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LNG SHIPPING - A HISTORICAL PERSPECTIVE AND CHALLENGES AHEAD

Khurrum Mirza, Executive Director, Pakistan National Shipping Corporation
31st January 2019

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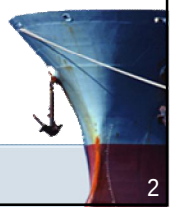
LNG'S HISTORY



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A BREIF HISTORY OF LNG

1873	German engineer, Carl von Linde pioneered the work in compressed refrigeration
1908	Dutch physicist Heike Kamerlingh Onnes was the first to liquefy helium, chilling helium through a series of stages until getting it to minus 452 degrees
1924	This research led the U.S. Bureau of Mines to produce the first liquid methane as a by-product of helium separation.
1917	The first commercial natural gas liquefaction plant was built in West Virginia
1960	The world's first LNG tanker, the Methane Pioneer, safely carries LNG from Lake Charles, Louisiana, USA to Canvey Island, United Kingdom
1964	The British Gas Council begins importing LNG from Algeria, making the United Kingdom the world's first LNG importer and Algeria as its first exporter

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METHANE PRINCESS

- **Methane Princess, was the first purpose built LNG carrier that carried the first commercial load of LNG, from Algeria to United Kingdom.**
- **The ship was fitted with Conch independent aluminum cargo tanks and had a capacity of 27,000 cu.m.**
- **The Methane Princess could carry up to about 500 million cubic feet of gas (after regasification). The average LNG tanker today is five times larger.**
- **It was operated for British Methane Ltd by Shell Tankers UK. The Methane Princess remained in service until 1997.**

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LNG: MAJOR ACCIDENTS & MALFUNCTIONS

Date	Location	Description
1944	Cleveland, Ohio, USA	At the Peak Shaving plant a tank failed and spilled its contents into the street and storm sewer system. The resulting explosion and fire killed 128 people. The tank was built with a steel alloy that had low nickel content, which made the alloy brittle when exposed to the extreme cold of LNG.
1964	Arzew, Algeria	During loading operations, lightning struck the forward vent riser of the Methane Progress and ignited vapor which was being routinely vented through the ship venting system. The flame was quickly extinguished by purging with nitrogen through a connection to the riser.
1965	Jules Verne Spill, Arzew, Algeria	LNG liquid spill caused by overflowing of a cargo tank that resulted in the fracture of the cover plating of the tank and adjacent deck plating.

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LNG: MAJOR ACCIDENTS & MALFUNCTIONS

Date	Location	Description
1971	La Spezia, Italy	This accident was caused by “rollover” where two layers of LNG with different densities and heat content form. The sudden mixing of these two layers results in the release of large volumes of vapor. In this case, about 2,000 tons of LNG vapor discharged from the tank safety valves and vents over a period of a few hours, damaging the roof of the tank.
1978	Das Island, UAE	An accident occurred due to the failure of a bottom pipe connection of an LNG tank. The tank had a double wall (a 9% nickel steel inner wall and a carbon steel outer wall). Vapor from the outer shell of the tank formed a large heavier than air cloud which did not ignite.

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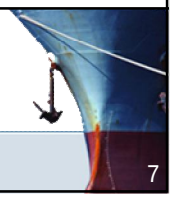
LNG: MAJOR ACCIDENTS & MALFUNCTIONS

Date	Location	Description
1983	Bontang, Indonesia	A rupture in an LNG plant occurred as a result of over pressurization of the heat exchanger caused by a closed valve on a blowdown line. The exchanger was designed to operate at 25.5 psig. When the gas pressure reached 500 psig, the exchanger failed and the explosion occurred.
2004	Skikda, Algeria	A steam boiler that was part of an LNG production plant exploded, triggering a second, more massive Vapor cloud explosion and fire. The explosions and fire destroyed a portion of the LNG plant and caused 27 deaths, 74 injuries, and material damage outside the plant's boundaries.



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LNG VESSELS

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LNG ENGINES

- LNG vessels are powered through LNG boil off.
- Therein, the small percentage of LNG which re-gasifies, while being transported, is siphoned off and used as a fuel to power the vessel.
- This maintains the required pressure in the tanks and eliminates the need to carry fuel separately.
- Boil-off minimization and cargo maximization is a key element in controlling costs and maximizing revenues.
- The LNG vessel market is increasingly fragmented as charterers prefer newer vessels with better boil-off management.

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LNG ENGINES

- Due to technological advancements, Boil-off in order to power a ship, has reduced from 0.25% to 0.08% with the latest ships. At that rate a speed of 15 knots can be easily maintained.
- Steam turbine engines which were traditionally the main method of LNG carrier propulsion, using a combination of regular marine fuel and LNG boil off gas.
- Owners now favor more efficient alternatives such as dual fuel, diesel electric engines, which can use LNG boil-off technology as well as HFO and marine diesel and have improved efficiency up to 15% compared to steam turbine engines.

Source: ABS Panel Future of LNG at Posidonia

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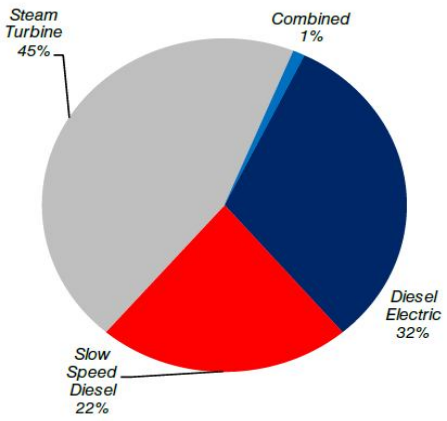
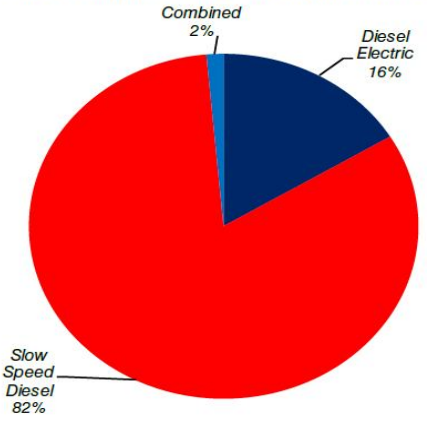
LNG ENGINES

LNG Carrier Fleet Engine Types



As at start June 2019. Data in terms of vessel numbers.

LNG Carrier Orderbook Engine Types



As at start June 2019. Data in terms of vessel numbers.

Source: Clarksons

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LNG ENGINES

- **Another factor of vital importance, particularly from an environmental perspective is methane slip.**
- **Emissions such as methane slip are not inherent to the natural gas instead the problem lies at the applied heat cycle, making the amount of methane slip dependent on technology of each engine.**
- **LNG powered engines run in either high or low pressure with both cycles having different combustion processes.**
- **Generally high pressure engines running in combination with diesel ensure that no methane escapes unburned.**
- **However it should be noted that the safety impact of high pressure engines as they age is debatable.**

Source: Safety for Sea

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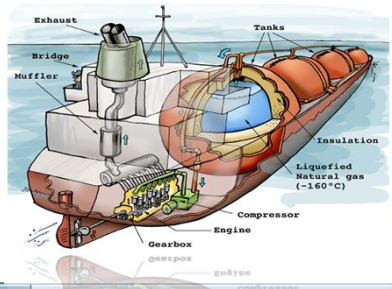
LNG VESSELS CONTAINMENT SYSTEMS

- There are two primary containment systems in place.
- Moss tanks, the IMO type B LNG tanks are spherical in shape.
- Most Moss type vessels have 4 or 5 tanks.



Source: Moss Maritime

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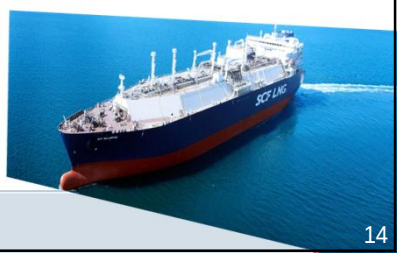
LNG VESSELS CONTAINMENT SYSTEMS

- Membrane containment systems are based on a very thin primary barrier which is supported through insulation and the inner hull forms the load bearing structure.
- There are two principal types of membrane systems in common use. TGZ designed by Technigaz. GT96 designed by Gaz Transport.
- These two companies have now combined into one, i.e. Gaz Transport & Technigaz (GTT).



Source: GTT

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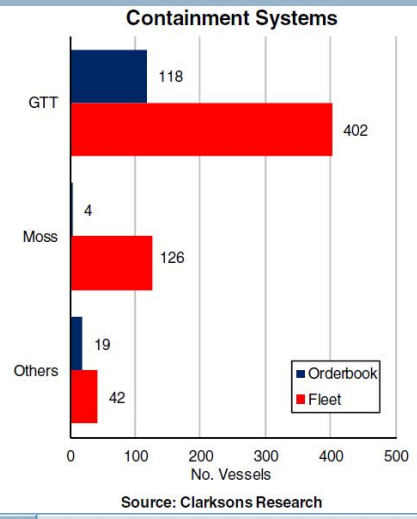
LNG VESSELS CONTAINMENT SYSTEMS



Source: Clarksons Research

Source: Clarksons

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LNG SHIPPING

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LNG SHIPPING

Distribution of LNG Carrier Ownership

Rank	Company Name	Fleet		Orderbook		Total	
		No.	Cap m³	No.	Cap m³	No.	Cap m³
1	Qatar Gas (Nakilat)	29	6,928,504			29	6,928,504
2	Mitsui OSK Lines	29	4,528,238	12	1,741,007	41	6,269,245
3	Maran Gas Maritime	20	3,385,423	13	2,258,400	33	5,643,823
4	Nippon Yusen Kaisha	26	3,852,066	9	1,566,000	35	5,418,066
5	Teekay LNG Partners	33	5,130,736			33	5,130,736
6	BW Gas	20	3,103,995	5	868,200	25	3,972,195
7	MISC	31	3,913,833			31	3,913,833
8	GasLog	11	1,769,000	8	1,416,000	19	3,185,000
9	Cardiff Marine	5	789,396	11	1,914,000	16	2,703,396
10	GasLog Partners	15	2,367,059			15	2,367,059
11	K-Line	15	2,295,529			15	2,295,529
12	Dynagas LNG	12	1,939,387	2	348,000	14	2,287,387
13	FLEX LNG	4	694,901	9	1,563,000	13	2,257,901
14	Knutsen OAS Shipping	11	1,600,360	4	570,000	15	2,170,360
15	Sovcomflot JSC	9	1,436,572	4	694,600	13	2,131,172
16	Bonny Gas Transport	13	2,030,874			13	2,030,874
17	Sinokor Merchant	15	1,945,014			15	1,945,014
18	Golar LNG	12	1,894,856			12	1,894,856
19	Nakilat, JC	8	1,697,968			8	1,697,968
20	BP Shipping	10	1,661,893			10	1,661,893
21	SK Shipping	8	1,208,309	1	180,000	9	1,388,309
22	Maran Nakilat	9	1,371,262			9	1,371,262
23	Hoegh LNG	7	1,145,158	1	170,000	8	1,315,158
24	Hyundai LNG Shipping	9	1,287,882			9	1,287,882
25	National Gas Shpg.	8	1,094,046			8	1,094,046
26	Golar LNG Partners	7	1,066,446			7	1,066,446
27	China Energy Shpg	6	1,045,938			6	1,045,938
28	Capital Gas			6	1,044,000	6	1,044,000
29	Oman Shipping Co	7	1,043,404			7	1,043,404
30	Schulte Group	6	1,021,934			6	1,021,934
31	Malt LNG	6	993,708			6	993,708
32	Chevron Transport	6	960,000			6	960,000
33	Korea Line	6	919,488	2	15,000	8	934,488
34	CLNG	6	883,076			6	883,076
35	Teekay Corp CLNG JV	3	517,956	2	345,304	5	863,260
36	Thenamaris	3	481,724	2	348,000	5	829,724
37	Tokyo LNG Tanker Co	5	773,222			5	773,222
38	Aust. LNG Ship Optg.	6	765,330			6	765,330
39	Excelerate Energy	5	764,220			5	764,220
40	STASCO (Shell)	5	760,338			5	760,338
41	Celsius Tankers			4	720,000	4	720,000
42	Exmar	5	715,834			5	715,834
43	Alpha Gas			4	693,600	4	693,600
44	Elcano	4	669,490			4	669,490
45	MiNT LNG	4	641,104			4	641,104
46	India LNG Transport	4	600,375			4	600,375
47	Brunei Gas Carriers	4	593,740			4	593,740
48	Nimic Ship Mgmt	4	589,774			4	589,774
49	TEPCO	4	568,946			4	568,946
50	H-Line Shipping	4	545,347			4	545,347

Table shows top 50 LNG carrier owners only. Owners ranked by combined fleet and orderbook capacity as at start June 2019.

Source: Clarksons

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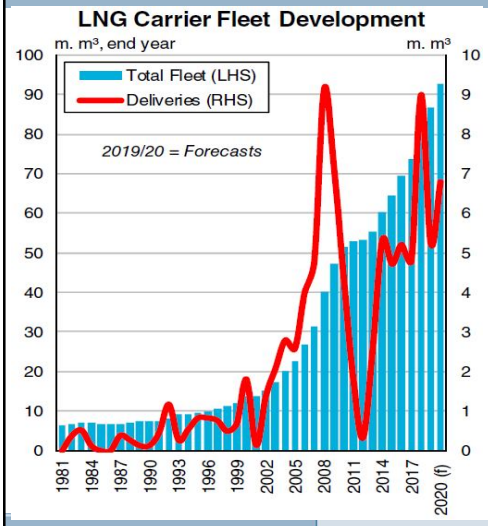
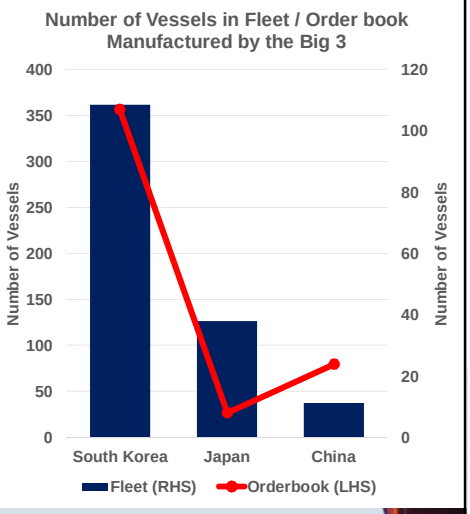
LNG FLEET DEVELOPMENT





Source: Clarksons

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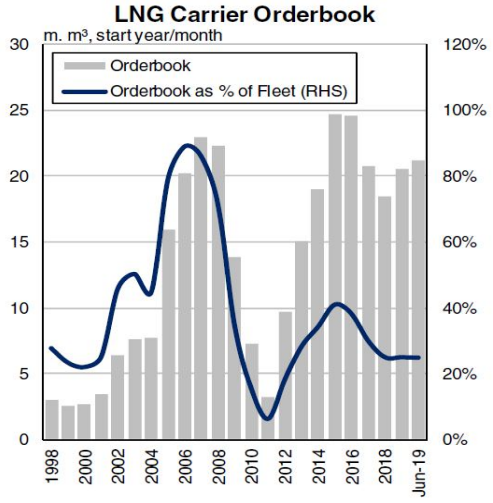
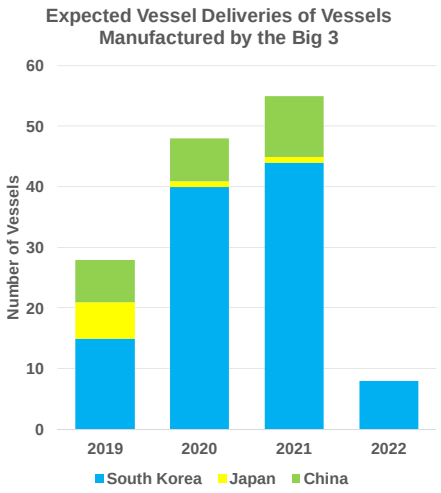
LNG FLEET ORDERBOOK





Source: Clarksons

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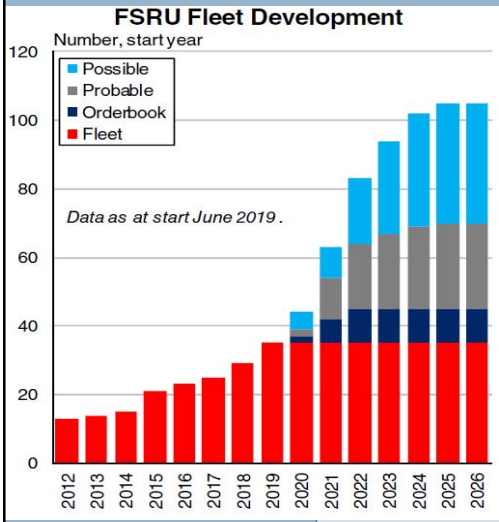
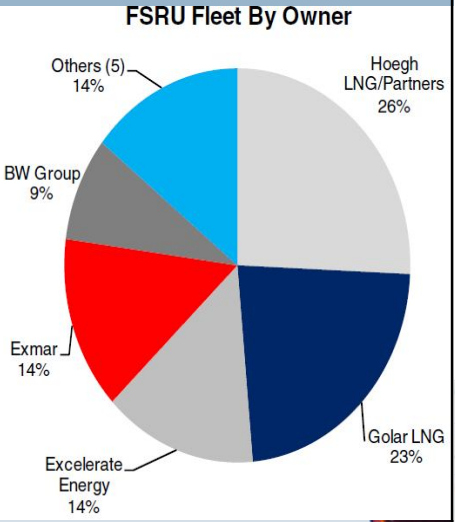
FSRU FLEET DEVELOPMENT





Source: Clarksons

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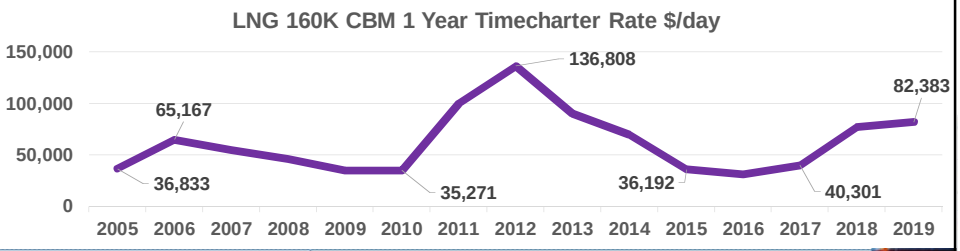
LNG SPOT MARKET TRADE

- Previously, LNG carriers were only acquired against specific projects. Due to recent developments in the global economy, a spot market has been created, in the mid-2010s, because of excess LNG production in combination with LNG carriers completing contractual commitments.
- As per experts, ship owners' returns are maximized when they have a long term contract in place, for a specific project. Chartering (in spot market) through tenders reduces the return for ship owners.



Source: Clarksons

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SHIP BUILDING

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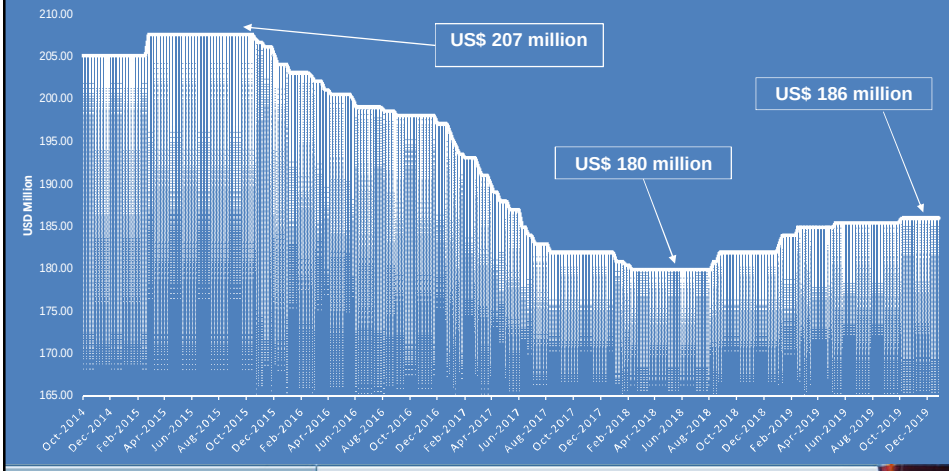
SHIP BUILDING

LNG CARRIER 174K CBM NEWBUILDING PRICES



Source: Clarksons

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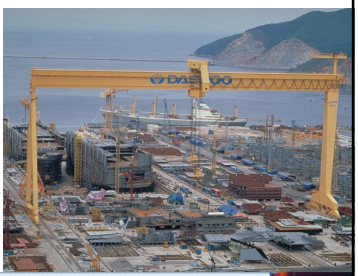
SHIP BUILDING

- Not many shipyards are capable of building LNG carriers. In China only Hudong has the capability, which is fully booked. Japanese are catering mostly to domestic clients and their capacity is low.
- The big three Korean shipbuilders (Hyundai, Samsung and Daewoo) have had their capacity reduced due to financial losses.



Source: ABS Panel Future of LNG at Posidonia

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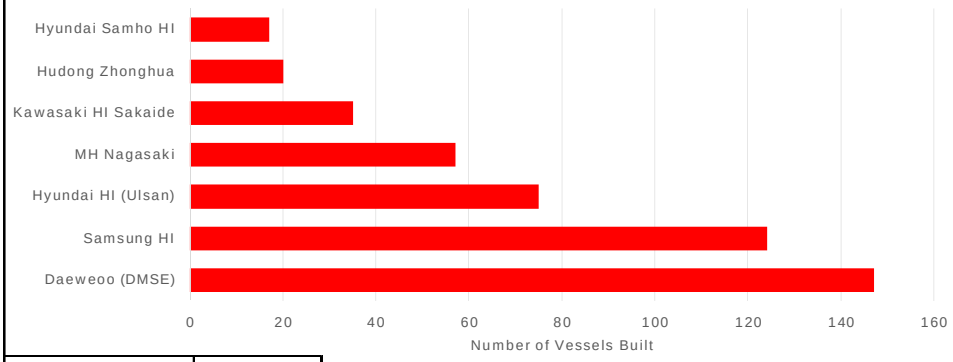
SHIP BUILDING



Builder	Number of Vessels Built
Daeweoo (DMSE)	147
Samsung HI	124
Hyundai HI (Ulsan)	75
MH Nagasaki	57
Kawasaki HI Sakaide	35
Hudong Zhonghua	20
Hyundai Samho HI	17

Source: Clarksons

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SECONDHAND MARKET

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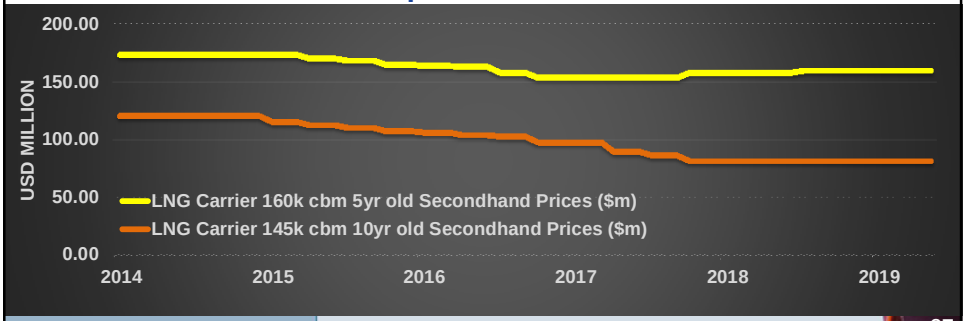
SECONDHAND MARKET

- Currently a stable secondhand market for LNG vessels does not exist.
- Only nine secondhand LNG carriers were sold in 2019.
- As the spot markets grows we may see a healthy secondhand sale and purchase market.



Source: Clarksons

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RECENT TRANSACTIONS

Name	Built	Size	Unit	Dwt	Builder	Sold	Currency	Price	Sellers	Buyers
Flex Endeavour*	2018	173,400	cu.m.	95,802	Daewoo (DSME)	2019-Apr-29	USD	420.00	FLEX LNG	Clients of Hyundai Glovis
Flex Enterprise*	2018	173,400	cu.m.	95,802	Daewoo (DSME)	2019-Apr-29			FLEX LNG	Clients of Hyundai Glovis
Flex Freedom*	2020	173,400	cu.m.	95,000	Daewoo (DSME)	2018-Oct-24	USD	186.00	Seatankers Mgmt	Clients of Flex LNG
Flex Reliance*	2020	173,400	cu.m.	90,000	Daewoo (DSME)	2018-Oct-24	USD	186.00	Seatankers Mgmt	Clients of Flex LNG
Flex Resolute*	2020	173,400	cu.m.	90,000	Daewoo (DSME)	2018-Oct-24	USD	186.00	Seatankers Mgmt	Clients of Flex LNG
Flex Vigilant*	2021	174,000	cu.m.	96,000	Hyundai Samho HI	2018-Oct-24	USD	180.00	Seatankers Mgmt	Clients of Flex LNG
Flex Volunteer*	2021	174,000	cu.m.	96,000	Hyundai Samho HI	2018-Oct-24	USD	180.00	Seatankers Mgmt	Clients of Flex LNG
British Innovator*	2003	138,287	cu.m.	75,074	Samsung HI	2018-Mar-16	USD	40.00	Lloyds Ind. Leasing	Clients of Sinokor
British Merchant*	2003	138,283	cu.m.	75,059	Samsung HI	2018-Mar-16	USD	40.00	Lloyds Ind. Leasing	Clients of Sinokor
Echigo Maru	1983	125,568	cu.m.	67,219	MHI Nagasaki	2017-Dec-05	USD	15.00	Nippon Yusen Kaisha	Clients of Sinokor
Excel	2003	138,107	cu.m.	77,773	Drydocks World Dubai	2017-Oct-09	USD	46.00	Exmar	Undisclosed interests
Solaris	2014	155,000	cu.m.	81,853	Samsung HI	2017-Sep-27	USD	185.90	GasLog	Clients of GasLog Partners

Source: Clarksons

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LNG TRADE

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LNG TRADE

- Since 2000, LNG trade has grown approximately 6.7% annually.
- In 2018, 316.5 MT of LNG was imported worldwide, with a 8.3% growth vs 2017.
- 99.3 MT was imported on a spot or short-term basis.
- 76% of global LNG demand is located in Asia.
- 32% of global LNG is imported on a spot or short-term basis.

Increased by **28.2MT**

Setting a new annual record of **316.5MT**

5th consecutive year of incremental growth

3rd largest annual increase ever (behind only 2010 and 2017)

Sources: Shell / Bloomberg / GIIGNL Annual Report 2019 / IGU Annual Report 2019

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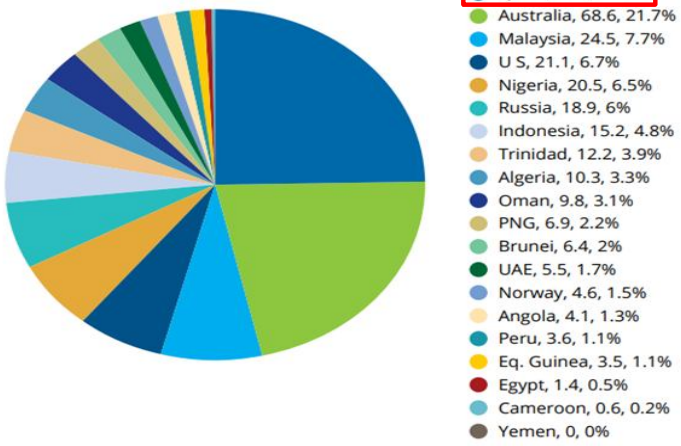
LNG EXPORTS

2018 LNG Exports and Market Share by Market (in MT)



Sources: IHS Markit, IGU

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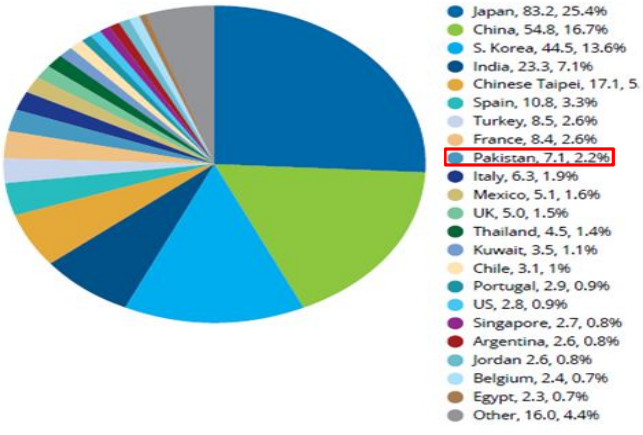
LNG IMPORTS

2018 LNG Imports and Market Share by Market (in MT)



Sources: IHS Markit, IGU

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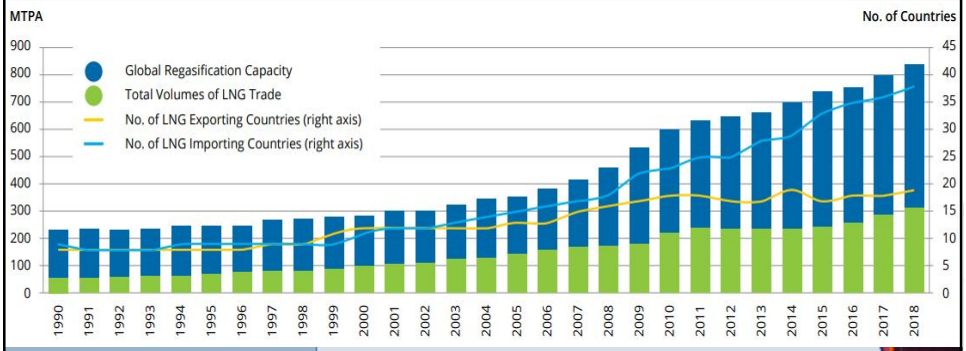
LNG TRADE

Year	Number of Importing Countries	Number of Exporting Countries
2000	10	12
2019	37	19



Sources: International Gas Union Annual Report 2019

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CHALLENGES AHEAD

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CHALLENGES AHEAD

- Limiting gas boil off whilst incorporating better and more efficient engines to maximize voyage efficiency.
- Enhancing fleet capacity in order to meet the exciting opportunities of a LNG spot market.
- Development of storage capacities to ensure wider global availability of LNG.
- Widespread development of low-cost gas resources will be critical for ensuring ongoing cost competitiveness of gas vs. other fuels.
- Infrastructure investment for accessing gas supply appears to be insufficient to achieve growth expectations.

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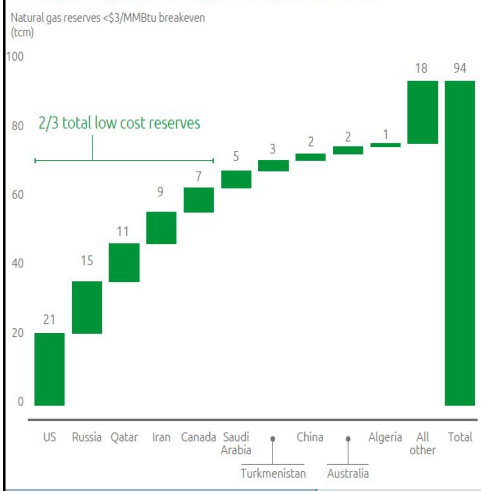
CHALLENGES AHEAD

Distribution of gas reserves <$3/MMBtu production cost



Commercialization of <$3/MMBtu reserves by region

Source: Global Gas Report 2019

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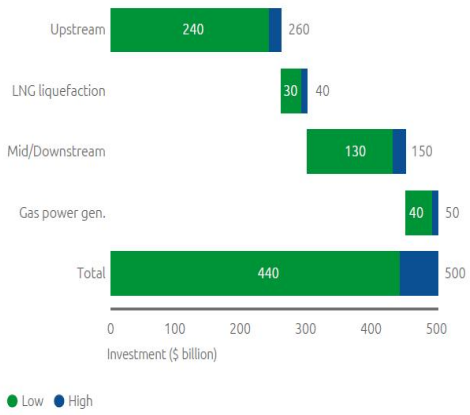
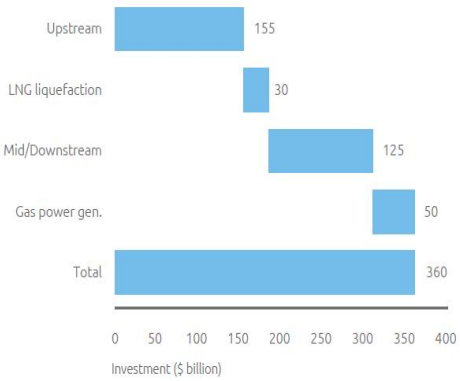
CHALLENGES AHEAD

Required investment to achieve natural gas market potential projections



Source: IEA, WoodMac; Oxford Institute for Energy Studies; BCG analysis.

2018 estimated natural gas infrastructure investment



Source: IEA, WoodMac; Oxford Institute for Energy Studies; BCG analysis.

Source: Global Gas Report 2019

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CHALLENGES AHEAD

- Address environmental concerns regarding methane slip and its harmful impact on the environment, particularly in light of IMO's goal to reduce total GHG emissions from international shipping by at least 50% by 2050 compared to 2008.
- Government policy will be critical for internalizing the cost of environmental impacts, supporting development of low carbon gas technologies, developing pathways for using gas to achieve deep GHG emission reductions.
- Development of upgrade pathways for older LNG vessels in order to stop market fragmentation.
- Enhanced co-operation with ship yards to expand production of LNG carriers and FSRUs.

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THANK YOU