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Dynamic Delivery –
America's Evolving Oil and Natural Gas Transportation Infrastructure
Made Available December 12, 2019

Topic Paper #4-11

LNG SHIPPING AND TERMINAL HANDELING

Prepared for the

Technology Advancement and Deployment Task Group

On December 12, 2019 the National Petroleum Council (NPC) in approving its report, *Dynamic Delivery – America's Evolving Oil and Natural Gas Transportation Infrastructure*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the study's Permitting, Siting, and Community Engagement for Infrastructure Development Task Group. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters.

These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents, but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency.

The attached paper is one of 26 such working documents used in the study analyses. Appendix C of the final NPC report provides a complete list of the 26 Topic Papers. The full papers can be viewed and downloaded from the report section of the NPC website (www.npc.org).

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Topic Paper

(Prepared for the National Petroleum Council Study on Oil and Natural Gas Transportation Infrastructure)

4-11	LNG Shipping and Terminal Handling
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SUMMARY

The global LNG market is well developed with a mature standards, regulations, and industry organizations. These standards, regulations, and industry organizations ensure safe transit and storage of LNG. Under this well regulated system, voyages and tonnage of cargo have increased dramatically and safely since 2010. The size and capacity of LNG tankers has also increased to further address market demand. Traffic management at ports and terminals is well developed with specific tugs dedicated to LNG vessels. Ship-to-shore transfer operations are equipped with emergency shutdown systems and specially designed loading arms. Development and exercising of emergency response plans further ensure the safe operations of the LNG shipping and storage industry.

The International Maritime Organization (IMO) is the main governing body that establishes international maritime regulations. The IMO is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships.

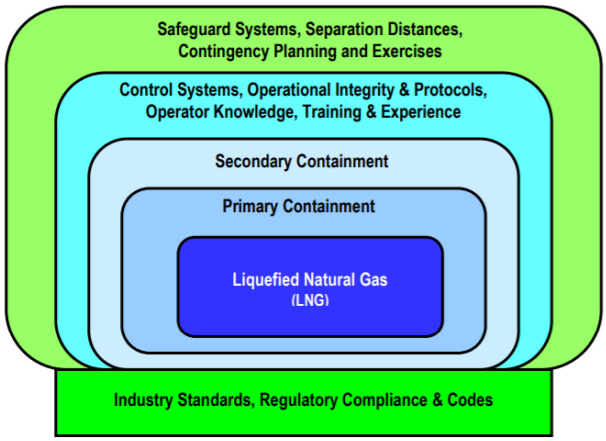
There are three international industry groups that play a critical role in LNG shipping and terminal operation:

- Oil Companies International Tanker Operator (OCIMF)
- Society of International Gas Tanker and Terminal Operators (SIGTTO)
- International Group of Liquefied Natural Gas Importers (GIIGNL)

Together, these bodies set the Standards, provide best practices and lessons learned within the industry and have representatives that sit on various IMO committees.

For LNG shipping, just like for LNG facilities, multiple layers of protection are implemented to minimize the likelihood of an LNG release and, if a release occurs, to mitigate the consequences (Figure 1). Industry standards and regulatory compliance create a comprehensive safety framework within which each protective layer functions to create a safe

operational environment for LNG facilities. While the specific language varies throughout the world, the layers of protection are employed by LNG operators to ensure the safe production, transportation, storage, and transfer of LNG

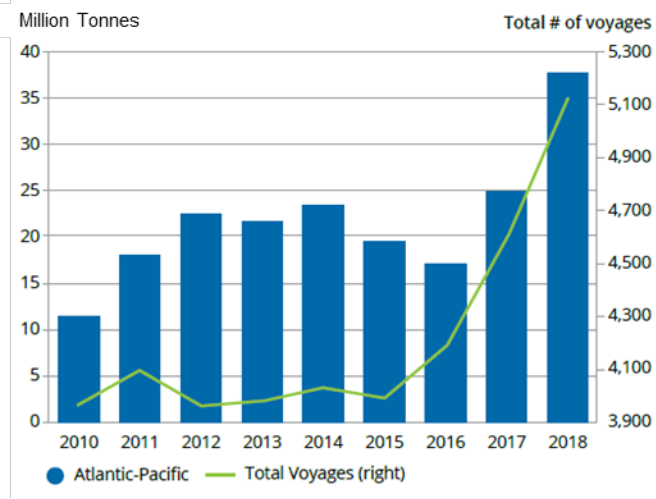


Source: International Group of Liquefied Natural Gas Importers (GIIGNL).

Figure 1. Illustration of Layers of Protection for LNG Containment Systems

The demand for cleaner burning fuel worldwide is creating greater opportunities for the US to export its energy, more so in the form of LNG from the various LNG liquefaction and export facilities either operating or sanctioned for investment. As the export of LNG from the US took off in 2016, it has become integrated into an international supply chain network that relies on reliable supply of natural gas supply and liquefaction capacity.

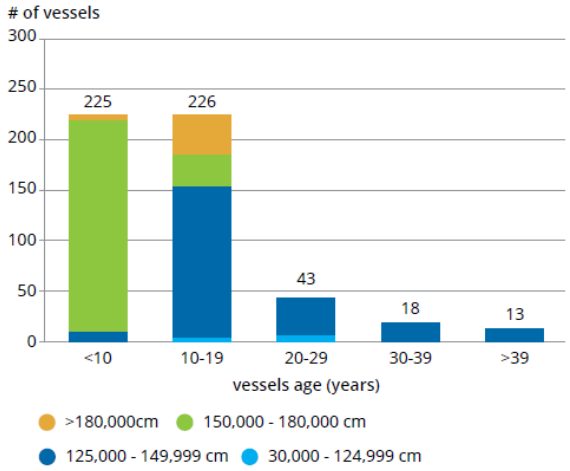
According to the IGU World LNG Report of 2019, the global LNG shipping fleet in 2018 consisted of 525 vessels. This total includes conventional LNG carriers, 31 LNG ships converted to Floating Storage and Regasification Units (FSRUs) and 5 floating storage units. In 2018, a total of 5,119 LNG trade voyages were completed, representing an increase of 8% over the previous year, and from a total of approximately 4,000 in 2015 (Figure 2)



Source: IHS Markit, IGU World LNG Report, 2019

Figure 2: Atlantic to Pacific Trade vs Total Number of Voyage Per year (2010-2018)

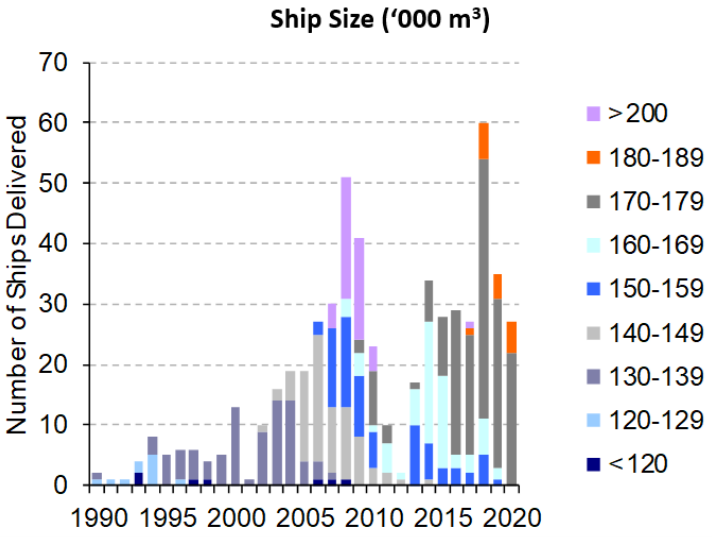
As the number of LNG shipments are increasing, so too is the size of LNG ships and their carrying capacities. According to the IGU World Report of 2019, most of the LNG vessels under 10 years are in the range of 150,000 m3 to 180,000 m3 (Figure 3).



Source: IHS Markit, IGU World LNG Report, 2019

Figure 3: Active Global LNG Fleet by Capacity and Age, end 2018

In a presentation to SIGTTO in June of 2019, Poten and Partners showed that the average LNG ship capacity has been increasing steadily where currently LNG carriers with capacity of approximately 180,000 m3 dominates compared to about a decade ago when the predominant capacity was approximately 150,000 m3 (Figure 4).



Source: Poten and Partners, 2019

Figure 4: Trending in LNG ship capacity

LNG Shipping and Terminal Interface

LNG shipping, port maneuvering and waterway suitability are typically validated by use of full mission bridge simulations involving captains, pilots and tug operators. Ship to shore interface, mooring and berthing analyses and modeling are undertaken using sophisticated software to satisfy an array of safety and environmental criteria established by OCIMF and World Association for Waterborne Transport Infrastructure (PIANC).[1] These design criteria ensure that LNG carriers are manuvered and safely berthed with suitable mooring lines before LNG transfer begins. For LNG terminals in more congested ports areas or narrower waterways, passing ship studies are completed as it is the industry practice to ensure that the LNG jetty structures and equipment are designed to safely hold the LNG carriers considering external influencing factors.

Additionally, most if not all LNG terminals have their own dedicated tugs and line handling services for the LNG traffic. The tugs are specially built vessels to a higher Fire Fighting Class 1 Standard (FiFi1): In some cases the tugs are available for use under a MOU by the larger local firefighting community, if required.

Ship to shore operations and transfer of LNG is a very controlled process that is designed and conducted in accordance with the requirements and principles of SIGTTO for handling liquefied gasses. The design incorporates emergency shutdown (ESDs) systems that are intended to ensure adequate protection to the LNG carrier and the terminal covering a wide range of possible upset conditions. The ESDs brings the LNG loading process to a safe stop, typically under thirty (30) seconds. The transfer of LNG from the Terminal to the Ship is via specialized marine loading arms that have several swivel joints to accommodate a range of ship motions

[1] PIANC refers to an earlier name of the World Association for Waterborne Transport Infrastructure. The abbreviation has been retained in usage after the organization's change to its name.

while connected to the terminal. Integrated into the LNG loading arms are emergency release couplings (ERC) between two adjacent ball valves which are intended to provide a clean break-away in case of an ESD between ship and shore and if deployed would result in a negligible spill of LNG. Some terminals may elect to install a 3D Constant Position Monitoring System (CPMS) that tracks the position of the arms in real time and will supplement the alarm management and ESD activation if ship motion becomes excessive.

OCIMF has published guidance for Marine Terminal Management and Self Assessment (MTMSA). This guide can be used to develop trends and support continuous improvement of safety and environmental performances. Together with shared knowledge across the industry, it ensures that best practices are being employed and that risks are systematically identified, analyzed and reduced to as low as reasonably practical.

Security and emergency requirements governing ships bound to the US, and in US waters must be in accordance with the Marine Transportation Security Act (MTSA). The Act also covers marine ports of entry and terminals. The MTSA regulatory requirements are applicable to all LNG shipping traffic and LNG marine terminal operations in the US.

The terminal and LNG ship have to comply with IMO International Ship and Port Facility Security (ISPS) Code which is regularly audited. US Terminals have their own Security plans which are audited and tested by the USCG. Following receipt of the 96 hr. notice of arrival message, the local USCG Captain of the Port (COTP) will assess whether any additional security inspection or escort is required, based on risk.

Emergency Response Plans (ERPs) are developed and exercised routinely at LNG terminals. ERPs, while typical for the LNG industry, are driven in the United States by regulations; 33 CFR Part 127 requires an emergency manual to be approved by the COTP. The manual addresses among other aspects, release response procedures, emergency shut down procedures and emergency procedures for mooring and unmooring a vessel. The USCG conducts an annual inspection of the facility for the areas under its jurisdiction, which is essentially the marine transfer area. Emergency response requirements for the LNG Plant facilities are required from other regulatory bodies like FERC and PHMSA, having areas of overlap with Part 127 at the marine transfer area.

LNG Technologies and Advances

Containment systems on LNG carriers were traditionally designed so that the rate of laden boil off gas (BOG) was 0.15% per day. Improvements in containment technology and insulation has reduced boil off rate to about 0.08% per day thus increasing transportation efficiency. For further efficiency the LNG carriers are now fitted with reliquefaction systems such that any excess boil off is reliquefied and returned to the cargo tanks.

Advances in cryogenic flexible hose technology offers significant benefits for ship-to-ship transfer of LNG as well as potential risk mitigation for ship-to-shore transfer of LNG in exposed marine conditions. LNG ship-to-ship transfers are now considered “normal operations” with more than 2,000 transfers completed inclusive of floating storage and re-gas operations.

Effective from January 1, 2020 the International Maritime Organization (IMO) will require that all ships burn fuel with a sulfur content of no more than 0.5% compared to current levels of 3.5%. Reduced sulfur limits have already been imposed on specific emissions controlled areas (ECAs). According to the US EIA (Figure 6 below) LNG will become more predominant as a suitable marine fuel in meeting the new emissions standard. As an example of this trend, in August of 2018, Conrad Industries delivered the first LNG bunker barge built in the US, to JAX LNG. The barge has a single GTT membrane LNG tank with a storage capacity of 2,200 m3 and is currently used to bunker two of TOTE's container ships operating on LNG fuel.

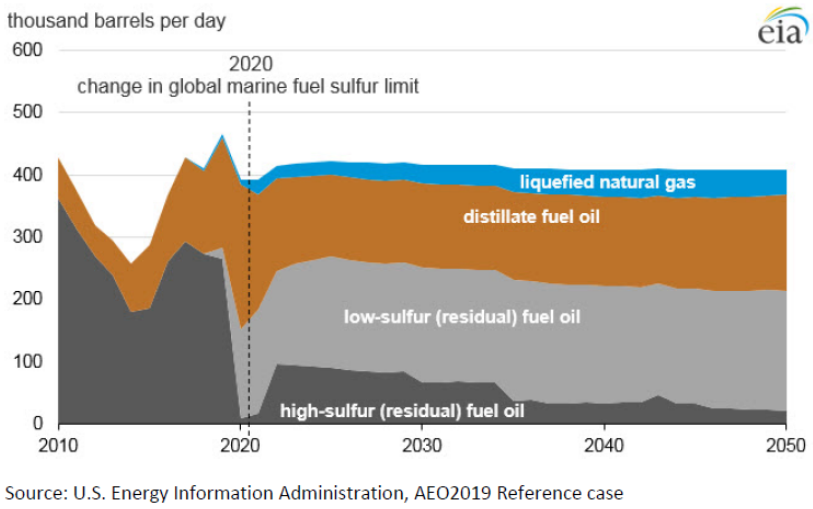


Figure 6: International marine shipping consumption (ocean-going vessel bunkering at US port