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CHALLENGES OF LNG (LIQUEFIED NATURAL GAS) CARRIERS IN 21st CENTURY

ABSTRACT

Natural gas is relatively cheap, environmentally friendly and energetically efficient fossil fuel that is gaining in attractiveness daily as it can be used in many sectors. As not all consumers can be reached by pipelines the technique of transporting natural gas in the liquefied form has been developed at the beginning of 20th century but it was only in 1959 that the first overseas transport of liquefied natural gas (LNG) occurred. In the fifty years of operation LNG shipping has shown immaculate safety records. LNG tankers can be described only in superlatives; they are without any doubt the most sophisticated and expensive ships that sail around the globe, they demand special attention when navigating to or out of harbours and need to be manned with the most educated and experienced crew. LNG market is expanding and changing; demand is surpassing the productivity, new importing and exporting countries appear, LNG fleet is growing in capacity and number at high pace, exploitation contracts for the ships are being modified giving the opportunity for new companies to enter (…). The paper gives an overview on liquefied natural gas market and the historic development of LNG shipping. It focuses on the recent boom in LNG shipping and emphasises questions concerning the safety, crewing and exploitation of the LNG tankers in the future.

KEY WORDS

natural gas, LNG carriers, LNG tankers, natural gas market

1. INTRODUCTION

Having in mind the problems of production, consumption, ecology, distribution, safety (…) of energetic resources, transport capacities, transport technologies in general and particularly those concerning the transportation of liquefied natural gas it is possible to state the problem of the present paper: the increased demand and consumption of natural gas has imposed many scruples to ship-owners which can imply increased investments in liquefied natural gas (LNG) ship capacities, improvement of handling and transportation technologies and finally aggravation of competition on global maritime market.

In accordance with the problem of this paper it is possible to define the topic of the research. It is: investigation and determination of the rules on production, export and import of natural gas, the rules on supply and demand of LNG vessel capacities, the rules on LNG transportation technologies and their safety and finally considerations on LNG shipping in 21st century.

The problem and the topic of the paper refer to two objects of investigation: natural gas and LNG ships.

The problem, topic and objects of the research present the basis to impose the fundamental hypothesis, which is: scientific knowledge on the production and distribution of natural gas, knowledge acquired about supply and demand of LNG shipping capacities and knowledge about natural gas transportation quantities, all of which represent *condition sine qua non* in considering LNG shipping in 21st century.

2. IMPORTANT CHARACTERISTICS OF NATURAL GAS MARKET

2.1 Main characteristics of natural gas

Natural gas is a fossil fuel mainly composed of methane but can also contain other gaseous hydrocarbons[1] as well as carbon dioxide, nitrogen and some noble gases which is found in reservoirs beneath the earth surface as an accompanying product in oil fields but also in autonomous natural gas fields or in coal beds. Natural gas must undergo extensive processing before becoming economically useful and was as such for a long time considered as useless by-product in oil industry.

Natural gas is cheaper and cleaner and thus environmentally friendlier than any other known fossil fuel; it has high heating capacity (> 10KWh/m^3) and its reserves are abundant and widely distributed. The use of natural gas is heterogeneous; it can be used as a source for electricity generation, as a fuel source for vehicles (hydrogen vehicles or natural gas – methane not only road vehicles but also for airplanes and ships), as a fertilizer, in various industries such as chemical industry or glass industry or can be supplied to homes for purposes of heating and cooking.

When natural gas is at atmospheric pressure cooled to temperatures around minus 161°C it condenses into colourless, odourless, non-toxic, non-corrosive and non-carcinogenic liquid. In liquefied state natural gas occupies only 1/600 of the volume of its gaseous state, so it is stored more effectively and transported more economically. Natural gas is commonly measured in metric tons when it is a liquid and in cubic feet when it is in its gaseous state.[2]

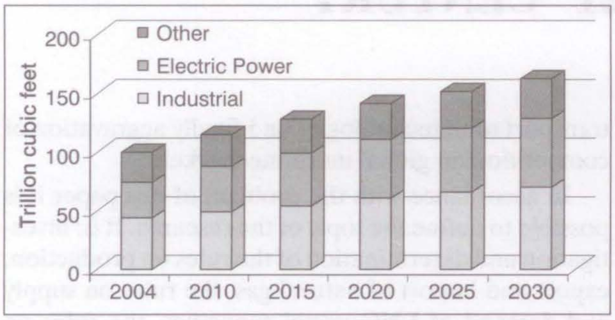
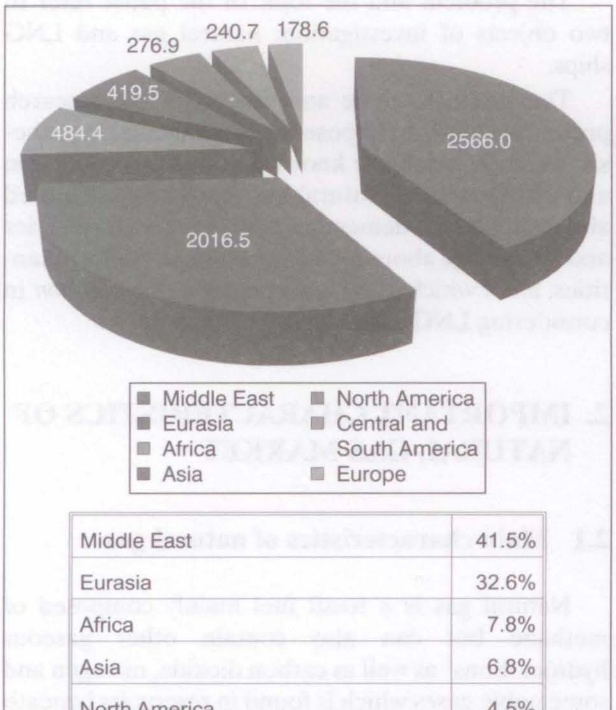


Figure 1 - World natural gas consumption by end-use sector, 2004-2030 [3]

Note: 1 trillion = 10^{12}, 1 m^3 = 35.314667 cubic feet, 1 cubic feet = 0.028317 m^3



Middle East	41.5%
Eurasia	32.6%
Africa	7.8%
Asia	6.8%
North America	4.5%
Central and South America	3.9%
Europe	2.9%

Figure 2 - World natural gas reserves by regions as of January 1, 2007 (in trillion cubic feet) [3]

Natural gas is measured in MMBtu[3] and the price for 1 MMBtu was around US$ 9 - 10 in March 2008. Just for comparison, in the same period, the price of crude oil was around 18 US$ per MMBtu [4].

2.2 Main locations of natural gas

The largest natural gas reserves are found in the Persian Gulf (Iran and Qatar) and in Russia (all three together are in possession of around two thirds of the known reserves). The world natural gas reserves are approximately 6,200 trillion cubic feet and since 1980 these reserves have more than doubled [5].[4]

The production of natural gas is most abundant in Russia, the United States of America and Canada. Indonesia is the world's largest LNG producer, exporting about one-fifth of the world's total volume in 2002. Most of Indonesia's LNG is imported by Japan with smaller volumes going to Taiwan and South Korea [6].

When possible, natural gas is under high pressure quickly and efficiently transported by widely spread pipelines. For final distribution the pressure is lowered and the pipelines are altered. International trade in pipeline gas is expected to grow as the conversion from oil and nuclear energy to natural gas gains momentum in Europe [7]. But it often happens that production regions are separated from consumption regions by oceans making the construction of pipelines difficult and expensive. So, in the absence of pipeline infrastructure, most of the demand for natural gas has to be fulfilled by liquefying gas and supplying it as liquefied natural gas or LNG. Liquefying natural gas is a competitive means of transporting it even if there is a possibility to build pipelines as liquefying natural gas and shipping it becomes cheaper than transporting natural gas in offshore pipelines for distances of more than 700 miles or in onshore pipelines for distances greater than 2,200 miles [8].

2.3 Analyses of LNG exports

The first LNG plant was built in West Virginia in 1912. Today, there are 26 existing export, so-called liquefaction marine terminals, located in 15 countries (see Table 1) and there are some 65 liquefaction marine terminal projects in preparation or under construction [9].

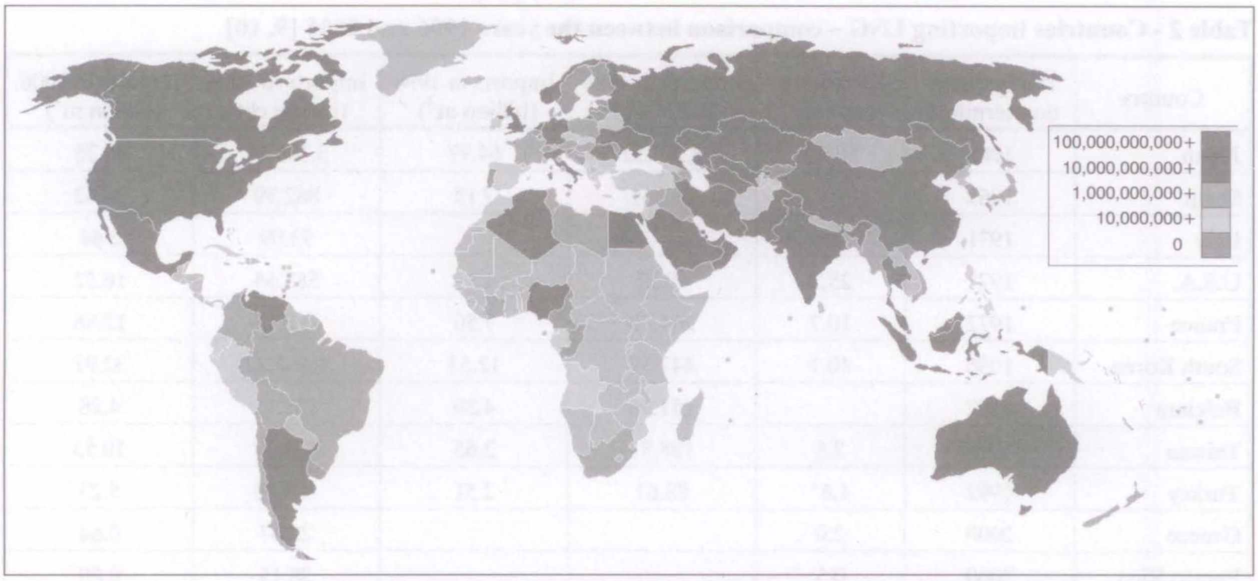


Figure 3 - Map of natural gas production in cubic meters per year [2]

Note: 100,000,000,000 cubic meters correspond to around 3.53 trillion cubic feet

Table 1 - Countries exporting LNG [9]

Country	1st liquefaction terminal
United States of America	1969
Libya	1970
Algeria	1971
Brunei	1972
Indonesia	1977
United Arab Emirates	1977
Malaysia	1983
Australia	1989
Qatar	1997
Nigeria	1999
Trinidad and Tobago	1999
Oman	2000
Egypt	2004
Equatorial Guinea	2007
Norway	2007

2.4 Analyses of LNG imports

Some countries, for example Japan, favour the use of natural gas for the industrial and domestic purposes although they do not have any natural gas resources. In the past the majority of natural gas trading activities were concentrated in the Pacific Basin, where in 2002 three countries, namely Japan, South Korea and Taiwan imported 68% of the total LNG trade. But lately the trade is becoming more present also in the Atlantic region as the United States and West European countries (see Figure 4) have recognized the benefits of natural gas usage.

At the moment there are 60 existing import, so-called regasification, marine terminals located in 17 countries (see Table 2). In addition to these existing terminals 182 regasification terminal projects have been either proposed or are under construction all around the world but it is not expected that all of the proposed terminals will be constructed [9].

The Asian region is the main importer of LNG, followed by Europe but the import of LNG records the biggest growth in the USA (see Table 2). The Asian countries import the majority of LNG from Indonesia, Malaysia, Australia, Qatar and Oman while Europe mainly imports LNG from Algeria, Nigeria, Egypt and Qatar as can be seen in Figure 4.[5]

The trade flows register considerable oscillations during the year; in winter season there is regularly higher demand for natural gas than during the rest of the year as can be seen in the Figure 5 which shows the number of sailings. This is the reason why unused quantities have to be stored in the summer season and unemployed LNG tankers can be used for that purpose as well. In such way they are employed during off-peak seasons.

LNG trade accounted for about 6% of world natural gas consumption and about 26 % of total international natural gas trade in 2002 [6]. But this ratio has changed in recent years and will change even more to the advantage of LNG as there are many potential countries such as Angola, Iran, Russia, Venezuela or Yemen and potential import countries, e. g. Bahamas, Brazil, Finland, Jordan and Lebanon [12].[6]

Table 2 - Countries importing LNG – comparison between the years 1996 and 2006 [9, 10]

Country	1st regasification terminal	Terminal's capacity	Imports in 1996 (billion cbf)	Imports in 1996 (billion m³)	Imports in 2006 (billion cbf)	Imports in 2006 (billion m³)
Japan	1969	188.3	2,294.52	64.97	3,135.11	88.78
Spain	1969		252.61	7.15	862.39	24.42
Italy	1971	2.6			93.09	2.64
U.S.A.	1971	25.2	40.27	1.14	583.54	16.52
France	1972	10.7	264.76	7.50	490.17	13.88
South Korea	1986	40.7	442.57	12.53	1,162.22	32.91
Belgium	1987		151.96	4.30	151.15	4.28
Taiwan	1990	7.5	128.81	3.65	372.47	10.55
Turkey	1992	4.6*	88.61	2.51	184.70	5.23
Greece	2000	2.0			22.67	0.64
Puerto Rico	2000	0.5			28.15	0.80
Dominican R.	2003	2.0			10.77	0.30
Portugal	2003	3.3			73.46	2.08
India	2004	5*			253.81	7.19
U.K.	2005*	3.3			120.04	3.40
China	2006	3.3			35.32	1.00
Mexico	2006				47.50	1.35
Total			3,664.11	103.76	7,626.56	215.96

Note: * In 1964 the United Kingdom was the first country to import LNG but the terminal on Canvey Island was removed in 1990 following the arrival of North Sea oil and gas. Terminals capacity as in 2002, in million tons; cbf – cubic feet

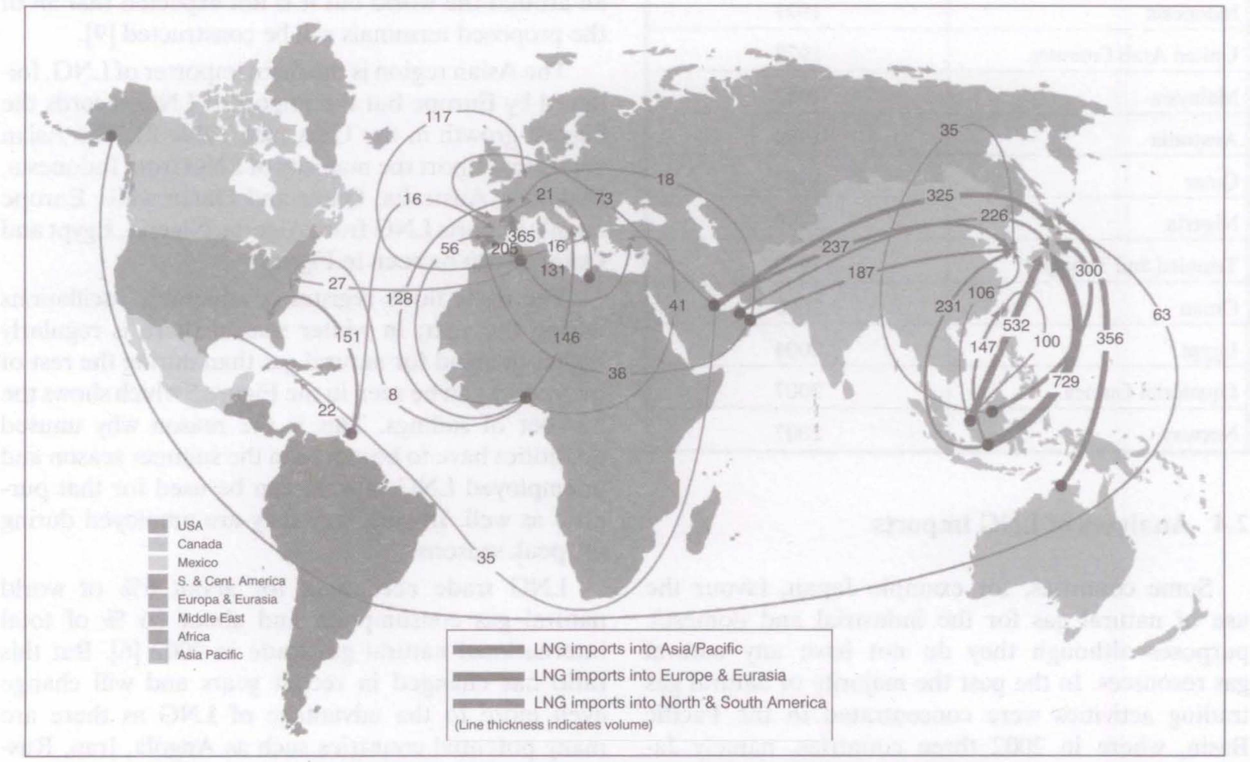


Figure 4 - Major LNG trade movements (in billion cubic feet) [6]

Note: The map comprises only flows greater than 5 billion cubic feet (Bcf) for imports into the United States, and flows greater than 15 Bcf for imports into all other countries.

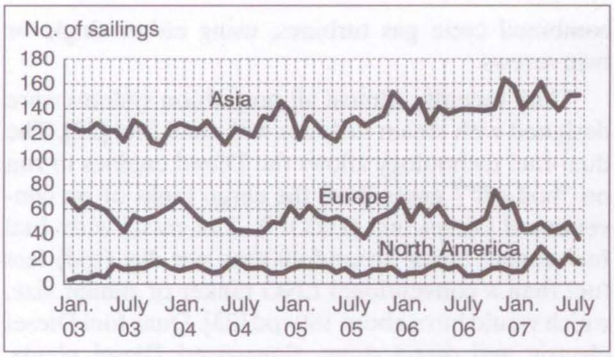


Figure 5 - Review of LNG imports throughout the years [11]

3. ANALYSES AND ESTIMATION OF LNG CARRIERS OPERATION

3.1 The development of LNG fleet

Godfrey Cabot patented a barge to carry liquefied gas in 1914 but there is no evidence that the barge was actually constructed. In 1959 "Methane pioneer", a converted cargo ship, demonstrated the possibility of waterborne liquefied gas transportation by performing the first waterborne liquefied gas voyage from Lake Charles, Louisiana, USA to Canvey Island, UK. Five years later, the first commercial LNG vessels were built; "Methane Princess" and "Methane Progress" which operated between Algeria and the UK. The following years registered huge development of liquefied gas transportation in terms of vessels volumes, safety and technology.

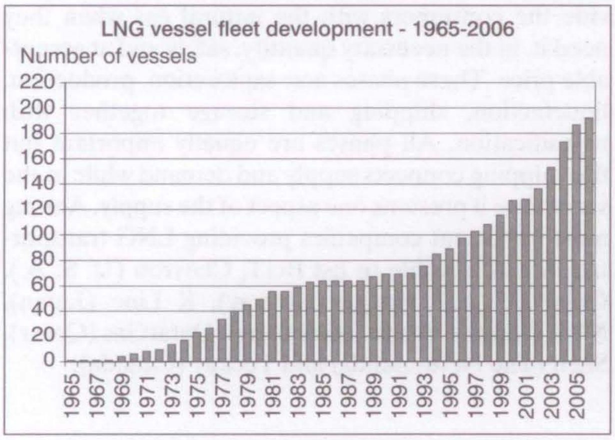


Figure 6 - LNG vessel fleet development: 1965-2006 [13]

Source: LNG Shipping Solutions

After the notable growth of the fleet in the 70s, the development of LNG fleet was in stagnation during the 80s. But since the beginning of the 90s the fleet is in expansion again, with the highest growth rate recorded in the new millennium. The development of the fleet was tightly connected to the energetic crises that the world faced.

The 70s had been years of expansion for LNG, and by the end of the decade Japan was receiving LNG from Alaska, Brunei, Abu Dhabi, and two Indonesian plants, all under long-term take-or-pay contracts[7] closely tied to crude oil prices. But the second oil shock of 1979 and the restructuring it engendered set back demand in Japan. The buyers, particularly the power companies, found out just how rigid those long-term take-or-pay contracts could be. They took the full volumes, but were not happy because LNG became difficult to sell. The Australian project did not come on stream until 1989, after significant delays. By that time oil prices had dropped, Japan had recovered, and power demand in the country was growing so rapidly that it could be met only by building gas-fired power plant. Suddenly LNG was in demand again. Korea, in 1986, and Taiwan (China), in 1990, had begun to take LNG, having bought incremental capacity from the Indonesian plants. The Korean market began growing at a phenomenal rate [15].

The following table presents the structure of LNG fleet by age and size.

Table 3 - Structure of LNG fleet in November 2007 [11]

	< 100,000m³		> 100,000m³		Total	
	No.	Capacity	No.	Capacity	No.	Capacity
Age						
Unclassified	1	0.08	25	4.19	26	4.27
0-4	7	0.18	108	15.78	115	15.96
5-9	3	0.11	32	4.40	35	4.51
10-14	6	0.29	26	3.44	32	3.73
15-19	0	0.00	7	0.90	7	0.90
20-24	1	0.00	8	1.01	9	1.02
25+	18	1.06	29	3.70	47	4.76
Total	36	1.72	235	33.43	271	35.15
Idle	3	0.12	26	4.32	29	4.44
Active fleet	33	1.60	209	29.11	242	30.71

Note: Capacity in million m³

As the demand for natural gas has been growing the LNG fleet was expanding rapidly in the last decade (which can be seen in the above Table: 150 out of 242 active tankers or 62% of the LNG tankers are less than 10 years old; 182 out of active 242 tankers or 75% of the LNG tankers are less than 15 years old) and is expected to continue so until at least 2010 when it should reach the number of 320 [16]. The LNG fleet saw record growth in 2006 with 27 new vessels delivered, expanding capacity by 16.6%. Further 14 deliveries in the first half of 2007 have added another 7.6% to capacity [17].

Even though there is a trend of ordering large-capacity LNG tankers there is also a market for smaller and cheaper LNG tankers which can serve remote industrial zones or regions without pipelines.

3.2 Development of LNG transportation technology

Since the Methane Pioneer, a converted vessel with 4,500m^3 capacity a lot has been done in the sector of LNG transportation.

Ships have grown to a size of over 200,000m^3, reaching the amazing 265,000m^3 with Q-max[8] series as the demand for natural gas grows and the phenomena of economy of scale becomes essential in the waterborne liquefied natural gas. For this reason the vast majority of newbuilding LNG tankers have membrane type tanks that have an important increase in total loading capacity plus the faster cool-down of tanks compared to the Moss spherical containment system.

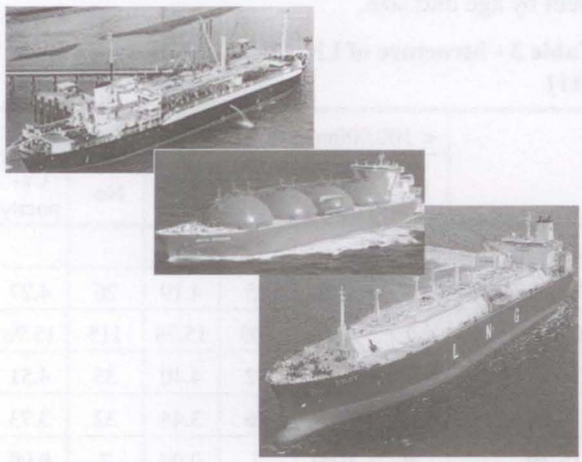


Figure 7 - The development of LNG transportation technology [19, 20, 21]

Parallel to the development of the size of LNG tankers the development of their hull and propulsion continued. LNG tankers use slow-speed Diesel engines, steam turbines, dual fuel, Diesel electric or combined cycle gas turbines, using either single or twin screws.

Until recently, almost all propulsion systems were designed with steam turbines with dual fuel [22]. The dual-fuel technology allows the Diesel engines to run on "boil-off"[9] gases from the cargo tanks or on conventional Diesel fuel (HFO[10]). The vessel with dual fuel engine burns around 40 tons per day (tpd) less fuel than a conventional LNG tanker of similar size, which would burn about 180 tpd [23]. Dual-fuel Diesel electric and direct drive, slow-speed Diesel plants, coupled with an on-board re-liquefaction plant to handle the cargo boil-off, appear to offer operational efficiencies for new designs. However, there is no single obvious propulsion system of choice. The choice depends on numerous factors such as gas price or trade route among others [24].

Due to the increase in cost of LNG, it is proposed to use alternative propulsion means in newbuilding LNG tanker although the usage of LNG as engine fuel is environmentally friendly which is important especially now, when the leaked United Nations report revealed the fact that the shipping industry causes around three times more CO_2 emissions than thought earlier, reaching 1.12 billion tons which is nearly 4.5% of all global emissions of the main greenhouse gas [25].

3.3 The analyses of supply and demand for LNG shipping capacities

LNG supply chain consists of four segments or phases which have to be harmonized in order to provide the consumers with the natural gas when they need it, in the necessary quantity, safely and at acceptable price. These phases are: exploration, production, liquefaction, shipping and storage together with regasification. All phases are equally important but the shipping connects supply and demand while at the same time it presents one aspect of the supply. Among most important companies providing LNG transportation it is possible to list BGT, Chevron (U. S. A.), Golar (U. K.), Hoegh (Norway), K Line (Japan), NYK (Japan), Pronav (Germany), QatarGas (Qatar), Shell (The Netherlands) and Teekay (Canada).

Table 4 - Emissions from LNG carriers [26]

	Fuel	NO_x	SO_x	CO_2
Steam turbine	HFO + LNG	200	2,400	180,000
Low speed diesel + re-liquefaction	HFO	3,950	1,800	120,000
Dual fuel electric	LNG only	240	0	100,000
Gas turbines	LNG only	850	0	108,000

Source: ALSTOM Emissions: Tonnes / year / ship

LNG tankers are very expensive as is the cargo that they carry. The newbuilding price for a conventional size LNG tanker remained above US$220 million at the end of 2007 upon a combination of factors including continued strong demand, high steel prices, heavy utilization of shipyard capacities and exchange rates. Q-flex[11] orders are priced around US$250 million and Q-max orders around US$300 million [27]. But the demand is rising at the moment and is forecast to rise in the future as well making such ships a profitable investment. The reasons for the increased demand can be found in the global economic growth followed by increased energy demand, environmental consciousness and finally dropped LNG prices due to dropped cost of liquefaction and regasification that resulted from technological improvements and more competing market.

3.4 Safety of LNG transportation

LNG hazards result from three of its properties: cryogenic[12] temperatures, dispersion characteristics, and flammability characteristic [28]. Flammability means that an uncontrolled release of natural gas poses a hazard of fire or even explosion in limited spaces. But in its liquid state, natural gas is not explosive. For an explosion to happen with LNG, it must first vaporize, then mix with air in the proper proportion, the so-called flammable range proportion, and then be ignited. The cryogenic temperature of the cargo would fracture the ship's steel if directly spilled on the deck (brittle fracture) or cause severe injuries to people. A vapour cloud arising from an LNG spill and drifted by the winds could endanger the populated areas.

But nevertheless, the LNG tanker industry proves impressive safety records: since international LNG shipping started in 1959, there have been over 45,000 LNG tanker voyages, covering more than 100 million miles, without major accidents or safety problems in ports or at high seas [29]. The safety is secured by high industry standards, industry experience and technological improvements. There is also a large number of acts, regulations and guidelines currently in existence which have a goal to prevent and diminish the consequences of LNG releases.

Similarly to LNG tankers, LNG terminals are also very safe; furthermore, they are low on environmental emissions, which is very important to keep the natural gas an environmentally friendly fuel.

4. CONSIDERATIONS REGARDING LNG SHIPPING IN 21ST CENTURY

4.1 Development trends in LNG shipping capacities

LNG shipping has registered extraordinary boom in the last few years making LNG market somewhat intense and making some shipyards (e. g. Korean shipyards) constructing only profitable LNG ships and rejecting other orders. LNG tankers were traditionally built in Japan or Korea, but by the end of 2005 China sailed off its first LNG ship making Chinese shipbuilding industry stepping into a new era [30]. Only a few European shipyards are qualified to build LNG tankers. It takes from 32 to 36 months to deliver an LNG tanker [31].

Table 5 - Order book for LNG vessels [11]

	< 100,000m³		> 100,000m³		Total	
	No.	Capacity	No.	Capacity	No.	Capacity
2007	0	0.00	7	0.94	7	0.94
2008	1	0.02	44	7.48	45	7.50
2009	1	0.07	55	9.18	56	9.25
2010/11	0	0.00	21	3.40	21	3.40
Total	2	0.09	127	21.00	129	21.09
% of fleet		5.7		62.8		60.00

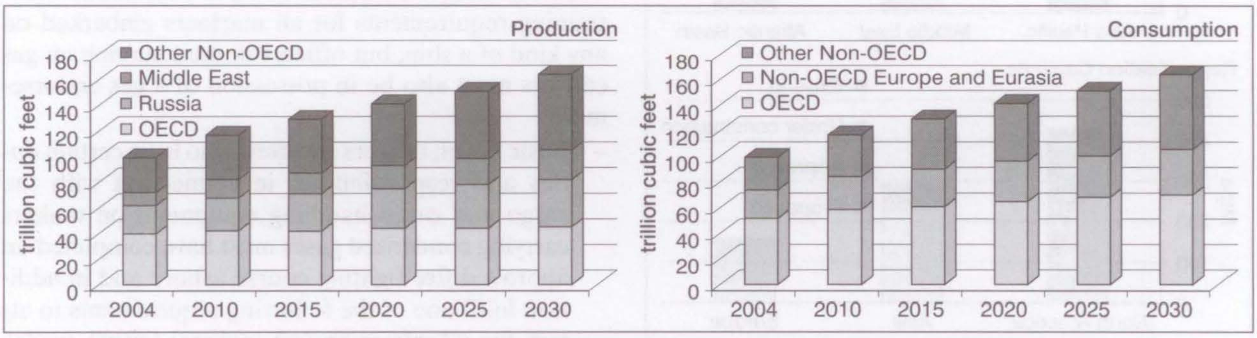


Figure 8 - World natural gas production & consumption by region, 2004-2030 [3]

Note: OECD – Organisation for economic cooperation and development; OECD countries are: Australia, Austria, Beglium, Canada, Czech R., Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, S. Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak R., Spain, Sweden, Switzerland, Turkey, U. K. and the USA.

The biggest LNG tanker built so far, Al Gattara is the first in a series of four ships heralding a new generation of Q-Flex LNG tankers that was constructed at the Hyundai Heavy Industries shipyard in South Korea. It can transport 216,000m^3 of LNG, which is approximately 40% more than the standard LNG vessels in service today. The ship also employs some of the most advanced technologies currently available, including a first-of-its-kind, on-board reliquefaction plant, which cools boil-off gas and converts it back to liquid for return to the tanks [32].

4.2 Trends in production and consumption of natural gas

According to the analyses of the Ocean Shipping Consultants [33], World LNG demand is forecast to rise from 158 billion cubic metres (bcm) in 2003 to over 269bcm by 2010 and to 428.5bcm by 2020. This growth represents an average annual LNG trade growth of 7.6% over the near-term, with a slowing to 5.4% through to 2015 and 4.9% up to 2020. This means over 70% of increase by 2010 and 171% increase by 2020. East Asian imports are set to increase to over 139bcm by 2010 and 181bcm by 2020 comparing to 109bcm in 2003. Trading patterns are expected to change significantly over the next decade as new markets and suppliers emerge, vessel capacities are increased and the spot market grows in prominence. New markets will appear in the Asian region, such as Thailand, the Philippines, Singapore and some others but also European and North American market will grow considerably.

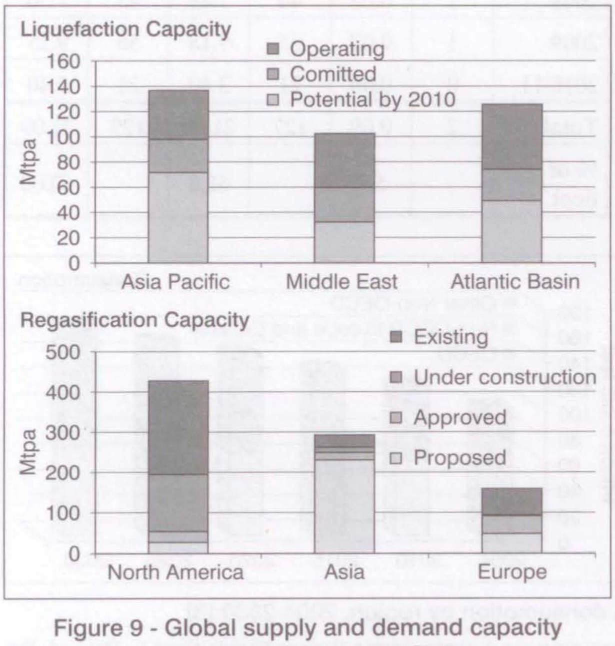


Figure 9 - Global supply and demand capacity as forecast up to 2010 [34]

Source: Teekay, CERA, Woodmac

There are a lot more regasification capacities than liqufacation capacities meaning that the trade can become very vivid as the flexibility is entering into the long term contracts and more short term contracts are being introduced. This means that production countries can start calculating with the prices of natural gas and select better buyers or better offers.

4.3 Safety issues of LNG transportation

LNG ships and LNG terminals have not been dangerous so far as only the best mariners and land employees have been accurately selected to crew technologically most sophisticated ships and ports terminals. But the expansion of the LNG fleet and the construction of many new terminals could lead into the employment of not properly trained and not so accurately selected personnel although both shipping companies and terminal operators assure that quality and safety are crucial aspects of their operation and both attributes can only be amplified.

Bigger threat could arise from possible terrorist activities as the LNG has raw explosive power and the explosion of LNG ship or LNG terminal would be more difficult to handle than an attack on a pipeline.[13] To amplify the safety of LNG ship manoeuvres as well as to secure environmental protection the LNG tankers are always tug assisted and even escorted if necessary (e. g. escorting is compulsory in all Japanese ports).

4.4 Management in focus of LNG shipping

Managing bodies in LNG shipping companies must deal with several issues, such as selection of adequate crew to man their vessels, appropriate employment of the ships, ecological issues, development issues (...).

4.4.1 Crew training

IMO's Standards of Training, Certification and Watchkeeping Convention (STCW 95), define basic training requirements for all mariners embarked on any kind of a ship, but officers or crew serving on gas carriers must also be in possession of a gas endorsement:

- Basic Level; officers and crew who have certain duties and responsibilities in connection with the cargo and cargo handling equipment on tankers carrying condensed gases must have completed an approved fire fighting course ashore and in addition fulfil one of the following requirements to attain the "Tankerman (oil tankers) lowest grade" (rule V/I) certificate:
  - completed and passed a test of an approved Oil Tanker course ashore (lowest grade), or

- completed at least three months systematic training on board a gas carrier, or
- completed and approved training program (lowest grade) on board a gas carrier, confirmed by owner or the master of the vessel.

– Management level; masters, deck and engine officers and others who have direct responsibility for loading, discharging and inspection of the condensed gases cargo during the voyage, on tankers they must fulfil the following requirements to attain the highest certificate according to STCW-95, "Tankerman (gas tankers) highest grade" certificate:

- completed and passed the requirements of Step I,
- completed and passed an approved Gas Tanker course Step II (highest grade), dealing with the handling and transportation of condensed gases in bulk,
- a minimum of three months relevant experience on gas tankers after receiving the "Tankerman (gas tankers) lowest grade", or
- completed and approved training programme (Highest Grade) on board gas carriers, confirmed by the owner or the master of the vessel.

It is obvious that the training of the potential LNG crew is time and money consuming. It has been estimated that the LNG shipping industry will require an additional 5,000 officers until 2010 to man all the ships currently on order. Such a number would double the current pool of LNG ship officers but the number could go much higher as many officers serving on the current LNG fleet are facing retirement from their seagoing careers [35]. This is the situation which can make currently rigid selection become somewhat loose. Adding to this, the fact that wages on LNG vessels considerably surpass the average wages in maritime transportation sector and as such attract many, possibly unskilled, mariners the so far existing immaculate safety records could be jeopardized.

4.4.2 Employment of LNG tankers

LNG ships are still mostly built to be employed under agreed long-term contracts to serve specific trades and customers but the market is changing and today short-term trades account for more than 10% of global LNG trade and such exploration of LNG tankers is expected to grow to 15 to 20% of the LNG market over the next decade [36].

Long-term contract means that the ship owners know the conditions of the ship employment often prior to her construction as the trade is defined in long term. In this way the ship-owners were sure about the employment of the ship but needed to take the risk of increases of operational costs. Recently, long term contracts have begun to be shorter and more flexible, having the charter rates based on true operating costs while charter has the possibility to influence the ship-owners decisions on crew and technical issues considering the chartered ship. Also some fresh long-term contracts are designed to provide only a base supply of LNG, which can be supplemented by short-term contracts during periods of high demand [6]. On the other hand, short term contracts are called spot market and the ship is employed to fulfil the market needs wherever there is a shortage of vessels' capacity.

Short-term rates spiked above 70,000 $/day occasionally, but on average remained in the 50,000 $/day range in 2007. Long-term charter rates continue to run in the vicinity of 65,000 $/day [36].

4.4.3 Development issues

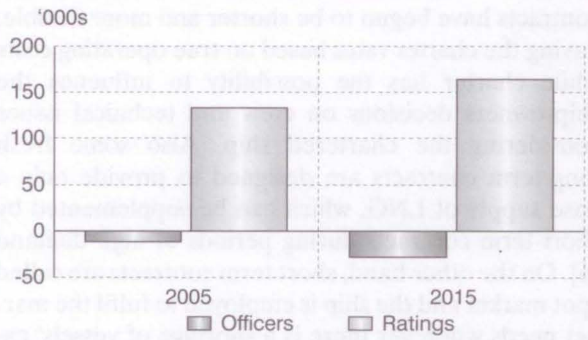
LNG shipping is like all other segments of the shipping industry affected by the environmental policy which demands the use of cleaner fuel, garbage management (...). Older ships are adapted and newbuildings are projected to fit the severe new standards

LNG tankers have been developing through the 50 years of marine transportation of liquefied gas to become world's most sophisticated ships and expensive ships with double, hydrodynamic, hull and state-of-the-art navigation and cargo manipulation equipment. LNG ships are more expensive than any other type of cargo ships but are also built to last longer thus everything concerning the LNG tanker must be carefully planned and immaculately constructed and installed.

5. CONCLUSION

LNG tankers are no longer built only in shipyards with long tradition in the industry. So, technologically, extremely demanding ships that should be equipped with state-of-the-art cargo monitoring, navigation and other safety systems (e. g. firefighting, distress...) are being built in the shipyards that have not been verified in the LNG industry so far but that does not necessarily need to mean that quality of the product is going to be diminished.

Ship owners and operators are faced with the problem of deficient crew availability, more precisely the officers. On the global level, there were approximately 466,000 active deck and engine officers in 2005, which is a deficit of around 2% compared to the needs of merchant maritime sector, and there was a surplus in the number of ratings which was calculated to 721,000 [37, p. 99]. The imbalances in supply and demand of



	2005		2015	
Officers	-10,000	-2.1%	-27,000	-5.9%
Ratings	135,000	18.8%	167,000	21.6%

Figure 10 - Global labour supply (projected) [38, 37, p. 100]

Source: BIMCO/ISF

crew in 2005 and projected imbalances in 2015 are presented in Figure 10.

It is important to stress that key personnel of LNG tankers must, besides training for conventional dry cargo ships, pass courses on safe handling of liquid cargoes, advanced (specialized) firefighting and sail aboard an LNG tanker as trainee (observer) prior to being embarked in any rank on any size of LNG tanker. Although it is a timely and costly process ship owners are determined to assure the highest possible quality of their service and thus continue the perfect safety records of LNG shipping. But anyway, the situation is difficult in particular for the ship-owners only now entering the LNG sector as their crews can have abundant experience of the company traditional fleet but are unfamiliar with LNG tankers.

Natural gas resources are quite well distributed around the world thus lessening the political influences on distribution. The trade of LNG is motivated by the constantly growing demand for natural gas which is nowadays used in many sectors as well as by the chance and need of gas-producing countries to monetize the valuable natural resource that they are in possession of. Across Europe, the USA and Asia, LNG regasification terminals are being built or expanded. New countries are entering the LNG trade but the liquefaction capacities in producing countries are growing less rapidly than regasification terminals in importing countries. This situation of demand exceeding the supply is helping to boost natural gas prices and to give the possibility to exporters to calculate with trading agreements if they are not already involved in long term agreements, even though the costs of liquefying, transporting, and regasifying LNG have fallen significantly over the past 20 years [6].

The changes in employment of LNG tanker capacities and changes in contracts that allowed the competition to increase may on the other hand reduce transportation costs of LNG but hopefully not on the account of reduced quality both in terms of construction and equipment as well as in terms of manning the ships.

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SAŽETAK

IZAZOVI LNG BRODARA U DVADESETPRVOM STOLJEĆU

Prirodni plin je relativno jeftino, za okoliš čisto i energetski učinkovito fosilno gorivo kojemu se svakodnevno povećava atraktivnost, a može se koristiti u mnogim sektorima. Početkom dvadesetoga stoljeća razvio se način prijevoza plina u ukapljenom stanju, budući da nije bilo moguće do svih korisnika doći putem plinovoda. No tek je 1959. godine zaplovio prvi brod s ukapljenim plinom. U sljedećih 50 godina prijevoza plina morem bilježe se vrhunski rezultati u pogledu sigurnosti. LNG tankere opisuje se samo u superlativima; bez imalo sumnje ti su tankeri daleko najsofisticiraniji i najskuplji među svim brodovima. Oni iziskuju posebnu pažnju kako u plovidbi tako i u lukama, a to mogu pružiti samo najškolovaniji i najiskusniji pomorci. LNG tržite raste i mijenja se; potražnja nadilazi proizvodnju, pojavljuju se nova izvozna i uvozna tržišta, flota LNG tankera strahovito brzo raste, brodovi postaju veći, ugovori za eksploataciju brodova postaju drugačiji, čime se daje mogućnost za ulazak na tržište novih kompanija (...). Članak je osvrt na tržište ukapljenog prirodnog plina, a daje i prikaz razvoja LNG brodarstva. Članak je posebice usredotočen na nedavni bum u LNG brodarstvu i naglašava pitanja kao što su dostupnost i odabir posade, sigurnost brodova, te njihova eksploatacija u budućnosti.

KLJUČNE RIJEČI

prirodni plin, LNG brodari, LNG tankeri, tržište prirodnoga plina

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3. Term definition [2]: MMBtu - One million Btu. 1 Btu = 1.054-1.060 kJ; In natural gas, by convention 1 MMBtu = 1.054615 GJ. Conversely, 1 gigajoule is equivalent to

26.8 m^3 of natural gas at defined temperature and pressure. So, 1 MMBtu = 28.263682 m^3 of natural gas at defined temperature and pressure. Btu - British thermal unit is defined as the amount of heat required to raise the temperature of one pound (0.45359237 kg) of water by one degree Fahrenheit (conversion from Fahrenheit to Celsius [°C] = ([°F] - 32) × 5/9).

4. In 1980 the world proved natural gas reserves were 2,580 trillion cubic feet
5. See video on LNG trade routes: http://www.teekay.com/index.aspx?page=gas_structure (March 2008)
6. Data filtered with comparison to Table 1 and Table 2
7. Definition of terms [14]: Take or pay - the minimum payment level guaranteed by a buyer of LNG, regardless of actual receipt of LNG. Buyer pays seller for the value of gas which it is unable to receive below the Take or Pay minimum quantity. Take or Pay minimum quantity normally defined as a percentage of ACQ. Annual contract quantity - the amount of LNG a buyer agrees to purchase from the seller over the length of a Contract Year, most accurately expressed in MMBtu, and measured in Gross heating value.
8. Size definition [18]: Qatar Membrane LLNG Ship (Q-Max), about 265,000m^3, 5 cargo tanks, 345m length, 55m beam, 12m draft.
9. Term definition•[14]: LNG that evaporates during storage and transport. Typically, any rise in temperature of LNG during storage and transport will be countered by allowing evaporated LNG to vent from storage tank. Boil-off gas is sometimes used to supplement fuel for tankers, or as a fuel at storage facilities.
10. Term definition [2]: HFO - Heavy fuel oil which is pure or nearly pure residual oil.
11. Size definition [18]: Qatar Membrane LLNG Ship (Q-Flex), capacity about 205,000m^3, 5 cargo tanks, 315m length, 50m beam, 12m draft and Qatar Membrane LLNG Ship (Q-Max), about 265,000m^3, 5 cargo tanks, 345m length, 55m beam, 12m draft.
12. Term definition [2]: Cryogenic temperatures are temperature below -150°C; Cryogenics is the study of the production of very low temperatures and the behavior of materials at those temperatures.
13. See more: The risks and danger of LNG (Preview of the documentary film) - http://www.lngdanger.com/ (March 2008)

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