LNG BUSINESS STRATEGIES : TRAINING FOR PARTICIPANTS FROM SAARC COUNTRIES

SAARC ENERGY CENTRE,
ISLAMABAD, 15-19TH NOVEMBER , 2021

Swami Dayal Prasad
Rajeev Mathur
R K Garg
Dr A K Balyan

Session 3

Key challenges in development of Global LNG Capacities

Key challenges in development of Global LNG Capacities

Outline

- A brief history of Liquefaction of NG and LNG transportation by Ocean Going Vessels (OGV)
- Liquefaction technologies
- Issues and Challenges in development of LNG Facility :
  - Primary requisite
  - Identifying markets
  - Key stakeholders & scale of investment
  - Financing
  - EPC and Financial Investment Decision (FID)
  - Approximate timelines and flow of investment.
- Status of global LNG Capacities : Operational, under construction (incl FIDs in 2019 & 2020) and Pre FID
- Key nations involved with developing LNG capacities
- LNG Shipping : Key characteristics, Fleet capacity, Vessel's cost, availability, and new orders, trends

Liquified Natural Gas (LNG)

Natural gas comprises of different hydrocarbons like Methane, Ethane, Propane, Butane along with Carbon-di-oxide, Oxygen, Nitrogen, Hydrogen sulfide, and some Rare gases.

- Methane, or the C-1 Hydrocarbon, comprises nearly 80 - 95 % of Natural gas.
- LNG is condensed natural gas which has been 'liquefied' to liquid form for ease of storage or transport.
- LNG occupies about 1/600th of the volume of NG, is odorless, colorless, non-corrosive, non-flammable and non-toxic, Density – 420 to 470 Kg/m3, hence, lighter than water
- Methane or the C-1 Hydrocarbon needs least energy to be gasified than the other Hydrocarbons in Natural Gas which are more complex molecules Depending on the composition. Methane is gasified at 112^{o} K or (-)161^{o} C, Ethane at 185^{o} K or (-)88^{o} C, and so on. [0^{o} K = (-) 273^{o} C]
- Entire Natural Gas can be completely liquefied at approximately -162^{o} Centigrade (-259^{o}F) at atmospheric pressure.
- Liquefaction of Natural gas requires 'Ultra-cold' refrigeration processes called 'Cryogenics'
- LNG is stored in heavily insulated containers, which are like thermos bottles.
- The liquefaction of natural gas also produces by-products like butane, propane, pentane, some quantities of hydrogen sulphide and rare gases like Helium.

A brief history of Liquefaction of NG

- From the seventeenth century onwards, Liquefaction of gases was pursued by scientists like Boyle, Joules, Lord Kelvin and many others.
- By 1908, all gases including helium at (-) 269^{o} C, had been liquefied.
- Methane was first liquefied in 1886, by condensing it at temperatures below 162^{o} centigrade.
- In 1915, liquefaction of natural gas in the US was carried out on a commercial scale for extraction of helium.
- In the 1930s, technology for storage of Methane below -162°C was developed in the United States.
- The abundant availability of natural gas led to commercial production of LNG and its transportation for consumption at far flung areas.
- The first commercial Liquefaction and storage plant was commissioned in 1940 by the East Ohio Gas Company at Cleveland, Ohio, for storing LNG and re-gasifying it for the peak shaving demand in winters.
- By 1942, the storage facility had four large cryogenic vessels for storing LNG for meeting the winter demand.
- In 1944, leakage of LNG from a tank led to a major explosion which claimed nearly 130 lives, and the facility was closed down.

The accident at Cleveland LNG facility stepped up research in low temperature alloys, insulation materials. It also led to a thorough review of technology and practices for safe storage and handling of LNG and paved the foundations for successful and safe utilization of LNG

A brief history of LNG & its transportation by Ocean Going Vessels (OGV)

- In 1958, backed by funding from the British Gas Council, a used WW-II cargo ship , ***Normati***, was converted as an LNG Vessel , the ***'Methane Pioneer',*** by Alabama Drydock and Shipbuilding Company, Alabama USA.
- This project was operated by a Joint Venture, formed between Conoco and Union Stock Yards, and was later joined by Shell.
- **In Jan 1959**, the first voyage by **'Methane Pioneer',** set sail from the Calcasieu River facility, Louisiana US for Canvey Island in England, carrying the first ever shipment of about 32,000 barrels of LNG and completed the voyage in 27 days.
- Meanwhile, the monetisation of a large discovery of NG reserves in Algeria in early 60s, catalysed LNG industry
- Commercial manufacturing of LNG Liquefaction facilities, Ship-building and Regasification terminals began in Britain, France & Spain.
- **In 1964,** the world's first purpose-built LNG carrier, the ***'SS Methane Princess'*** along with a sister ship ***' SS Methane Progress',*** were manufactured for the **British Gas** by **Vickers Shipyard** for supplying **LNG from Algeria to England.**
- Meanwhile, **Gaz de France (GDF)** was also pursuing development of the LNG shipping technology and various prototypes were manufactured in different shipyards. **In Jan 1965**, ***'Joules Verne'*** began transporting LNG on the Algeria – France route.

A brief history of LNG

- Throughout the decades of 60-70s, the United States, which already had sizeable gas reserves and pipeline infrastructure for domestic and commercial consumption, restarted its LNG industry with a series **of Liquefaction and Re-gasification plants** . The activity was mostly **on the east coast of the USA to import LNG** mainly for winter peak shaving demand.

- In the 70s and 80s, many gas producing countries like Brunei (1973), Indonesia (1977), Malaysia (1983), Australia (1989) ,Qatar (1997) started producing LNG.

- **After the shale gas boom, US turned a net exporter of gas.** This led to many of these facilities in the US being converted to LNG export terminals.

Liquefaction technologies

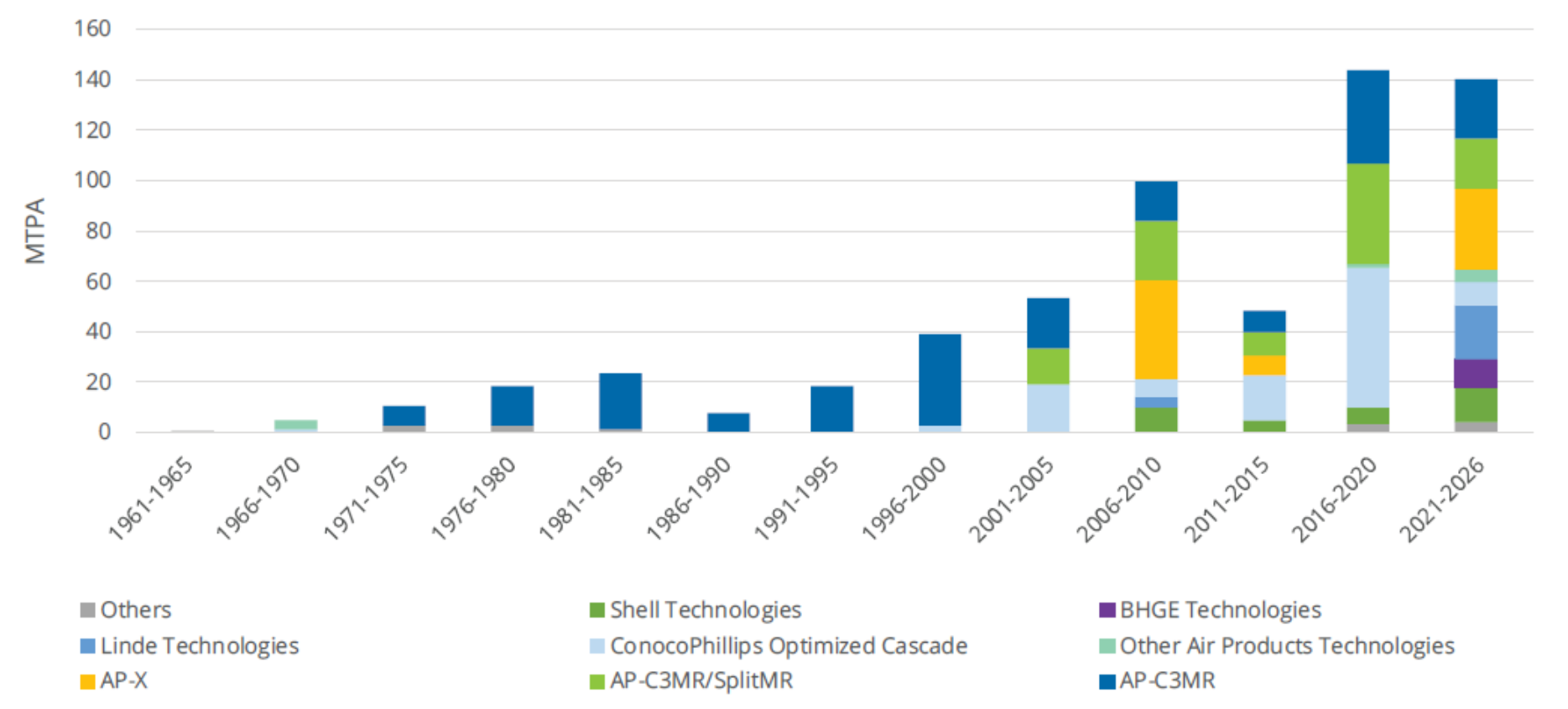
- There are two popular methods for commercial liquefaction.
  - The fist method uses a refrigerant to cool the natural gas in stages and is referred as **'cascade method'.**
  - The second method is based on the **'Joule-Thomson effect'** that a compressed gas cools when expanded through an orifice.

- Most of the Liquefaction companies have developed their own customised liquefaction processes. The popular ones are
  - Air Products' liquefaction technologies (namely AP-C3MR, AP-C3MR/SplitMR, AP-X, AP-N), has a 67% share in the global installations.
  - Conoco Philip's Optimized Cascade Process is the next most popular technology
  - The above are followed by proprietary processes of Shell, Linde and others.

- The compressors were initially powered by Steam Turbines, but have given way to Gas Turbines.
- Based on the techno-economic considerations, these technologies can be customised for manufacturing a wide range of Liquefaction capacity.
- Each liquefaction process unit is called a 'train'. A Liquefaction facility selects one or multiple 'trains' of suitable capacity / size.
- Over the years, for optimizing costs / achieving economies of scale, individual train capacity has gone up to 7.8 MTPA.

Liquefaction technologies

- As per Rystad Energy, in the last decade, the most popular Liquefaction technologies were provided by Air Products followed by Conoco Philips.
- For the next 5 years, the trend continues, followed by Linde Technologies & Shell Technologies.



Source : IGU 2021 World LNG Report

Development of LNG Facility : Key Features

- **High CAPEX**

  As per a report of Oxford Institute of Energy Studies (OIES), the data of about 50 LNG projects analysed by EY in 2014, indicated that the capital outlay for an average LNG liquefaction project size, worked out to about 10-11 Bn $.

- **Project delivery time**

  It is usual for a Greenfield project, where no prior construction infrastructure or utilities are available, to take 8-10 years from the conceiving of project to delivery of the first cargo.

  In brownfield expansions, the time can be effectively reduced.

LNG Liquefaction : Scale of investment

The CAPEX requirement for a 'Greenfield' LNG capacity comprises of investments for the following:

- **Gas supplies** : This includes the cost of developing a gas reserve and the transportation. This can vary across geographical markets and depends on the average price of production and connecting pipeline costs. The global benchmarks are between 2 to 3.5 $/mmbtu. Alternately, gas supplies can be contracted from a major supplier and a pipeline connectivity is planned.

- **LNG plant** : This is the most cost intensive and complex element of supply chain. As discussed before the cost varies for Greenfield and Brownfield development. In terms of levelized costs of gas, this can translate from 2 to 4.5 $/mmbt

- **Shipping** : The costs depends on ordering the capacity and size of a suitable fleet of LNG vessels. The average cost of vessels for a LNG vessel of capacity 180,000 cubic metres (cm) is around 180 to 190 Mn USD for ME-GI or XDF type technology. The long-term charter cost will depend on CAPEX and at present are about 70,000 $/day, though they vary depending upon the type of vessel. The bunker fuel costs depend upon distance and the route of the voyage.

LNG Liquefaction : Scale of investment

Illustration : LNG Canada (Source – OIES)

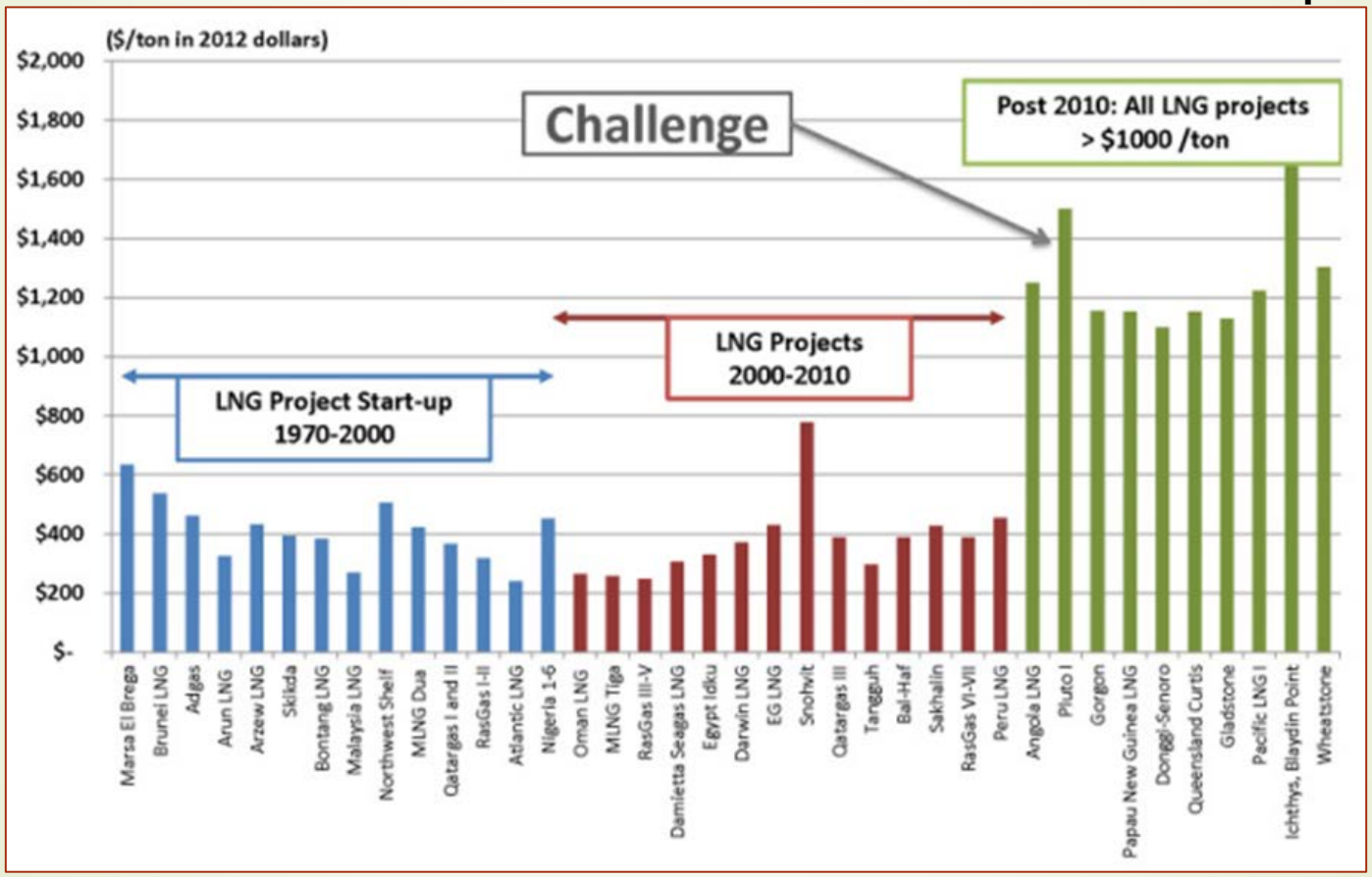
- LNG Canada, is a greenfield facility of 14 MTPA, coming up in Western Canada.
- The project comprises of development of the gas reserves in Montney area, a 670-km pipeline for transporting gas to the port of Kitimat, British Columbia, and a Liquefaction Plant initially of 14 MTPA with provision for future brownfield expansion.
- The FID presentation provided indicative prices of LNG (Delivery at Terminal price). CAPEX is to the tune of **$31.2 Bn ,** break-up as under :
  - Upstream development of Gas Reserves : 12.4 Bn USD
  - Pipeline from gas fields to Liquefaction facility : 4.8 Bn USD
  - Liquefaction Plant : 14.0 Bn USD
- To mobilise finances and certainty of off-take, the developers roped in the Buyers / Affiliates, who are Oil & Gas portfolio players from UK, China, Malaysia, Japan and Korea to participate in the equity. The lead partner, Royal Dutch Shell holds about 40% equity and the rest is from Petronas Malaysia (25%), PetroChina (15%), Mitsubishi Corp (15%) and Korea Gas (5%).
- Break-up of the target price of DAT (Delivery at Terminal) JKTC was as follows:

Break-up of LNG Cost	Cost in #/mmbtu	Share in the LNG Cost
Upstream gas cost	2.0	24%
Pipeline Tariffs	0.5	6%
Gas Supply cost to LNG Plant	2.5	29%
Liquefaction costs (14 MTPA @ 1,000 $/tpa	3.5	41%
LNG Shipping (Kitimat, West Canada to JKTC)	1.0	12%
Gross Margin	1.5	18%
DAT JKTC	**8.5**	**100%**

- The FID was achieved in Oct 2018. The project is half-way through and first cargo is targeted for delivery in 2023 or 2024

Capex Analysis of Liquefaction Plants

$/Ton of LNG Capacity



Source: Apache from Public Data

Developing of LNG Facility

- **Primary requisite** : Availalbility of gas , Pipeline, proximity to port
- **Identifying markets** : **Long-term committed buyers** :
- **Technology of Liquefaction & Shipping** : A capable and committed team of professionals required for EPC is required for the entire lifecycle of the project.
- **Committed Financing** : Balance Sheet Equity or Project Finance
- **Project implementation** : Ensure flow of investment and meet that the project's targets

Developing of LNG Facility : Primary Requisites

- **Primary requisite** :
  - Availability of surplus natural gas or reserves,
  - E & P Capabilities,
  - Pipeline connectivity or feasibility, Land near a suitable port

LNG Liquefaction : Identifying markets

- LNG is targeted as a fuel substitute for markets that do not have indigenous production of fossil fuels and depend on imports of crude oil and refined products. Supply of LNG at prices that would offer fiscal benefit to consumers was the key enabler.
- The **End-users** and **Portfolio players** in the identified markets have been targeted. Portfolio players are LNG stakeholders who have off-take stakes in in LNG supplies from different regions / Liquefaction plants and own multiple Regasification terminals, Shipping fleet and storage capacity.
- The new trend in identifying upfront consumers for an upcoming LNG facility is **'Affiliate Marketing'**, wherein, the affiliates (including end-users or portfolio LNG companies) invest in exchange of a share in the off-take.

Developing of LNG Facility : Technology / EPC

- **Key Considerations for technology :** Safe, Reliable, Economical or Optimal
- **Technology of Liquefaction & Shipping** :
  - A capable and committed team of professionals required for EPC is required for the entire lifecycle of the project.
  - Site selection : Proximity to gas supplies and a port
  - Feasibility
  - Pre- Front end Engineering and Design (FEED) & Detailed FEED
  - Techno-economic studies and selection of trains / technology
  - Flexibilities
  - Utilities
  - Storage
  - Berthing
- **Project implementation Issues** : Ensure that the project's targets are met and ensure commensurate cash flow

LNG Liquefaction : Project Cycle

- Pre FID
- FID
- Post FID

LNG Liquefaction : Pre- FID

- **Feasibility studies** :
  - Gas Supplies on Long-term : As a thumb rule, at least 1 tcf of reserves are required for 1 MTPA plant for 20 years' supplies.
  - Pipeline Connectivity :
  - Adjoining port and identification of sites, and
  - The feasibility also addresses all local issues (land, local laws, regulations, permits & licence, free access),
- **Pre-FEED (Front end Engineering & Design):** Addresses technical issues like capacity of connecting pipelines, plant capacity, configuration, efficiency, draft and berthing at port, benchmark EPC costs for the plant, port, logistics, shipping etc.
- **Marketing** : To firm up buyers (End users, Portfolio players, Traders, Shareholders). Key issues are :
  - Take-or-Pay, along with mitigations
  - Price Indexation
  - Operational / Commercial flexibilities,
  - Dispute Resolution mechanism are discussed and a Letter of Intent (LoI) followed by an Heads of Agreement (HoA) is signed
- **FEED :**
  - Complete engineering for project's **technical specifications and cost estimates**,
  - Finalize the **tender documents for the EPC contracts or packages**,
  - **invite bids and complete all the pre-award discussions**.
  - Also finalize **Long-term ship charter agreements** or orders on shipyards,
  - **Complete the pre-order stage for all long-lead materials / plant equipment, Port infrastructure**
- **After final FEED data is available**, a negotiated Sale Purchase Agreement (SPA) with Buyers is finalized

LNG Liquefaction : Project Cycle

Financial Investment Decision

- Finalize structure of the Project Finance Model
- A thorough due-diligence is carried out for all contracts, viz, SPA, Gas supply, Gas Transportation, EPC Contracts and Ship Charters.
- Based on the anticipated costs and revenues, the IRR is worked out.
- The reports are reviewed by decision making bodies and FID is accepted or deferred for more data, risk analysis and mitigations etc.
- Along with the FID, main orders for equipment, EPC, Shipping, Port Infrastructure etc. are also approved by the Functional Committees / the Company Board / Shareholders as per the prevailing statutory regulations / policies.

LNG Liquefaction : Post - FID

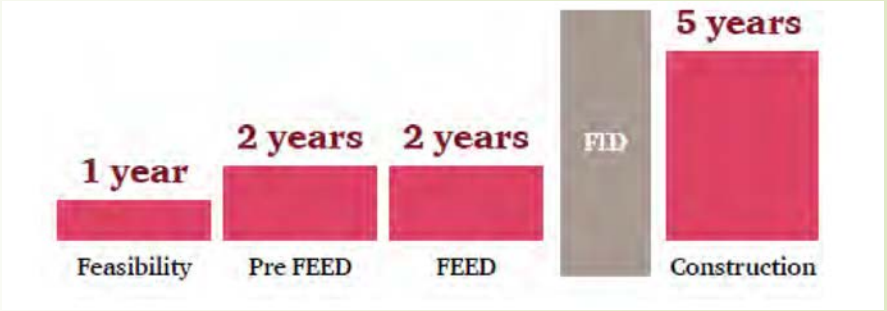
- The key post-FID activities are
  - Award of all the contracts, i.e., EPC, Long lead equipment, Ship charters / Acquisition
  - Project Management & Cash flows,
  - HSE, HRD, Manpower and other operational issues.

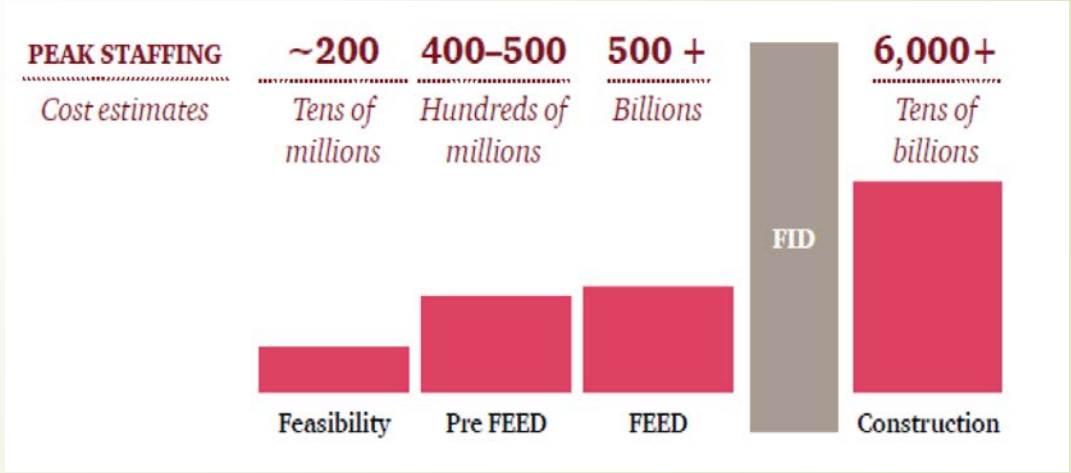
- In a study by PWC on risks in LNG projects, 13 of the 20 large-sized LNG projects faced cost and time overruns. The key attributes are:
  - Project execution issues, accounting for nearly two-thirds of the delays,
  - the rest are due to Management delays in decision making and unforeseen environment/ government/ local interferences and issues.

- The delays in an LNG project can upset the IRR in the long run.

LNG Liquefaction : Timelines for Implementation, Manpower requirements and flow of Investment

- As per a study by PWC, (Canada) it can take about 5 years to complete the Pre-FID (Feasibility, Pre-FEED and FEED) and nearly same time for the Post-FID stage for implementing the
- The study reveals that the manpower requirement may be about 400-500 for completing the Pre-FEED and FEED
- Pre-FEED activities can cost several hundred millions of dollars.
- FEED can cost a billion dollar or more
- Construction of the Liquefaction facility along with the Ports, Shipping and Terminal can cost tens of billions and require manpower staffing of 6,000 .





In spite of the complexities in installing LNG Liquefaction capacity, ***what is the near future and long-term outlook ?***

Do we have the comfort of ***adequate Liquefaction capacities coming up ?***

Global LNG Capacities

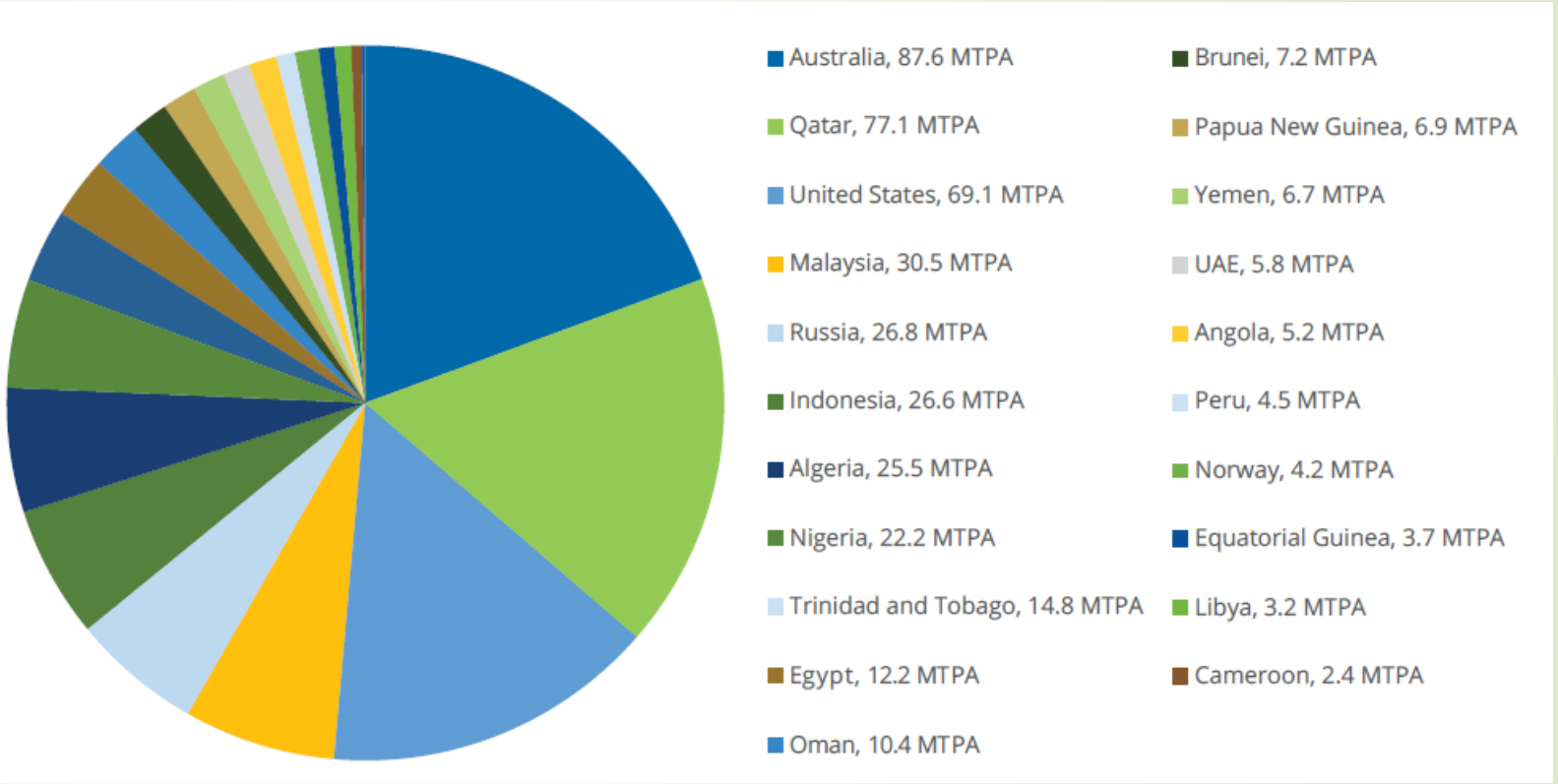
- Operational capacities and their utilization
- Under construction, FIDs in 2019 & 2020,
- Pre-FID capacities
- Key nations involved with developing LNG capacities

Global LNG Capacities : Operational

452.9 MTPA as in Feb 2021

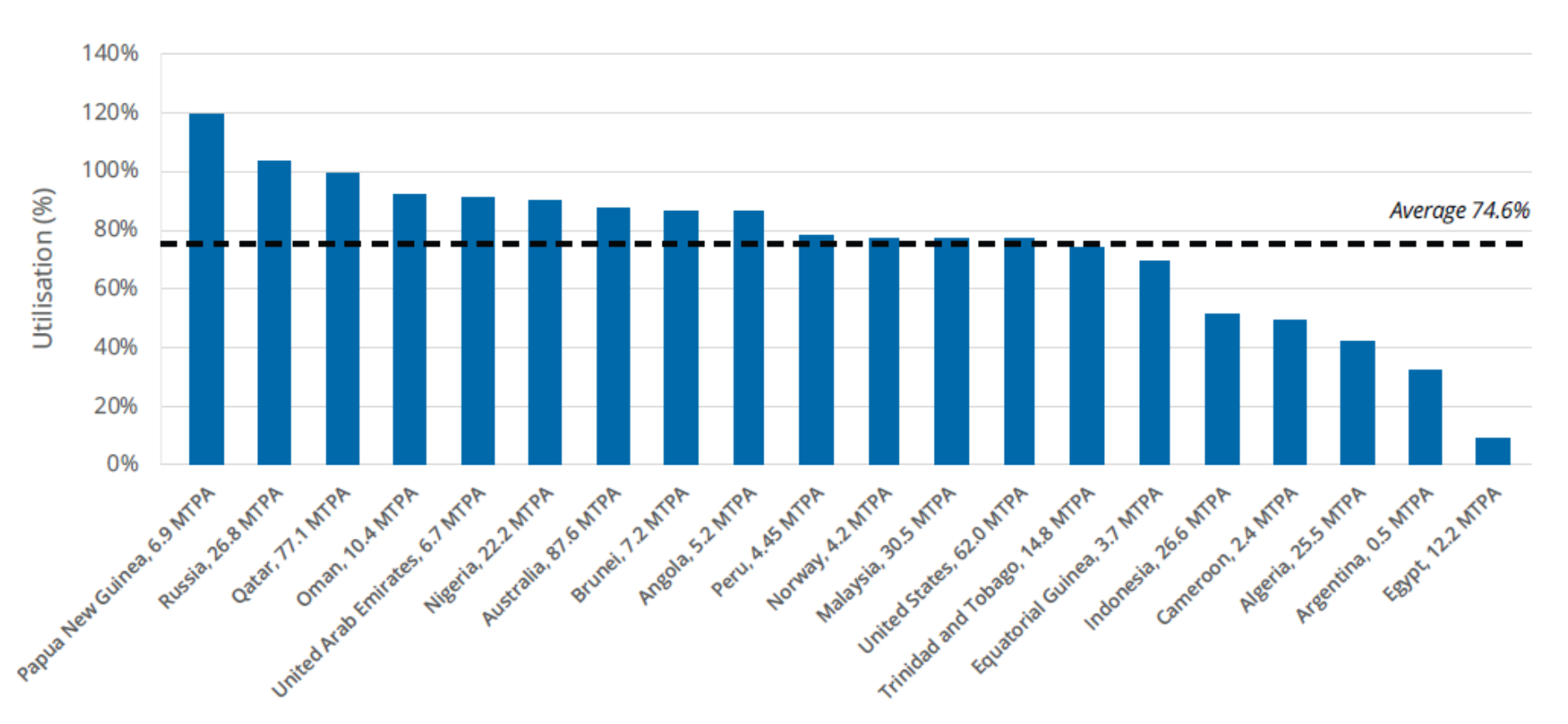
As per IGU / Rystad Energy

- Global LNG – 452.9 MTPA
- Capacity added in 2020 was 20 MTPA, all by the USA
- Due to COVID 19, many LNG Trains in Russia, USA, Malaysia and Indonesia could not be made operational.
- Australia is the global leader with 87.6 MTPA, followed by Qatar with 77.1 MTPA
- USA has a capacity of 69.1 MTPA of operational capacity.



Global LNG Capacities : Utilization

- As per IGU / Rystad Energy, Utilization of the Operational LNG capacity in 2020 was impacted by COVID 19
- It was about 74.6%, with PNG, Qatar and Russia recording 100% or more.



Global Liquefaction Capacities : Under construction
139.1 MTPA (Including FIDs in 2019 & 2020)

As per the World LNG Report by IGU, In 2019, a record FID for nearly 70.6 MTPA capacity was achieved

Final Investment Decision for LNG Capacities achieved in 2019				
Month	**Project**	**Country**	**Capacity (in MTPA)**	**Promoters**
Feb-19	Golden Pass	USA	15.6	Qatar Petroleum (70%) and ExxonMobil (30%)
Jun-19	Mozambique LNG	Mozambique	12.9	Total
Jun-19	Sabine Pass	USA	4.7	Cheniere
Aug-19	Calcasieu Pass	USA	10	Venture Global
Sep-19	Arctic LNG -2	Russia	19.8	Novatek
Dec-19	Nigeria LNG Train -6	Nigeria	7.6	Nigeria National Petroleum Corp., Shell & Total
Total Capacity			**70.6**	

- COVID 19 impacted the FIDs slated for 2020. Only the 3.25 MTPA Energia Costa Azul LNG in Baja California, Mexico achieved FID.
- In Feb 2021, Qatar achieved FID for 4 Trains totalling about 32 MTPA.
- The FID Capacities under construction / approved for construction as in Feb 2021 were about 139.1 MTPA, which is about 30% of the existing operational capacity
- About 8.37 bcfd (about 66 MTPA) capacity is under construction in the USA alone.
- With 69.1 MTPA of operational capacity, and is likely to emerge as the largest exporter of LNG by 2024/2025

LNG Liquefaction : USA

FERC approved Capacities Under construction : 21 April 2021

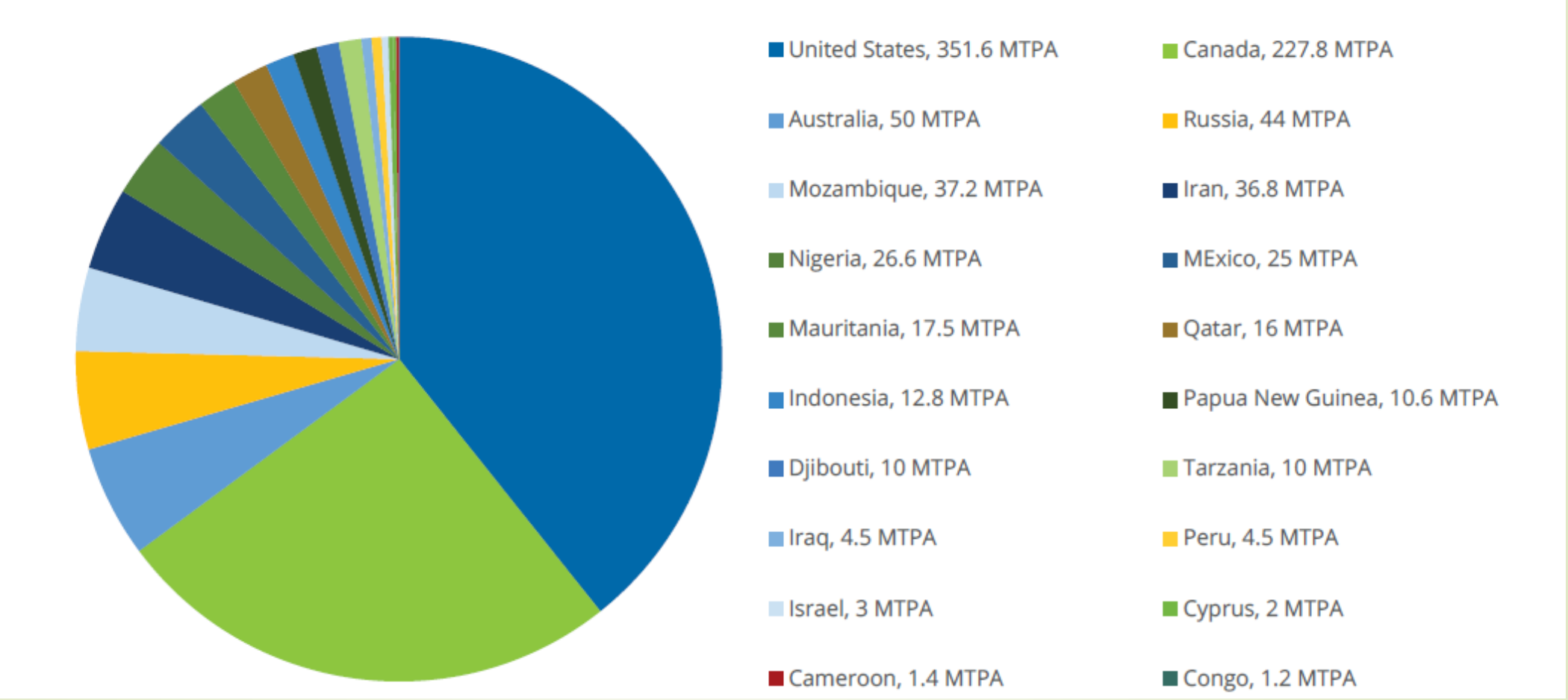
- About 8.37 BCFD (66 MTPA) of FERC Approved capacities are under construction as on 21st April 2021

FERC- Approved - Under Construction Capacity (April 2021)

Sl No	Project	Capacity (in Bcfd)	Description
1	Sabine Pass LA	0.7	Sabine Pass Liquefaction T-6
2	Cameron Parish LA	1.41	Venture Global Calcacieu Pass
3	Sabine Pass TX	2.26	ExxonMobil-Golden Pass Trains 1,2,3
4	Calcasieu Parish LA	4	Driftwood LNG
	Total	**8.37**	

LNG Liquefaction Capacities : Pre - FID

- As per Rystad Energy, nearly 892.4 MTPA, mostly in the North America (USA & Canada) are in the Pre-FID stage (Refer : IGU's 2021 World LNG Report)



LNG Liquefaction Capacities

Countries active in LNG Liquefaction capacity

- **USA : Out of about 352 MTPA of Pre-FID projects, 176 MTPA had obtained FERC approval (May 2020)**
- **Qatar :** In 2019, it discovered of 17.60 tcf in North Field, and plans to increase its capacity **to 126 MTPA by 2027**
- **Russia :** In 2018, Russia successfully commissioned Yamal LNG, thereby commercializing its stranded Arctic gas assets. Russia exported 29.3 MMT in 2019. The largest proposed LNG project, The 3-Train Arctic LNG-2 (Total 19.8 MTPA) achieved its FID in September 2019. Amongst its proposed LNG terminals are :
  - An additional 5.2 MTPA at Sakhalin-2.
  - Another Far East LNG terminal of 6.2 MTPA and
  - Another 10 MTPA at its Baltic Sea **.**
- **Indonesia** Construction of Train 3 at the Tangguh project (3.8 MTPA) is progressing well and is likely to get commissioned in 2021. The 9.5 MTPA Abadi LNG (Masela LNG) has been approved and is awaiting FID from its Japanese promoters, for incorporating CCS and Climate Change related technologies.
- **Mozambique.** It is likely to become one of the largest exporter of LNG. A capacity of 3.4 MTPA is under construction. The 12.9 MTPA capacity LNG plant in Area 1 (now being developed by Total) achieved its FID in Sep 2019. The Rovumma LNG, in the adjacent Area-4, (being developed by ExxonMobil with ENI), has received an Initial Investment Decision of 500 Mn USD. It was expected to achieve FID in 2020.
- **Papua New Guinea**. The FID for the three-train PNG Expansion is expected was late 2020 or in 2021. The country has a Pre-FID capacity of 12 MTPA.

LNG Liquefaction : USA

FERC Approved capacities, not under construction, as on 21st April 2021

- About 22.128 bcfd (about 176 MTPA) capacity approved by FERC is awaiting FID (as on 21.04.2021)

FERC- Approved - Not Under Construction Capacity (April 2021)

Sl No	Project	Capacity (in Bcfd)	Description
1	Lake Charles LA	2.2	Lake Charles LNG
2	Lake Charles LA	1.186	Magnolia LNG
3	Hackberry LA	1.41	Sempra- Cameron Train 4 & 5
4	Port Arthur TX	1.86	Port Arthur LNG Trains 1 & 2
5	Freeport TX	0.72	Freeport LNG Train 4
6	Pascogoula MS	1.5	Gulf LNG Liquefaction
7	Jacksonville FL	0.132	Eagle LNG
8	Plaquemines Parish LA	3.4	Venture Global LNG
9	Brownsville TX	0.55	Texas LNG
10	Brownsville TX	3.6	Rio Grande LNG
11	Corpus Christi TX	1.86	Cheniere Corpus Christi LNG
12	Sabine Pass LA		Sabine Pass Liquefaction
13	Coos Bay OR	1.08	Jordan Cove
14	Nikiski AK	2.63	Alaska Gasline
	Total	**22.128**	

LNG Shipping

What makes LNG Shipping a ‘niche’ business ?

Will LNG Shipping emerge out of its ‘niche’ position ?

Will the ownership costs attract marine shipping lines ?

Will it ‘mature’ to provide the much sought ‘liquidity’ ?

What are the emerging trends / issues ?

LNG Shipping

- Key characteristics
- Fleet capacity,
- Vessel's cost,
- Availability
- New orders

LNG Shipping : Key characteristics

- Transportation / shipment of LNG requires special vessels, with cryogenic containment capable of ensuring that the LNG remains as liquid and there is minimal 'boil-off' during the voyage.
- The manufacturing is more expensive as compared to the oil tankers. A very large oil tanker (VLCC) costs 90-100 Mn USD, while an LNG vessel (170-180,000 cubic metre) costs 180-230 Mn USD.
- Key characteristics of LNG Shipping are
  - **Customised Specifications:** For Long-term contract, the ports for loading / unloading, along with draft, voyage time etc are known in advance. The technical specifications for vessels are customised and are very specific.
  - **Limited Deployment:** The long-term trade between a seller and buyer leave little room for their deployment for laden / ballast voyage for other locations or any other commodity.
  - **Limited fleet** : The LNG trade volumes are several times less than crude with strict 'Take-or-pay' clause for about 90% of the contracted quantity. Global fleet size is limited, as per the LNG Liquefaction capacities

LNG - Containment Technology

Two designs were initially conceived for LNG containment. The **Moss Rosenberg (now Moss Kvaerner)** system started in 70s and consists of multiple spherical storage tanks, the top half exposed on the vessels and distinctly visible. The other popular design is 'Membrane' type design, developed by **Gaz Transport** and **Technigaz (now GTT)**, wherein the containment is covered by metal membranes packed with high quality thermal insulation in a sandwich construction.

Spherical Moss Containment

- No 'Sloshing' Issues
- Less Fuel efficient
- Less maneuverable

Membrane Containment

- 'Sloshing' issues
- Lower Fuel Consumption
- Better maneuverability

LNG Shipping : Key characteristics

- **Integral Part of the LNG Value Chain**
  - Following principles of 'cash flow waterfall', the investments risks in procuring LNG vessels are mitigated by ensuring returns from the revenue income. The investment risks are therefore included in the costs for the Buyers.
  - Its ownership rests with the stakeholders of a LNG project, i.e., producers or buyers (including end-users or portfolio players). This also explains why the LNG prices are 'Delivery Ex-Ship' (DES) or delivered basis. Owing to these factors, only niche marine lines maintained a minimal fleet for the 'spot' market trades.
  - These salient features limit nearly 85% of deployment of LNG vessels for long-term charters of upto 20 years and specifically serve the associated ports
  - Thus, the majority of LNG Vessels become an integral part of the LNG Value chain right from the FID stage of a Liquefaction facility.

- **Limited secondary market for sale-purchase** :
  - It had not been possible to establish the assessment of the 'residual value' of LNG vessels as very few vessels are available for second-hand trade.
  - This is unlike for normal oil tankers, which can be easily resold in the secondary markets. In absence of a standard valuation method, financial borrowing is constrained as bankers are unable to assess their 'residual value', which they do in case of normal oil tankers. Therefore, LNG vessel ownership remained with very few elite players having deep pockets.

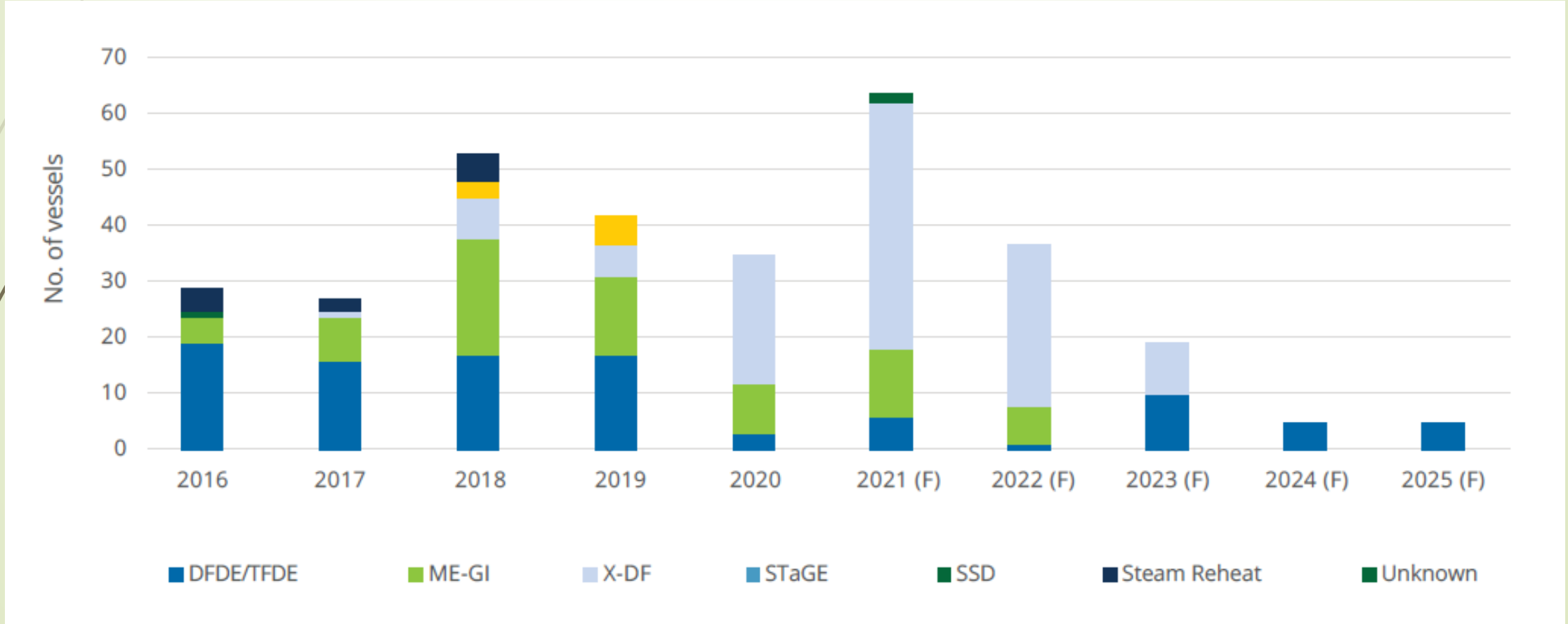
LNG Shipping : Propulsion Systems

- A number of propulsion systems are available and offered as an optional features to buyers
- Earlier LNG carriers used steam turbines as their propulsion system.
- From 2000 onwards, with increase in costs of bunker fuels, the need for propulsion efficiency catalysed development of new propulsion systems using Boil off gas (BOG) as well as HFO or Marine Diesel Oil (MDO).
- The most popular systems being ordered now are:
  - DFDE /TFDE (Dual or Triple Fuel Diesel Electric)
  - ME-GI (MAN designed-Electronically controlled, Gas Injection)
  - X-DF (Wartsila designed two-stroke slow speed dual-fuel engines)
- DFDE/TFDE are about 20% more fuel efficient than Steam Turbine driven propulsions.
- ME-GI & XDF are 15-20% more efficient than DFDE and gaining popularity in new orders.
- ME-GI (MAN B&W Type) are'Hi-pressure Slow speed' engines, which use BOG as well as Diesel
- The X-DF (Wartsila / Winterthur Gas & Diesel Type) are 'Low-pressure Slow-speed' engines that use BOG as well as Diesel. These are now less capital intensive and find favour with Charter lines.
- STaGE : Steam Turbine and Gas Engine. Use waste heat. More emissions friendly. Developed by Mitsubishi. No current orders.
- ABB Azipod ARC7 Icebreaker System for Arctic LNG Vessels : 360^{o} rotation is possible. 15 vessels.

LNG Shipping Propulsion systems

Source : IGU / Rystad Energy

- The recent trends in the orderbooks indicate that X-DF & ME-GI propulsion systems are gaining popularity.
- It indicates that shipowners are increasingly aligned towards efficiency and lower ownership costs.

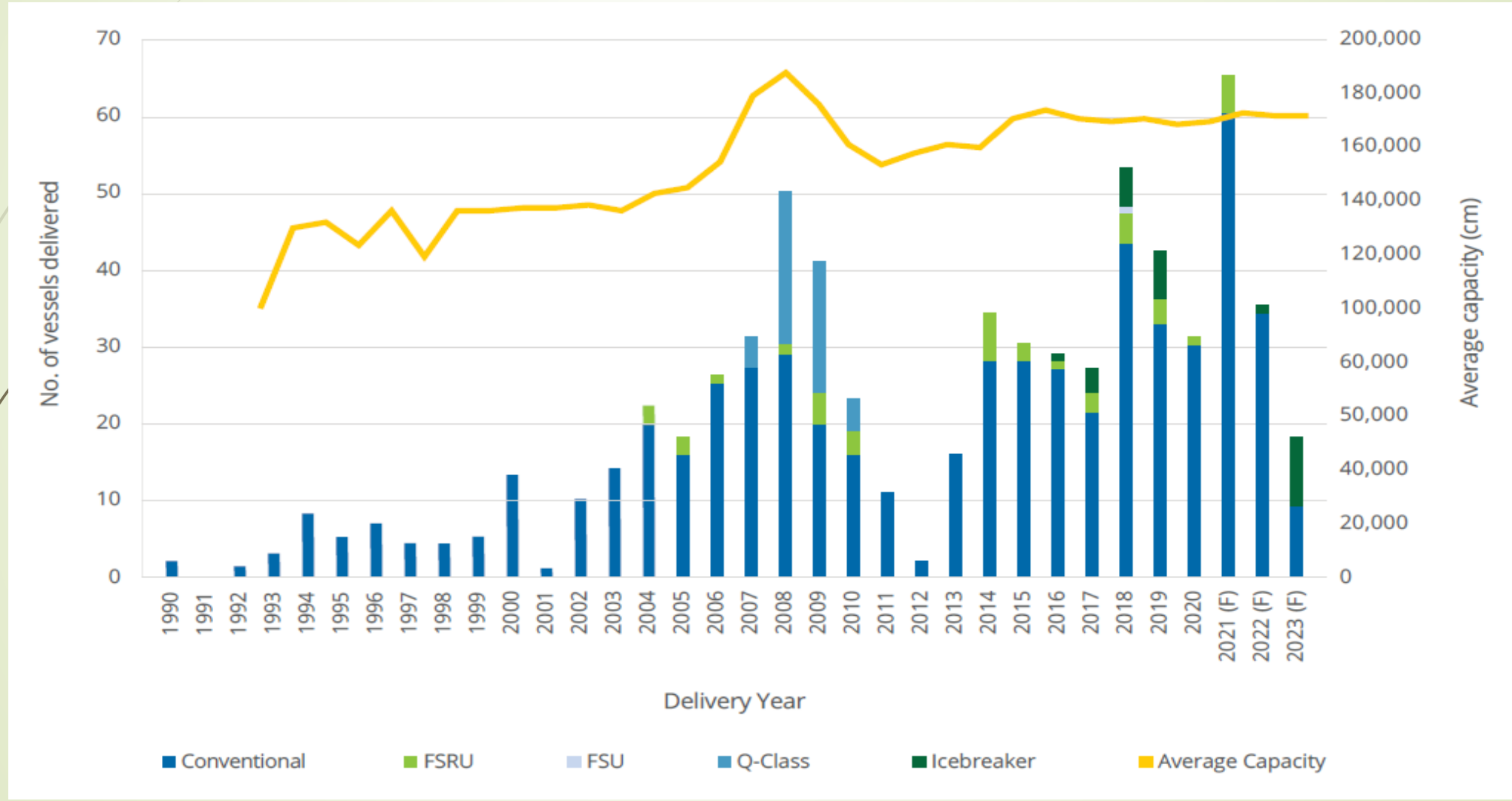


LNG Shipping : Overview of Fleet & Capacity

As per IGU

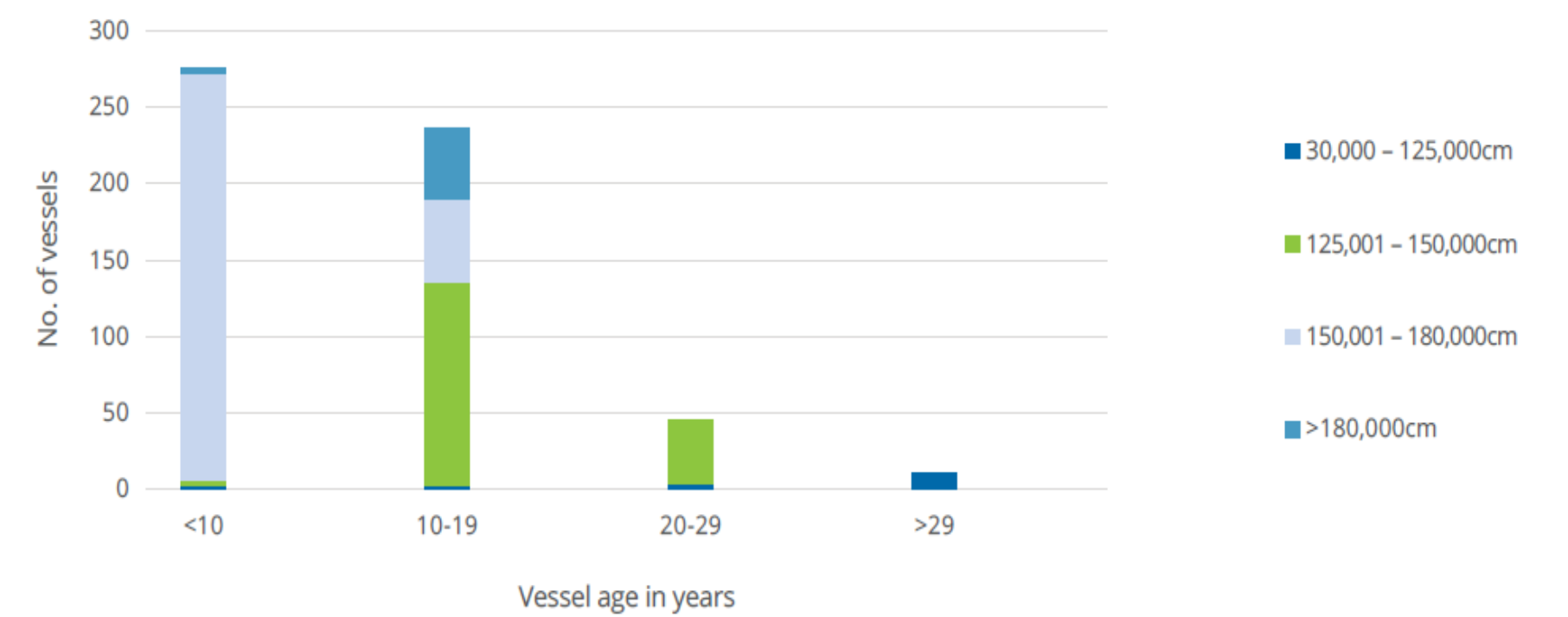
- The global LNG Fleet size is 572 , with 35 new vessels added in 2020
- The above includes 37 FSRU and 4 FSUs
- The average vessel capacity is now around 170,000 Cubic Metres
- The containment systems, whether Moss-type (Moss Kvaerner) or the Membrane-type (GTT) have improved over the years. Features have been added to make navigation and manoeuvrability safe and efficient. The patented technology have been licenced to many Shipyards, mainly in Korea, Japan and China.
- While new containment systems have been designed by Mitsubishi, Korea Gas and others, yet the buyers are more inclined to opt for reliable and safe GTT or Moss technology.
- In orderbooks for 2/3 of new build vessels, buyers have opted for XDF propulsion system
- Age of the fleet :Nearly half the fleet is less than 10 year old, ,augers well for a healthy availability in the mid to long-term

LNG Shipping : Fleet & Capacity



LNG Shipping : Age of the Fleet

- A key factor in availability of vessels is the age of vessels.
- Nearly half the fleet is less than 10 years old.
- The off-voyage period in dry docks is likely to be low.

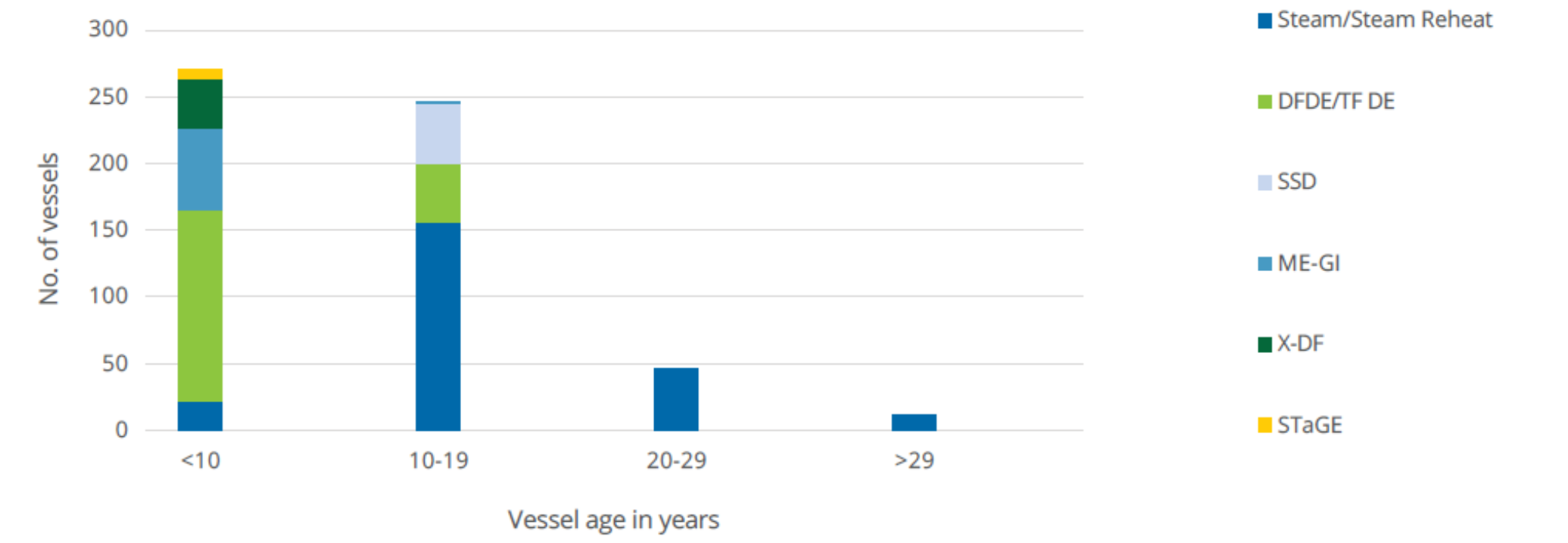


Source: Rystad Energy

LNG Shipping : Efficient Propulsion systems

Source : IGU / Rystad Energy

There is a larger share of the efficient propulsion systems in the fleet that is less than 10 years old.

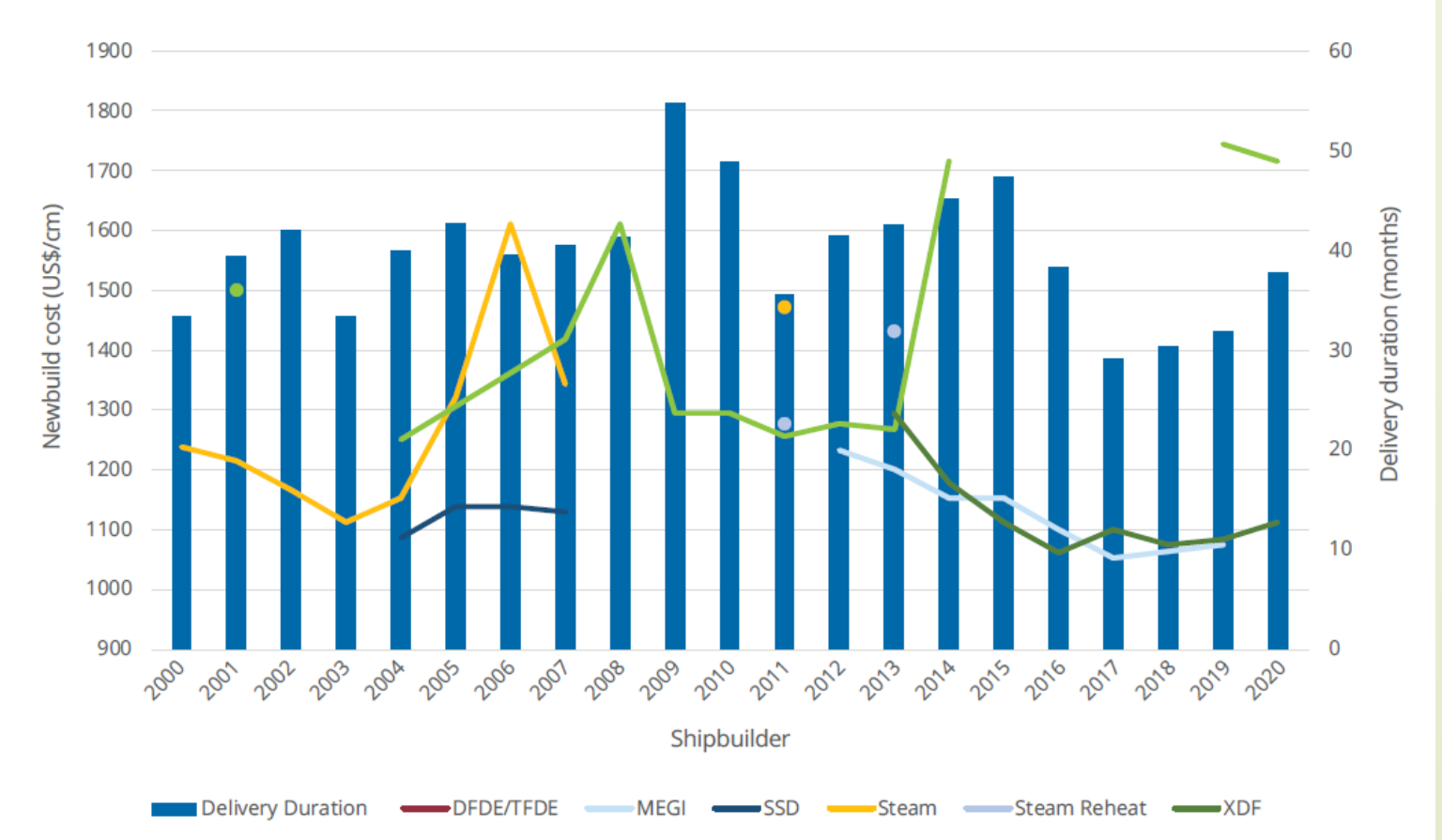


LNG Shipping : Vessel Costs & Delivery period

- Prior to 2014, vessel costs hovered between $1300 to 1700 per cm.
- The higher prices were for the ice-breaker LNG vessels for Yamal LNG.
- However, post 2014, the South Korean shipyards, bid aggressively to bring down the prices to well under $ 1100 per cm.
- With more orders for the Neo Panamax sizes (180,000 – 200,000 cm), the rates have stabilised to below $ 1100 per cm.
- The normal delivery schedule for an LNG vessel varies between 30 -50 months, depending upon the propulsion system. In case a shipping line orders a sister vessel, it can be delivered in just 24 months

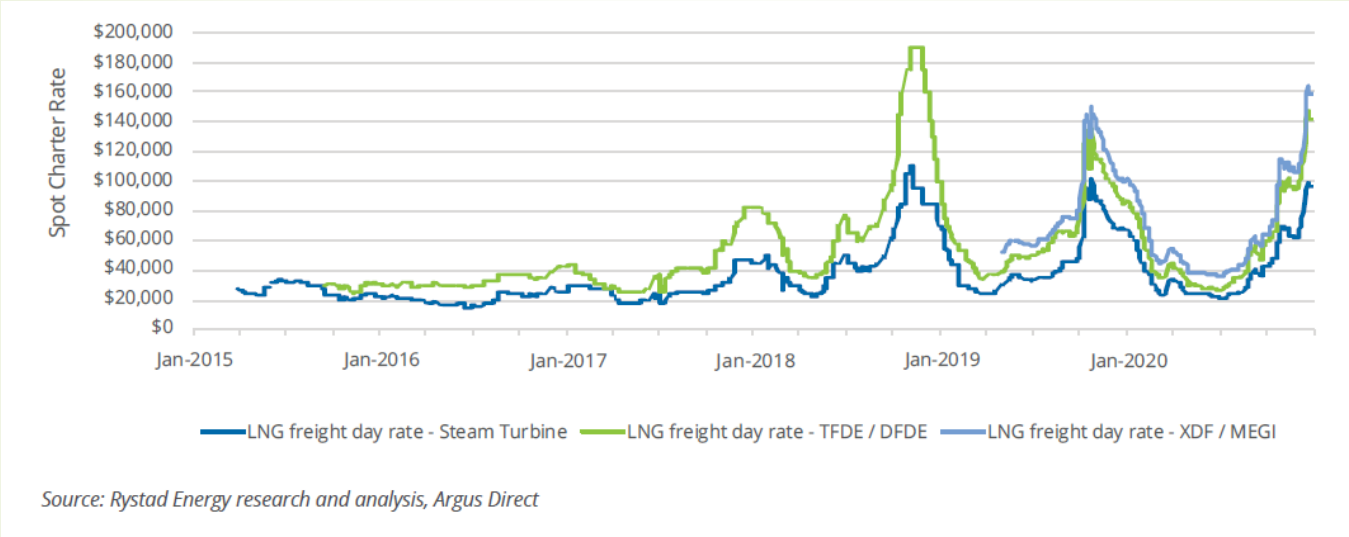
LNG Shipping : Vessel Costs & Delivery period

- As per IGU, prices for new build X-DF & ME-GI have stabled at around 1100 $/ cubic metre
- The Ice-breaker class vessels had high prices of about 1700 $/cm



LNG Shipping : Fleet Availability & Charter Rates

- As per IGU, the average Charter Rates in 2020 were 105,000, 150,000 and 165,000 $ for Steam, DF/TFDE and X-DF/ME-GI vessels respectively.



Source: Rystad Energy research and analysis, Argus Direct

- Volatility in charter rates is likely to ease out as markets get softer.
- About 64 vessels are due for delivery in 2020.
- Majority of the orderbook is for short-term / spot trade.

LNG Shipping : Fleet Utilization and Standardization

Fleet Utilization in voyages travelled

- Fleet utilization is measured in the number of voyages undertaken by the vessels.
- The voyages in 2020 were 5757, as compared to 5,701 & 5,119 voyages in 2019 & 2018 respectively.
- With the onset of exports from USA, the average voyages per tanker in 2018 had come down to 10.5 from 11 voyages/year in 2017. However, the LNG voyages to Europe increased disproportionately in 2019 due to the spurt in LNG exports.

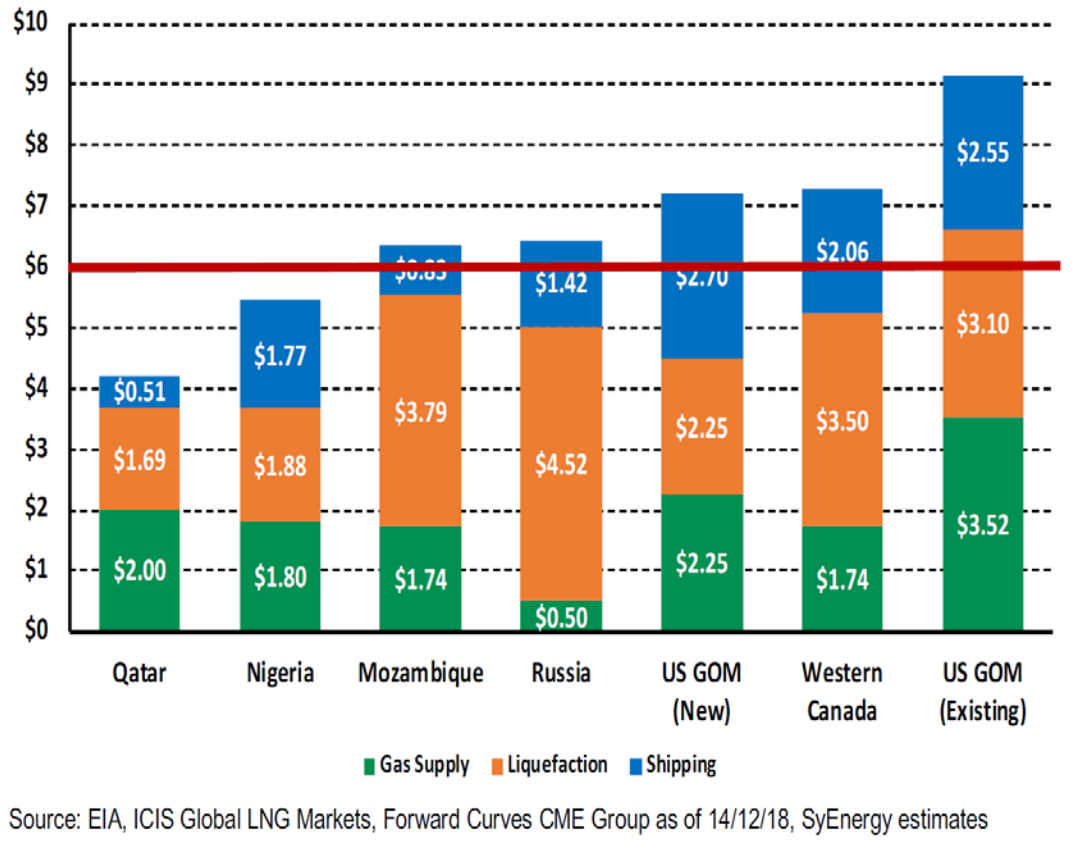
LNG Shipping : Emerging trends

- **Post - 2012, LNG shipping has witnessed a paradigm shift**
  - the long-term contracts saw changes favouring lower off-take quantities, mitigation for 'Take-or-pay', flexibility in off-take schedules, flexibility in the end-use destinations and provision for resale by the off-takers.
  - Accordingly, new orders of LNG vessels spell flexible manoeuvrability and acceptance at multiple ports.
  - Another visible trend vessels have been ordered without long-term charters, and it augers well for liquidity in 'Spot' charters.
- The number of Fleet owners (with active / ordered vessels) have swelled to well over 65 in numbers as in Feb 2021
- The average vessel capacity is now around 170,000 Cubic Metres, which can navigate through Suez and Panama
- The LNG Shipping is characterized by a limited numbers of loading ports and destinations. As of now, there are 34 active LNG load ports and 134 LNG Dischargs ports.
- With increase in the order for vessels for Short-term/Spot trades, there is a need for standardization of vessels, port control, cargo vetting and contracting terms so that the charter contract are understood in a fair manner.
- Shell has developed a contract, 'ShellLNGTime', which addresses these issues and facilitate fast contracting required for spot/short-term trade.

LNG Shipping : Emerging issues

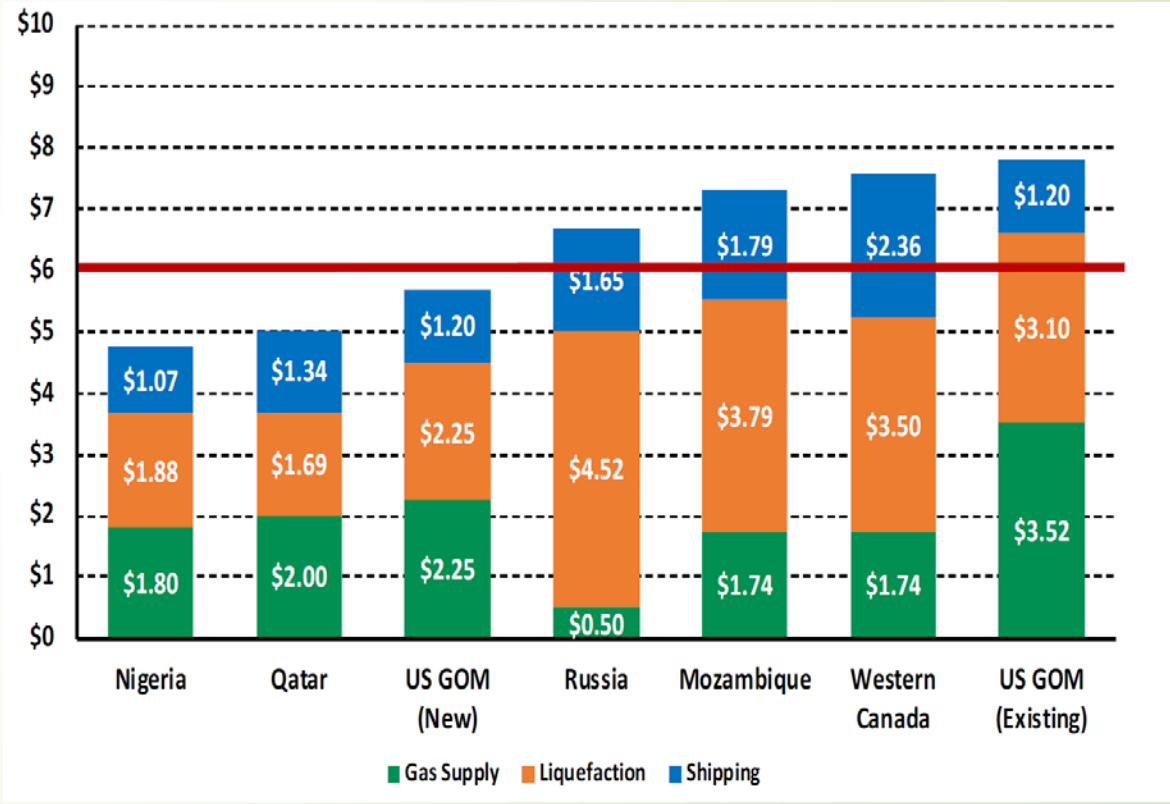
- IMO and its Marine Environment Protection Committee has been considering several measures and regulations to minimise the impact on environment. It is committed to reduce carbon dioxide, NOX and Sulphur emissions.
- In 2013, IMO introduced Energy Efficiency Design Index
- In 2020, a cap of maximum 0.5% of sulphur in Bunker Fuels was introduced
- New regulations include
  - Energy Efficiency Existing Ship Index (EEXI)
  - Carbon Intensity Index
- As the older vessels cannot be scrapped, there would be new measures which would alleviate the emission hazards.
- For new vessels, the compliance to the norms / regulations would become strict.

Key findings on affordability in regions of different income segments ($/mmbtu)



Low Income Markets : India-Pakistan-Bangladesh in 2025

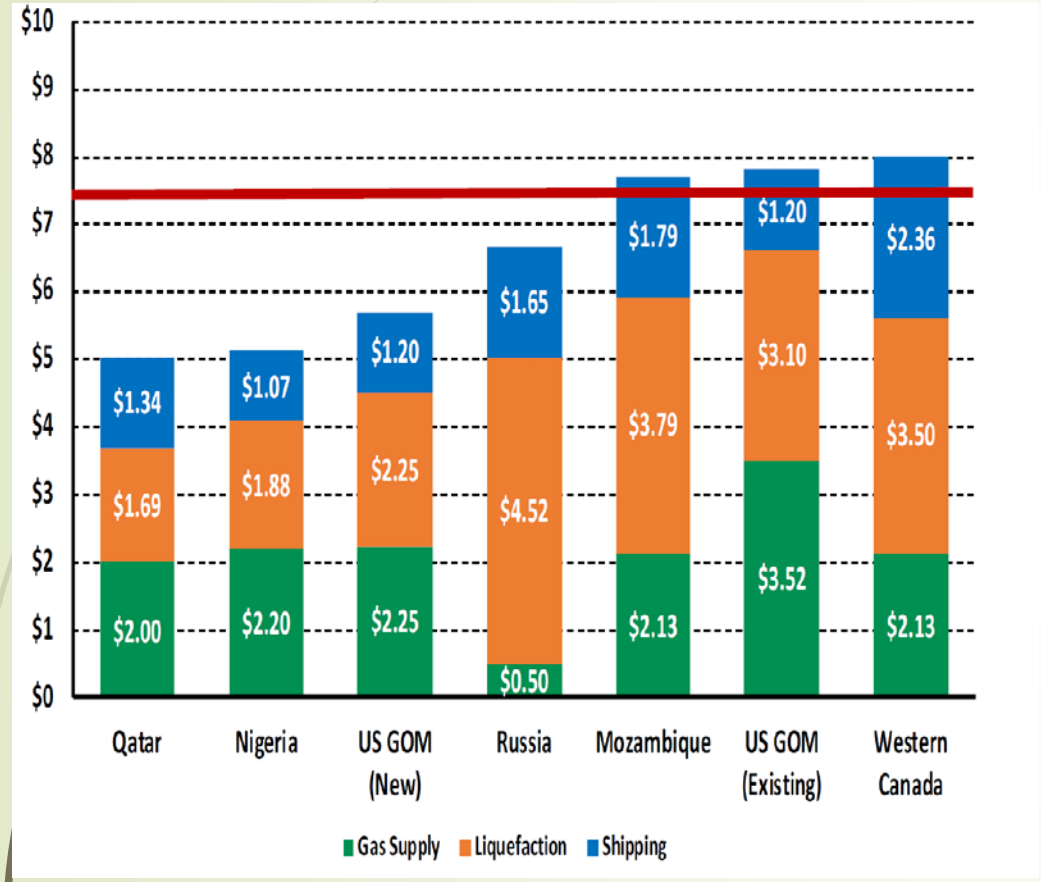
Source : OIES Paper NG 142



Low Income Market : North West Europe in 2025

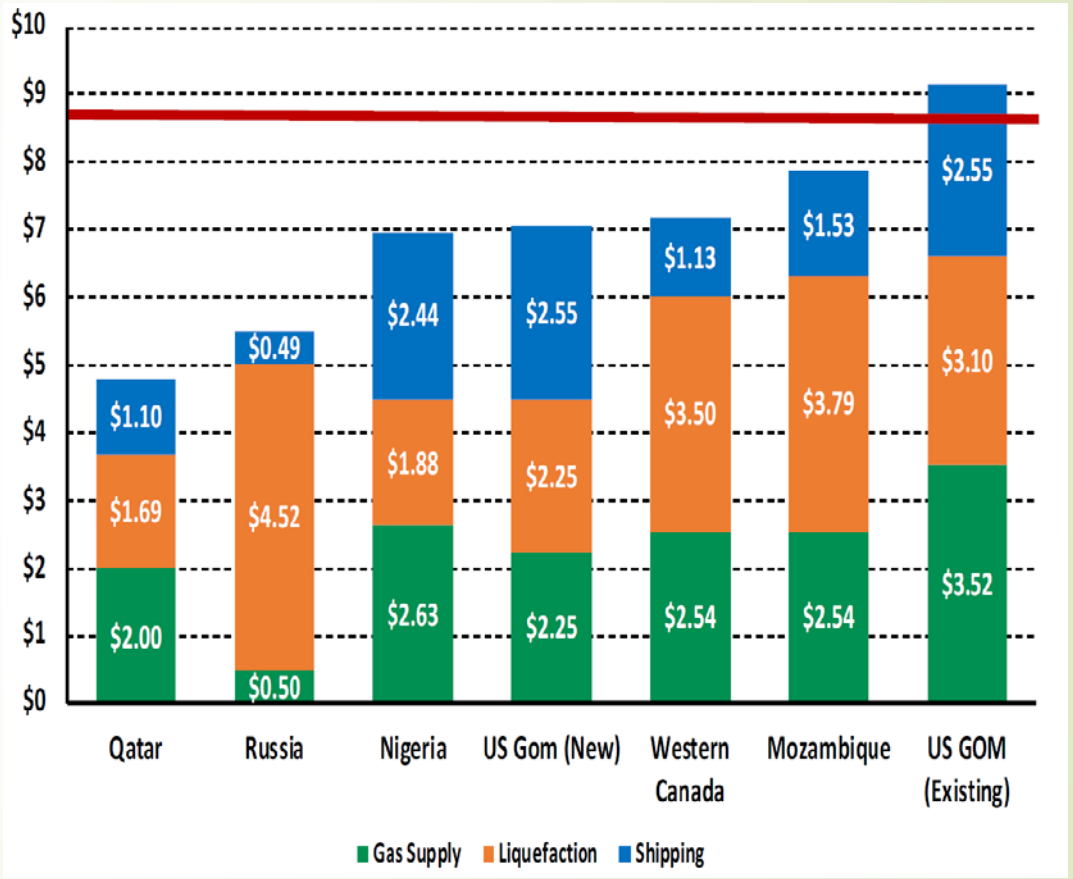
Source : OIES Paper NG 142

Key findings on affordability in regions of different income segments *($/mmbtu)*



High income North & West Europe in 2025

Source : OIES Paper NG 142



High Income Market (Japan Korea Taiwan China) in 2025

(Source : OIES)

Conclusion

- LNG Liquefaction capacity building has its complexities
- Its understanding helps in understanding the nature of trade and the contracts, pricing, shipping charges, terms & conditions etc
- The global LNG Liquefaction capacities, along with shipping, are growing at a decent rate , with a fair assurance of long-term availability
- There have been cost reductions in developing Liquefaction and Shipping

Thank you

LNG Liquefaction : Financing, EPC and Financial Investment Decision (FID)

- In view of the capital intensive nature, it is apparent that a detailed analysis of risks, its mitigation measures are carried out
- A business model with a healthy IRR is developed before the ‘Final Investment Decision’ (FID) is arrived upon.
- The project cycle can be divided between Pre-FID & Post-FID activities.

Gas Pipelines and their impact on LNG

It is imperative that in any market that imports gas, Transnational Pipelines compete with LNG. In this context, the following Trans-national pipeline projects are expected to significantly contribute to gas exports and are likely to affect future LNG trade for Europe and China.

- **Nord Stream II (Russia – Germany, 1222 kms)**
- **Nord Stream I** is the existing longest sub-sea twin pipeline of 48 inches connecting Russian gas fields to mainland Europe, from Vyborg, Russia to Greifswald, Germany. The capacity of Nord Stream I twin pipelines is about 55 bcm (approx 150 mmcmd) and became operational from Nov 2011 & Oct 2012 respectively.
- **Nord Stream II (Ust-Luga to Greifswald) also has 48-inch twin pipelines. The project started in 2018-19.**
  - The project cost was estimated at about 14.8 Bn Euros (6 Bn Euros for On-shore pipelines and 8.8 Bn Euros for Off-shore pipelines).
  - Target completion was middle of 2020. Gazprom holds 51% equity and the rest is with Uniper (Germany), Engie (France), Gasunie (Dutch gas company) & others. Gazprom has financed 50% of the cost and the rest is as loans from Banks/FIs/Project Stakeholders.
  - However, with only laying of the last 150-200 kms of pipeline remaining, the US has imposed sanctions in Dec 2019, aimed to marginalize the increased dominance of Russia over European gas supplies. Both, Russia & Germany have strongly criticised the sanctions. The EU is divided and a sizeable lobby supports completion of this project as many of the contracting agencies are from Europe. Ukraine, Poland and some Central & Eastern European countries support the sanctions.
  - **Russia deployed its own resources including its own special Vessel (earlier deployed on the Pacific coast in East Russia) for laying sub-sea pipelines. The testing has commenced. The completion is likely to get delayed till 2022.**
  - **Once completed, the gas supplies will ease European demand for LNG by about 30-40 MTPA.**

Gas Pipelines and their impact on LNG

- **TANAP (1841 kms) (Trans-Anatolian Natural Gas Pipeline)**
  - This pipeline supplies gas from Azerbaijan to Turkey and Europe. The pipeline was commissioned on 30th Nov 2019. The existing through-put is about 16 BCM (or 44 MCMD, 28 for Europe and 16 for Turkey).
  - Backed up by future supplies from Turkmenistan, **the pipeline shall be scaled upto 23 BCM by 2023, 31 BCM by 2026 and 60 BCM by 2030.**
  - This is likely to ease the gas supplies for Turkey, Greece, Albania and Italy, and reduce their dependence on gas imports from Russia and LNG

- **TurkStream (930 kms, set of two 32 inch pipelines, Final capacity 31.5 bcma)**
  - It is a **twin 32-inch pipeline** project for supplies from Russia across the Black sea in two legs, one for Turkey, and the second one for Bulgaria, Serbia, Hungary, Slovakia & Austria.
  - It can carry about **44 MMCMD in each stream**. This pipeline also faced US Sanctions imposed in Dec 2019 under PEEPSA. However, the first part of the pipeline upto Turkey has been commissioned in Jan 2020. The gas flows on from Turkey to Bulgaria and from there to Romania, Ukraine, Greece and North Macedonia via the Trans-balkan Pipeline.
  - The completion of the second part shall further ease in meeting the energy requirements for the receiving nations and help Russia to monetise its gas assets, besides in leveraging economic clout in the region.

Gas Pipelines and their impact on LNG

- **Iran – Pakistan /Iran - Pakistan – India**
- **Turkmenistan – Afghanistan - Pakistan – India**

Accessibility: TAPI Pipeline project

Countries with Proven Gas Reserves / LNG Capacities

Sl No	Country	Proven Reserves	Production in 2018	
		Trillion Cubic Metres (TCM)	Billion Cubic Metres (BCM)	LNG Export (in MTPA)
1	Russia	38.9	670	19
2	Iran	31.9	240	
3	Qatar	24.7	175	79
4	Turkmenistan	19.5	61	
5	USA	11.9	831	23
6	Venezuela	6.3	33	
7	China	6.1	161	
8	S Arabia	5.9	112	
10	UAE	5.9	64	6
11	Nigeria	5.3	49	21
12	Algeria	4.3	92	10
13	Iraq	3.6	13	
14	Indonesia	2.8	73	15
15	Australia	2.4	130	69
16	Malaysia	2.3	72	24
17	Europe (Excl Norway & CIS	2.3	130	
18	Egypt	2.1	58	2
19	Azerbaijan	2.1	18	
20	Kazakhstan	2.1	24	
21	Canada	1.9	184	
22	Kuwait	1.7	17	
23	Norway	1.6	120	5
24	India	1.3	27	
25	Oman	0.7	36	10.5
26	Peru	0.4	13	4
27	Trinidad & Tobago	0.3	34	12.5
28	Papua New Guinea	0.2	5	7
29	Cameroon	0.1	5	1
30	Eq Guinea	0.1	6	4
31	Yemen	0.1	3	Refer Footnotes
32	Angola	0.1	6	4
World		**196.5**	**3867**	**316**

(Source: BP Statistical Review, IGU, Others)

Notes:

1. Countries exporting LNG or with reserves of more than 1 TCM have been conciderd.
2. Yemen's LNG capacity of 6.7 MTPA is shutdown since 2015 due to local security concerns.
3. Actual reserves may be more.
4. Production of LNG.