

Examples of Changing Technology and the Expanding LNG Market

*In the 1967 film The Graduate, young Benjamin Braddock gets this career guidance from a colleague of his father: "I just want to say one word to you. Just one word. 'Plastics.'" If they remake that movie anytime soon, the advice could be "LNG."*¹

I. Introduction:

a. Purpose

In the energy world, liquefied natural gas (LNG) is becoming an ever more important player. This valuable commodity is making waves in energy circles and



Source: The BP Magazine

has even caught the attention of the President who “strongly support[s] developing new LNG capacity in the United States”.² Improved

technology and market fluctuations are making LNG much more attractive to energy suppliers and thereby to producers, shippers and investors as well. While LNG trade is unlikely to become as important as oil, the once relatively

¹ Bechtel, Corp., Bechtel Briefs (07/2006), http://www.bechtel.com/briefs/Online_Features/LNG.htm.

² U.S. Department of Energy, <http://www.fossil.energy.gov/programs/oilgas/storage/index.html> (last visited Nov. 30, 2006).

insignificant LNG markets around the globe are maturing and on a path to become an ever more independent part of the global energy market.

As the industry continues to grow, questions arise as to exactly how LNG will settle as a market worldwide. The answer lies in a number of factors, but is primarily tied to price. As long as LNG can contribute to consumers' fuel needs at a price that is competitive with other options, there will be a market. Furthermore, when the cost of LNG becomes very attractive, investors and producers will scramble to get their share of the profits and create market expansion. An increase in tanker orders is just one indicator that the global LNG industry is currently in just such a growth phase. As of July 2006, there were some 204 LNG tankers operating worldwide with an additional 139 on order.³ This increased fleet capacity, and the capital investment it represents shows that major energy companies are quite serious about their plans for the future. As the market grows, producers, suppliers and investors will use technology to improve the economic benefits of LNG while increasing safety and reliability. Often, the capital investments associated with the industry will require long-term contracts on multiple sides of the market. Because of this, planners will need to exercise great care when structuring LNG deals such that they are flexible enough to withstand the uncertainties of the future but also firm enough for the parties involved to reach their goals, be they economic or otherwise.

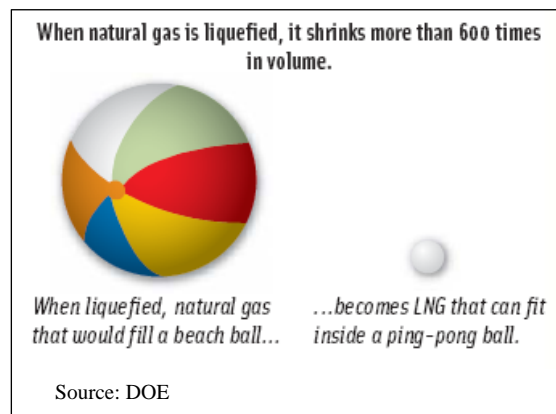
Integral to the strategies of parties to any LNG contract will be a thorough understanding of the LNG process and what the current industry trends are. With

³ *LNG tankers: present and future*, LNG Observer (statistics section), July-September 2006, available at <http://downloads.pennnet.com/pnet/surveys/lng/0607lng-tankers.pdf>. (Also included in Appendix 1)

this knowledge, planners may seek to avoid problems which might crop up over time. The purpose of this analysis will be to give an overview of the LNG process as it exists now and to shed light, through the use of examples, on current trends which have been precipitated by new technologies and point to the future of the industry. The intention is to provide the reader with a “big picture” understanding of this fascinating subject before making some final comments regarding legal issues of particular importance for those interested in LNG.

b. What is LNG and why do people care about it?

LNG is little more than natural gas which has been cooled to -256° Fahrenheit, the temperature at which it condenses.⁴ “By converting natural gas to LNG, it can be shipped over the oceans and great distances from the countries where it is produced to those where it is in demand”.⁵ Without condensation (also known as liquefaction) natural gas is not cost effective to transport over



long distances. Because LNG occupies 1/600 of the volume of natural gas, it provides attractive economies of scale even though the cryogenic temperature must be maintained over a long voyage.⁶ Furthermore, the liquefaction process

⁴ *LNG Safety and Security*, University of Houston Law Center Institute for Energy, Law & Enterprise, Oct. 2003, at 12.

⁵ *Id.* at 8.

⁶ *Id.* at 12.

itself is useful in that it removes certain impurities normally found in gas when it comes out of the ground.⁷

Despite the benefits of LNG, several limitations must also be considered. Most importantly, LNG is expensive to produce. Although costs of production are declining, the most expensive component of the LNG value chain is the liquefaction plant.⁸ Reasons for this expense include remote locations of the facilities, strict safety standards and the cryogenic materials needed.⁹ Likewise, LNG is expensive to ship because it requires a specialized type of carrier which often requires a specialized and hard to find crew.¹⁰ Furthermore, anything that comes in contact with LNG, be that a storage tank, pump or other machinery, must be constructed of expensive materials that can withstand the harsh temperature without becoming brittle or suffering from catastrophic size changes.¹¹ Finally, LNG must be returned to a gaseous state that can be transported through an existing system of pipes.¹²

⁷ *Id.*

⁸ *LNG Industry Costs Declining*, Energy Info, Admin, Dep't of Energy, available at <http://www.eia.doe.gov/oiaf/analysispaper/global/lngindustry.html> (last visited Nov. 30, 2006)

⁹ *Id.*

¹⁰ James Gaughan, *Economics, environment driving new generation of LNG carriers*, LNG observer, July 1, 2006, available at http://www.ogj.com/display_article/259342/94/ARCHI/none/none/Economics,_environment_driving_new_generation_of_LNG_carriers/

¹¹ *LNG Safety and Security* at 27

¹² *Liquefied Natural Gas: Understanding the Basic Facts*, Dep't of Energy, available at http://www.fossil.energy.gov/programs/oilgas/publications/lng/LNG_primerupd.pdf (last visited Sept, 30, 2006).

II. Historical perspective: Where LNG is today and how it got there

a. The early days

As an independent industry, LNG was slow to develop. Although the concept had been around since the First World War, LNG was first stored commercially in 1939.¹³ Unfortunately, tragedy struck soon after when, in 1944, a storage tank failed in Cleveland, OH and resulted in numerous fatalities.¹⁴ This disaster, combined with an expanded post-war gas pipeline network made LNG relatively unattractive for many years.¹⁵ Still, by the late fifties, the first ocean-going LNG transport vessel began trips from Lake Charles, LA to Canvey Island, UK.¹⁶ By the late sixties and early seventies, several companies were dealing in trans-oceanic LNG, but the quantities were low. Imports to the U.S. were under 5 billion cubic feet (bcf) per year and came exclusively from Algeria.¹⁷

During the oil crisis of the early seventies LNG became both economically and politically troublesome because its price was tied to oil. In 1974, LNG imports fell to zero and the next twenty years saw a bumpy road of ups and downs for further imports.¹⁸ It would not be until the mid-to-late 1990's that LNG imports would begin a steady increase.

¹³ Brian D. O'Neill, *6 Conventional Energy Sources: Production, Transmission, Distribution, and End Uses*, Energy Law and Transactions at 56.02[1][b], 2006.

¹⁴ *Id.*

¹⁵ *Id.*

¹⁶ *Id.*

¹⁷ *Natural Gas Imports, Exports, and Net Imports, Selected Years, 1949-2005*, Annual Energy Review, Energy Information Admin., available at <http://www.eia.doe.gov/emeu/aer/txt/ptb0603.html>. (See also Appendix 2)

¹⁸ *Id.*

b. The change

Despite a troubled start, LNG had made dramatic inroads by the turn of the new century. This was in no small part due to a new short-term, or “spot”, market which had appeared. Where long-term contracts had once been needed to justify the expense associated with LNG operations, the opening of new facilities, such as those in Australia, the UAE, Trinidad and Tobago and Malaysia, enabled a spot market to become more active.¹⁹ Fueling the fire were rising energy prices and growing market demand for cheap, clean-burning fuel. Thus, gas that had once been seen as a nuisance to be flared off, would become a commodity to be sold on the open market. This represented a shift from the traditional contract—often of twenty or more years—which was designed to ensure repayment for the massive capital expenditures associated with producing, shipping and receiving LNG.²⁰ Although long term contracts are still a significant part of the LNG business.²¹, a growing number of interests are placing bets on a very different market where gas will be sold to the highest bidder on a per shipment basis.²² Interests, such as BP have openly said that these markets figure into their plans for the future.²³ This demonstrates some investors’ belief that LNG has reached a level where long-term contracts are not always needed.

¹⁹ O’Neill, *supra*.

²⁰ Martin Quinlan, *It’s All About to Happen*, *Petroleum Economist*, Nov. 2004, at 14.

²¹ Robert C. Olsen, Chairman and Prod. Dir., ExxonMobil Int’l Ltd, *The Upstream Challenge and the Role of Technology*, Presented to the Offshore Europe 2005 Exhibition and Conference (Sept. 6, 2005) available at http://www.esso.co.uk/UK-English/Newsroom/UK_NR_Speech_olsen_OE060905.asp.

²² Quinlan.

c. Current situation—the markets

Buyers must have a use for the product when they buy it and LNG is only useful in those parts of the world with the proper infrastructure to supply gas to consumers. Currently, the only places with the pipeline networks able to service a supply of LNG are North America, Europe and Parts of Asia.²⁴ The greatest need for LNG is in Japan, which consumes more than half the world's LNG production.²⁵ Ironically, it is the lack of infrastructure in places where gas is abundant that makes LNG desirable in the first place. People who can not use the gas they have so much of send it to buyers who need it and are willing to pay for it. Thus, where the demand for gas is such that the costs associated LNG are outweighed by the benefits of its importation, a market will exist and, as technology reduces the extra cost of LNG, the market should expand.

The global buzz surrounding LNG is paralleled by activity in the US, centering on the reception facilities needed for importation. Currently, there are five domestic facilities receiving LNG: Everett, MA, Cove Point, MD, Elba Island, GA, Lake Charles, LA and the off-shore facility located in the Gulf of Mexico.²⁶ The expansion of the LNG industry has led many groups to begin the process of adding new terminals, but before construction can start, there are a number of

²³ *New Horizons*, The BP Magazine 50 (Barbara Peen, ed., Issue 1, 2004) available at http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/B/BPM_04one_P_48-51_LNG.pdf.

²⁴ *Liquefied Natural Gas: Understanding the Basics*, Supra at 5.

²⁵ *Id.* at 4.

²⁶ *Existing and Proposed North American LNG Terminals*, Fed. Energy Res. Comm'n, Office of Energy Projects, available at <http://www.ferc.gov/industries/lng/indus-act/terminals/exist-prop-lng.pdf>. See also Appendix 3.

regulatory hurdles that must be overcome. Such aspects as location and environmental studies must be approved by the appropriate agencies. To date, some 16 proposed new facilities have been fully approved by the Federal Energy Resource Commission (FERC) with some 20 sites seeking additional approval from the various authorities.²⁷

Once the LNG is delivered to a terminal in the U.S., there are two options for its use. It can either be converted to gas and injected into the network, or it can be stored for future use. If the LNG is to be stored, massive cryogenic tanks are employed to keep the liquid below its boiling point. These tanks are similar to giant thermoses, except that they use insulation rather than a vacuum to keep



The Pine Needle, North Carolina peak-shaving facility, one of the largest in the nation, has a storage capacity of 4 Bcf. A sendout capacity of .4 Bcfd empties the tanks in 10 days of peak usage.

Source: DOE

heat out.²⁸ There is also another storage solution employed primarily in the Northeast. Where demand for heating fuel can vary greatly between the summer and winter months, LNG will often be trucked inland and stored near its final destination. This process,

known as peak shaving, makes it possible for gas companies to more easily and cost-effectively meet increased demand for gas during the cold months.²⁹

d. Current situation—the producers

²⁷ *Id.*

²⁸ Liquefied Natural Gas: Understanding the Basic Facts, *Supra* at 14.

²⁹ *Id.* at 7.

The new century has seen several LNG-producing facilities come online and even further expansion is scheduled through the latter part of this decade. Countries like Nigeria, Oman and Qatar are all beginning or expanding production but, globally, Indonesia remains the largest producer of LNG.³⁰ Having been the primary source of LNG for decades, Algeria continues to play a major role in U.S. importation, but since beginning shipments to the U.S. in 1999, the Atlantic LNG facility on the island of Trinidad has become the largest single LNG supplier to the U.S., having sent some 462bcf in 2004.³¹

Also of note is the single American facility currently exporting LNG. It is located on the Kenai Peninsula in Alaska and services primarily the Japanese market. Having been in operation since 1969, the facility currently exports roughly 60-65bcf each year.³²

III. Effect of Technology on Value-Chain Segments

a. The big picture

In his 2005 presentation, *The Upstream Challenge and the Role of Technology*, ExxonMobil chairman and production director Robert C. Olsen was able to sum up the driving force behind the current LNG trend with a single point:

The increase in train size, is the result of process changes, state-of-the-art turbines, compressors and heat exchangers. When you combine these large trains with bigger, more efficient ships and

³⁰ *Id.* at 5.

³¹ *Natural Gas Imports*, *Supra.*

³² *Id.*

receiving terminals the total cost of supplying and delivering LNG to the U.S. and Europe in 2009 is reduced by more than 30%.³³

These two sentences shed light on what is going on right now. As energy companies, large and small, maneuver to maximize profits in the ballooning LNG market, they are developing ways to obtain maximum efficiency at each stage of the LNG value-chain. That chain begins with raw natural gas, transitions through the process of converting the gas to LNG, the shipment of the LNG to a market terminal and finally ends with the conversion back to natural gas. At each stage, small changes are currently being implemented, perhaps bringing a 3% savings in one area and a 7% savings elsewhere. On aggregate, these small benefits translate into major cost savings. When these cost savings are coupled with the predicted increase in gas prices, it becomes easy to see why LNG is so attractive to suppliers and consumers alike.

Despite the divergent strategies taken by the various interests, it seems everyone in the international energy industry is making some sort of move. Some companies have chosen a conservative path to the future. ExxonMobil, for example will rely on long-term contracts to justify its major investment in Qatar.³⁴ On the other hand BP has taken the risky but potentially profitable position that emerging spot markets are the best bet for a new fleet of tanker ships.³⁵ Whether either strategy is more viable remains to be seen, but change within the industry is clearly fueled by technological developments across the value-chain which

³³ Olsen, *Supra*.

³⁴ Tom Nichollos and Helen Avati, *Taking the Lead*, *Petroleum Economist*, Nov., 2004 at 19.

³⁵ *New Horizons*, *Supra*.

(mtpa).³⁶ It used a three-tiered process known as The Phillips Optimized Cascade Process, which incorporates three stages to make LNG.³⁷ Through the successive use of propane, ethylene and methane, this process cools gas until it is fully condensed into LNG.³⁸ Although there have been some very technical modifications over the decades, this basic process has withstood the test of time and is being incorporated into the world's largest LNG train at the Atlantic LNG complex on Trinidad.³⁹ Atlantic's train 4 alone has a capacity of 5.4mtpa.

With such a large scale, the question must be asked: How big is too big? Bechtel, the contractor at the Atlantic complex, has published findings related to this question. In its study, Bechtel found that the horsepower needed by its fourth and most recent train to produce a ton of LNG was improved by 10% as compared to the first train.⁴⁰ This significant increase in efficiency indicates that



Source: www.Bechtel.com

³⁶ Philip Hunter, et al, *Lowering LNG Unit Costs Through Large and Efficient LNG Liquefaction Trains—What is the Optimal Train Size*, Technical Paper for Bechtel, Apr. 29, 2004, available at <http://www.bechtel.com/PDF/BIP/29867.pdf>.

³⁷ *Id.*

³⁸ *Id.*

³⁹ Amos Avidan, et al, *Atlantic LNG Train 4, the World's Largest LNG Train*, Technical Paper for Bechtel, 2004, available at <http://www.bechtel.com/PDF/BIP/29881.pdf>.

⁴⁰ *Id.*

the future trend will be to build bigger LNG trains which benefit further from the economies of scale. In another Bechtel study, conducted in conjunction with Conoco-Phillips, researchers concluded that LNG “mega” trains, producing as much as 8mtpa would be feasible under certain circumstances.⁴¹ However, according to the study, this size was at or near the upper bound of economically reasonable LNG trains.⁴² Trains built larger than this would present problems with construction as parts would have to be fabricated and shipped by expensive specialists.⁴³ Furthermore, in situations where a facility already exists, expanding the facility’s capacity with a mega train is less attractive because there would be an additional cost associated with buying and warehousing spare parts that were not compatible with existing trains.⁴⁴ Furthermore, despite possible redundancies that can be built into a single LNG train, complete system failure is always a possibility. In this case, it might be advantageous to have two 4bmtpa trains in lieu of one 8bmta train.

c. Over the rail

Despite improvements in production, the most fascinating technological changes are in shipping. With so many carriers on order, it's no wonder that designers are proposing new ideas which they hope will propel their ships to the forefront of efficiency. As an added bonus, improving efficiency often means less environmental damage. Itself a good thing, environmental friendliness improves

⁴¹ Hunter, *Supra*.

⁴² *Id.*

⁴³ *Id.*

⁴⁴ *Id.*

image and makes capital easier to come by as large energy companies demonstrate their commitment to being better world citizens.

Within the shipping sector, some changes, such as increased capacity, are predictable while others are somewhat more unusual, such as an orange and grey color scheme developed by BP Shipping to reduce boil-off of LNG.⁴⁵ The wide-ranging developments indicate that designers are exploiting all conceivable areas of improvement in the hopes that small efficiencies, once added together, will translate into major economic benefits.

One of the more obvious ways to increase efficiency is with larger ships. According to *The LNG Observer*: "Among the rapid developments in recent years in the design and construction of LNG carriers, the most visible has been the increase in size."⁴⁶ When the first LNG carrier set sail more than forty years ago, its capacity was 27, 400 cubic meters (cu m).⁴⁷ Around the turn of the century, a 140,000cu m capacity was considered very large,⁴⁸ but today, there are ships on order ranging up to 270,000cu m.⁴⁹ This dramatic increase is primarily due to two factors. First, capacity of LNG producing facilities has gone up. Second, the

⁴⁵ The BP Magazine 6 (Barbara Peen, ed., Issue 2, 2006) available at http://www.bp.com/liveassets/bp_internet/globalbp/STAGING/global_assets/downloads/B/bp_magazine_is_sue2_06_ship_shape.pdf.

⁴⁶ Gaughan, Supra.

⁴⁷ Joseph H. Cho, et Al, *Large LNG carrier poses economic advantages, technical challenges*, Oil & Gas Journal, available at http://www.ogi.com/Articles/Article_Display.cfm?Section=ARTCL&ARTICLE_ID=237513&VERSION_NUM=3&p=94 (last visited Nov. 30, 2006).

⁴⁸ Gaughan, Supra.

⁴⁹ *Id.*

technical and commercial challenges faced in the past have been overcome.⁵⁰ LNG's outstanding safety record and proven policies make large capital expenditures less worrisome to investors.⁵¹

If there is one very obvious aspect of LNG carriers, it is the design of their characteristic tanks. Currently, there are two principal designs used by LNG carriers, the spherical design and the membrane design.⁵² Each design has its own costs and benefits. Principally, the membrane design is able to carry more LNG within given hull dimensions.⁵³ The problem with this design is that it is structurally less sound due



Source: DOE

to tank integration into the hull. Spherically designed tanks, on the other hand, don't carry as much cargo, but typically sit atop a frame to which the stress of thermal expansion and contraction can be transferred.⁵⁴ Spherical tanks are also heavier than membrane tanks of like capacity, but building a ship around them is cheaper and easier because tank and hull construction may be carried out

⁵⁰ Cho, *Supra*.

⁵¹ *Id.*

⁵² Ian Harper, *Future Development Options for LNG Marine Transportation*, Presented at the American Institute of Chemical Engineers, Mar. 10-14, 2002, available at <http://www.wavespec.com/pdfs/FutDev.pdf> see also *Marinelog.com*, available at <http://www.marinacivil.com/articulos/articulo.asp?ida=2462> (last visited Nov. 30, 2006).

⁵³ *Id.*

⁵⁴ *Id.*

simultaneously.⁵⁵ One major drawback of membrane systems is that they are particularly sensitive to sloshing when the tank is not full.⁵⁶ Because most LNG carriers still deplete their cargo by using boil-off for fuel (see below), this can cause a major problem. One reason that more and more ships are being ordered with a membrane system is that there is a growing trend towards liquefaction at sea, which reduces the problem of sloshing.⁵⁷

The other LNG carrier design debate of note involves boil-off and engine type. While nearly all modern shipping design has shifted away from steam propulsion, LNG has remained a holdover. Because shipboard liquefaction has been cost prohibitive, shippers have accepted the fact that some of their cargo will boil. In order to avoid pressure build-up which could lead to an explosion, something must be done with gas produced from the boiling LNG. Rather than venting or flaring the gas, designers realized that they could burn it as fuel for steam turbines. This method made economic sense thirty years ago, but modern designers face a dilemma relating to their choice of power plant.

With advances in diesel technology, most modern ship designers have moved away from steam power. Steam poses several problems when compared to the diesel turbines. Most importantly, steam turbines are less efficient than diesel engines, obtaining roughly 30% and 50% efficiency, respectively.⁵⁸

⁵⁵ *Id.*

⁵⁶ Marintex, available at http://www.sintef.no/content/page1_2802.aspx (last visited Nov, 30, 2006).

⁵⁷ *LNG Carrier Propulsion by ME Engines and Reliquefaction*, Report prepared for Man B&W Diesel, available at <http://www.manbw.com/files/news/files/2958/p9011-0903.pdf>, (Last visited Nov. 30, 2006).

⁵⁸ *Id.*

Methane propulsion also poses certain dangers because it requires bringing the gas into the enclosed environment of the engine room where the risk of explosion or asphyxiation must be protected against.⁵⁹ System redundancies, double-walled piping, detectors for gas and other safety measures are costly and must be taken into consideration when designing a new ship of this type. Expounding on this issue, a major nautical publication sums up the problems of steam propulsion as follows:

[The industry] seems absolutely certain not to feature steam turbines – apart from being expensive and inefficient, they require huge gearboxes and most significantly, engineers with steam experience to tender them – such men are a rapidly declining band while there are only two designers of large steam turbines remaining: Kawasaki and Mitsubishi.⁶⁰

Despite the foregoing, LNG transport by diesel poses its own challenges which must be examined and overcome by naval architects, designers and financiers alike. An obvious economic issue begs the question: Why waste space with heavy fuel oil (HFO) tanks when there is a vast supply of fuel already on board? Clearly, if markets are such that it is cheaper to burn diesel, then the economist will chose that design. However, there is a hidden problem. In the early days of LNG carrier design, projects typically had a specific route in mind. Thus a ship would be built to travel from Alaska to Japan or from Algeria to England. This is important because, if designers know the route the carrier will travel, they will be able to predict how much fuel capacity will be needed for the

⁵⁹ Gaughan, *Supra*.

⁶⁰ *Future LNG tanker design firming up?*, The Naval Architect, Nov. 2003, available at <http://www.rina.org.uk/rfiles/navalarchitect/nov03editorial.pdf>.

voyage. With the growing spot-market, however, this is no longer the case. New ships built to take advantage of this market, would have to forgo cargo capacity in exchange for HFO capacity because it would not be possible to predict how long the next voyage would be. Thus, on short-haul trips, where relatively little HFO was needed, profits would be lost to wasted space. A possible solution to this problem would be a gas injection, dual fuel diesel engine, such as that produced by MAN B&W, which allows a ship to burn any ratio of HFO and gas desired.⁶¹

Dual fuel systems offer an added bonus in that they also alleviate the boil-off problem.⁶² Where marginal cost is significant, the energy needed for reliquefaction of boil-off can be crucial. Some experts are dismissive of plans to fit reliquefaction plants to LNG carriers because of this cost.⁶³ Despite this, however, at least one company currently manufactures and sells units specifically designed for onboard liquefaction.⁶⁴

In fact, even traditional steam turbine LNG carriers are already capable of burning multiple fuels. One of the reasons LNG has tended toward steam traditionally is because prudent safety standards dictate that gas supply to the engine room must be quickly shut off in case of a leak. If gas is shut off, an alternate (liquid) fuel must be at the ready.⁶⁵ Steam lends itself to many kinds of

⁶¹ Cho, *Supra*.

⁶² *Id.*

⁶³ *Future LNG tanker design firming up?*, *Supra*.

⁶⁴ Moss Maritime, available at <http://www.mossw.com/mossmaritime/>, (last visited Nov. 30, 2006).

⁶⁵ *LNG Carrier Propulsion*, *Supra*.

fuels.⁶⁶ Switching a steam turbine to a back-up fuel does not increase its efficiency, though, and diesel turbines do not normally lend themselves to multiple fuels.⁶⁷

Another problem with diesel turbines is that they are more difficult to repair, which leads to safety concerns.⁶⁸ Repair work for most cargo vessels is carried out during loading and unloading, but this is not possible for an LNG carrier because it must maintain a ready-to-sail status during cargo transfer in case of emergency.⁶⁹ Thus maintenance requires either a backup method of propulsion or extra down time. Several multiple-engine design possibilities are considered safe within the shipping community, but experts disagree on what the best solution is. One possibility is to construct ships with two independently driven propellers.⁷⁰ In such a scenario, each must have enough power to adequately propel the ship away from its mooring without substantial loss of maneuverability.⁷¹ As might be expected, this solution involves extra construction costs. Additionally, however, a two screw system can have lowered efficiencies due to changed hydrodynamics.⁷² Therefore, several diesel systems have been designed which involve only one propeller. Chief among these are a duel engine

⁶⁶ *Id.*

⁶⁷ *Id.*

⁶⁸ *Id.*

⁶⁹ *Id.*

⁷⁰ *Id.*

⁷¹ *Id.*

⁷² *Id.*

system which incorporate gears and/or a clutch that enables one engine to be disconnected while the other is operational and or duel engine generator system where an electric motor is used to spin the propeller shaft.⁷³ Whereas the former solution is better tested, but sacrifices weight and space, the latter is loses efficiency between the various motors but seems a promising possibility as technology develops.⁷⁴

As should now be obvious, there are numerous changes currently appearing or under development in the world of LNG shipment. In addition to those outlined above are many, often highly technical, improvements which have recently come on the scene as well as many new theories. Taken together, all the changes represent a new era for the industry, which was perhaps best summarized by *The Naval Architect* like this:

[S]hip sizes up to 150,000m³ are being considered for the future in various parts of the world, as demand for gas increases rapidly. At the same time, the gas industry is seeking new goals of cost reduction, much more flexible operation, reliability and a 'green image'. Clearly, technically exciting times lie ahead, and the way seems open for a totally new era of LNG tankers, both in type and size.⁷⁵

c. End of the line—the terminal

Existing LNG terminals in the U.S. are old and were not designed for the capacities expected in the foreseeable future. Not only will equipment such as mooring lines and connection hoses need to be upgraded, but deeper channels will have to be dredged and wider safety zones will have to be maintained.

⁷³ Future LNG tanker design firming up, *Supra*.

⁷⁴ *Id.*

⁷⁵ *Id.*

Larger ships will require larger onshore storage tanks which, in turn, will require bigger retaining walls and safety perimeters. Larger cargoes also bring greater variance in the event of bad weather or other situations which delay delivery.⁷⁶ One very promising solution to the storage problem is known as the Bishop Process, which has gained support from the government.⁷⁷ This idea—which has never been put into actual practice—is to pump slightly pressurized LNG into salt caverns, where it may be stored until needed.⁷⁸ However, at this time there are no confirmed reports of serious plans to implement the practice.

Although change to existing terminals is significant, the major buzz in the world of LNG importing into the U.S. focuses on the construction of new terminals. With some 30 new sites currently under some stage of development, it is clear that creating new capacity is a major topic. Exemplary of the trend, is Cheniere Energy, which has been working hard in recent years to overcome the regulatory hurdles associated with new facilities.⁷⁹ Cheniere, which is working with ExxonMobil and Sempra Energy, plans to provide terminal facilities not only for those companies locked into long-term supply, but also those seeking to sell spot cargo.⁸⁰ Headed up by Lebanese immigrant Charif Souki, Cheniere plans to build several facilities, mostly on the Gulf Coast, despite the threat of major

⁷⁶ Cho, *Supra*.

⁷⁷ *DOE Touts Bishop Process for LNG Terminals*, LNG Insight, Vol. 1 Issue 2 Aug. 2003.

⁷⁸ *Id.*

⁷⁹ Cilfford Krauss, *A Big Bet on Natural Gas*, N.Y. Times, Oct. 4, 2006

⁸⁰ *Id.*

storms.⁸¹ According to Mr. Souki, the Gulf and the areas it services comprise a major market and systems can be built to withstand the threat posed by Mother Nature.⁸²

III. Conclusion

a. legal implications

Given the changing times, maintaining a relationship between parties over the course of a long contract term is a major concern. Companies enter long-term contracts because they do not wish to bear the risk of uncertainty in future markets, but, ironically, long-term contracts may cause more difficulty than they avoid. Unpredictable costs for labor or infrastructure could easily sweeten a deal for one party and sour it for another. Over longer periods of time, catastrophic events and political changes are more likely to be an issue. While force majeure clauses will provide some protection, there is no guarantee of their effectiveness as different courts look on such clauses with varying perspectives. Even domestically, unforeseen changes have caused major problems for long-term energy contracts, as was the case in Eastern Airlines v. Gulf Oil.⁸³ In that case, the federal government changed its method for calculating the index used by the parties for fuel pricing.⁸⁴ When such a scenario divides international parties, the outcome is much less certain. Similarly, a major technological

⁸¹ *Id.*

⁸² *Id.*

⁸³ Eastern Air Lines, Inc. v. Gulf Oil Corp., 415 F.Supp 429, (S.D. Fla. 1975).

⁸⁴ *Id.*

breakthrough could fundamentally alter the economics of a deal and possibly entice one party to seek avoidance of a contract or contract terms. Furthermore, because foreign energy concerns are typically government-owned enterprises, conflicts of interest might arise where local rulings go against those of international courts. This was the case in Karaha Bodas Company v. Perusahaan Pertambangan Minyak Dan gas Bumi Negara, where an Indonesian court “asserted jurisdiction over an arbitration the parties had explicitly sought to isolate from its power, and then annulled an award on unpredictable and unprincipled grounds.”⁸⁵ As the industry develops, all of these concerns will need to be thought out carefully and in great detail by those in the legal profession as well as investors.

LNG presents an awesome opportunity to realize profits, but any interested party is well-advised to proceed with caution. Contract terms should be spelled out in great detail and cover all possible scenarios. In the event of changing circumstances, parties should know what the exit strategy is and what the penalty for it will be in terms of money and future dealings. The prudent investor should also be sure that there is some real way to recoup a loss from a failed deal or favorable judgment. If, for example, the foreign party has no assets reachable by a domestic or international court, the investor might seek some explicit security to mitigate risk.⁸⁶

⁸⁵ Noah Rubins, *The enforcement and Annulment of International Arbitration Awards in Indonesia*, 20 Am. U. Int'l L. Rev. 359, 363 (2005) (Citing generally, *Karaha Bodas Company v. Perusahaan Pertambangan Minyak Dan gas Bumi Negara*, 335 F.3d 357, 360-63 (5th Cir. 2003).

⁸⁶ *Id.*

b. Final thoughts

“Technical advances and economies of scale have seen LNG facilities costs fall substantially in the last 30 years. This and a sharp increase in the number of competing gas-supply projects have several important financial and legal implications for project owners, operators and finance providers.”⁸⁷

This Petroleum Economist headline exemplifies what any decision maker in the LNG industry should be thinking about now. LNG contracts are growing more sophisticated and cost structure is changing.⁸⁸ Fueled by technology and changing prices, the industry is expanding and becoming more competitive. When all the advances are added up, cost for liquefaction have been halved since the 1980's and that of shipping is down about 63% in the same time period.⁸⁹ At some point, it will be most economically efficient to break existing long-term contracts and pay damages because of the possible benefits of newer deals.⁹⁰

Even with the risks, the future for LNG looks bright. Many of the potential problems mentioned above will abate as the new market settles. Piece of mind is also gleaned from the fact that the growing market means a dispute in one part of the world can be offset if an investor looks elsewhere. Ultimately, the basic rules of economics must be trusted. There is a supply of something in one place and a demand for it somewhere else. Although it might take some finesse and good lawyering, the market will see to it that supply meets the demand.

⁸⁷ Steven A. Wardlaw & Pooya Alai, *Up the learning curve, down the cost curve*, Petroleum Economist (Nov. 2004).

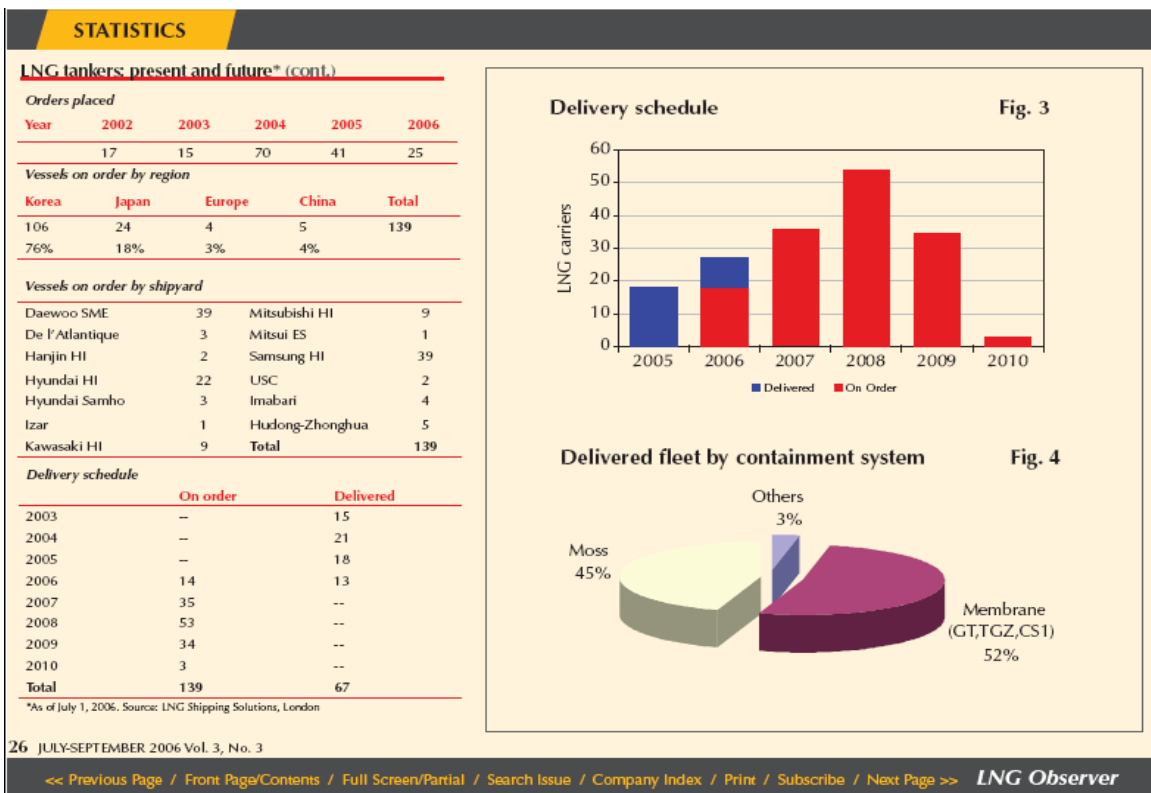
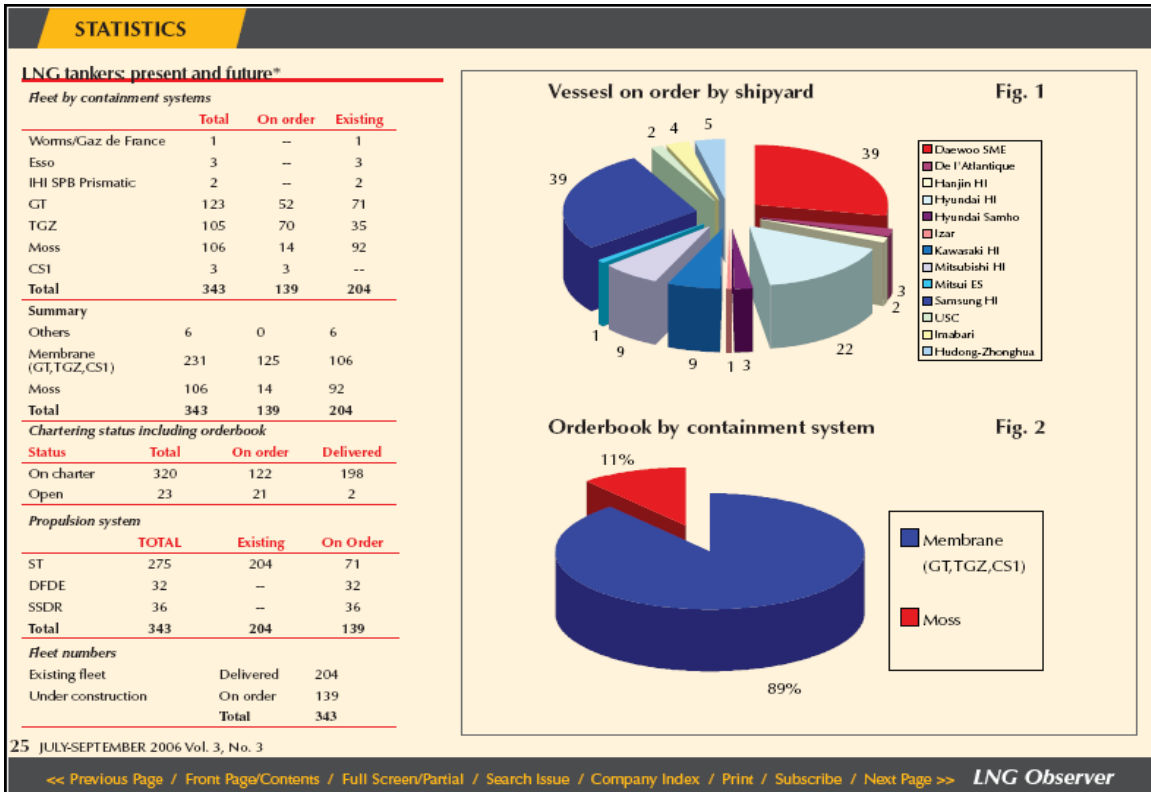
⁸⁸ *Id.*

⁸⁹ *Id.*

⁹⁰ *Id.*

Appendix 1: LNG Tanker Statistics

Source: LNG Observer



Appendix 2: Gas Import/exports

Source: EIA

Table 6.3 Natural Gas Imports, Exports, and Net Imports, Selected Years, 1949-2005
(Billion Cubic Feet, Except as Noted)

Year	Imports by Country of Origin									Exports by Country of Destination				Net Imports ¹	
	Algeria ²	Australia ²	Canada ³	Mexico ³	Nigeria ²	Oman ²	Qatar ²	Trinidad and Tobago ²	Total ⁴	Canada ³	Japan ²	Mexico ³	Total	Total	Percent of U.S. Consumption
1949	0	0	0	0	0	0	0	0	0	(s)	0	20	20	-20	(⁵)
1950	0	0	0	0	0	0	0	0	0	3	0	23	26	-26	(⁵)
1955	0	0	11	(s)	0	0	0	0	11	11	0	20	31	-20	(⁵)
1960	0	0	109	47	0	0	0	0	156	6	0	6	11	144	1.2
1965	0	0	405	52	0	0	0	0	456	18	0	8	26	430	2.8
1970	1	0	779	41	0	0	0	0	821	11	44	15	70	751	3.6
1971	1	0	912	21	0	0	0	0	935	14	50	16	80	854	3.9
1972	2	0	1,009	8	0	0	0	0	1,019	16	48	15	78	941	4.3
1973	3	0	1,028	2	0	0	0	0	1,033	15	48	14	77	956	4.3
1974	0	0	959	(s)	0	0	0	0	959	13	50	13	77	882	4.2
1975	5	0	948	0	0	0	0	0	953	10	53	9	73	850	4.5
1976	10	0	954	0	0	0	0	0	964	8	50	7	65	899	4.5
1977	11	0	997	2	0	0	0	0	1,011	(s)	52	4	56	955	4.9
1978	84	0	881	0	0	0	0	0	966	(s)	48	4	53	913	4.7
1979	253	0	1,001	0	0	0	0	0	1,253	(s)	51	4	56	1,198	5.9
1980	86	0	797	102	0	0	0	0	985	(s)	45	4	49	936	4.7
1981	37	0	782	105	0	0	0	0	924	(s)	56	3	59	845	4.4
1982	55	0	783	95	0	0	0	0	933	(s)	50	2	52	882	4.9
1983	131	0	712	75	0	0	0	0	918	(s)	53	2	55	864	5.1
1984	36	0	755	52	0	0	0	0	843	(s)	53	2	55	788	4.4
1985	24	0	926	0	0	0	0	0	950	(s)	53	2	55	894	5.2
1986	0	0	749	0	0	0	0	0	750	0	50	2	61	859	4.2
1987	0	0	993	0	0	0	0	0	993	3	49	2	54	939	5.5
1988	17	0	1,276	0	0	0	0	0	1,294	20	52	2	74	1,220	6.8
1989	42	0	1,339	0	0	0	0	0	1,382	38	51	17	107	1,275	6.7
1990	54	0	1,448	0	0	0	0	0	1,532	17	53	16	86	1,447	7.5
1991	84	0	1,710	0	0	0	0	0	1,773	15	54	80	129	1,644	8.4
1992	43	0	2,094	0	0	0	0	0	2,138	68	53	96	216	1,921	9.5
1993	82	0	2,267	2	0	0	0	0	2,350	45	56	40	140	2,210	10.6
1994	51	0	2,596	7	0	0	0	0	2,624	53	63	47	162	2,462	11.6
1995	16	0	2,316	7	0	0	0	0	2,341	26	65	61	154	2,657	12.1
1996	35	0	2,883	14	0	0	0	0	2,937	52	68	34	153	2,784	12.3
1997	66	10	2,899	17	0	0	0	0	2,994	56	62	38	157	2,837	12.5
1998	69	12	3,052	15	0	0	0	0	3,152	40	66	53	159	2,993	13.5
1999	76	12	3,368	55	0	0	20	51	3,586	39	64	61	163	3,422	15.3
2000	47	6	3,544	12	13	10	46	99	3,782	73	66	106	244	3,538	15.2
2001	65	2	3,729	10	38	12	23	98	3,977	167	66	141	373	3,604	16.2
2002	27	0	3,785	2	8	3	35	151	4,015	189	63	263	516	3,499	15.2
2003	53	0	R3,437	0	50	9	14	378	R3,944	R271	R66	R343	R680	R3,264	R14.7
2004	120	15	3,807	0	12	9	12	462	4,259	395	62	397	854	3,404	R15.2
2005P	97	0	3,654	1	8	2	3	439	4,285	364	65	358	787	3,498	15.9

¹ Net imports equal imports minus exports.

² As liquefied natural gas.

³ By pipeline, except for very small amounts of liquefied natural gas imported from Canada in 1973, 1977, and 1981 and exported to Mexico beginning in 1998.

⁴ Included in the total but not shown separately are liquefied natural gas imports from Brunei in 2002; Egypt in 2005; Indonesia in 1986 and 2000; Malaysia in 1999 and 2002 forward; and United Arab Emirates in 1996-2000.

⁵ Not meaningful because there were net exports during this year.

R=Revised. P=Preliminary. (s)=Less than 0.5 billion cubic feet.

Note: Totals may not equal sum of components due to independent rounding.

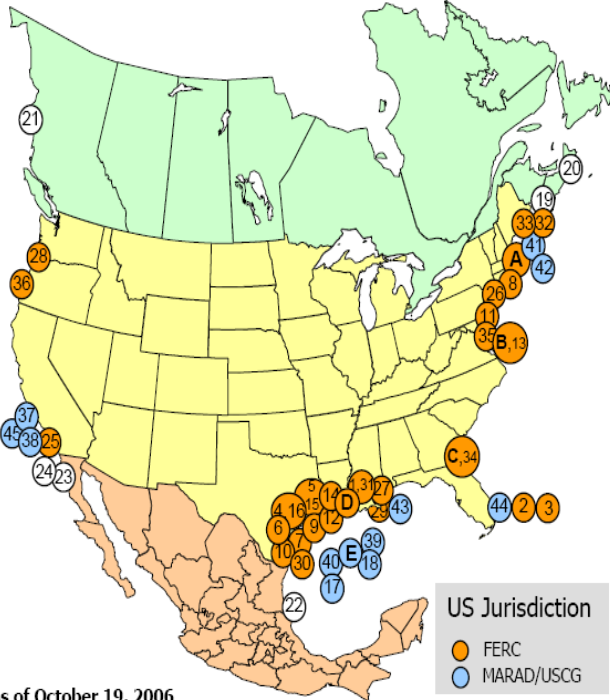
Web Pages: • For data not shown for 1951-1988, see <http://www.eia.doe.gov/emeu/aer/natgas.html>.

• For related information, see http://www.eia.doe.gov/oil_gas/natural_gas/info_glance/natural_gas.html.

• Sources: Percent of U.S. Consumption: Calculated. All Other Data: • 1949-1954—Energy Information Administration (EIA), Office of Oil and Gas, Reserves and Natural Gas Division, unpublished data. • 1955-1971—EIA, Federal Power Commission, by telephone. • 1972-1987—EIA, Form FPC-14, "Annual Report for Importers and Exporters of Natural Gas." • 1988-2000—EIA, *Natural Gas Annual*, annual reports. • 2001 forward—EIA, *Natural Gas Monthly* (March 2006), Table 6.

FERC

Existing and Proposed North American LNG Terminals



As of October 19, 2006

* US pipeline approved; LNG terminal pending in Bahamas
** Construction suspended

Office of Energy Projects

CONSTRUCTED

- A. Everett, MA : 1.035 Bcfd (SUEZ/Tractebel - DOMAC)
- B. Cove Point, MD : 1.0 Bcfd (Dominion - Cove Point LNG)
- C. Elba Island, GA : 1.2 Bcfd (El Paso - Southern LNG)
- D. Lake Charles, LA : 2.1 Bcfd (Southern Union - Trunkline LNG)
- E. Gulf of Mexico: 0.5 Bcfd (Gulf Gateway Energy Bridge - Excelerate Energy)

APPROVED BY FERC

- 1. Hackberry, LA : 1.5 Bcfd (Cameron LNG - Sempra Energy)
- 2. Bahamas : 0.84 Bcfd (AES Ocean Express)*
- 3. Bahamas : 0.83 Bcfd (Calypso Tractebel)*
- 4. Freeport, TX : 1.5 Bcfd (Cheniere/Freeport LNG Dev.)
- 5. Sabine, LA : 2.6 Bcfd (Sabine Pass Cheniere LNG)
- 6. Corpus Christi, TX : 2.6 Bcfd (Cheniere LNG)
- 7. Corpus Christi, TX : 1.1 Bcfd (Vista Del Sol - ExxonMobil)
- 8. Fall River, MA : 0.8 Bcfd (Weaver's Cove Energy/Hess LNG)
- 9. Sabine, TX : 2.0 Bcfd (Golden Pass - ExxonMobil)
- 10. Corpus Christi, TX : 1.0 Bcfd (Ingleside Energy - Occidental Energy Ventures)
- 11. Logan Township, NJ : 1.2 Bcfd (Crown Landing LNG - BP)
- 12. Port Arthur, TX : 3.0 Bcfd (Sempra)
- 13. Cove Point, MD : 0.8 Bcfd (Dominion)
- 14. Cameron, LA : 3.3 Bcfd (Creole Trail LNG - Cheniere LNG)
- 15. Sabine, LA : 1.4 Bcfd (Sabine Pass Cheniere LNG - Expansion)
- 16. Freeport, TX : 2.5 Bcfd (Cheniere/Freeport LNG Dev. - Expansion)

APPROVED BY MARAD/COAST GUARD

- 17. Port Pelican: 1.6 Bcfd (Chevron Texaco)
- 18. Louisiana Offshore : 1.0 Bcfd (Gulf Landing - Shell)

CANADIAN APPROVED TERMINALS

- 19. St. John, NB : 1.0 Bcfd (Canaport - Irving Oil)
- 20. Point Tupper, NS : 1.0 Bcfd (Bear Head LNG - Anadarko)
- 21. Kitimat, BC : 0.61 Bcfd (Galveston LNG)

MEXICAN APPROVED TERMINALS

- 22. Altamira, Tamulipas : 0.7 Bcfd (Shell/Total/Mitsui)
- 23. Baja California, MX : 1.0 Bcfd (Energy Costa Azul - Sempra)
- 24. Baja California - Offshore : 1.4 Bcfd (Chevron Texaco)

PROPOSED TO FERC

- 25. Long Beach, CA : 0.7 Bcfd, (Mitsubishi/ConocoPhillips - Sound Energy Solutions)
- 26. LI Sound, NY : 1.0 Bcfd (Broadwater Energy - TransCanada/Shell)
- 27. Pascagoula, MS : 1.5 Bcfd (Gulf LNG Energy LLC)
- 28. Bradwood, OR : 1.0 Bcfd (Northern Star LNG - Northern Star Natural Gas LLC)
- 29. Pascagoula, MS : 1.3 Bcfd (Casotte Landing - ChevronTexaco)
- 30. Port Lavaca, TX : 1.0 Bcfd (Calhoun LNG - Gulf Coast LNG Partners)
- 31. Hackberry, LA : 1.15 Bcfd (Cameron LNG - Sempra Energy - Expansion)
- 32. Pleasant Point, ME : 2.0 Bcfd (Quoddy Bay, LLC)
- 33. Robbinston, ME : 0.5 Bcfd (Downeast LNG - Kestrel Energy)
- 34. Elba Island, GA : 0.9 Bcfd (El Paso - Southern LNG)
- 35. Baltimore, MD : 1.5 Bcfd (AES Sparrows Point - AES Corp.)
- 36. Coos Bay, OR : 1.0 Bcfd (Jordan Cove Energy Project)

PROPOSED TO MARAD/COAST GUARD

- 37. Offshore California : 1.5 Bcfd (Cabrillo Port - BHP Billiton)
- 38. Offshore California : 0.5 Bcfd, (Clearwater Port LLC - NorthernStar NG LLC)
- 39. Offshore Louisiana : 1.0 Bcfd (Main Pass McMoran Exp.)
- 40. Gulf of Mexico: 1.5 Bcfd (Beacon Port Clean Energy Terminal - ConocoPhillips)
- 41. Offshore Boston: 0.4 Bcfd (Neptune LNG - SUEZ LNG)
- 42. Offshore Boston: 0.8 Bcfd (Northeast Gateway - Excelerate Energy)
- 43. Gulf of Mexico: 1.4 Bcfd (Bienville Offshore Energy Terminal - TORP)
- 44. Offshore Florida: ? Bcfd (SUEZ Calypso - SUEZ LNG)
- 45. Offshore California: 1.2 Bcfd (OceanWay - Woodside Natural Gas)