biomass usage.

[108] Financial Review, December 2018

Thailand	○ Limited scope for new gas-fired power plants (both large and small-scale) as the government plans to decrease the proportion of natural gas used for power generation and substantially increase coal-fired power generation; however, there is an increasing need for natural gas imports because of declining domestic production. ○ Industries, primarily for fertilizers and petrochemicals. ○ Road transportation, using CNG. ○ LNG bunkering – a bunkering facility is proposed for the port of Bangkok. ○ Residential segment – as a replacement for biomass usage.

Table 17: Potential for Future Gas/LNG Demand and Infrastructure Development by Economy

Papua New Guinea

Demand

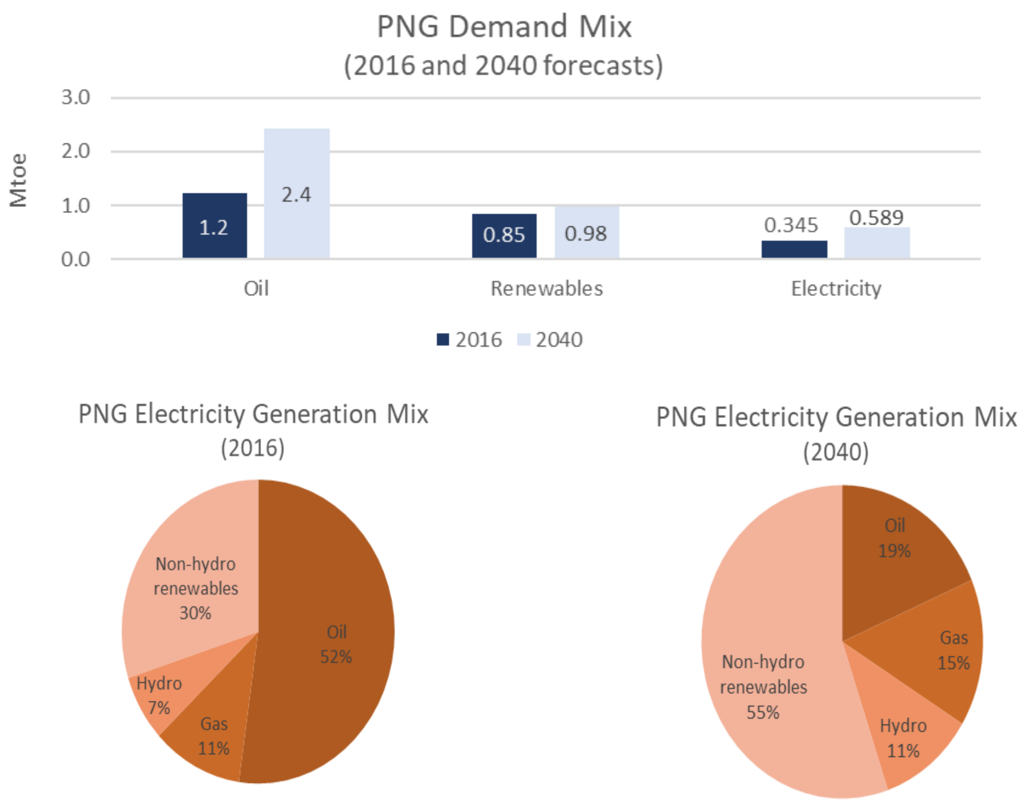


Figure 50: PNG Demand and Electricity Generation Mix [109]

PNG's demand is driven by the availability of oil products (e.g. diesel, petrol and HFO) and renewables (e.g. biomass – derived from wood, crop waste, or garbage). In 2016, energy demand accounted for about 2.4 Mtoe, with expectations for this number to almost double to 4 Mtoe by 2040[110]. The electricity (power) generation mix was dominated by oil products, specifically diesel (52%). This is expected to change with non-hydro renewables representing the largest proportion

[109] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[110] (APEC Energy Working Group 2019)

of the electricity (power) generation mix by 2040 (55%). Gas consumption in electricity generation is also expected to be more significant, increasing from 12% to 15% of the mix by 2040.[111] Figure 50 shows the demand mix by fuel together with the 2016 and forecasted 2040 electricity (power) generation mix.

In 2016, the greatest energy demand was from commercial buildings (42%), followed by the industrial sector (30%), domestic transportation (24%), and other sectors (4%) including residential, commercial, and agriculture consumption. Figure 51 shows that the buildings and transportation segments are expected have the greatest growth, reaching 1.4 and 1.6 Mtoe respectively, by 2040.

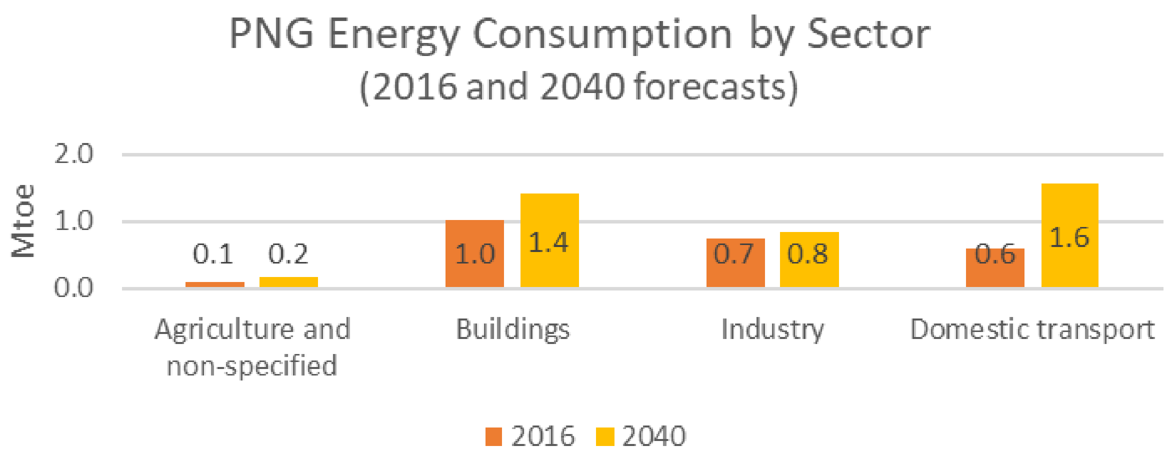


Figure 51: PNG Energy Consumption by Sector[112]

PNG has limited electrification saturation with most of the population residing in rural areas and relying on biomass consumption for cooking. About 90% of households used fuelwood for cooking and 3% of households used LPG. Over half of the population relies on kerosene lamps as their main source of light, while almost a quarter of the population relies on fire.[113] Based on the National Electrification Rollout Plan, completed in 2017, PNG targets to achieve 70% household electrification access by 2030, although there is no clear plan about how this goal could be achieved. Figure 52 highlights the existing power network of PNG. The blue, red, and green dots show demand centers, which contrast with the rest of the economy where interconnections are lacking.

[111] (APEC Energy Working Group 2019)
[112] (APEC Energy Working Group 2019)
[113] (International Renewable Energy Agency (IRENA) 2013)

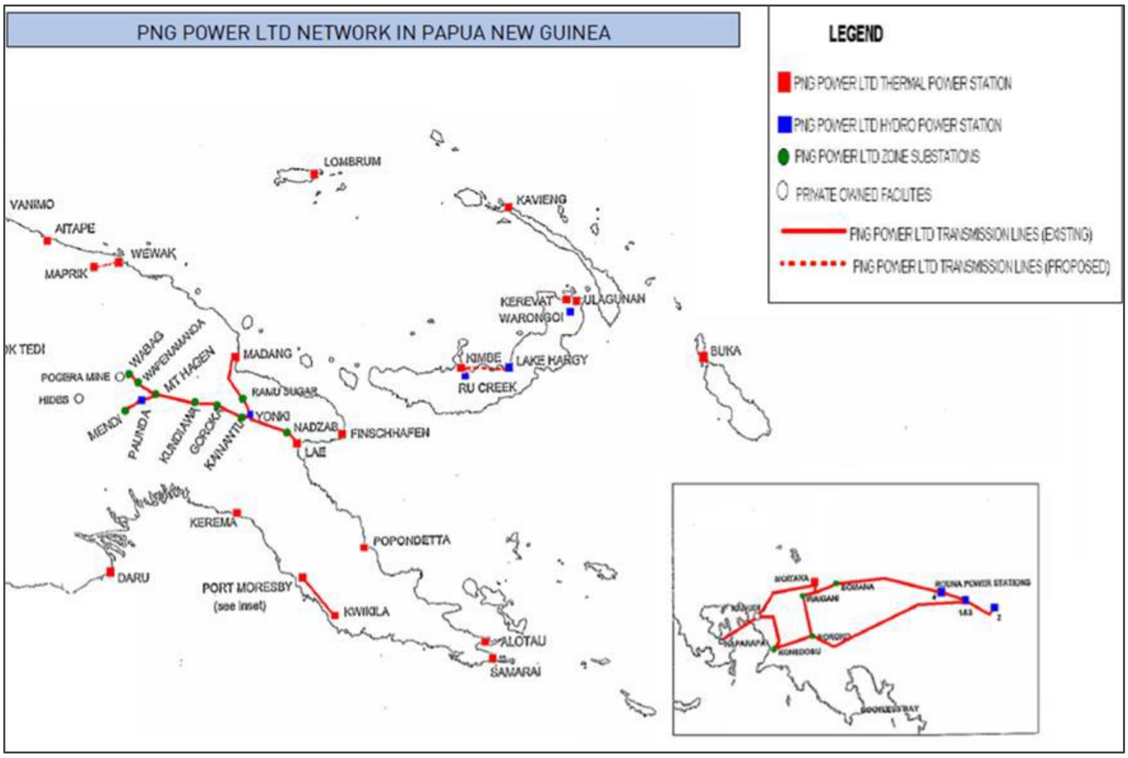


Figure 52: Overview of PNG Power Network [114]

Supply

In 2016, the PNG supply mix was dominated by oil products (diesel) – accounting for 1.9 Mtoe, and which is expected to reach 2.9 Mtoe by 2040. Natural gas is projected to follow a similar growth pattern, anticipated to increase by 64% by 2040, reaching 2.3 Mtoe, as shown in Figure 53.

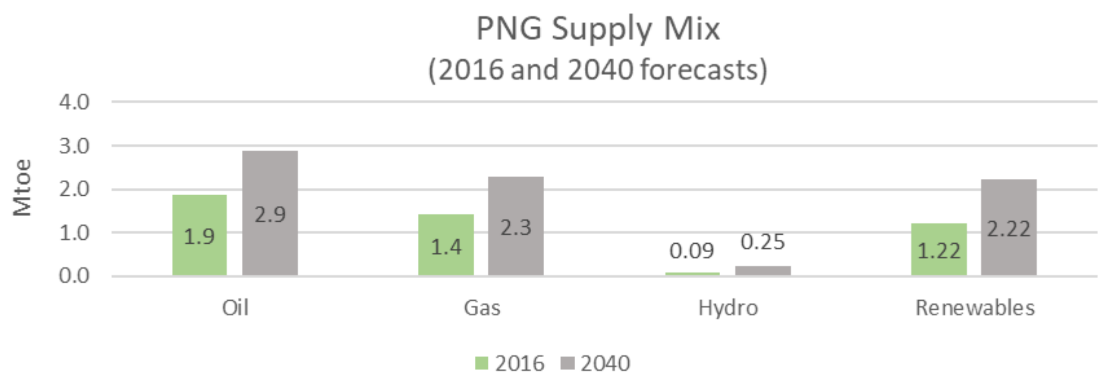


Figure 53: Overview of PNG Supply Mix[115]

PNG's economy relies predominantly on exports of oil and gas from its domestic production, with an existing LNG export plant operational since 2014 and other projects in the expansion or development stage. Figure 54 shows the various oil and gas projects in PNG. The PNG train 1 and train 2 have a nominal LNG production capacity of 6.9 MTPA (although production reached

[114] (PNG Power Ltd 2016)
[115] (APEC Energy Working Group 2019)

8.6 MTPA in 2016), and an additional 5.4 MTPA of export capacity is under development (estimated completion by 2024), significantly expanding PNG's LNG producing capacity for future years.[116]

Under the existing contractual arrangements, almost all domestic gas production is being exported as LNG and domestic consumption is limited to marginal electricity generation (although this is expected to change as the Government is aiming to reserve greater amount of gas for domestic market in future). Considering PNG's growing energy requirements, driven by increasing GDP per capita, combined with greater competitiveness of domestically produced gas, natural gas could play an important role in satisfying PNG's future energy needs, replacing polluting and expensive diesel for electricity generation.

In terms of industrial usage, the growing mining sector depends on diesel power stations for operations, representing a significant potential for gas-to-power development, replacing diesel.[117] In addition, natural gas could be used as a viable replacement for biomass usage, servicing the residential sector in small rural areas. This is recognized in the PNG Energy Policy Plan (2018-2028). However, it is difficult to quantify the potential for gas demand to replace biomass as compared to electricity generation, because good data on this topic is not available.

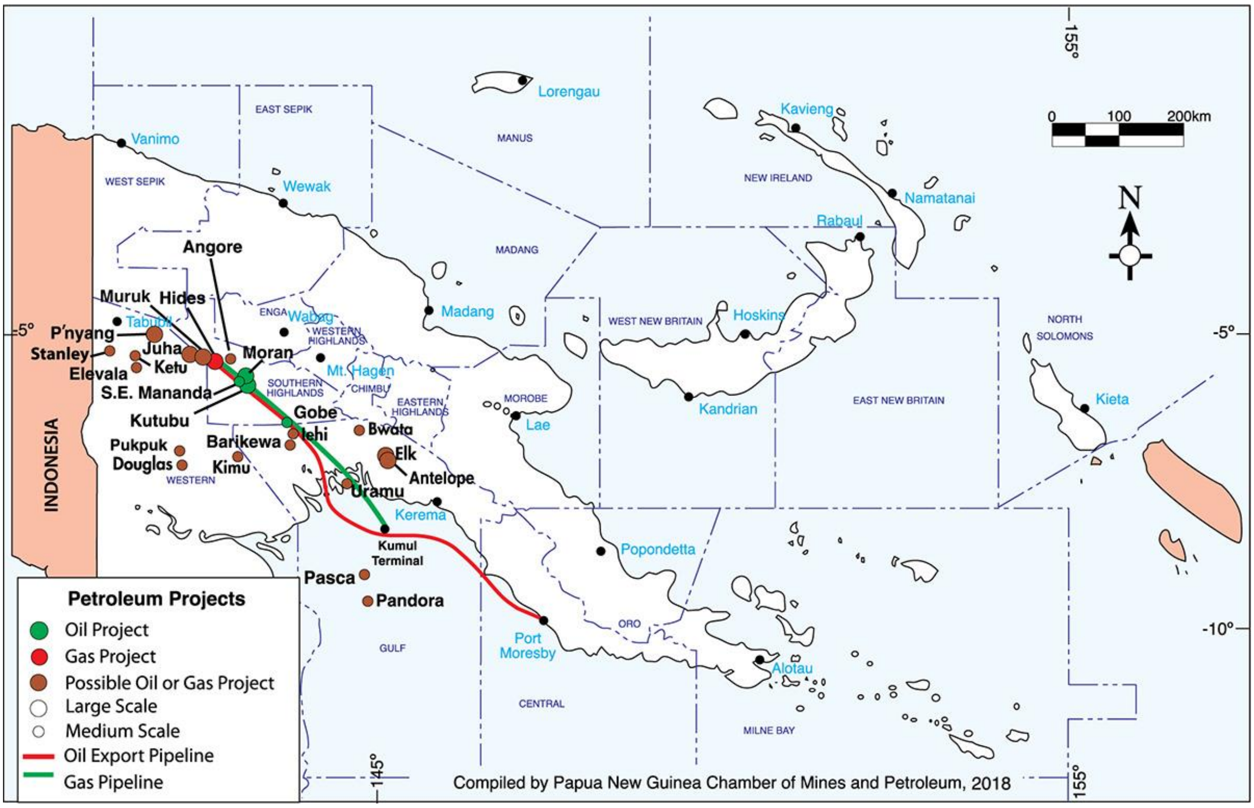


Figure 54: Overview of PNG Oil and Gas Projects [118]

116 (PNG Power Ltd 2016)
117 (Asian Development Bank (ADB) n.d.)
118 (PNG Chamber of Mines and Petroleum 2018)

Viet Nam

Demand

Figure 55 shows Viet Nam's energy demand mix, which is composed of oil (32% or 20.5 Mtoe), renewables (23% or 14.7 Mtoe), coal (22% or 14.4 Mtoe), electricity generation (21% or 13.6 Mtoe) and gas (2% or 1.6 Mtoe). By 2040, oil consumption is expected to double, reaching approximately 42.5 Mtoe, mostly to fulfill transportation needs. Coal consumption is also expected to increase to approximately 24 Mtoe driven by industrial sector needs and installation of new coal-fired power plants in central and southern Viet Nam between 2016-2030.[119]

About 66% of Viet Nam's population lives in rural areas, while the remaining 34% is concentrated in urban areas. The rural population Viet Nam has high electrification rates, reaching 99.9% as of 2017. In 2016, electricity was generated predominantly from coal (49%), followed by gas (29%), hydro (21%), oil (1%), and non-hydro renewables (0.01%). Electricity consumption in Viet Nam is expected to increase significantly, reaching approximately 25.8 Mtoe in the residential and service sectors. Both coal and gas are expected to retain a large share of power generation, about 47% and 34%, respectively, by 2040.[120]

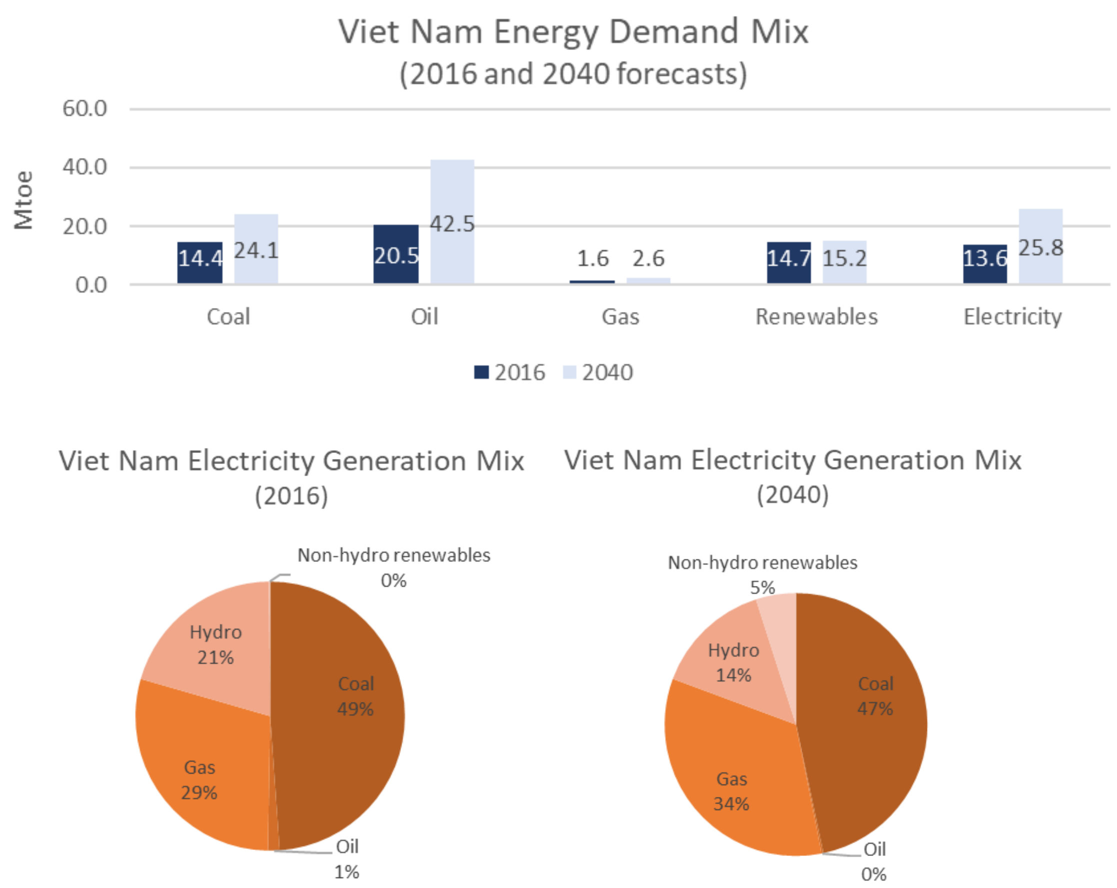


Figure 55: Overview of Viet Nam Energy Demand Mix and Electricity Generation Mix [121]

As of 2016, the majority of Viet Nam's energy demand came from buildings (42%), followed by the industrial sector (30%), domestic transportation (24%) and other sectors including agriculture

[119] (APEC Energy Working Group 2019)
[120] (APEC Energy Working Group 2019)
[121] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)

(4%). Energy consumption in buildings (residential and commercial users) and transportation is expected to increase significantly by 2040, reaching 1.4 and 1.6 Mtoe respectively. Natural gas utilization is primarily concentrated in the industry and power generation segments. (See Figure 56).

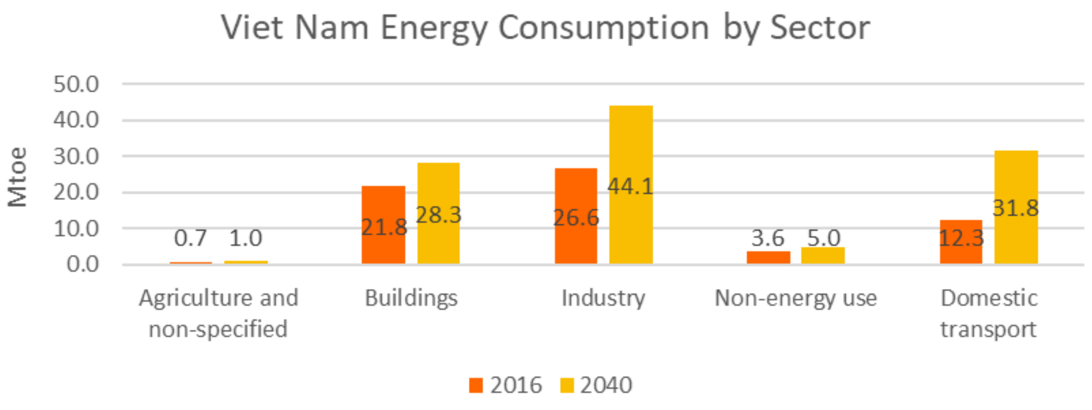


Figure 56: Viet Nam Energy Consumption by Sector [122]

Supply

Viet Nam has a significant amount of natural resources, including oil, gas, coal, and renewables. These resources meet most of Viet Nam's energy demand, as shown in Figure 57. Specifically, it is estimated that Viet Nam has proven resources of about 4.4 billion barrels of oil reserves from offshore fields and from declining onshore fields in southern Viet Nam; 620 billion cubic meters (bcm) of natural gas from its southern and western regions; and about 3,900 M tons of coal. Its renewable potential is also significant, with the government supporting the development of wind, solar, biomass, and municipal waste projects over the next 15 years. In 2016, the supply mix was dominated by coal, approximately 27.6 Mtoe, with the expectation to reach 50 Mtoe by 2040. Oil and gas are expected to face similar growth patterns, with oil likely to increase about 95%, reaching 42.9 Mtoe by 2040 and gas increasing 122%, up to 22 Mtoe by 2040.[123]

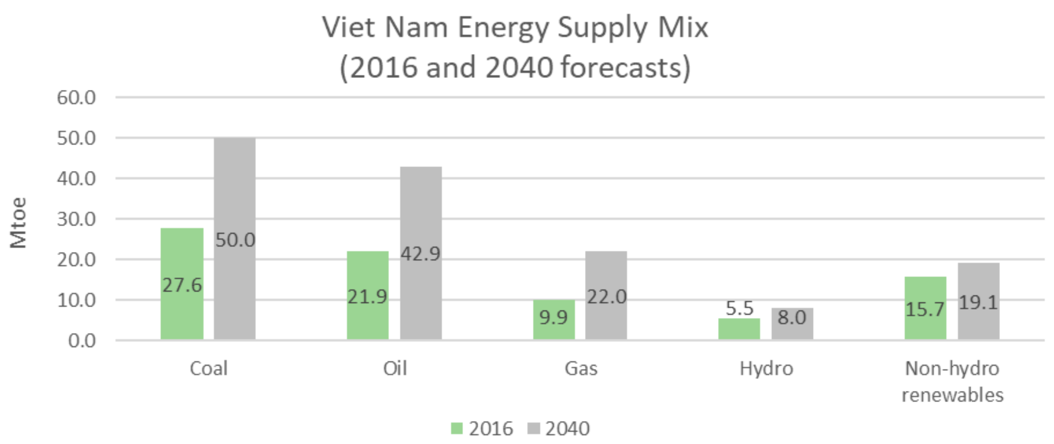


Figure 57: Viet Nam Energy Supply Mix [124]

[122] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[123] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[124] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)

As of 2019, Viet Nam is self-sufficient in natural gas. This is expected to change in the not too distant future due to declining natural gas production and rising natural gas demand for power generation and fertilizer and petrochemical production. While the government is planning to develop additional gas supplies from its domestic reserves, it is also planning to start LNG imports by 2021-2022.[125] Initially, the LNG imports are expected to account for 0.75 - 3 MTPA (from commencement of import through 2025), increasing to 4.5 - 7.5 MTPA from 2026 - 2035.[126]

Seven LNG import projects are in the planning stage, as seen in Figure 58, but no construction has commenced as of October 2019. Although all proposed projects are large-scale (over 1 MTPA), there is the potential for SSLNG import infrastructure deployment to service minor industries or hubs in central Viet Nam.

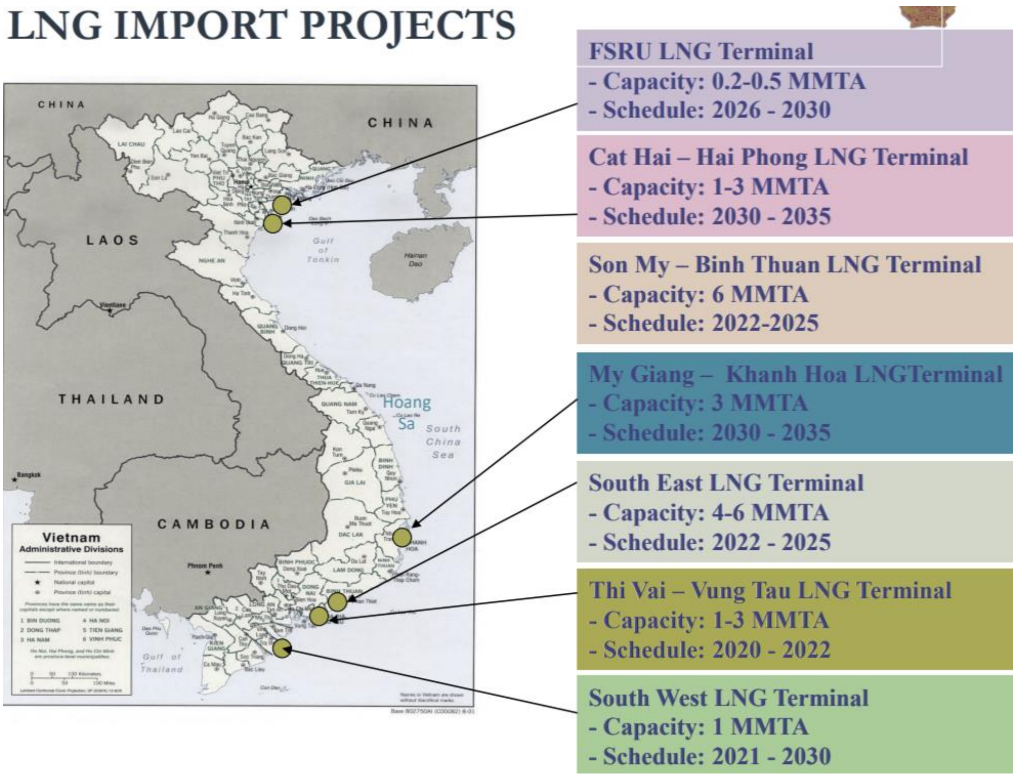


Figure 58: Planned LNG Import Projects in Viet Nam [127]

The Philippines

Demand

As shown in Figure 59, the energy mix in The Philippines in 2016 was dominated by oil and its derived products (53% or approximately 16.6 Mtoe), followed by electricity (20% or 6.4 Mtoe), renewables (18% or 5.6 Mtoe), coal (9% or 2.7 Mtoe), and gas (0.001% or 0.1 Mtoe). Oil is expected to retain its leading position in the energy mix, increasing to 23.9 Mtoe by 2040, followed by electricity at 14.3 Mtoe. The Philippines has an average electrification rate of about 83%, with

[125] (Petrovietnam n.d.)
[126] (Danish Energy Agency 2017)
[127] (Department of Oil, Gas and Coal Ministry of Industry and Trade 2018)

94% in urban areas and 73% in rural areas. It also has about 23 million people relying on biomass for cooking and lighting.[128]

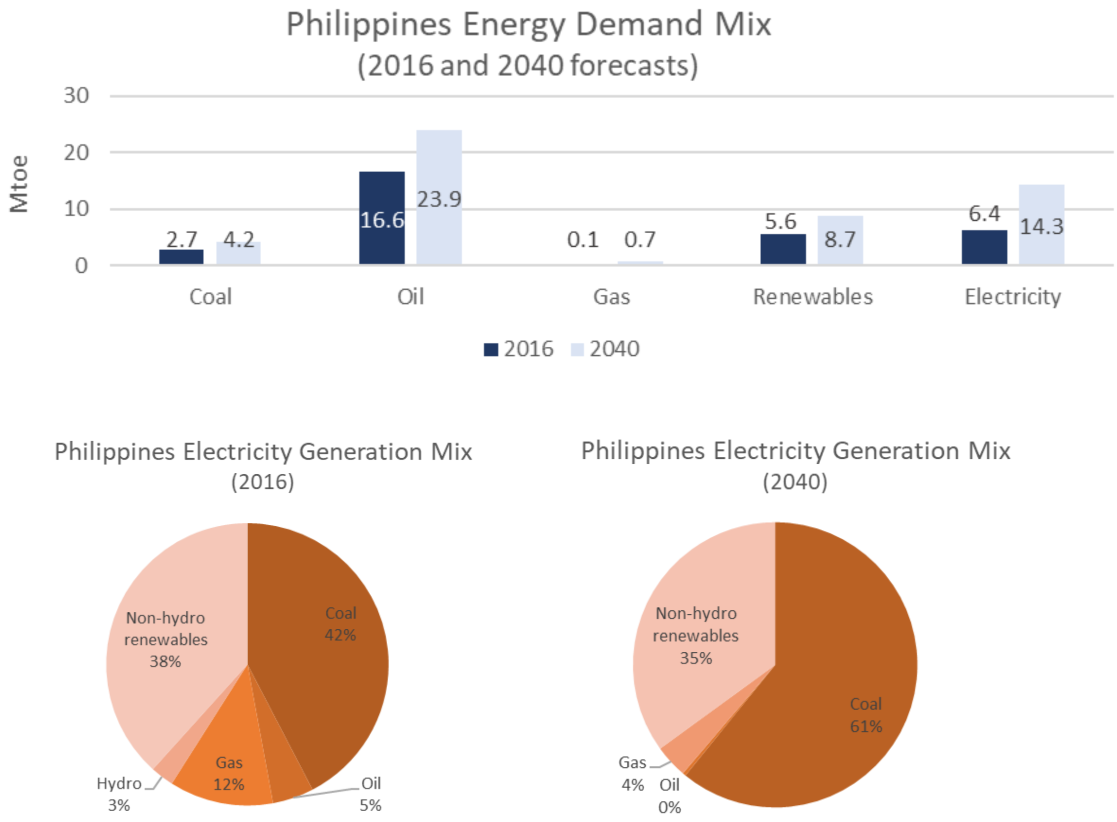


Figure 59: Overview of the Philippines Energy Demand Mix and Electricity Generation Mix [129]

Figure 59 also shows that coal generates approximately 42% of electricity, non-hydro renewables 38%, and gas 12%. By 2040, coal is expected to be the dominate fuel for electricity generation with 60% of the electricity mix, while natural gas-fired power generation is estimated to account for only 4%. This is driven by the Philippines Conventional Energy Contracting Program (PCECP), the goal of which is to maximize the exploration and development of indigenous coal, and to a lesser extent oil and gas resources. Electricity generated from coal is cheaper in The Philippines than that generated from natural gas. [130]

The power generation targets in the Philippines are set at 70% for baseload, 20% for mid-merit, and 10% for peaking capacity, with gas used as a baseload and mid-merit fuel. The Philippines has three large combined cycle gas-fired power plants in Batangas, with a total installed capacity of about 2,880 MW. These power plants operate in a baseload regime due to high take-or-pay gas supply contracts supplied by the Malampaya gas field. The Philippines also has two newer gas-fired power plants which are using gas in a mid-merit regime (San Gabriel) and a peaking mode (Avion). [131]

[128] (Philippines Institute for Development Studies n.d.)
[129] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[130] (Department of Energy Republic of The Philippines 2018)
[131] (Department of Energy Republic of The Philippines 2018)

Figure 60 shows that the majority of energy demand in 2016 came from the domestic transportation sector (36%), followed by buildings (35%), industry (24%), and other sectors including agriculture (5%). By 2040, energy consumption in buildings (residential and commercial consumers) and the transportation sector are expected to grow the most, reaching 20.6 and 19 Mtoe, respectively. The transportation sector is the largest consumer of oil products, followed by the industrial sector, while the largest consumers of coal are industries and coal-fired power plants. The largest consumer of renewable energy is the residential sector, with biomass used for cooking and lighting in rural areas. Natural gas is used predominantly in power generation and, to a small extent, in industry (e.g. petrochemical sector).[132]

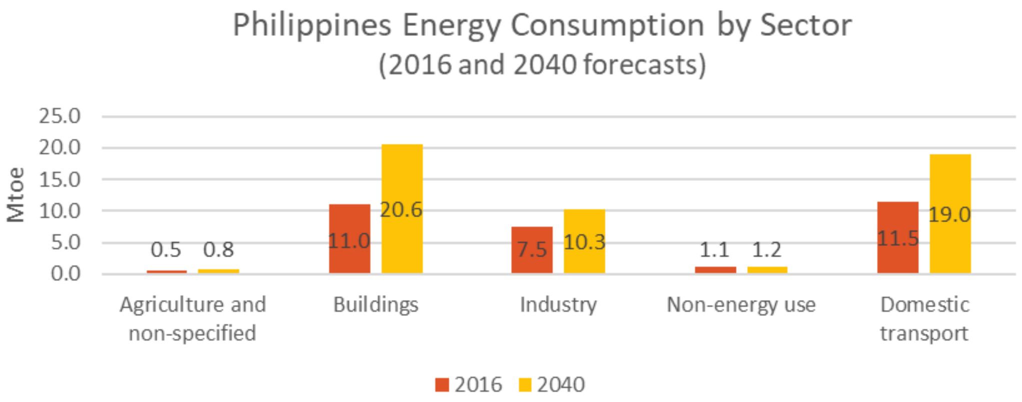


Figure 60: The Philippines Energy Consumption by Sector [133]

<u>Supply</u>

The Philippines has proven reserves of about 76 million BOE, with about 24 billion cubic feet of natural gas and about 440 million tons of coal.[134] However, 51% of energy supplies in 2016 were imported rather than sourced domestically, specifically crude oil, oil products, and coal. In line with the PCECP, the Philippines has an objective to decrease its fossil fuel imports and develop its domestic natural resources by attracting foreign investment. It also has an objective to increase renewable energy production by encouraging more investment in solar and wind energy.

Figure 61 shows that the Philippines supply mix in 2016 was dominated by oil products, accounting for 18.4 Mtoe, with the expectation to reach 26.5 Mtoe by 2040. This was closely followed by renewables at 17.8 Mtoe, and are which expected to grow significantly by 2040, reaching 29.8 Mtoe. Renewables are comprised mainly of biomass and geothermal energy. Coal is expected to experience the largest growth, increasing by 154% between 2016 and 2040. This is mainly driven by government incentives for coal utilization. Gas supplies are expected to diminish in line with the gradual depletion of the Malampaya gas field.

Increased LNG imports are likely to occur because The Philippines will require natural gas to feed existing gas-fired power plants in the Batangas area and as an alternative fuel for industrial customers. Industry relies heavily on diesel or HFO and requires cleaner and more cost competitive fuel alternatives (e.g. steel mills). In addition, increased natural gas supplies could potentially be used to replace biomass in the residential sector for cooking and lighting.

[132] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[133] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[134] (Department of Energy Republic of The Philippines 2018)

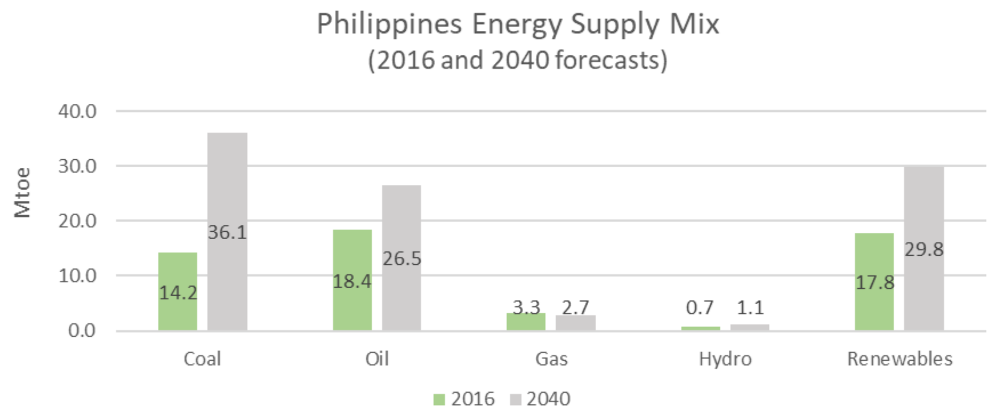


Figure 61: The Philippines Energy Supply Mix [135]

Indonesia

Demand

Figure 62 shows that the energy demand mix in Indonesia in 2016 was comprised of oil (40% or 66.5 Mtoe), renewables (34% or 57 Mtoe), electricity generation (12% or 19.8 Mtoe), gas (8% or 13.5 Mtoe), and coal (6% or 9.5 Mtoe). By 2040, Indonesia is expected to double its energy requirements, with the increases to come from coal (300% increase), electricity (200% increase), gas (114% increase), oil (82% increase), and renewables (20% increase). The growth in future coal consumption is driven by the government's plans for increased electrification, using domestically sourced resources. The Electricity Supply Business Plan (RUPTL) lays out the construction of an additional 56 gigawatts (GW) of power plants, of which 54% will be coal-fired. The rise in coal production is seen as a response to growing domestic electricity consumption as well as increasing industrial coal demand.[136]

Indonesia had about 60 GW of electricity generation capacity in 2016, predominantly fueled by coal (49%), non-hydro renewables (25%), natural gas (19%), oil (5%), hydro (2%), and other (0.01%). The government currently is promoting gas usage by implementing price controls to ensure competitive gas prices for end-users. Upstream and midstream prices are based on long-term contracts using a cost-plus margin mechanism.[137] The reason behind this government initiative is the need to expand and diversify local power generation, as well as the government's commitment to lowering emissions by 29% by 2030.[138] Based on the latest 2019 RUPL plan, gas-fired power generation will account for about 22% of the total 56 GW of planned generation capacity by 2028. [139]

[135] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[136] (Ministry of Energy and Mineral Resources 2019)
[137] (SKK Migas 2018)
[138] (Oxford Business Group 2018)
[139] (Ministry of Energy and Mineral Resources 2019)

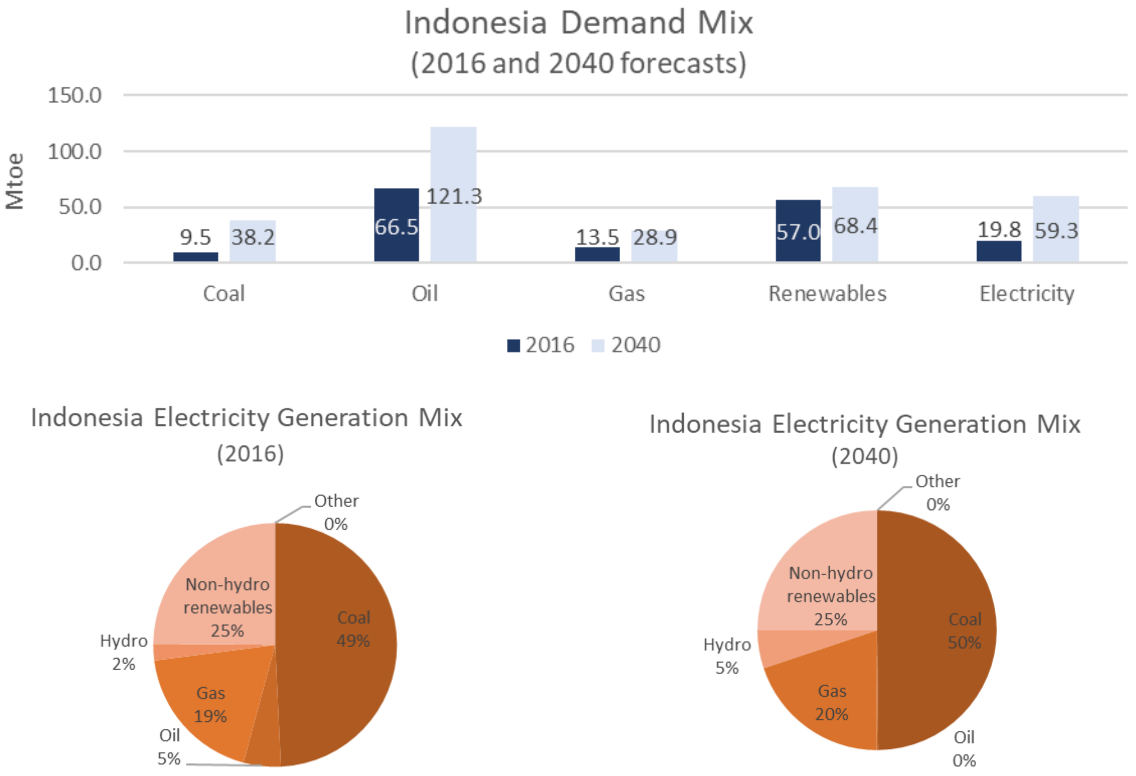


Figure 62: Overview of Indonesia Energy Demand Mix and Electricity Generation Mix [140]

The majority of Indonesia's energy demand in 2016 occurred in buildings (42% or 69 Mtoe), domestic transportation (29% or 47.5 Mtoe), and the industrial (24% or 40.1 Mtoe), residential, commercial, and agricultural (5% or 9.7 Mtoe) sectors, as seen in Figure 63. By 2040, the energy consumption in buildings (both commercial and residential) and for industrial production is expected to experience the most growth, reaching 108.7 and 94.4 Mtoe, respectively. The expected growth in residential energy demand is mainly driven by planned increases in electrification and city gas networks. Within the industrial sector, the largest gas consuming industries include fertilizers, petrochemicals, ceramics, cement, steel, and glass. Between 2019 and 2040, demand for gas for fertilizer and petrochemical production is expected to experience the greatest growth. [141]

Approximately 97.5% of Indonesia's population had access to electricity in 2018. The government aims for 100% electrification coverage by 2024. Indonesia's electrification saturation has increased substantially since 2010, when 67% of its population had access to electricity. The electrification program has resulted in an expanded transmission network to eastern Indonesia in order to reach remote demand centers. A solar home program has also been launched and is expected to reach about 2,500 villages that currently do not have access to electricity by the end of 2019. [142] The government also launched a city gas network development program, the objective of which is to connect 3 million households to the city gas network by 2020 and 5 million households by 2030. This program will reduce LPG consumption and replace it with natural gas.[143]

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[140] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[141] (Indonesia-Investments 2016)
[142] (APEC Energy Working Group 2019)
[143] (Ministry of Energy and Mineral Resources 2017)

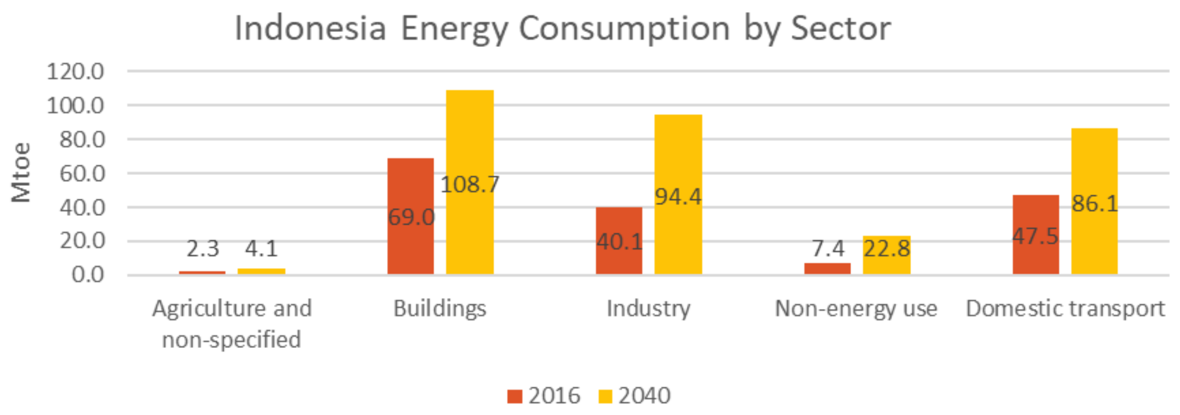

Figure 63: Indonesia's Energy Consumption by Sector [144]

Supply

Indonesia has proven reserves of about 3.3 billion barrels of oil, 101 trillion m^3 of natural gas, and 29 billion tons of coal. It is a net exporter of energy, in 2015 having exported 20% of its oil production, 46% of its natural gas production (34% as LNG and 12% piped to Singapore and Malaysia), and 79% of its coal production. Indonesia is one of the largest coal producers in the world. [145] Most of Indonesia's natural gas reserves are located in Aceh, East Kalimantan, South Sumatra, Makassar Strait, Natuna Sea, Papua and Maluku, East and West Java. There are three LNG export projects in this economy (Bontang, Tangguh, and Donggi-Senoro) with total capacity of 21.1 MTPA.[146]

While Indonesia has substantial natural gas resources that could meet existing and future domestic demand, a large proportion of its natural gas is committed as LNG to foreign buyers under long-term SPA contracts. In addition, new exploration licenses have been delayed. Even though Indonesia is a net exporter of natural gas under these LNG contracts, it needs additional gas supply to meet certain localized gas demand. Some of that unserved demand is met through local small-scale LNG facilities. As of July 2019, Indonesia had a combined regasification capacity of about 8.1 MTPA in Lampung, Nusantara, Arun, and Benoa.[147] Most of the regasification projects are being used for domestically sourced gas. However, Indonesia also imports foreign LNG to serve these markets. In 2017, approximately 0.4 MTPA of foreign LNG was imported into Indonesia[148]. Two LNG import projects are currently under construction in Indonesia, the Jawa Satu Power FSRU (2.4 MTPA) and a small-scale mini LNG terminal in Flores (0.1 MTPA).[149] Several other LNG terminal projects are in development and are waiting for government approval. [150]

Figure 64 shows that renewables are the largest supply of energy in Indonesia, with 33% market share (76.6 Mtoe), followed by oil with 30% share (70.1 Mtoe), coal with 20% share (46.8 Mtoe), gas with 16% share (38.9 Mtoe), and hydro with 1% share (1.7 Mtoe). By 2040, coal, oil, and gas are projected to experience substantial growth, increasing by 160%, 92%, and 80% respectively.

[144] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[145] (APEC Energy Working Group 2019)
[146] (GIIGNL 2019)
[147] (GIIGNL 2019)
[148] (GIIGNL 2019)
[149] (Katadata 2018)
[150] Galway database

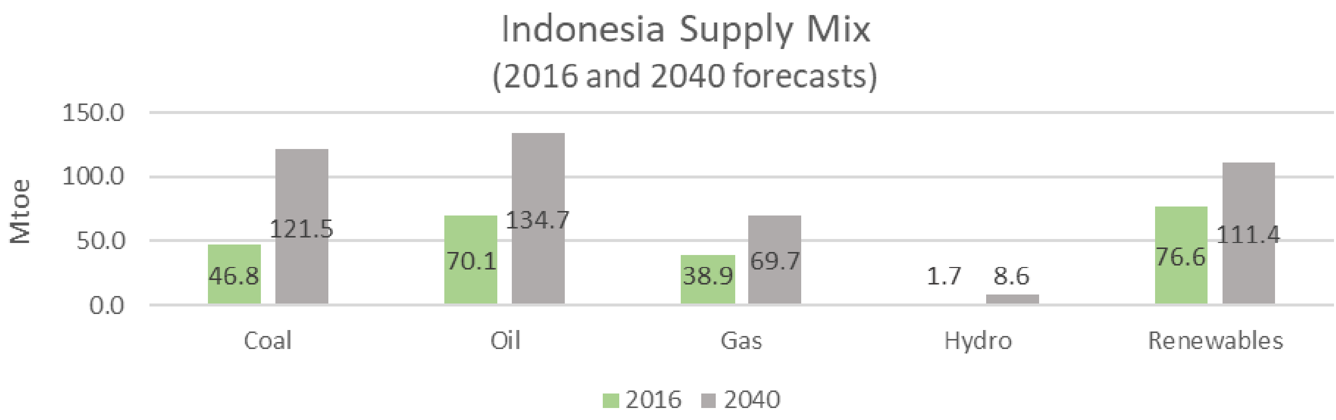

Figure 64: Indonesia's Energy Supply Mix [151]

Thailand

Demand

The energy demand mix for Thailand in 2016 was met predominantly by oil (55% or 53.8 Mtoe), electricity consumption (17% or 16.7 Mtoe), renewables, including biomass and solid waste (14% or 13.8 Mtoe), gas (7% or 7.2 Mtoe), and coal (6% or 6.1 Mtoe). By 2040, Thailand is expected to increase its energy demand by 60%, with the biggest demand increase from electricity consumption (96% increase). This electricity growth is expected to be met through higher coal and renewables usage (78% increase), oil (50% increase), coal (33% increase), and gas (31% increase)[152] (See Figure 65).

The electricity saturation rate in Thailand essentially was 100% in 2016, with total power generating capacity of 41.5 GW. The Thailand Power Development Plan emphasizes the improvement of the reliability of the power grid by increasing the share of power generation fueled with coal, sourced from domestic supplies or imports from neighboring countries, and with the use of clean coal technology and renewable energy. [153] In line with these government plans, the proportion of natural gas in power generation is anticipated to drop from 52% to 23% by 2040.

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[151] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[152] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[153] (EGAT 2015)

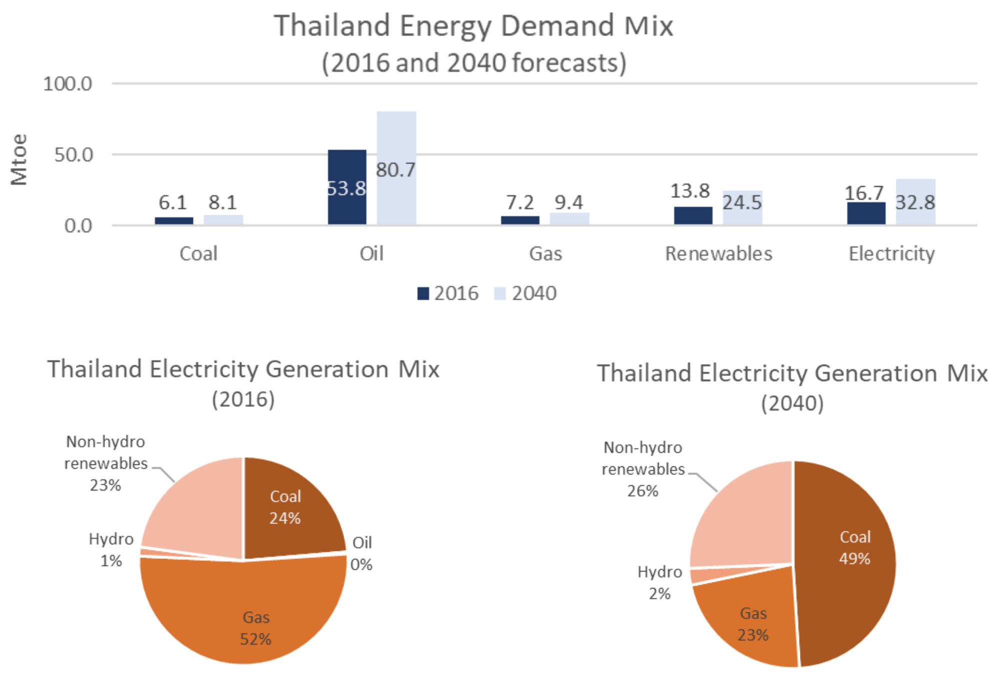

Figure 65: Overview of Thailand's Energy Demand and Electricity Generation Mix [154]

Figure 66 shows that, in terms of energy consumption by sector in 2016, the majority of energy demand in Thailand was represented by the industrial sector (32% or 31.4 Mtoe), domestic transportation (26% or 25.2 Mtoe), non-energy use, as defined in section 6.14 above (23% or 22.9 Mtoe), buildings (15% or 14.4 Mtoe), agriculture and non-specified sectors (4% or 3.6 Mtoe). The largest future demand is represented by the industrial sector, reaching 51 Mtoe by 2040. Gas demand is expected to marginally increase across the industrial and transportation sectors where natural gas has been promoted as a replacement for conventional diesel or gasoline.

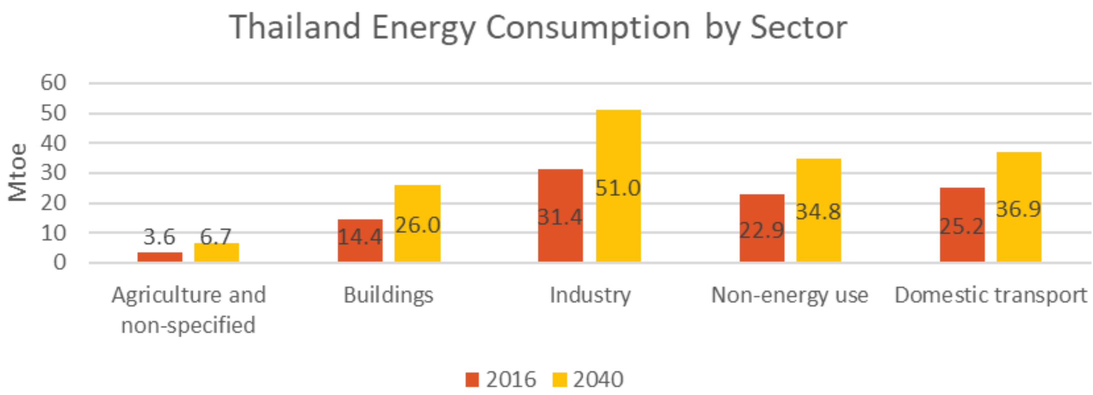

Figure 66: Thailand's Energy Consumption by Sector [155]

[154] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
[155] (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)

Supply

Thailand has proven reserves of about 405 million barrels of oil, 220 bcm of natural gas, and 1,036 million tons of coal. This is significantly less than Viet Nam, Indonesia, or PNG. Thailand is likely to deplete its gas resources by 2023 and its oil resources by 2020.[156] Having limited domestic energy resources, Thailand currently is and will become even more dependent on foreign imports. In 2016, 84% of oil supplies and 25% of gas supplies were imported.[157] Current natural gas imports into Thailand come via pipeline from Myanmar and LNG imports through the Map Ta Phut LNG import terminal, which has a nominal capacity of 10.7 MTPA.[158]

An overview of Thailand's energy supplies is provided in Figure 67. Thailand's energy supply mix in 2016 was 40% oil (54.6 Mtoe), 27% gas (36.6 Mtoe), 21% renewables (28.2 Mtoe), 12% coal (16.2 Mtoe), and .44% hydro (0.6 Mtoe). By 2040, demand for coal is expected to increase 188%, followed by an increase in renewable demand by 89% and oil demand by 50%. On the other hand, gas demand is expected to decrease by about 12% over the same period. This is mainly due to depletion of domestic sources of gas and lower gas-fired power generation use.

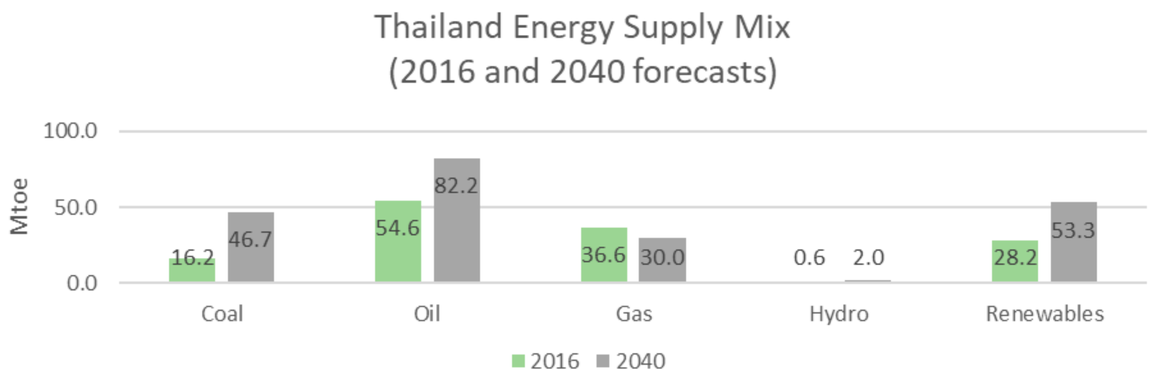

Figure 67: Thailand's Energy Supply Mix [159]

In order to meet the expected increase in gas demand, other LNG import projects have been proposed, including one in Rayong province (Nong Fab LNG), the EGAT FSRU to be located in southern Bangkok area, and the Siam Gas onshore LNG project.[160] (See Figure 68).

156 (BP 2019)
157 (Energy Policy and Planning Ministry of Energy of Thailand n.d.)
158 (GIIGNL 2019)
159 (APEC Energy Working Group 2019) (International Energy Agency (IEA) 2019)
160 (Bangkok Post n.d.)

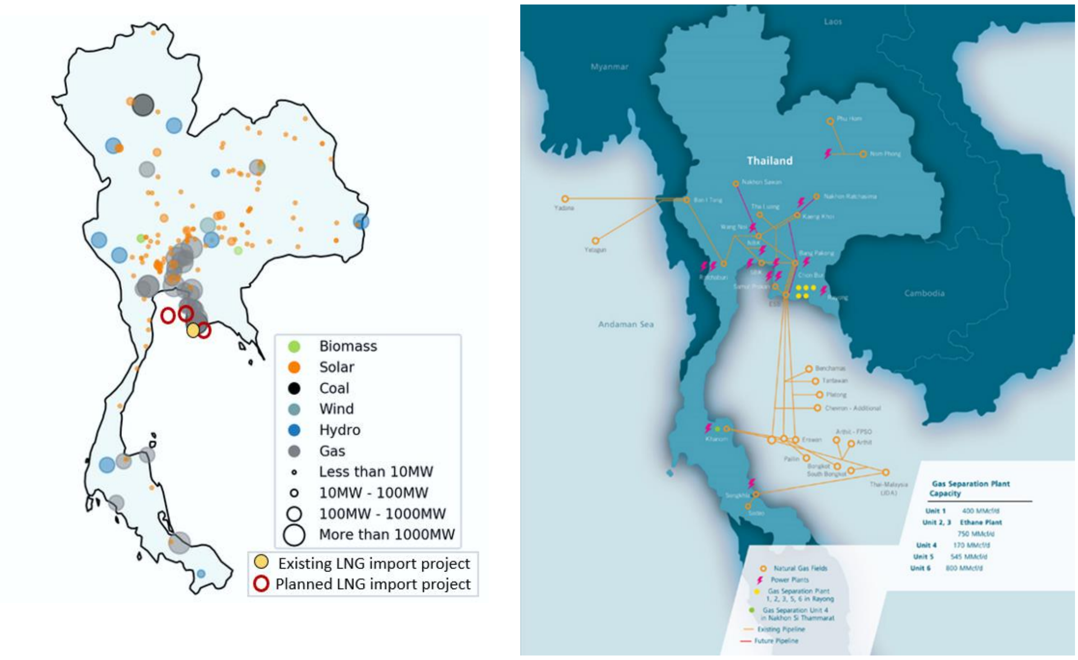

Figure 68: Thailand Planned and Existing LNG Import Projects

7.3 Evaluating the Fit for Various Shallow Water SSLNG and FSRUs

Papua New Guinea

Papua New Guinea (PNG) is a coastal APEC economy, with a population of about 8.2 million people in 2017[161]. Most of the population lives in rural areas and about 18% in urban areas. PNG's most populous area is in its south near Port Moresby, the capital city, which has about 280,000 inhabitants. Other major towns include Lae (76,255), Arawa (40,266), Mount Hagen (33,623), Popondetta (28,198), Madang (27,419), Kokopo (26,273), and Mendi (26,252), as shown in Figure 69.

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161 (The World Bank n.d.)

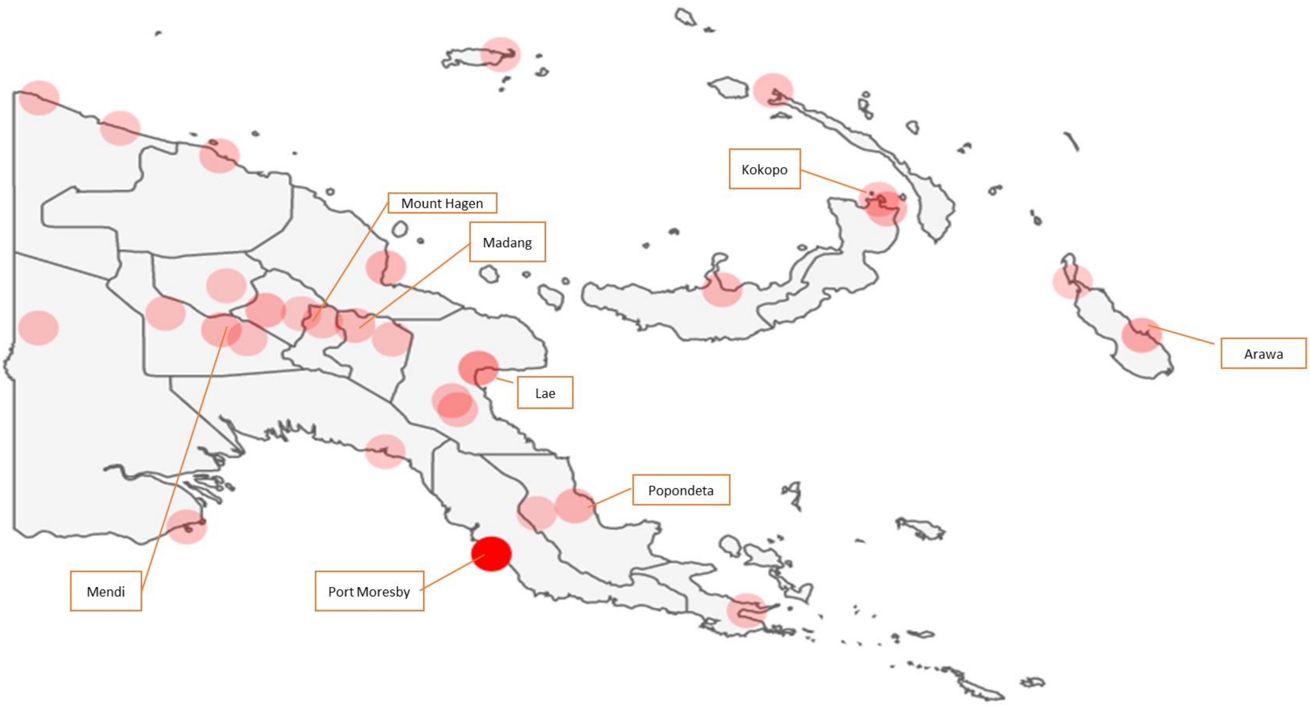

Figure 69: Most Densely Populated Areas in PNG [162]

PNG is comprised of the eastern part of New Guinea and over 600 other islands. Road accessibility is generally limited to the main population centers as much of the land area is only accessible by coastal or river barges. About 60% of PNG's population resides near coasts, rivers, and swamps which are suitable for water navigation. PNG has about 11,000 km of waterways and about 22 declared ports, of which only 5 ports have appropriate port infrastructure and receive international, as well as local coastal, traffic. The remaining ports are in poor condition and have limited traffic.

The state-owned PNG Ports Corporation Limited owns and operates 16 ports, with others being owned by private companies. The largest port is Lae, followed by Port Moresby. Outside of port areas, there are also about 400 piers, jetties, and landings by which small water craft can access remote communities. (See Figure 70).

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[162] (World Population Review n.d.)

Figure 70: Location of Major Ports in PNG [163]

The road network in PNG is generally inadequate for trucking to remote locations, with sea transportation being the most practical means of servicing coastal areas. Target locations for SSLNG infrastructure in coastal and river areas are highlighted in Figure 71. The identification of such locations has been based on an assessment of regional population concentration, expected energy demand, existing and planned gas producing fields and supply projects, pipelines, available and planned electricity networks, power plants, port infrastructure, coastal areas, inland waterways distribution, as well as bathymetry.

PNG's oil and gas projects are in its south-east and central areas, with an existing gas pipeline from Moran to the capital city of Port Moresby, where the LNG export terminal is located. The existing infrastructure at the terminal could be used as a break-bulk facility by adding the required auxiliary infrastructure to accommodate small-scale shipments and to service the domestic SSLNG distribution network across PNG's archipelago. The identified target locations are spread across PNG's north-east, west, and central regions. Depending on the individual demand centers, milk-run or hub-and-spoke delivery concepts could be used.

PNG benefits from deep water accessibility in many of the identified locations (of about 15 m), as shown in Figure 71, as well as some existing port infrastructure (e.g. jetties) that could be used or retrofitted to accommodate both large-scale and SSLNGCs. The deep-water access in many identified locations means that significant project economies could be achieved, as smaller jetty infrastructure would be required in areas where no existing jetties are available.

[163] Papua New Guinea Department of Transport and Infrastructure

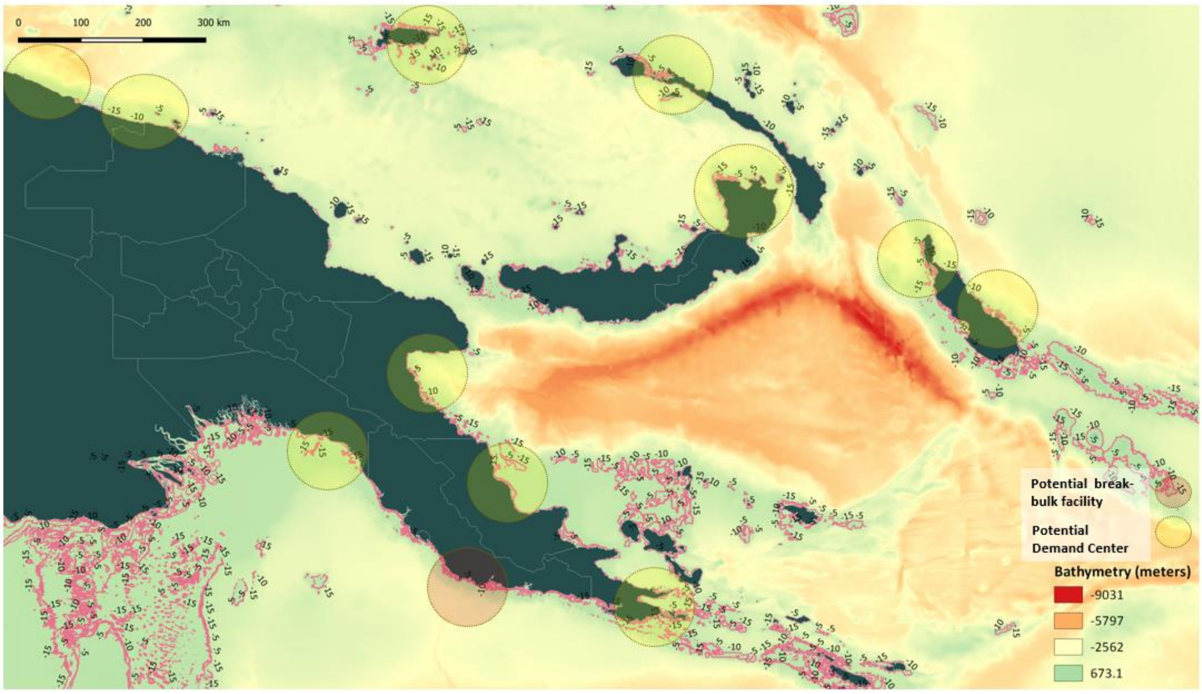

Figure 71: PNG Bathymetry and Potential Demand Locations[164]

Note: The bathymetry highlights water depth in coastal areas between 100m and 2 km from the coast.

While coastal transportation represents a significant potential for future transport of LNG in the region, one needs to recognize that PNG is located in the "Ring of Fire", an area frequently affected by earthquakes, tsunamis, and volcanic eruptions. The occurrence of these events could provide technical challenges and potentially limit the viability of floating infrastructure.

[164] Galway Group

Viet Nam

Viet Nam is one of the largest and most densely populated economies in the region, with about 95 million people in 2017. The most populated areas are in its southern and northern coastal areas, with the largest cities being Ho Chi Minh City (8.63 million), Hanoi (7.78 million), Haiphong (2 million), Can Tho (1.6 million), Bien Hoa (1.25 million), and Da Nang (1.23 million), as shown in Figure 72.[165]

Viet Nam has a coastline of over 3,200 km, with significant importance for transportation of goods for domestic commerce. In addition, Viet Nam has about 41,000 km of natural waterways, of which 8,000 km are used commercially. From these, about 5,000 km are navigable by vessels of up to 1.8m draft. The main waterways are the Mekong and Red Rivers.

Viet Nam has about 114 seaports, of which 14 are suitable for accommodating large maritime vessel traffic and international trade. Most of the other ports are relatively small with obsolete facilities and poor support services. Deep-sea ports include Cai Mep Port (south), Haiphong Port (north), and Da Nang Port (central).[166] (See Figure 73.)

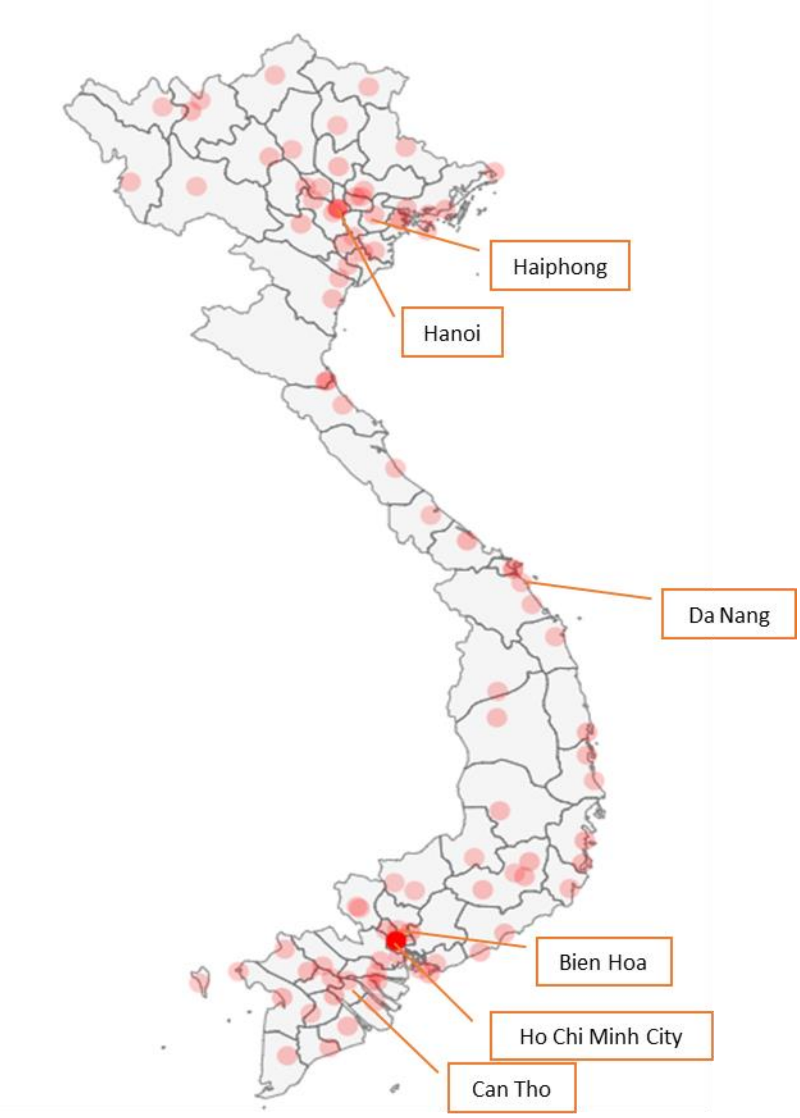

Figure 72: Most Densely Populated Areas in Viet Nam[167]

Viet Nam has considerable potential for future transportation using SSLNGCs along its coastal areas or inland waterways. The coastal regions which could be locations for SSLNG infrastructure are highlighted in Figure 74. These were identified based on concentration of population (regionally), expected energy demand, existing and planned gas producing fields and supply projects, pipelines, power plants, planned LNG import terminals, port infrastructure, coastal areas and inland waterways distribution, as well as bathymetry. The identified locations are spread across central, northern, and southern Viet Nam.

The planned regasification terminals, mostly proposed for Viet Nam's south and north, could be used as loading and/or break-bulk facilities for the distribution of LNG among coastal demand centers. This network could use SSLNGCS or ISO container barges to deliver LNG for further re-distribution inland by truck. In addition, for shallow waterways such as the Mekong and Red Rivers, shallow-water barges could provide a suitable technical solution since the draft in these areas, approximately 3m, is not suitable for SSLNGCs.

[165] (The World Bank n.d.)
[166] (DLCA.JSON n.d.)
[167] (World Population Review n.d.)

Figure 73: Major Ports of Viet Nam[168]

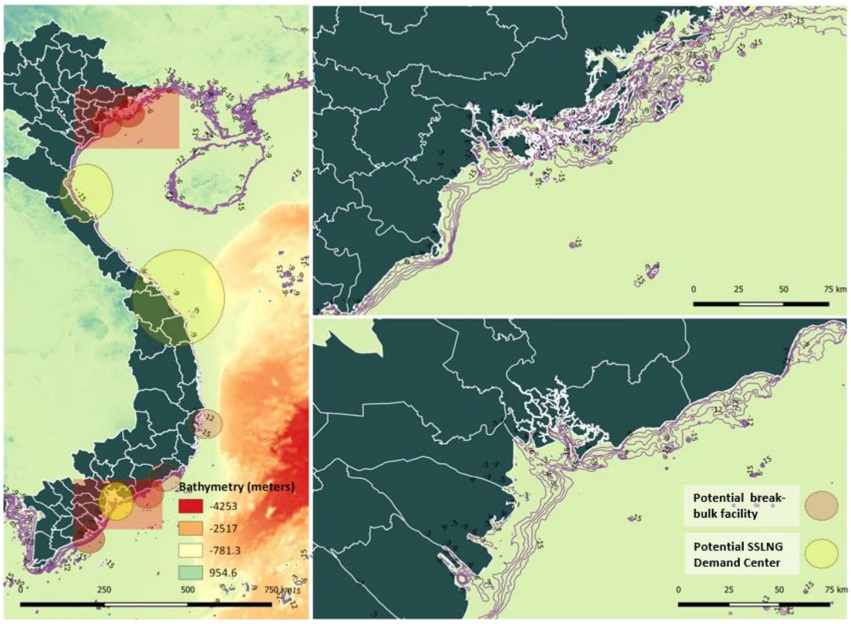

Figure 74: Viet Nam Bathymetry and Potential Demand Locations[169]

[168] (DLCA.JSON n.d.)
[169] Galway Group

The Philippines

The Philippines is an archipelago, composed of over 7,000 islands with population of about 104 million in 2017. The Philippines is divided into three main areas: Luzon, Visayas, and Mindanao, with the majority of commercial and industrial activities located in Quezon City or its surroundings[170] (See Figure 75). The most populated cities of the Philippines are: Quezon (2.9 million), Manila (1.8 million), Caloocan (1.6 million), Davao City (1.6 million), and Cebu (0.9 million).

The Philippines has a coastline of about 36,000 km, about 3,219 km of waterways, and 821 commercial ports (of which 26 are large ports suitable for international shipping[171]). The Port of Manila is the largest port, with other major ports being Batangas, Cagayan de Oro, Cebu, Davao, and Liman, as shown in Figure 76.

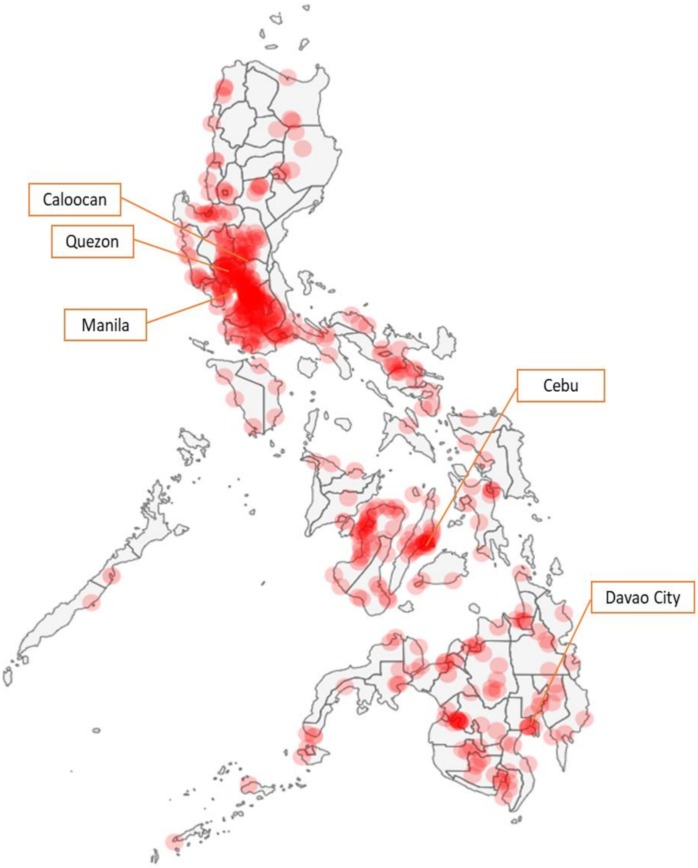

Figure 75: Most Densely Populated Areas in the Philippines [172]

Coastal and river areas which could be potential locations for the deployment of SSLNG infrastructure are highlighted in Figure 77. These locations have a sufficient concentration of population (regionally) with expected energy demand growth; existing/planned gas producing fields, pipelines, power plants, LNG regasification projects, port infrastructure; and coastal and inland waterways, as well as sufficient bathymetry.

SSLNG distribution networks could be developed by leveraging the planned LNG import projects in the Batangas area by using such facilities for break-bulk for SSLNG distribution for further redistribution to coastal areas in Batangas, Mindanao, Visayas, and Palawan. Palawan and Mindanao are the two regions that could benefit the most from SSLNG deliveries, as their population and industries (e.g. mines, cement, and steel) face frequent power shortages and mainly use diesel for power generation.

[170] World Bank
[171] Philippines Port Authority
[172] (World Population Review n.d.)

Figure 76: Location of Major Ports in the Philippines[173]

Many existing or planned steel mills and cement plants are/will be located in the Batangas area and will have growing fuel needs driven by the construction industry. These markets could be potential users of a small-scale LNG distribution system either by using SSLNGCs (where coastal accessibility exists) or trucks. Overall, the distribution of LNG using SSLNGCs across the Philippines would be more viable than using large-scale LNGCs, mainly due to limited deep-water access near potential demand centers, with bathymetry ranging predominantly between 6 and 12 meters.

[173] (DLCA.JSON n.d.)

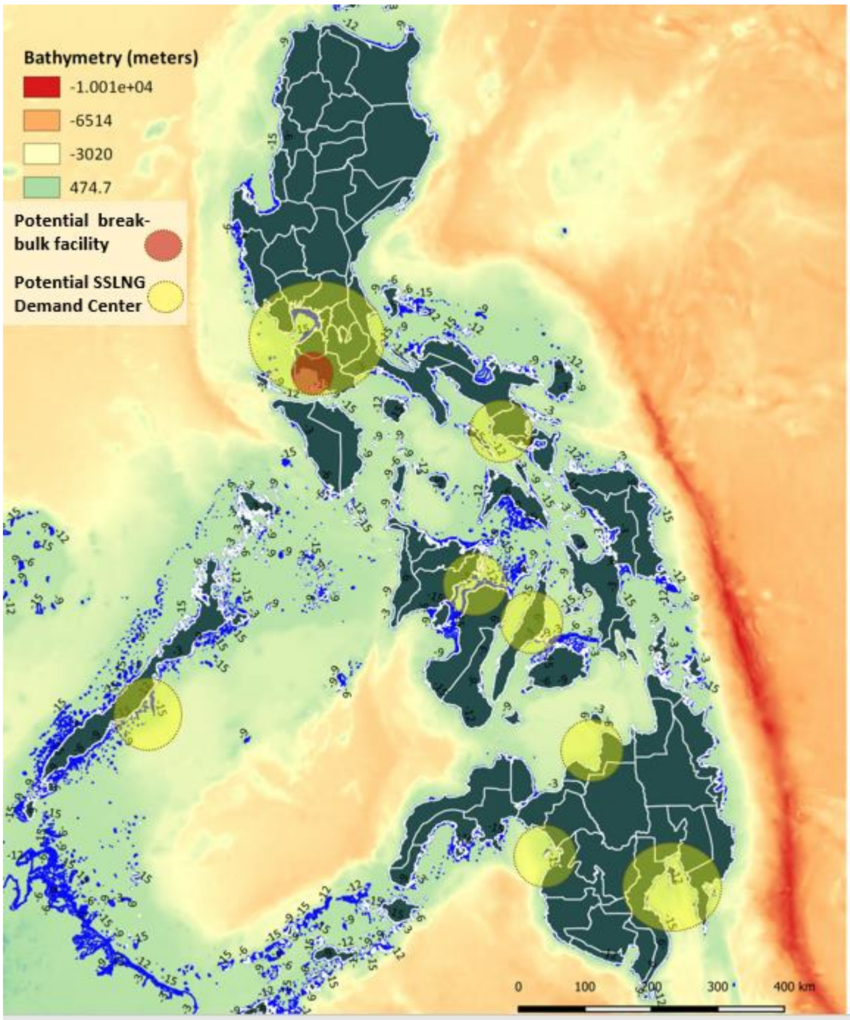

Figure 77: The Philippines Bathymetry and Potential Demand Locations[174]

While there is a significant potential for further development of marine transportation to access remote locations of the archipelago, similar to PNG, the Philippines is also situated on the "Ring of Fire", an area frequented by earthquakes, tsunamis, or volcanic eruptions. This may limit the availability of floating infrastructure.

Indonesia

Indonesia is the fourth most populated economy in the world, with a total population of about 264 million in 2017. About 57% of the population lives on the island of Java, the largest commercial and industrial hub in this member economy. Indonesia has 11 cities with a population of over one million inhabitants, with the largest being: Jakarta (10 million), Bekasi (3 million), Medan (2.3 million), Tangerang (2 million), Depok (1.8 million), and Palembang (1.5 million).[175] Figure 78 shows the areas of greatest population density in Indonesia.

[174] Galway Group
[175] (The World Bank n.d.)

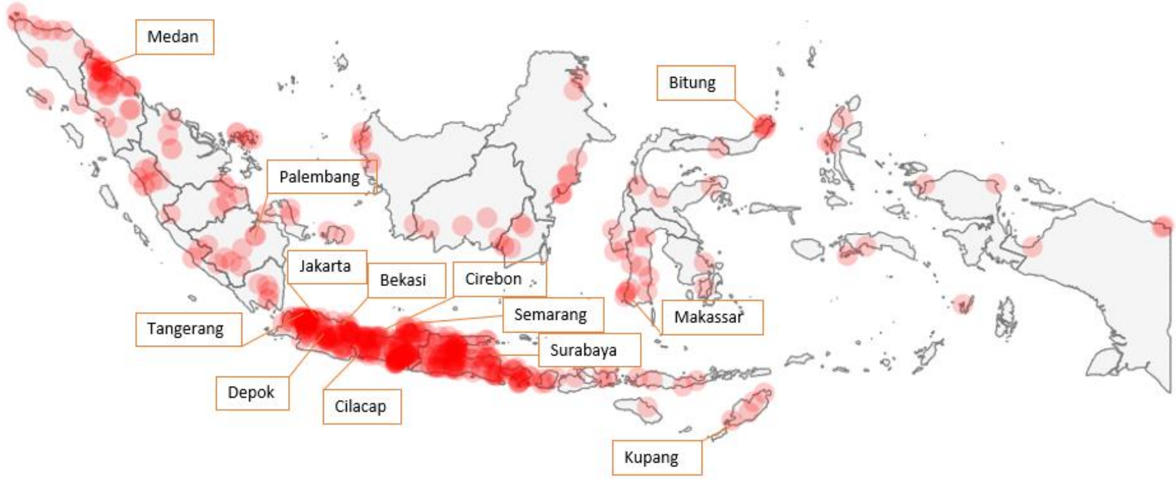

Figure 78: Most Densely Populated Areas in Indonesia[176]

Indonesia is comprised of about 17,000 islands and 21,579 km of waterways. Maritime shipping provides an essential link among the islands[177]. Indonesia has 89 international seaports and 52 container terminals, with additional 8 seaports in development and planning stages.[178] Major ports include Bitung, Cilacap, Cirebon, Jakarta, Kupang, Palembang, Semarang, Surabaya, and Makassar. Commercial shipping and fuel delivery across Indonesia are complex processes, due to its geography.

SSLNG could be a viable option for dispersed areas in Indonesia, which are either coastal or traversed by rivers with water depths navigable by SSLNGCs. Potential target locations in coastal regions are highlighted in Figure 79. This identification takes into account population concentration (regionally), expected energy demand growth, existing/planned gas producing fields, pipelines, power plants, LNG regasification projects, port infrastructure, coastal areas and inland waterways, as well as bathymetry.

The potential target locations for SSLNG distribution include the islands of Kalimantan, Sulawesi, West Papua, and Banda, as well as minor islands in the Timor Sea. Gas demand would most likely be to service small-scale gas-to-power projects or small industries. The bathymetry of these locations broadly ranges between 5m to 10m (in some places, 15m). LNG could be sourced from one of the existing and/or planned terminals that would have re-loading capabilities and would be able to accommodate SSLNGCs. Other than coastal LNG transportation, there also is the potential for river distribution. For example, south Sumatra is one of the provinces which has a network of rivers that can be traversed by large cargo vessels (12m draft). However, factors such as tides, seasons, and sedimentation would need to be taken into account in order to determine if vessels would be able to traverse each area throughout the year. In the event large ship passage is not viable throughout the year, SSLNGCs or river barges become options.

[176] (World Population Review n.d.)
[177] (DLCA.JSON n.d.)
[178] (The Jakarta Post News Desk 2018)

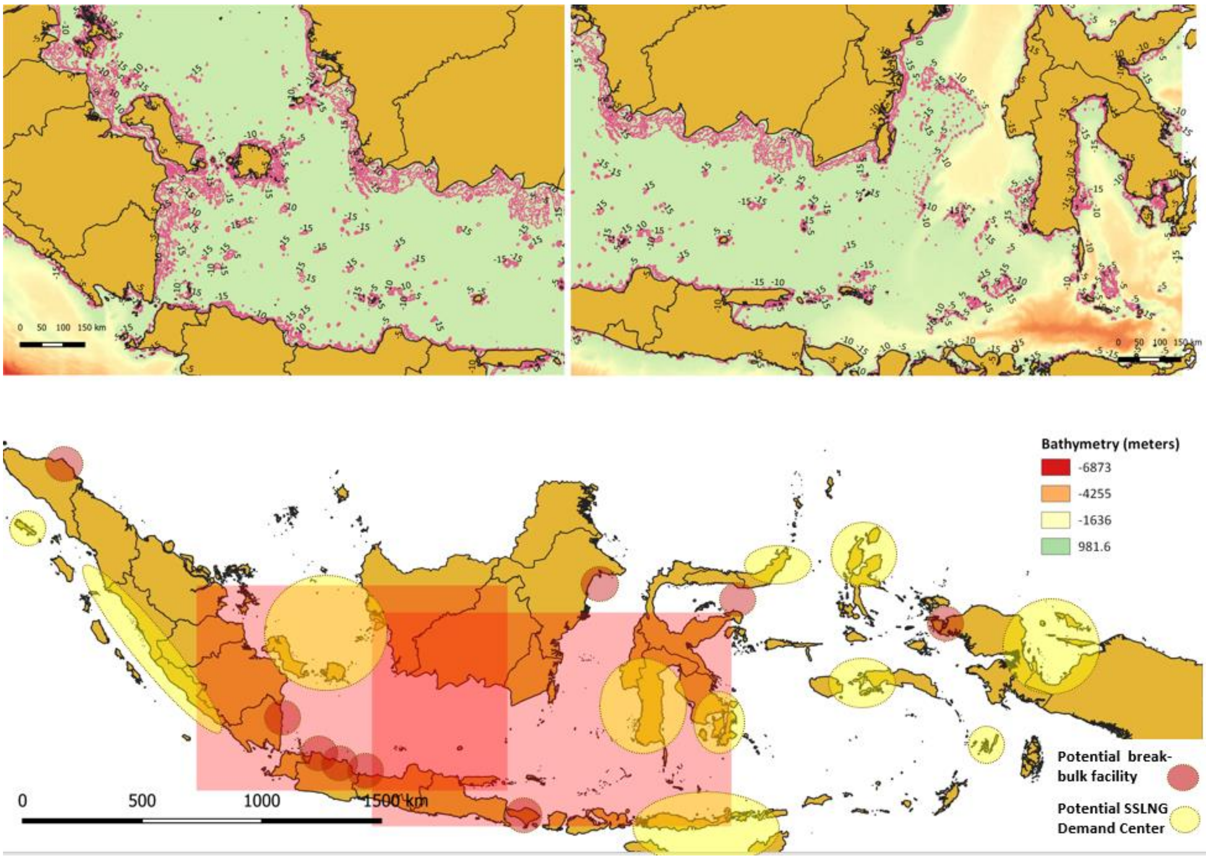

Figure 79: Indonesia Bathymetry and Potential Demand Locations[179]

179 Galway Group

Thailand

Thailand is one of the largest Asian economies, with a population of about 69 million, in 2017. Its population is spread along its coastal areas as well as its central region, with the majority living in the capital city of Bangkok (approximately 8.2 million people). Other cities are significantly smaller, with the second largest being Phuket with 386,000 inhabitants, Samut Prakan with 380,000 inhabitants, Mueang Nonthaburi with 290,000 inhabitants, Udon Thani with 240,000 inhabitants, Chon Buri with 219,000 inhabitants, and Nakhon Ratchasima with 208,000 inhabitants.[180] Figure 80 provides a population density map.

Thailand has a coastal area of 3,219 km, about 4,000 km of inland waterways, and 21 commercial ports of which 8 are operational international deep-sea ports and 4 are private ports for container cargo handling as shown in Figure 81.[181]

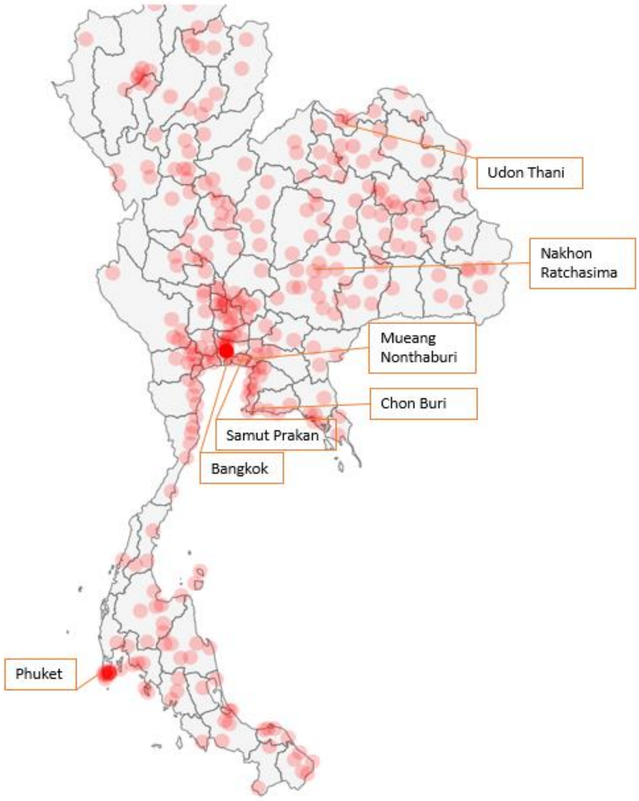

Figure 80: Most Densely Populated Areas in Thailand[182]

The major ports are Bangkok Port, Laem Chabang, Map Ta Phut, Ranong, Phuket, Songkhla, Sattahip, and Si Racha. Laem Chabang is the main deep-sea port.[183] Thailand also has a number of regional river ports, with the most important being Chiang Saen Port on the Mekong River, the Chiang Khong Port located in the Chiangrai Province, and the Ranong Port on the eastern bank of the Kra Buri River.[184] There are also hundreds of small-scale river ports, piers, and jetties offering accessibility to remote island and river locations.

180 (The World Bank n.d.)
181 (World Port Source n.d.)
182 (World Population Review n.d.)
183 (Thailand Board of Investment 2018)
184 (Marine Department Ministry of Transport Thailand n.d.)

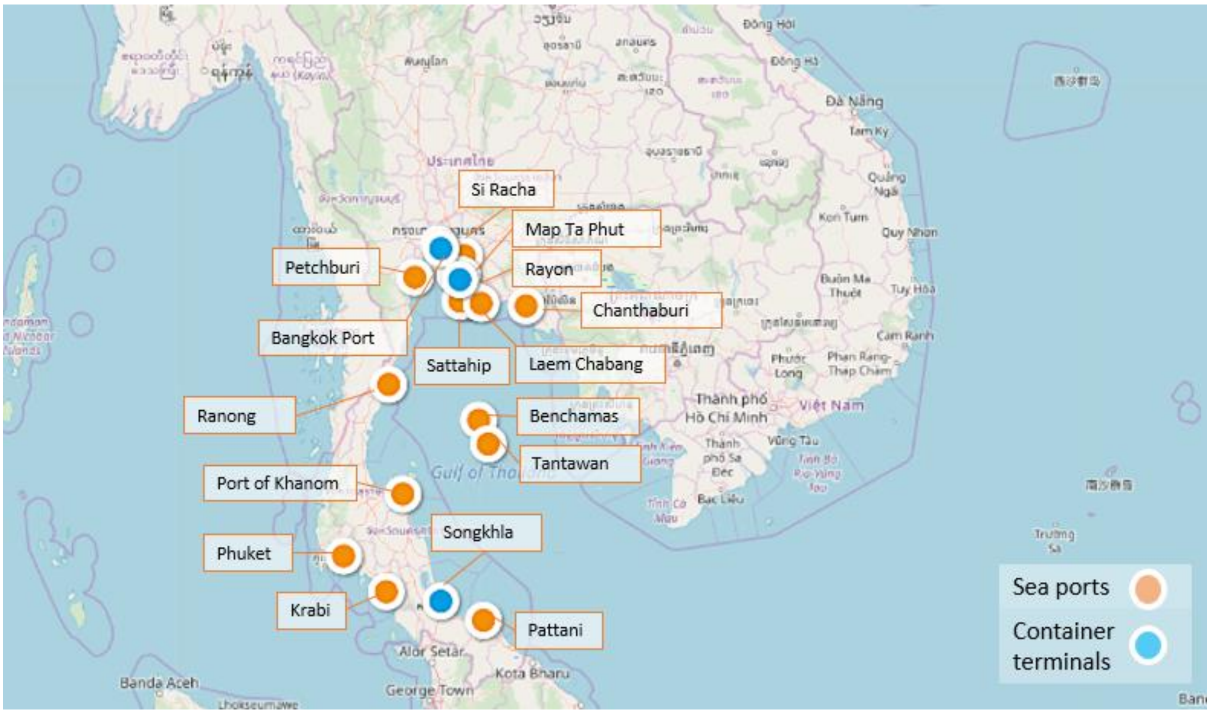

Figure 81: Location of Major Ports in Thailand

The coastal and river areas which potentially could be target locations for the deployment of SSLNG infrastructure are highlighted in Figure 82. The identification of such locations takes into account population concentration (regionally), expected energy demand, existing gas producing fields, gas pipelines, power plants, LNG regasification projects, port infrastructure, coastal areas and inland waterways, as well as bathymetry.

These potential demand centers are located in the southern part of Bangkok Bay (e.g. Prachuap Khiri Khan), western Thailand close to the Cambodian border (e.g. Trat), and southeastern Thailand (e.g. Phuket). These areas have bathymetry ranging between 9 to 15m.

Other than Phuket, which is a major touristic destination with energy consumption driven mainly by commercial buildings (e.g. hotels), the other two areas (e.g. Prachuap Khiri Khan and Trat) include industries that could be a potential target market for gas delivered by small-scale solutions.

LNG could be loaded into SSLNGCs at one of the existing/proposed LNG terminals, located in South Bangkok Bay, which would be able to accommodate small-scale vessels for re-loading operations. From there, LNG could be transferred to demand centers in Prachuap Khiri Khan, Trat, or Phuket.

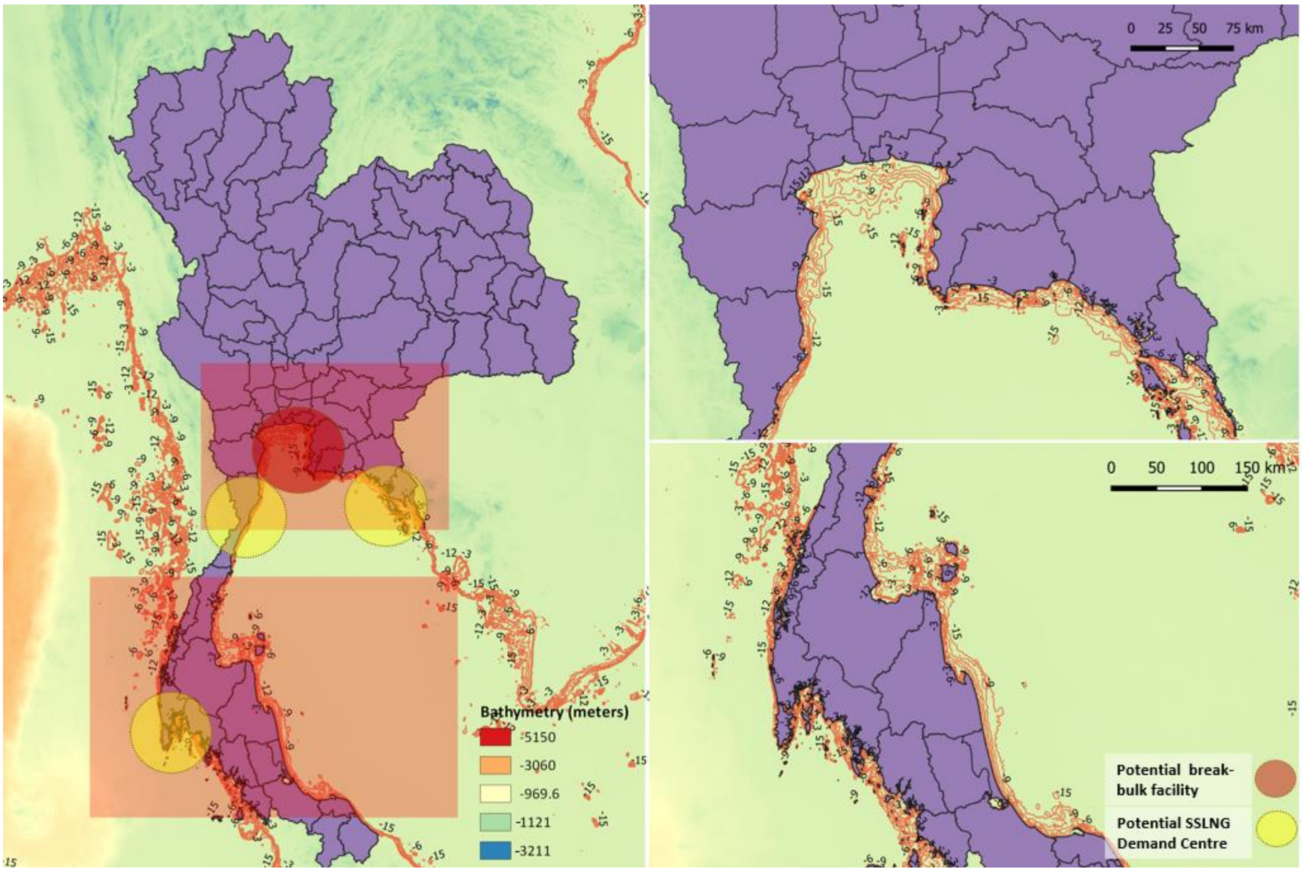

Figure 82: Thailand Bathymetry and Potential Demand Locations[185]

7.4 Charting the Economies in Terms of Potential Opportunities for Small-Scale Value Chain Opportunities that Challenge the Socio-Economic Status and Promote Clean Energy Trade

The energy sector is particularly affected by gender disparities.[186] Women in APEC economies face greater political, economic, and social barriers than men. Institutional structures in different economies, coupled with generalized stereotypical views of women's roles in society, can hinder women's power to make decisions and gain access to basic needs.[187]

The roles assigned by society to different genders result in different needs for each, including energy needs. In economies where the main source of cooking fuel is biomass, food preparation entails the time-consuming task of fuel collection and presents additional health risks associated with being exposed to high temperatures and smoke. Although these activities entail a higher health risk, household chores are not usually recognized as "labor" and thus, women's ability to multi-task and manage the energy needs of the home go unnoticed.[188] Figure 83 provides an outline of the role of women as household energy managers, with some associated risks and mitigation strategies.

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185 Galway Group
186 (Asia-Pacific Economic Cooperation 2019)
187 (Prosperity Fund Business Case n.d.)
188 (Global Gender and Climate Alliance 2012)

ENERGY USE	CONSTRAINTS	TRADITIONAL COPING MECHANISMS	IMPLICATIONS
Cooking fuel	Fuel wood becoming scarce. Reduced availability of crop wastes as fuel and fodder.	Increased time and effort spent in fuel wood collection. Change in cooking practices and food habits.	Less time available for other household activities. Children, especially girls, enlisted to assist in fuel collection. Adverse impact on family health.
Fetching water	Environmental degradation leading to depletion of water sources like springs and wells.	Increased time and energy spent in water collection.	Conflicts and social disharmony, adverse health impacts of using poor quality water. Complete neglect of women's knowledge relating to water quality and needs in policies.
Fodder management	Decreased availability of fodder because of loss of common lands.	Increased time and energy spent in fodder collection.	Less time available for other household activities.
Home bound micro enterprise	Biomass based fuel becoming scarce.	Increased time and effort spent in fuel collection. Switch to inferior fuels.	Increased indoor air pollution impacting family health.

Figure 83: Daily Household Energy Management[189]

This outline facilitates the understanding of the importance of addressing each gender's energy needs and why women need to play a fundamental role regarding household energy decisions, including energy production and utilization. Access to affordable and reliable energy improves the standard of living both at the macro and at the household level. At a macro level, access to energy allows for the establishment of new industries (whether macro or micro businesses). This allows for the increase in productivity due to an extension of operating hours, improvement of working conditions, streamlining of production, preservation of products, and communication with non-local markets. At the household level, access to energy allows for improvement of health through better food safety (e.g. refrigeration), improved knowledge through access to media, better productivity due to access to timesaving electric appliances, and greater safety and mobility due to interior and exterior lighting.

Various case studies show how access to energy has improved the health and empowerment of women. For example, in the United States household electrification was associated with higher school attendance during 1930s-1960s, while access to time-saving household appliances contributed to the increased participation of married women in the work force during the 1960s. In South Africa, female employment, particularly within microenterprises, increased by 9.5% in electrified communities. In Nicaragua, the propensity of rural women to work outside the home increased 23% in areas with access to reliable electricity due to an increase in household productivity (e.g. lighting and cooking appliances).[190]

The five selected APEC economies were ranked from the highest to the lowest regarding the impact of the implementation of SSLNG/FSRU solutions on the lives of women. This was done based on the role and needs of women regarding energy, along with the information gathered from the previous sections. To attain this ranking, new variables were used such as the percentage of total population with access to electricity, followed by percentage of the total population that has access to clean fuels and technologies for cooking. In addition, the total percentage of coal and oil used for electricity generation in the member economy was taken into consideration. Table 18 below shows the ranking, with PNG in the first position, as it is the member economy with the least population access to electricity as well as the least access to clean fuels and technologies for cooking. The percentage of females in the total population did not vary greatly among the member

[189] (Food and Agriculture Organization of the United Nations 2006)
[190] (Deloitte n.d.)

economies, with only a 4% difference between PNG (where 49.13% of the total population is female) and Thailand, (where 51.20% of the total population is female.)[191] Although Indonesia has a higher percentage of use of coal and oil for generating electricity and a comparable percentage of population with access to electricity, the Philippines ranked higher due to less than half of the population having access to clean fuels and technologies for cooking.

		Access to electricity (% of population)	Access to clean fuels and technologies for cooking (% of population)	Use of coal and oil for electricity generation (%)
1	PNG	49.4	13.43	52.00
2	The Philippines	92.3	43.22	47.00
3	Indonesia	97.6	58.37	54.00
4	Viet Nam	100.0	66.92	50.00
5	Thailand	100.0	74.43	24.00

Table 18: APEC Economy Ranking for the Implementation of SSLNG/FSRU Solutions[192]

Women's role in energy goes beyond that of immediate access to affordable energy sources for household activities. Gender inequality strongly correlates with national poverty levels and tackling the latter helps mitigate the first. Combining energy access with income-generating activities is a favorable way to address both. To achieve this, greater female involvement is required in roles that have been traditionally viewed as male dominated. Past policies and regulations enacted in these economies have largely missed the opportunity to better integrate women into decision-making positions and have not considered their role in shaping energy consumption habits.[193]

Barriers faced by women in the energy sector are not different from those faced in other male-oriented occupations in developed countries. For the years 1980-2017, female representation in the energy sectors of two major APEC economies, Australia and Chile, is shown in Table 19.[194]

	Australia	Chile
Energy-related ministers	11%	11%
Parliamentary committees related to the energy sector		
Chair	67%	50%
Vice Chair	25%	50%
Members	29%	15%
Energy companies		
President	0	0
CEO or similar	6%	12%
Board of Directors	18%	12%

Table 19: Female Representation in the Energy Sectors of Australia and Chile

[191] (The World Bank n.d.)
[192] (The World Bank n.d.) (APEC Energy Working Group 2019)
[193] Prosperity Fund Business Case, ASEAN Low Carbon Energy Programme: Accelerating sustainable growth in ASEAN through improving green finance flows for low carbon energy, and increasing energy efficiency.
[194] IEA, Status report on Gender Equality in the Energy Sector,

Meeting energy needs in an efficient and responsible manner requires a multi-dimensional approach: economic, political, technological, and social. Economic and environmental considerations suggest the integration of cleaner, safer, more reliable, and affordable fuels. Politics suggests the drafting of energy policies that focus on meeting immediate needs, while planning for future demand. Technology needs to be used, alongside the other factors, in securing a solution that optimizes around the other elements. The social issues need to be addressed by adding gender neutrality in energy policies. This can be accomplished by taking into account the needs of rural households and by understanding gender implications of energy issues. This understanding can be achieved by studying current decision-making roles and by paving the way for further gender integration.

8 Conclusions

SSLNG are projects aimed at satisfying demand needs between 0.1 and 1 MTPA. LNGCs of less than 30,000m^3 of storage capacity are used for these projects. The SSLNG value chain can be fulfilled with onshore elements (e.g. small-scale jetty, bullet tanks or flat bottom storages, ISO containers and LNG trucks), offshore elements (e.g. FSUs/FSRUs) or a combination of both. Some of the drivers for implementing SSLNG solutions are: (1) demand-supply matching, (2) the economics of SSLNG (3) the lack of available infrastructure, (4) access to shore, and (5) environmental initiatives. For example, Indonesia and the Philippines are pursuing SSLNG solutions for LNG distribution across their archipelagos, while the United States is exploring SSLNG possibilities for bunkering and inland distribution of LNG. China is exploring SSLNG for coastal distribution and LNG bunkering purposes.

SSLNGCs can have ultra-shallow draft requirements (between 5.5 to 6 meters) and shallow draft requirements (between 6 to 8 meters). One of their main advantages is the low upfront CAPEX requirement when compared to conventional LNGCs, as the first requires approximately US$65 million while the latter requires approximately US$200 million. Still, due to a loss in economies of scale, SSLNGCs' cost per unit is higher than that of a conventional-sized carrier as distance increase has a direct correlation to cost increase. However, this may be compensated with their flexibility, although limited, and accessibility to shallow areas, as SSLNGCs can be used for other operations (e.g. break bulking) as well as scheduled for particular seasonal demands.

A complementary element for the SSLNG supply chain is the use of FSUs/FSRUs. FSRU operations are similar in function to onshore terminals, but with added complexity and technology to manage such operations offshore. Traditionally, there has been a lack of infrastructure to meet the needs of scattered energy demand centers in archipelago countries like Indonesia or vast countries like Brazil and Argentina with long coastlines. In such cases, distribution of natural gas (post LNG regasification) received at an onshore facility through cross-economy pipelines becomes cumbersome, expensive, and infeasible. In such cases, an FSRU may present an appropriate solution that can be brought online quickly and with low up-front capital investment.

There are two main business models for SSLNG and FSRUs: the merchant model and the service/tolling model. In the merchant model, the commodity and the assets are owned by the same party, while in the service/tolling model a third party owns the commodity and pays a service or tolling fee to the terminal owner. Delivery of the commodity can be monetized by using a milk-run model or a hub-and-spoke model. The hub-and-spoke model consists of point-to-point delivery from the source to the end-user, while the milk-run model consists of the delivery of partial cargoes within the same shipping route. The milk-run concept has been studied for Indonesia, however, no developments have taken place as of 2019.

A recommendation tool was developed to guide decision-makers as to the most beneficial strategy. This tool considers:

1. **Demand Parameters**- size of demand center, typology of end-user, likelihood of demand occurring, stability of demand/seasonality and potential demand upside;
2. **Infrastructure Parameters-** accessibility by sea/road/pipeline/rail, distance and development timeline;
3. **Technical Parameters-** water depth, wave height, wind speed, current speed, and occurrence of typhoons; and
4. **Economy Parameters-** credit rating, availability of project funding, affordability of gas, and availability of subsidies.

Depending on the size and typology of demand, the distance to be covered and the investment requirement, the cost of LNG delivery can increase or decrease significantly. In order for the infrastructure solution to be economically and technically viable, an optimal balance needs to be achieved between these factors. For sites which are accessible by sea (either through a port or a dedicated jetty), it is important to evaluate the draft availability, ultimately determining accessibility of certain typologies of LNGCs (e.g. small or large-scale). The minimum draft requirement depends on vessel size, with larger vessels requiring deeper drafts.

Metocean considerations, including waves, currents, and wind are of vital importance for safe, secure, and continuous operation of LNG facilities and play an imperative role in assessing the suitability of a project site, the configuration of the asset, and technology selection. Depending on site specific metocean conditions, an FSRU can assume one of multiple configuration options and the mode of LNG transfer, berthing, and mooring. Choice of mooring impacts an FSRU's reliability to regasify LNG and send-out natural gas to end-users on a continuous basis. The mode of berthing and LNG transfer (across the berth, STS) determines acceptability among LNG suppliers. In addition, provision of breakwaters may have to be considered depending on the hydrographic conditions of the site, adding further CAPEX into the project development cost.

Five APEC economies were shortlisted as potential candidates for the implementation of SSLNG solutions: Papua New Guinea (PNG), Viet Nam, the Philippines, Indonesia, and Thailand. The factors considered for this shortlisting were: GDP per capita based on PPP; TPES per capita; location as a coastal South-East Asian member economy, and impacts on the lives of women. The potential for SSLNG in each member economy is:

- PNG's transmission grid only covers parts of urban and industrial areas. Since large parts of PNG lack an electricity grid, there is substantial potential for gas-to-power project development to facilitate new electricity generation needs. In particular, there is potential for replacement of some of the old and inefficient power plants fueled by diesel, many of which need rehabilitation to improve reliability and lessen technical losses.

- In Viet Nam, the potential for SSLNG is directed at replacing biomass in the residential sector as well as to service the growing transportation sector by means of CNG. Gazprom and PetroViet Nam are proposing CNG infrastructure deployment across eight provinces in southern Viet Nam. Another potential use for SSLNG is for LNG bunkering facilities, though no concrete developments have been announced as of 2019.

- Potential for SSLNG in the Philippines exists in Batangas (to service local industries), Mindanao, and Visayas (where industrial and power customers predominantly use diesel and coal to meet their energy needs and face inadequate power supplies, especially in Mindanao). Small-scale gas-fired power plants could be used where existing diesel/coal power plants are obsolete. However, there is limited scope for deployment of new large-scale gas-fired power plants since the government incentivizes usage of coal for power generation.

- For Indonesia, LNG bunkering has potential. In 2018, Indonesia announced plans to provide LNG bunkering services at its Arun regasification terminal as an alternative to Singapore's bunkering services. As gas-fueled shipping traffic in the region increases, other bunkering facilities may be required. In addition, there might also be potential for SSLNG infrastructure development to service customers residing in remote areas not interconnected to the electricity network or city gas network. However, taking into account the current rapid implementation of the member economy's electrification program and city gas network development program, the energy requirements of such customers are rapidly being fulfilled by the Indonesian government.

- Potential for SSLNG projects in Thailand exists to service some industrial customers, particularly fertilizers and petrochemical plants, and in the residential sector as a replacement fuel for biomass used for cooking. There could be potential for future gas usage in the road transportation (CNG) and marine transportation sectors (bunkering). An example of an LNG bunkering project under consideration is that of PTT and Marubeni for the port of Bangkok to service gas fueled ships, particularly as new IMO regulations are being implemented by 2020.

9 Appendix

– List of Existing SSLNGCs

Built	Name	CBM	Cargo Type	Trading Area	in LNG?	Ship Owner/Operator
1974	Seagas	187	LNG	Sweden	Yes	AGA
1988	Kayoh Maru	1517	LNG	Japan	Yes	Daiichi
1993	Aman Bintulu / Lucia Ambition	18928	LNG	Malaysia - Japan	Yes	Perbadanan/NYK
1996	Surya Aki	19475	LNG	Indonesia - Japan	Yes	MCGC
1997	Aman Sendai	18928	LNG	Malaysia - Japan	Yes	Perbadanan/NYK
1998	Aman Hakata	18800	LNG	Malaysia - Japan	Yes	Perbadanan/NYK
2000	Triputra	23096	LNG	Indonesia - Japan	Yes	MCGC
2003	Pioneer Knutsen	1100	LNG	Norway	Yes	Knutsen
2003	Shinju Maru No.1	2540	LNG	Japan	Yes	Shinwa
2005	North Pioneer	2500	LNG	Japan	Yes	Japan Liquid Gas
2007	Sun Arrows	19531	LNG	Malaysia - Russia - Japan	Yes	Mitsui
2008	Kakurei Maru	2536	LNG	Japan	Yes	Hogaki Zosen
2008	Shinju Maru No.2	2540	LNG	Japan	Yes	Shinwa
2009	Coral Methane	7551	LNG/LPG/Ethylene	Northwest Europe/Baltics	Yes, sometimes	Anthony Veder
2010	Norgas Creation	10000	LNG/LPG/Ethylene	Worldwide	No	Norgas Carriers
2010	Norgas Innovation	10000	LNG/LPG/Ethylene	Worldwide	No	Norgas Carriers
2011	Akebono Maru	3556	LNG	Japan	Yes	Chuo Kaiun
2011	Norgas Bahrain Vision	12000	LNG/LPG/Ethylene	Worldwide	No	Norgas Carriers
2011	Norgas Conception	10000	LNG/LPG/Ethylene	Worldwide	No	Norgas Carriers
2011	Norgas Invention	10000	LNG/LPG/Ethylene	Worldwide	No	Norgas Carriers
2011	Norgas Unikum	12000	LNG/LPG/Ethylene	Worldwide	No	Norgas Carriers
2012	Coral Energy	15600	LNG	North-West Europe/Baltics	Yes	Anthony Veder
2013	Coral Anthelia	6500	LNG/Ethylene	Unknown	Yes	Anthony Veder
2013	JX Energy TBN	2500	LNG	Japan	Yes	JX Energy
2013	Kakuyu Maru	2500	LNG	Japan	Yes	Tsurumi Sunmarine
2014	LNG-Oil combi	2000	LNG	Germany	Yes	Veka
2014	Short Sea LNG Tanker	4000	LNG	Germany	Yes	Veka
2015	Small carriers TBN	5000	LNG	Unknown	Yes	Bimantara Group
2015	Jahre TBN	6200	LNG	Norway	Yes	Donsotank/Jahre Marine
2015	JS Ineos Ingenuity	n/a	LNG/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2015	JS Ineos Insight	n/a	LNG/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2015	JS Ineos Intrepid	n/a	LNG/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2015	LNG Barge TBN	3000	LNG	US Coast	Yes	LNG America
2015	LNG bunker barge 1	2250	LNG	China	Yes	Anhui Huaqiang Natural Gas
2015	LNG bunker barge 2	2250	LNG	China	Yes	Anhui Huaqiang Natural Gas
2015	LNG bunker barge 3	2250	LNG	China	Yes	Anhui Huaqiang Natural Gas
2015	LNG Inland bunker	800	LNG	Germany	Yes	Veka

2015	Norgas TBN	17000	LNG/LPG/Ethylene	Worldwide		Norgas Carriers
2015	Norgas TBN	17000	LNG/LPG/Ethylene	Worldwide		Norgas Carriers
2015	PetroChina TBN	30000	LNG	China		PetroChina
2015	TBN	14000	LNG	China	Yes	Zhejiang Huaxiang
2015	TBN 1	27500	LNG	Unknown		Danyang
2015	TBN 2	27500	LNG	Unknown		Danyang
2015	TBN 3	27500	LNG	Unknown		Danyang
2016	Clean Jacksonville	2200	LNG	US Coast	Yes	CME
2016	Dalian TBN	28000	LNG	China	Yes	Dalian Inteh Group
2016	Hai Yang Shi You 301	30000	LNG	Bali FSU	Yes	CETS (CNOOC)
2016	JS Ineos Independence	27500	LNG/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2016	JS Ineos Innovation	27500	LNG/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2016	JS Ineos Inspiration	27500	LNG/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2016	LNG Prime	2250	LNG	North-West Europe	Yes	Veka Deen LNG
2016	Navigator Aurora	n/a	Ethane/Ethylene	Markus Hood - Stenungsund	Ethane, for Borealis	Navigator
2016	Gaschem Beluga	n/a	Ethane/Ethylene	US - Teeside	Ethane, for Sabic	Gaschem Services
2016	Gaschem Orca	n/a	Ethane/Ethylene	US - Teeside	Ethane, for Sabic	Gaschem Services
2016	Ocean Yield TBN	n/a	Ethane/Ethylene	US - Teeside	Ethane, for Sabic	Gaschem Services
2017	Cardissa	6,500	LNG	North-West Europe	Yes	Shell
2017	Yuan He 1	30,000	LNG	China	Yes	CSR
2017	ENGIE Zeebrugge	5,000	LNG	North-West Europe	Yes	NYK
2017	CME TBN	2,200	LNG	US Coast	Yes	CME
2017	CME TBN	2,200	LNG	US Coast	Yes	CME
2017	Coral Energy	18,000	LNG	North-West Europe/Baltics	Yes	Anthony Veder
2017	Coralius	5,800	LNG	North-West Europe/Baltics	Yes, for Skangas	Anthony Veder
2017	JS Ineos Invention	n/a	LNG/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2017	JS Ineos Intuition	n/a	LNG/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2017	LNG-Gorskaya TBN	7,300	LNG	Russia	Yes	LNG-Gorskaya
2017	LNG-Gorskaya TBN	7,300	LNG	Russia	Yes	LNG-Gorskaya
2017	LNG-Gorskaya TBN	7,300	LNG	Russia	Yes	LNG-Gorskaya
2017	Navigator Eclipse	n/a	Ethane/Ethylene	US	Ethane	Navigator
2017	Navigator Nova	n/a	Ethane/Ethylene	US	Ethane	Navigator
2017	Navigator Prominence	n/a	Ethane/Ethylene	US	Ethane	Navigator
2018	Shell Bunker Barge TBN 2	6,500	LNG	North-West Europe	Yes	Shell
2018	Shell Bunker Barge TBN 3	6,500	LNG	North-West Europe	Yes	Shell
2018	Shell Bunker Barge TBN 4	3,000	LNG	North-West Europe	Yes	Shell
2018	Bernhard Schulte TBN	7,500	LNG	Baltic	Yes	Bernhard Schulte
2018	CME TBN	2,200	LNG	US Coast	Yes	CME
2018	Evergas TBN	n/a	Ethane/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas

2018	Evergas TBN	n/a	Ethane/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2018	Evergas TBN	n/a	Ethane/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2018	Evergas TBN	n/a	Ethane/Ethylene	Markus Hook - Rafnes	Ethane, for Ineos	Evergas
2019	KLine TBN	7,500	LNG	Korea	Yes	Korea Line
2019	KLine TBN	7,500	LNG	Korea	Yes	Korea Line
2019	Stolt TBN	7,500	LNG	Mediterranean	Yes	Stolt-Nielsen Gas
2019	Stolt TBN	7,500	LNG	Mediterranean	Yes	Stolt-Nielsen Gas
2020	Stolt TBN (option)	7,500	LNG	Option	Yes	Stolt-Nielsen Gas
2020	Stolt TBN (option)	7,500	LNG	Option	Yes	Stolt-Nielsen Gas
2020	Shell Bunker Barge	4,000	LNG	US Coast	Yes	Q-LNG Transport / Harvey Gulf
2021	Stolt TBN (option)	7,500	LNG	Option	Yes	Stolt-Nielsen Gas

Source: Galway Database and https://small-lng.com/

– List of Operational FSUs/FSRUs Deployed as Terminals

Region	Economy	Project Name	Developer	Capacity (MTPA)
Americas	Argentina	GNL Escobar FSRU (Excelerate Expedient)	Excelerate Energy (Charterer: UTE Escobar, YPF)	4.5
Asia	Bangladesh	Moheshkhali FSRU (Excelerate Excellence)	Excelerate Energy (Charterer: Petrobangla)	3.8
Americas	Brazil	Bahian FSRU (Golar Winter)	Golar (Charterer: Petrobras)	3.8
Americas	Brazil	Pecem FSRU (Excelerate Experience)	Excelerate Energy (Charterer: Petrobras)	6
Asia	China	Tianjin FSRU (Höegh Esperanza)	Höegh LNG (Charterer: CNOOC)	3
Americas	Colombia	Cartagenan FSRU (Höegh Grace)	Höegh LNG (Charterer: Sociedad Portuaria El Cayao)	3
Africa	Egypt	Sumed FSRU (BW Singapore)	BW Group (Charterer: Egas)	5.7
Asia	Indonesia	Benoa FRU & FSU (replaced with FSRU)	JSK Group, PT Pelindo III	0.3
Asia	Indonesia	Lampung FSRU (Höegh PGN)	Höegh LNG (Charterer: PGN)	1.8
Asia	Indonesia	Nusantara Regas Satu FSRU (Golar)	Golar LNG (Charterer: PT Nusantara Regas)	3
Middle East	Israel	Haderan FSRU (Excelerate Excelsior)	Excelerate Energy (Charterer: INGL)	3.5
Europe	Italy	Toscanan FSRU (OLT Offshore)	OLT (Uniper, IREN, Golar)	2.8
Americas	Jamaica	Montego Bay FSRU (Golar Freeze)	Golar (Charterer: Jamaica Public Service Company)	3.6
Americas	Jamaica	Port Esquivel FSU (Golar Arctic)	Golar (Charterer: New Fortress Energy)	1.2
Middle East	Jordan	Aqaban FSRU (Golar Eskimo)	Golar (Charterer: Jordan's Ministry of Energy and Mineral Resources)	3.8
Middle East	Kuwait	Mina Al Ahmadi FSRU (Golar Igloo)	Golar (Chartere: KPC)	5.8
Europe	Lithuania	Klaipedan FSRU (Höegh Independence)	Höegh LNG (Charterer: Klaipedos Nafta)	2.9
Asia	Malaysia	Melaka FSU (Tenaga Empat and Satu)	Petronas	3.8
Europe	Malta	Delimara FSU (Armada LNG Mediterrana)	Bumi Armada (Charterer: Electrogas Malta)	0.5
Asia	Pakistan	Port Qasim GasPort FSRU (BW Integrity)	BW Group (Charterer: Pakistan GasPort)	5
Asia	Pakistan	Port Qasim Karachi FSRU (Excelerate Exquisite)	Excelerate Energy (Charterer: Engro, Vopak, IFC)	4.8
Europe	Russia	Kaliningrad FSRU (Marshal Vasilevskiy)	Gazprom	2.7
Middle East	Turkey	Dortyol FSRU (MOL Challenger)	MOL (Charterer: Botas)	4.1
Middle East	Turkey	Etki FSRU (Höegh Neptune)	Höegh LNG, MOL, Tokyo LNG (Charterer: Total/Kolin)	3.7
Middle East	UAE	Jebel Ali Dubai FSRU (Excelerate Explorer)	Excelerate Energy (Charterer: Dubai Supply Authority - DUSUP)	6

Source: Galway FSRU Database, Public, Corporate Reports, and GIIGNL

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