CHEMSYSTEMS
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Floating LNG Production

Liquefaction Technology, Capital & Operational Costs, Safety Considerations (Risks), Stranded Offshore Liquefied Natural Gas, Storage & Re-Gasification Units (FSRU), Off-Loading Systems (FPSO), and New Developments are presented.

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Report Abstract

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Nexant

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INTRODUCTION - Nexant sees innovative offshore applications

Offshore natural gas liquefaction is expected to be the next technology and commercial breakthrough for monetizing stranded natural gas resources. In recent years, there has been an increase of research and development activities to apply existing and new technologies in offshore liquefied natural gas (LNG) service.

The "marinization" of LNG technology is seen to be a key success criterion for selecting and applying the most appropriate technology concepts. While onshore LNG facilities have traditionally focused on thermodynamic efficiency as a key criterion for process selection, offshore LNG will require blending this traditional efficiency requirement with space, weight, safety, and marine operability considerations.

Ideally, the safety record of land-based LNG plants can be extended to offshore LNG applications by appropriately adapting process options and equipment design for a marine environment. However, operational risks and safety concerns associated with equipment congestion and flammable hydrocarbon handling must be carefully assessed in order to mitigate system failures and minimize incident escalation.

Nexant has developed a report, summarized below, that reviews and discusses the various technical, safety, and commercial considerations that must be resolved to successfully implement an offshore LNG project. The objective is to familiarize the reader with the offshore LNG technology concepts and the key issues and risks associated with adapting these technologies to Floating LNG Production service.

Technology Concepts

After the successful and proven track record of offshore crude oil field developments employing floating production, storage and offloading systems (FPSO), industry is now looking with great interest into solutions for monetizing stranded offshore gas fields through the integration of onshore LNG and offshore FPSO technology concepts. The integrated application is known as Floating LNG Production or LNG FPSO.

The LNG FPSO concept has generated interest because it offers the potential to:

- Enhance the permitting and approval processes
- Eliminate the need for potentially long pipelines to shore
- Avoid flaring or re-injection of associated gas
- Lower LNG production costs
- Monetize smaller and more remote gas fields

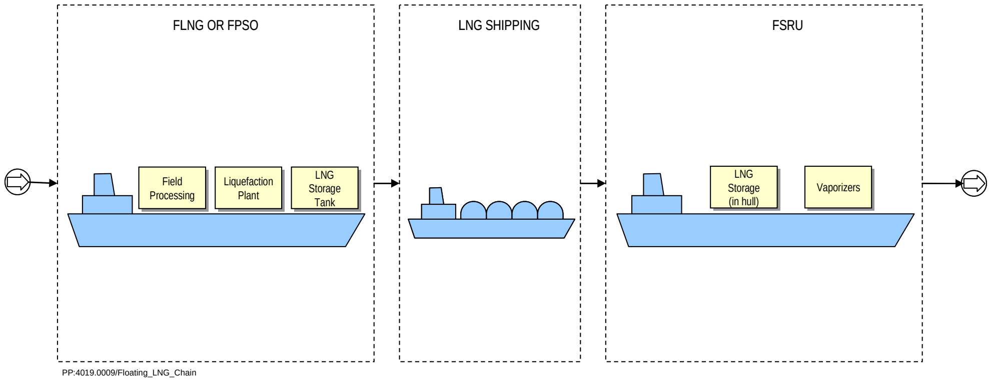
The LNG FPSO concept is based on a ship-like vessel that will be able to produce, store and offload LNG in a marine environment. In some designs being considered, the concept includes production, storage, and re-gasification onboard a self-propelled LNG carrier. This innovative approach is the integration of the LNG FPSO concept with the proven LNG FSRU and LNG Shipping technologies.

Floating LNG Value Chain

The traditional LNG value chain consists of the onshore gas conditioning and liquefaction facilities located in the producing region or supply source, the LNG tanker carrier segment, and the onshore LNG receiving terminal near the consuming region or market.

In contrast to this traditional concept and as illustrated in Figure 1, the offshore LNG value chain will consist of floating gas conditioning and liquefaction on vessels located at the offshore field site, the LNG tanker carrier segment, and the floating storage and re-gasification units (FSRU) near the market.

The Floating LNG Value Chain



The elimination of onshore LNG production, storage and transfer infrastructure could potentially benefit a project that has unique business and regulatory criteria that is affecting the development of an LNG project. Although the LNG FPSO vessel must also meet stringent environmental and security regulations, the offshore location and operation of the vessel may facilitate the permitting and approvals required to achieve a final investment decision.

Technical and Operational Challenges

LNG Transfer

The transfer of LNG cargo is considered one of the principal challenges facing offshore LNG systems. Whereas the petroleum industry has significant experience in oil transfers in FPSO operations and ship-to-ship (STS) transfers that have demonstrated that berthing and connection of two vessels in open seas can be performed in a safe and reliable manner, the transfer of crude oil and products is not fully representative of the specific issues associated with the cryogenic systems used in LNG transfers and of the potential sloshing effects in partly filled tanks caused by vessel movement in an open sea environment.

Vessel Motion and Product Sloshing

The effects of vessel motion are also potentially manifested in heat exchangers and process columns through mal-distribution of fluid phases and decreased heat and mass transfer efficiencies. Furthermore, LNG product sloshing is a stochastic phenomenon for which the impact on the containment system cannot be predicted with certainty.

Space Limitations

In a Floating LNG Production vessel topside space will be significantly constrained. For this reason, the system process modules will be box-like units that contain a section of processing equipment and associated piping. Designs of the modularization concept can consist of as many as 14 integrated modules, which include gas treating facilities, liquefaction trains, power generation plants, and offloading and transfer systems.

The gas liquefaction processes that employ a single refrigeration cycle and use non-hydrocarbon refrigerants have the potential to be extremely compact because they feature an all gas service that does not require large refrigerant storage and mixing systems. These processes can potentially reduce plot size requirements, depending on the size of the plant.

In contrast, the multiple cycle liquefaction processes have an inherent lack of compactness because they require refrigerant storage and two-way, two-phase flow heat exchangers, and corresponding piping layout. Additionally, the flammable nature of the hydrocarbon refrigerants required in these processes place additional constraints on offset distances to ensure adequate safety code compliance.

The use of parallel liquefaction equipment to increase the reliability and availability of a Floating LNG Production system, regardless of the liquefaction technology employed, will also increase process complexity and require more space.

Safety Considerations

The safety concerns of the LNG FPSO concept as compared to onshore designs are primarily in the safe offloading of products to carriers under potentially difficult environmental conditions, the control of vessel collision hazards, highly complex and compact process equipment installed in a limited area, and the storage of LNG in the proximity of process equipment and worker accommodations. The control of onboard process related hazards are related to the mechanical integrity of the process equipment, the ignition source control systems, and the designs to minimize and withstand explosion overpressure hazards.

Based on industry studies, the highest risk category for an LNG FPSO system is the hazard to onboard workers. An LNG FPSO vessel will be a workplace and home to a significant number of workers, with offshore manning requirements of at least 86 employees for a plant of 3.0 million metric tons per year of production capacity.

Liquefaction Technology

The selection of the liquefaction technology and corresponding equipment to be employed in an LNG FPSO is critical to reducing risks and increasing project viability, while meeting production and market targets and controlling costs.

Liquefaction technologies vary in sophistication and power requirements such that selecting the optimum design depends on many factors, which vary from project to project. Over the years, the design of individual base load liquefaction train capacity has increased steadily from less than 1.0 to over 8.0 million metric tons per year.

Industry studies, including those performed by Nexant, suggest that liquefaction technology on its own does not substantially make one liquefaction process more efficient than any other. Rather each technology is competitive within certain ranges of feed gas specifications, ambient conditions, and train sizes.

The refrigeration system is the key section of base load LNG plants, typically accounting for 30-50 percent of the total installed investment. The liquefaction trains of base load LNG plants have three basic design philosophies: one cycle, two cycle or three cycle cooling systems. The design of small capacity liquefaction technologies is associated with one-cycle liquefaction processes. In contrast, the design of medium to large capacity liquefaction trains is typically associated with the two and three-cycle processes.

The comparative analysis presented in Nexant's Floating LNG Production report focuses on the application of proprietary liquefaction technologies for each of the three design philosophies when used in an offshore location. The technologies compared are the one-cycle Nitrogen Expander process, the two cycle Dual Mixed Refrigerant process, and the three-cycle Optimized Cascade process.

Commercial Drivers

Generally speaking, the commercial framework of an offshore Floating LNG Production project will mirror that of a land based LNG project because all segments of the commercial value chain must be effectively combined to ensure a successful business venture. Thus, the commercial drivers for all value chain segments must be aligned, including those of the parties involved (Governments, Investors, EPC Contractors and Technology Providers).

The principal economic driver for Floating LNG Production systems will be to produce the maximum amount of LNG that the natural gas reserves will allow. To this end, the key considerations in the design of the facility will be the technical and safety limitations associated with the size and configuration of the compression train and on the ultimate impact that these constraints can have on LNG production.

Capital Costs

For a Floating LNG Production system with a production level of 6.0 million metric tons per year, the specific (unit) capital costs range from US$590 to US$750 per ton, depending on the liquefaction process employed and corresponding electric power requirements. In contrast, the specific capital cost of an onshore base load liquefaction plant of similar capacity can be as high as $1,000 per ton of LNG production, when the pipeline to shore, site preparation, harbor dredging, and docks are included. It should be noted that these are indicative unit costs for liquefaction facilities that would process relatively dry gas and would therefore not require NGL recovery facilities and associated infrastructure. These costs also exclude field development and shipping costs.

Operating Costs

The annual specific (unit) operating costs range from US$22 to US$29 per ton of LNG produced to storage, depending on the liquefaction process employed. These costs comprise labor, fuel gas requirements, the consumption of catalyst, refrigerants, chemicals and lubricant, and maintenance programs that include materials, supplies, support services, and offshore logistics.

Delivered Costs

Although the LNG FPSO facility is a vital element of an offshore LNG project, the economics of an offshore LNG project must be viewed in context of the complete supply chain. The LNG value chain is capital intensive, with each segment requiring substantial levels of investment in order to deliver the products to the consumers.

Table 1 shows the supply chain gas delivery costs for LNG product that is being delivered to Japan from supply sources located the Middle East and South-East Asia.

Delivered Gas Costs
(US$ per MMBtu)

	Middle East to Japan	South-East Asia to Japan
Gas Development and Production	0.50	1.00
Gas Liquefaction	2.25	2.25
LNG Shipping	1.50	0.70
LNG Re-gasification	0.80	0.80
Total	5.05	4.75

The total supply chain delivery cost ranges from US$4.75 to US$5.05 per MMBTU. For similar LNG FPSO systems, the South-East Asia to Japan route would have a lower shipping price as the result of a shorter shipping distance, which more than offsets the higher gas development and production costs in South-East Asia.

The development of LNG FPSO projects will be driven by the ability to deliver gas from the supply source to the market at a total value chain cost that is competitively below the price of gas that the market can sustain during the project life cycle. Thus, if gas reserves and markets are not limiting factors, the netback price from the market to the LNG plant will drive the development of offshore LNG plants. Furthermore, if safety considerations can be adequately managed and the netback thresholds can be sustained, there could potentially be an economic advantage to installing larger plants. However, it remains to be proven that the safety considerations associated with larger plants can be managed to the satisfaction of the owners and projects financiers, considering their increased complexity and equipment count.

New Technological Developments

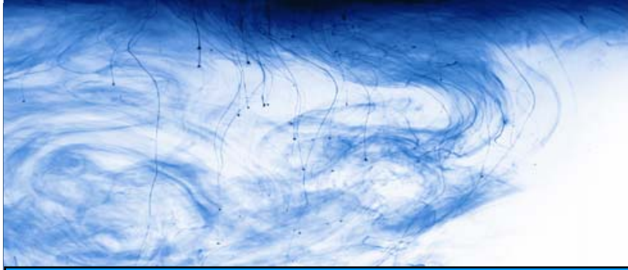
Combining technology innovation with new business development ideas will provide new supply opportunities and open-up new LNG markets. As new LNG projects continue to be developed, there will be opportunities to integrate newer technologies to the offshore LNG value chain. Over the last decades, the most notable achievements in LNG technology include the development of new process licenses, equipment modularization, and mechanical drivers for the refrigeration compression trains.

Within the specific realm of offshore LNG technology the most notable achievements include developments in the following areas:

- Cryogenic transfer technology
- Integrated gas treating technology
- Heat exchanger technology
- Mini scale technology

Among the offshore designs that incorporate one or more of these technological developments are the following:

- Generic LNG FPSO design
- M-Flex design
- Multi-Functional SRV design
- LNG Smart® design
- Niche LNG FPSO design



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