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# LNG shipping market analysis

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International Transport and Logistics

For Master Degree of Science

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**WORLD MARITIME UNIVERSITY**

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# LNG Shipping Market Analysis

**By**

**Guangchuan Xia**

**China**

**For the degree of**

**MASTER OF SCIENCE**

**In**

**INTERNATIONAL TRANSPORT AND LOGISTICS**

**DECLARATION**

**I certify that all the materials in this dissertation that is not my own has been correctly identified and marked, and no materials is included for which a degree has previously been conferred on me.**

**The contents of this dissertation represent only my own personal views, and are not necessarily endorsed by the University.**

**(Signature):_______**

**(Date):___________**

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# ABASTRACT

**Title of Dissertation: LNG Shipping Market Analysis**

**Degree: Master of Science in International Transport and Logistics**

**Abstract:** Since China faces the serious environmental problems, and energy demands rocket up in the past few years, it is critical for us to address LNG market for its development in a healthy way. But LNG, compared with domestic natural gas, is of higher price, how can we cope with this? The purpose of this article is to try to find ways to minimize the cost of the whole supply chain of LNG source to China. And I tried to analyze different LNG export countries from perspectives of political stability, energy market, and sea distance to find an optimal LNG source. And also I tried to analyze the LNG fleet by addressing different LNG builders and its LNG vessel details from which we can see that LNG shipping capacity is abundant for the time being. As to LNG demand in China, I tried to analyze from two points of view, that is, consuming per capita in China, and consuming by sectors, from which we can see that LNG demand is huge when compared with developed countries. And I did include some forecast on natural gas production and consuming in China, a gap which leaves space for LNG import in China.

**KEYWORDS: LNG, PNG, ANFIS，Natural Gas, Forecast, Global Warming, Kyoto Protocol, Qatar, Q-max, LNG fleet.**

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**LNG** **liquefied natural gas**

**NG** **natural gas**

**PNG** **pipeline natural gas**

**Bcf** **billion cubic feet**

**Bcm** **billion cubic meters**

**Tcf** **trillion cubic feet**

**ANFIS** **Artificial Neuro-Fuzzy Inference Systems**

**Btu** **British thermal meter**

# LNG Shipping Market Analysis

## Chapter 1 Backgrounds

### 1.1 Problems in China

Ever since the industrial revolution, Man began to use huge amount of fossil fuel to fuel the economic growth, which, in turn, resulted in drastic increase of green house gases like carbon dioxide etc. in atmosphere. The global warming and climate change and rising sea level are now facing us. The negative impacts of those problems on ecological system and human beings and water resources intensified. To inhibit the green house gases emission around the world, the United Nations passed the Kyoto Protocol in 1992 to control the green house gases concentration at a level that would prevent dangerous anthropogenic interference with the climate system. The Kyoto Protocol establishes legally binding commitments for the reduction of four greenhouse gases (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride), and two groups of gases｛hydrofluorocarbons(like $CH_2F_2$) and perfluorocarbons(like $CF_4$)｝produced by "Annex I" nations (industrialized), as well as general commitments for all member countries[1]. As of 2008, 183 parties have ratified the protocol(as shown in figure 1), which was initially adopted for use on 11 December 1997 in Kyoto, Japan and which entered into force on 16 February 2005. Under Kyoto, industrialized countries agreed to reduce their collective GHG emissions by 5.2% compared to the year 1990. National limitations range from 8% reductions for the European Union and some others to 7% for the United States, 6% for Japan, and 0% for Russia. The treaty permitted GHG emission increases of 8% for Australia and 10% for Iceland. China signed the UNFCCC in 1992. In 1998 it signed the Kyoto Protocol and ratified it in 2002. As the Kyoto Protocol came into effect on February 16 2005, Vice Minister Liu Jiang of the National Development and Reform

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[1] http://en.wikipedia.org/wiki/Kyoto_Protocol

Commission (NDRC) stated that China will honor its commitments in accordance with the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, and will work together with the international community to seek effective measures addressing climate change[2].

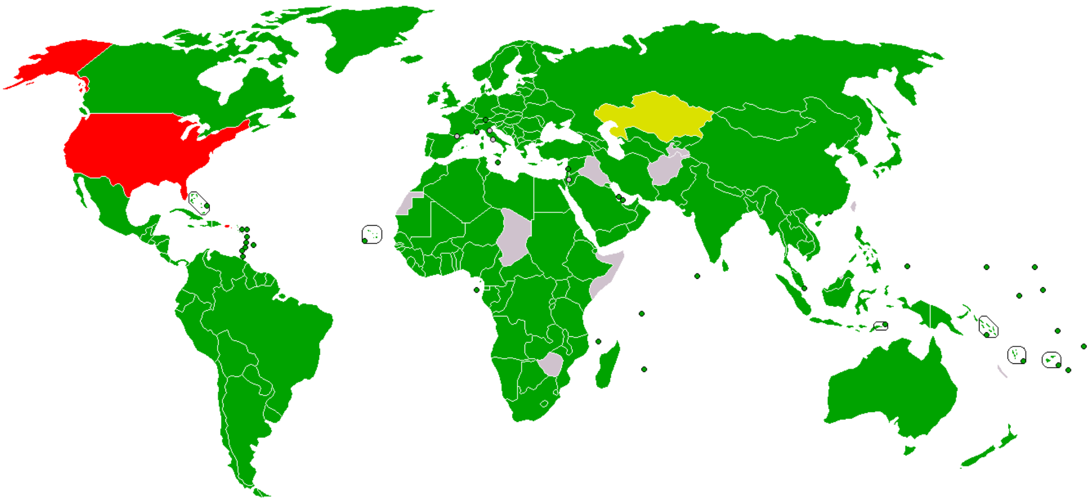

Figure 1.1 Participation in the Kyoto Protocol

Signed and ratified

Signed, ratification pending

Signed, ratification declined

Non-signatory

**Source**: Wikipedia (http://en.wikipedia.org/wiki/Kyoto_Protocol).

Besides that, our government set an ambitious goal to cut energy consumption per unit of GDP by 20 percent in five years, but it failed to reach a 4 percent cut during the first year, in 2006. Why? Because more than 70 percent of China's energy needs are met by burning dirty coal, which is also the fuel with least burning efficiency and highest pollution rate. On 24 October 2006, LinFen of Shanxi Province in China is among the ten most-polluted locations in the world,

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2 http://www.sdpc.gov.cn/

according to research carried out by the New York-based Blacksmith Institute. The World Bank even estimated that 16 of the 20 most polluted cities in the world were in China. In 2007, the Blacksmith Institute stated that the 6 out of the dirty thirty were in China, namely, Wanshan, China; Tianying, China; Huaxi, China; Lanzhou, China; Linfen, China; Urumqi, China.

So China now faces two urgent businesses, one is from the Kyoto Protocol, green house gas reduction, the other is from inside need, the environmental problems. The central government should take the living status of people in LinFen into their consideration really, who lived as if they were under death sentence. Where is the way out? We need to find out the new and cleaner energy resources to support the development of the country. LNG is not new, but, in china, it's really something new, recently explored market.

### 1.2 Benefits of natural gas

Although LNG in china, which is short for liquefied natural gas, came into existence not long ago but china is among those countries in the world that firstly use the natural gas, whose main component is methane, chemical formula as $CH4$. According to its chemical formula, we can see that methane has the lowest carbon percentage among all the hydrocarbons. Carbon percentage = 12/ (12+4) *100%=75%. Low carbon percentage means that it burns completely easier in the atmosphere, because carbon consumes more oxygen than hydrogen when burning. So less carbon monoxide emission will happen, and less carbon dioxide, known as GHG will emitted into air too, by 25% than oil, which means natural gas is more favorable for protecting environment. (see figure 2) Natural gas is considered as clean energy fuel globally, while LNG, being desulphurized and decontaminated, is even more environmental friendly. The thermochemical equation of methane is as follow, which show that it has high heat value. $CH4(g)+2O2(g)==CO2(g)+2H2O(l)$;

△ H=－890kJ/mol. Pipeline Natural Gas (PNG) is composed primarily of methane (at least 90 %). When purified NG is cooled to a temperature of approximately -160 ℃ at atmospheric pressure it condenses to a cold liquid called liquefied natural gas (LNG). The liquefaction process removes the impurities such as carbon dioxide, sulphur compounds, volatile organic compounds, oxygen, nitrogen, and water.

Furthermore, LNG is odorless, colorless, non-corrosive, and non-toxic.

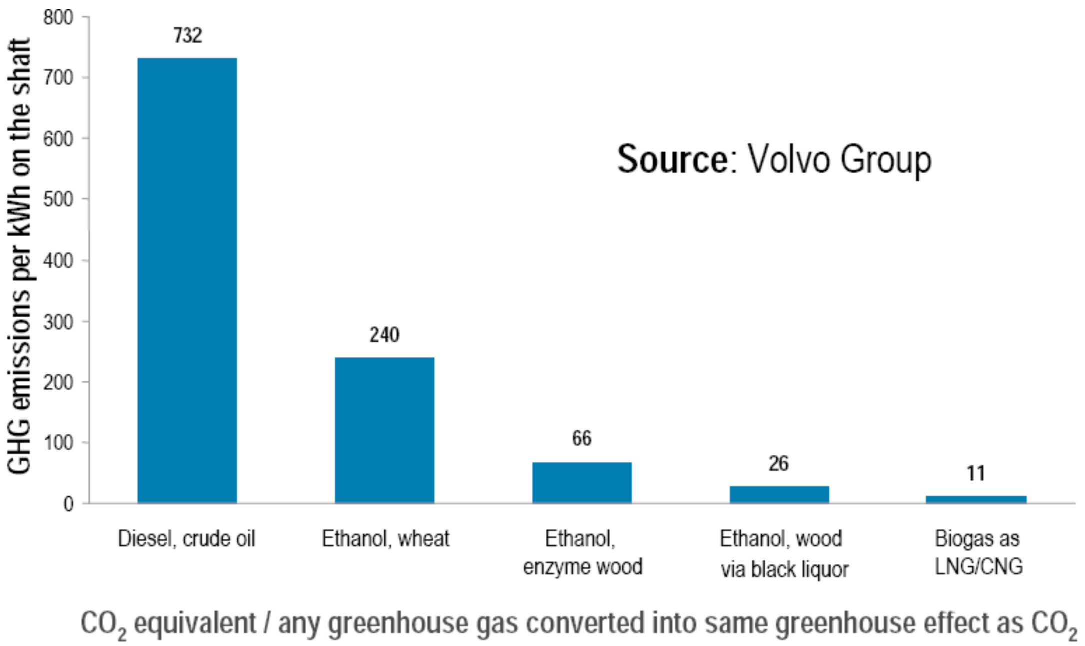
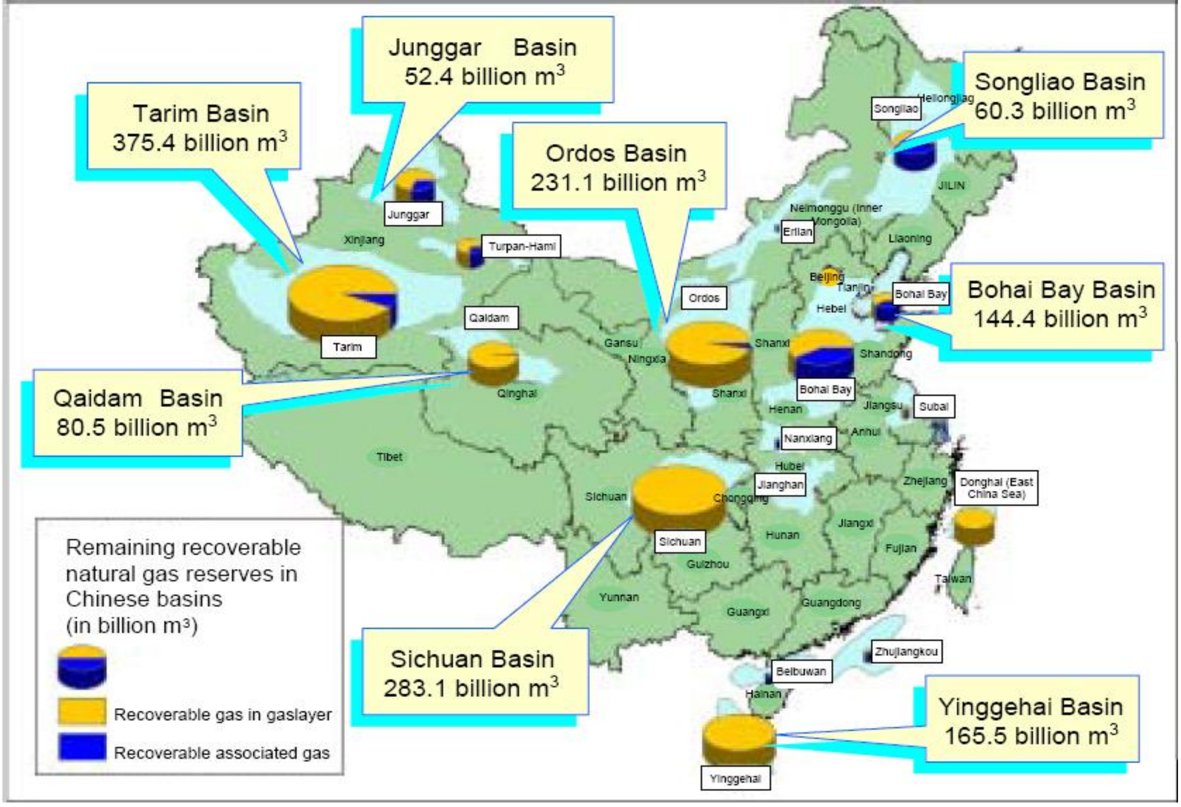



Figure 1.2 Comparison of LNG and other energies

**Source**: Volvo Group

And the Chinese government also made a lot of efforts to boost domestic natural gas consuming. China’s production of natural gas has rapidly increased ever since 1990s, production totaled 17.947 billion m3 in 1995, 27.726 billion m3 in 2000, 30.344 billion m3 in 2001, 32.633 billion m3 in 2002. Most reserves of natural gas exist in the middlewest, where major gas fields such as Tarim, Junggar, Qaidam, Ordos, and Sichuan have been discovered. In particular, Sichuan is the traditional, largest production area in China.（see figure 3）, while the energy consuming places

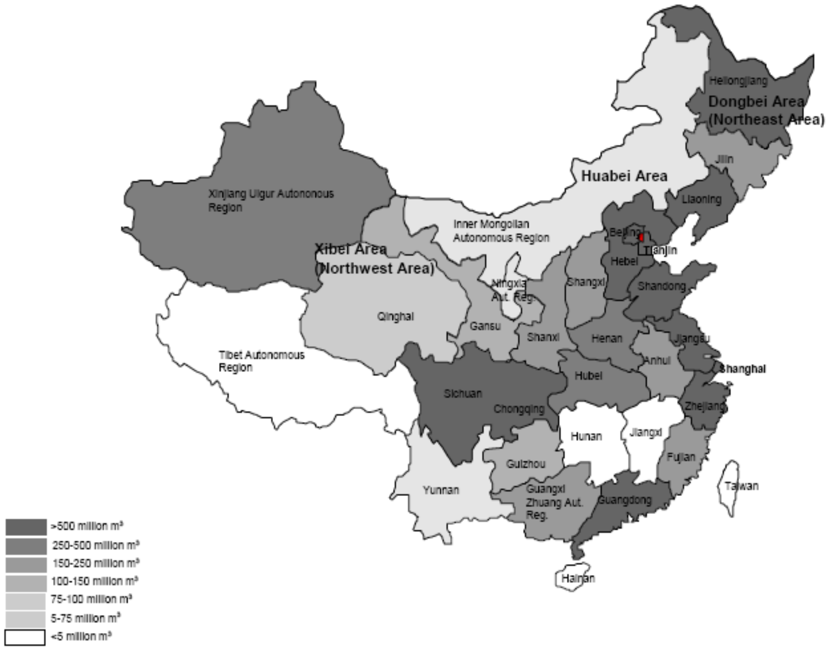



are mainly in south east china. It is interesting to point out that energy consuming per GDP is higher in west part of china, such as Ningxia, Guizhou, and Qinghai.

Figure 1.3 Natural gas reserves China

**Source**: Institute of Energy Economics, Japan (based on 1994 official figures)

So china's government invested in pipe line gas to transport the natural gas to southeast part of china, such projects include: west-east pipe line gas project, north-south gas project, and Sichuan-east pipe line gas project. But that's not efficient enough to meet the high demand for clean fuel such as natural gas in coastal cities (see figure 1.4).




Source: Institute of Energy Economics, Japan

Figure 1.4 Projected 2010 natural gas demand by province

**Source**: Institute of Energy economics, Japan.

LNG is well characterized and provides high energy density that makes it easily stored and transported. It is clean-burning and safe to handle and use. The only economical way of transporting natural gas when pipe line is not available is LNG shipping over long distance. And Chinese government appreciate the opportunity of developing LNG market, and have establish a lot of receiving terminals along its coast line, such as Dalian, Qingdao, Yangkou, Yangshan, Ningbo, Fujian, Guangdong etc. LNG can serves as complementary source of pipe line gas and peak shaving methods as needed, especially in winter.

## 1.3 **Goals and Points of the thesis**

As mentioned above, LNG is a kind of purified natural gas, which has high heat content and very little environmental impacts. But china only starts to import LNG in 2006, with the import amount of LNG at 2.91 million tons in 2007. So LNG market in china is still small but growing rapidly. As we know Chinese government limits the coal generated electricity price at a certain level, what and how can we do to make this new LNG market develop healthily? If we successfully manage this new market then the goal of our government that reduces the energy consuming and GHG emission and controls the pollution will be met.

The world now is experiencing the economic crisis, and the whole world is cooling down with reduced energy demand, and all the fuels' price fell down including LNG from 16 US dollars to 6 per MBTU, it's a good opportunity for china to grasp the LNG market that used to be dominated by developed countries like Japan, Korea etc. because china has very high energy demand, especially for clean fuels.

# Chapter 2 Literature Review

## 2.1 LNG shipping market

Since LNG accounted for a small portion of Chinese energy market, and came to exist not long ago, so people in china made only a few researches on LNG shipping market. In 2004, MR. HaiZong wrote a thesis on LNG shipping market development studies of China for his master degree. In his thesis, he first described characteristics, advantages of LNG, and main consuming areas of LNG in china, and then he analyzed the structure of the LNG vessels and their development trends, and the supply of the LNG shipping market. Inevitably, he said something about the distribution of natural gas reserves around the world. When it came to forecasting, he used two forecast techniques, namely, qualitative methods and quantitative methods for predicting the future imports of LNG. He analyzed the difference of the needed natural gas and produced natural gas in china, a huge gap, and then he used the Back Propagation (BP) model to forecast the amount of imported LNG in China, and he concluded that it was necessary and feasible and a good occasion to enhance the

LNG market in china .

In 2007, Mr. Oweixin wrote his thesis on the LNG fleet planning for a south china shipping company. His main aim was to establish mathematic models to study the fleet development strategy for LNG shipping companies in China. But he happened to analyze the LNG shipping market and did some predicting work on the LNG shipping market. He also described the world LNG market and the Chinese LNG market including the LNG importing port in china, which is something new when compared with the Mr. HaiZou above stated. The main technique he used for forecasting was multiple linear regressions. After modeling he predicted that the amount of LNG imports for 2007 was 6.1 million tons and that of 2008 was 9.9 million tons and 32.38 million tons for 2009. But the actual amount of LNG Imports for 2008 was 2.91 million tons, though taking the economic recession into consideration in 2008, there still exist a big difference, so it is necessary to remodel and reforecast using different methods or exactly, improved methods.

Mr. Eugenio Fco. Sánchez-Úbeda and Ana Berzosa provided a prediction model that deals with forecasting in a medium-term horizon (1-3 years) with a very high resolution based on a decomposition approach. The forecast is obtained by the combination of three different components: one that captures the trend of the time series, a seasonal component based on the Linear Hinges Model, and a transitory component to estimate daily variations using explanatory variables[3]. The flexibility of this model allows describing demand patterns in a very wide range of historical profiles. Furthermore, the proposed method combines a very simple representation of the forecasting model, which allows the expert to integrate judgmental analysis and adjustment of the statistical forecast, with accuracy and high computational efficiency.

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[3] Energy Economics, Volume 29, Issue 4, July 2007, Pages 710-742

This forecasting model is attractive because it is simple and fully interpretable, so a straightforward physical interpretation may be attached to their components, allowing engineers and system operators to understand their behavior. Furthermore, this decomposition model allows exploiting the advantages of both judgmental and statistical forecast while avoiding their drawbacks. The main weakness of the proposed approach is the fitting algorithm that is not fully automatic, requiring the human specification of the internal structure of both the trend and the transitory component. The core of the proposed method is a novel statistical decomposition model, designed to allow both extracting useful information from historical data as well as including the possible knowledge and judgmental information about the future. this model first allows breaking the initial daily time series into a set of independent subseries, where each subseries groups days with similar behavior. For example, the subseries of the Monday values, the time subseries of the Tuesday values, and so forth. Note that in practice many industrial demand series can be modeled using only two subseries (one for the working days and a different time subseries for the weekends and holidays) or even only one subseries (i.e. the initial series directly). Each time subseries is modeled independently. The mathematical description of the proposed model is: $y(t)=M(t)+N(t)$.

## 2.2 **Methodology**

As to forecasting methods, we know that is an important prerequisite for efficient supply chain management or planning. The above mentioned two papers used BP, a kind of neural network system and multiple linear regressions respectively. The former one fits the real situation more closely. Because forecasting on LNG demand in China is very limited so I chose the following thesis on bulk shipping market.

Mrs. Xuping wrote her thesis on forecasting based on wavelet analysis and neural net work after he compared the cons and pros of the two methods. He pointed out that neural network is a kind of method that approaches the limitation as closely as possible, self-error-correcting, while wavelet method conquered the cons of neural network, so she combined the two methods together to forecast the BFI, using wavelet methods to reduce noise of data collected and then forecasted in neural network method, it is a good trial and got the good result.

As mentioned above it is good when combining two methods together, so in this dissertation I will use the Adaptive-Network-based Fuzzy Inference Systems or ANFIS for forecasting because it is a kind of combined methods which has the strong point of the two methods.

# Chapter 3 LNG export countries

Since I chose LNG shipping market as theme of my thesis, so I have to address the supply side of this market, I know that supply of LNG shipping market is decided by the volume of LNG used for international trading, so the primary aim seems to study LNG export cargo volume solely, but political structure, international issues, economical structure, political risks of LNG exporting countries dose have significant influences on production of LNG and thus affect amount of trading LNG around the world, that’s why I tried to analyze main LNG export countries from above mentioned aspects, I did that so as to rank these countries or decide which country is most suitable for China to choose as its supplier, disregarding political facts between the two countries.

## 3.1 **Qatar**

### Political Structure

HH Emir Hamad Khalifa al-Thani assumed power in 1995, following a bloodless palace coup against his father. The coup was prompted by a prolonged period of disagreement between the two men, though it was not clear whether it also related to the growing calls for a democratization of the country. As before, Qatar is ruled exclusively by the Emir and his immediate family. There is a Consultative Assembly of 35 appointed members. A new constitution came into effect in 2005. It establishes a 45-member parliament – thirty elected by voters, fifteen appointed by the Emir – which is responsible for monitoring the functioning of government and has the power to pass or reject the state budget.

## International Issues

The government's close links with the US have created anger in a region where anti-US sentiment is typical. Qatar's relations with some of its neighbors are also shaky as a result of the Emir's policy of broadcasting uncensored news via satellite. Relations with Saudi Arabia are tense at times. In 2008, the government successfully brokered an agreement between various Lebanese factions which pulled that country from the brink of civil war. The government hopes to join the Gulf Cooperation Council monetary union by 2010.

## Energy Markets

With proven reserves of 911 trillion cubic feet, Qatar's natural gas resources rank third in size behind Russia and Iran. Most of this natural gas is located in the offshore North Field, which is the largest known non-associated natural gas field in the world. Currently Qatargas 1 supplies LNG under long term contracts to customers in Japan and Spain. Qatargas 2, Qatargas 3 and Qatargas 4 supply markets in Europe, the USA and the UK beginning in 2008.

Qatargas 1 is jointly owned by Qatar Petroleum at a stake of 65%, ExxonMobile at a stake of 10%, Total, 10%, Mitsui, 7.5%, Marunbeni, 7.5%. It has three trains each with a capacity of 3.2 MTPA, 11 LNG ships with cargo volume of about 135,000 cubic meters, and offshore facilities of three platforms and one pipeline at 32". It can produce 1,600 million standard cubic feet or 45 million cubic meters per day of raw gas, and the condensate production is 51,000 barrels per day.

The first cargo shipped from Qatargas 1 was in 1996.

Table 3.1 Qatargas 1 Share

| Share holders | Qatar Petroleum | Exxon Mobil | Total | Mitsui | Marunbeni |
|---|---|---|---|---|---|
| Share | 65% | 10% | 10% | 7.50% | 7.50% |

**Source**: www.Qatargas.com

Qatargas 2 is also jointly owned by three companies, among which Qatar Petroleum has 70% of Train 4, and ExxonMobil has 30% of Train 4. Qatargas 2 Train 5 is jointly owned by three companies, Qarat Petroleum with 65%, ExxonMobli with 18.3%, and Total 16.7%. It has two trains with a capacity of 7.8 MTPA, 14 LNG vessels with cargo capacity ranging from 210,000 to 266,000 cubic meters, and offshore facilities of three platform and two pipelines at 34". It was constructed under Heads of Agreement-Qatar-UK gas supply deal in June 2002, the first shipment was delivered in 2008.

Table 3.2 Qatargas 2 Train 4 shares

| Share holders | Qatar Petroleum | Exxon Mobil |
|---|---|---|
| Share | 70% | 30% |

Source: www.Qatargas.com

Table 3.3 Qatargas 2 Train 5 Shares

| Share holders | Qatar Petroleum | Exxon Mobil | Total |
|---|---|---|---|
| Share | 65% | 18.3% | 16.7% |

**Source**: www.Qatargas.com

Qatargas 3 is jointly owned by three companies, Qatar Petroleum with a share of 68.5%, ConocoPhillips 30%, Mitsui & Co. Ltd 1.5%. It only has one train with capacity of 7.8 MTPA, 10 ships ranging from 210,000 to 266,000 cubic meters, and offshore facilities of three platforms, two pipelines at 38", shared with Qatargas 4. Its first cargo is expected in 2009, main market in USA.

Table 3.4 Qatargas train 3 shares

| Share holders | Qatar Petroleum | ConocoPhillips | Mitsui & Co. Ltd |
|---|---|---|---|
| Share | 68.5% | 30.0% | 1.5% |

**Source**: www.Qatargas.com

Qatargas 4 is joint ly owned by Qatar Petroleum with a share of 70% and Royal Dutch Shell with share of 30%. It has one train with a capacity of 7.8 MTPA, 8 ships ranging from 210,000 to 266,000 cubic meters, and offshore facilities of three platforms, two pipelines at 38", shared with Qatargas 3. Its first cargo is expected at the end of a decade.

Table 3.5 Qatar gas 4 shares

| Share holders | Qatar Petroleum | Royal Dutch Shell |
|---|---|---|
| Share | 70.0% | 30.0% |

**Source**: www.Qatargas.com

Political Stability and Risks

Several thousand members of one clan have been stripped of their citizenship on the grounds that they were acting in support of Saudi interests. To prevent arguments over succession, the Emir named his third son as heir. Indeed, the only major threats to the current situation would come from external claims on the country's territory or resources.

Table 3.6 Natural gas Qatar

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 691.5 | 778.7 | 1027.7 | 953.5 | 1041.8 | 1108.9 | 1383.3 | 1617.4 | 1790.5 | 2111.8 | NA |
| consumption | 522.3 | 492.6 | 531.8 | 386.7 | 392.3 | 431.2 | 530.8 | 660.4 | 692.5 | 724 | NA |
| Net exports/imports | 169.2 | 286.1 | 495.8 | 566.8 | 649.4 | 677.7 | 852.5 | 957 | 1097.9 | 1387.9 | NA |
| Proved reserves | 300,000 | 300,000 | 300,000 | 393,830 | 508,540 | 508,540 | 910,000 | 910,000 | 910,520 | 910,500 | 905,300 |

**Source**: EIA

## 3.2 **Malaysia**

### Political Structure

Malaysia is a constitutional monarchy in which the monarch is elected every five years from among the tribal elders of peninsular Malaysia. The influence of the monarchy is limited, however. All effective power is exercised by the Prime Minister, who reports to a bicameral legislature. The House of Representatives (or Lower House) is composed of 222 members elected for five years, while the 70 members of the Senate serve 3-year terms, with 26 of them elected by the state legislatures and 44 appointed by the monarch. Constitutional amendments in 1993 reduced the legal immunity of the nine Malay rulers. A new federal capital, Putrajaya, is being built near Kuala Lumpur.

### International Issues

Malaysia rejects a claim by the Philippines for the sovereignty of Sabah. Malaysia is pressing Indonesia for the return of two islands, Sipadan and Ligitan, and is one of many claimants for the Spratly Islands in the South China Sea. The government's crackdown on illegal laborers has heightened tensions with Indonesia. The worsening violence in southern Thailand has further stressed bilateral relations between Malaysia and Thailand.

**Energy Markets**

Malaysia has 75 trillion cubic feet (Tcf) of proven natural gas reserves. Natural gas production has been rising steadily in recent years, reaching 2.2 Tcf in 2004. Malaysia is one of the world's leading exporters of LNG. In 2005, the country exported 21.2 million metric tons (MMt) of LNG, or about 1,031 Bcf of regasified natural gas, accounting for 15 percent of total world LNG exports. The majority of Malaysia's shipments went to Japan, South Korea, and Taiwan, although small amounts of LNG were also sent to the United States and Spain. Its major Natural Gas Fields are Bedong, Bintang, Damar, Jerneh, Laho, Lawit, Noring, Pilong, Resak, Telok, Tujoh. LNG is primarily transported by Malaysia International Shipping Corporation (MISC), which owns and operates 23 LNG tankers, the single largest LNG tanker fleet in the world by volume of LNG carried. MISC is 62 percent-owned by Petronas and also has significant involvement in oil shipping activities.

Table 3.7 Malaysia's LNG Infrastructure

| Plant | Ownership | Capacity (MMt/y) | Start-up |
|---|---|---|---|
| MLNG | Petronas (65%), Shell (15%), Mitsubishi (15%),Sarawak local government (5%) | 8.1 | 1983 |
| MLNG Dua | Petronas (60%), Shell (15%), Mitsubishi (15%),Sarawak local government (10%) | 7.8 | 1996 |
| MLNG Tiga | Petronas (60%), Shell (15%), Nippon Oil (10%),Sarawak local government (10%), Diamond Gas (5%) | 6.8 | 2003 |

**Source**: Petronas

### Political Stability and Risks

Although the country's Indians and Chinese minorities and the Malay majority coexist in harmony there is little interaction between the communities. The distribution of income and wealth is somewhat inequitable with Malaysia having one of the highest Gini coefficients in Asia.

The government's affirmative-action programme has succeeded in reducing poverty among ethnic Malays, but ethnic Malays, who make up 60% of the population, still hold only a 19% share of the Malaysian economy. Poverty rates also vary significantly from state to state.

Table 3.8 Natural gas Malaysia

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 1370.2 | 1422.1 | 1498.1 | 1657.7 | 1712.8 | 2005.9 | 2204.7 | 2242.5 | 2189.5 | 2277.8 | NA |
| consumption | 614.8 | 653.3 | 721.8 | 910.1 | 990.2 | 1117 | 1204.9 | 1172.5 | 1136.4 | 1161.9 | NA |
| Net exports/imports | 755.4 | 768.8 | 776.2 | 747.6 | 722.5 | 888.9 | 999.8 | 1070 | 1053.1 | 1116 | NA |
| Proved reserves | 79,800 | 81,700 | 81,700 | 81,700 | 75,000 | 75,000 | 75,000 | 75,000 | 75,000 | 75,000 | 83,000 |

**Source:** EIA

## 3.3 **Indonesia**

### Political Structure

The People's Consultative Assembly is composed of 1,000 members. Half the assembly is elected by universal franchise with the remainder appointed by the president, often from the armed forces. The House of People's Representatives has 550 members, elected for a five year term by proportional representation in multi-member constituencies. The president and vice president are elected for five-year terms by universal franchise.

## International Issues

Relations with Papua New Guinea are strained and Indonesia faces claims from Malaysia for the return of two islands, Sipadan and Ligitan, where Jakarta wants to develop tourist facilities. Indonesia is also one of the claimants of the Spratly Islands in the South China Sea, where oil deposits are thought to have been located. Although Indonesia is a member of the Organization of Petroleum Exporting Countries (OPEC), it has become a slight net importer of oil and is reportedly considering leaving the organization.

## Energy Markets

Indonesia currently holds proven oil reserves of 4.3 billion barrels, down 13% since 1994. Much of the oil reserve base is located onshore. Central Sumatra is the country's largest oil producing province. During 2007, national crude oil production averaged just less than 1.1 million barrels per day (bbl/d). This represents an increase over output in recent years, though Indonesia continues to be a modest net importer of oil.

The Cepu field in Java, which is Indonesia's only undeveloped field, is estimated to hold reserves of at least 600 million barrels of oil. Production is scheduled to begin in 2008, with peak production expected to reach 180,000 bbl/d.

Indonesia also has 97.8 trillion cubic feet (Tcf) of proven natural gas reserves. More than 70% of these reserves are located offshore, with the largest reserves found off Natuna Island, East Kalimantan, South Sumatra, and West Papua. Indonesia also has eight refineries, with a combined capacity of 992,745 barrels per day. A new 300,000-bbl/d joint venture refinery is planned for Pare-Pare in South Sulawesi.

## Political Stability and Risks

The repeated terrorist attacks in Bali and Jakarta set back foreign investment and the tourist industry but both began to recover in 2007. The earthquake which struck in

May 2006 cost the country more than US$3 billion but its consequences were temporary.

The government's ambitious decentralization agenda still poses significant problems. The transfer of funds from the central government to regions continues to rise but the latter are frequently unable to spend the funds owing to capacity limitations. In 2007, regions were thought to hold almost US$10 billion (more than 3% of GDP) in cash deposits.

In 2005, the Free Aceh Movement (GAM) signed a peace agreement with the government. The deal commits GAM to end its 29-year fight for a separate homeland. There has been little progress in Papua, the country's other separatist-driven region.

Table 3.9 Natural gas Indonesia

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 2269 | 2506 | 2359 | 2341.4 | 2484.4 | 2606.2 | 2662.8 | 2606.2 | 2016.5 | 1977.6 | NA |
| consumption | 982.8 | 1124.4 | 1081.3 | 1182.3 | 1218.4 | 1221.9 | 1309.5 | 1324.7 | 801.7 | 826.4 | NA |
| Net exports/imports | 1286.2 | 1381.5 | 1277.7 | 1159 | 1266 | 1384.3 | 1353.3 | 1281.6 | 1214.8 | 1151.3 | NA |
| Proved reserve | 72,268 | 72,268 | 72,268 | 72,268 | 92,500 | 92,500 | 90,300 | 90,300 | 97,786 | 97,780 | 93,900 |

**Source: EIA**

## 3.4 **Egypt**

### Political Structure

Egypt's 1972 Constitution provides for an executive president. The People's Assembly is the principal legislative body with 454 members, ten of whom the president appoints personally. The People's Assembly is elected by universal suffrage for a term of five years and then elects the president for a six-year term. There is also a 264-member Shura Council (upper house), of which 176 are elected by popular vote and 88 are appointed by the president, all serving 6-year terms.

## International Issues

Egypt's relations with Syria have improved but are still not warm. The country also has had strained relations with Sudan and Iran. In the past, Cairo has accused both countries of fomenting religious discontent.

## Energy Markets

Egypt's estimated proven oil reserves stand at 3.7 billon barrels, while crude oil production averages 665,000 barrels per day. Despite discoveries and improved oil recovery techniques, annual production continues to fall. Offshore oil production possibilities in the Mediterranean are being explored.

Due to major recent discoveries, natural gas is likely to be the primary growth engine of Egypt's energy sector for the foreseeable future. Natural gas production averages 1.86 trillion feet per day. Egypt’s estimated proven gas reserves stand at 58.5 trillion cubic feet.

## Political Stability and Risks

Terrorist attacks on tourists have shattered several years of relative calm. Mubarak has promised a more pluralist political system with appropriate amendments to the constitution but few expect this. Cairo's control over the political scene is pervasive and there are fears that any demonstrations could quickly turn into a forum for expression of discontent. Many assume that Mubarak, who is in his late 70s, is in the twilight of his political career.

Despite recent economic gains, poverty is widespread. Analysts estimate that only about 8 million have disposable incomes that allow more than subsistence consumption. The World Bank estimates that one in five Egyptians cannot meet basic living needs. As much as three-quarters of the population is not benefiting from the economy's gains.

Table 3.10 Natural gas Egypt

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 485.2 | 518.1 | 646.3 | 867 | 882.9 | 1058 | 1150 | 1501 | 1596 | 1678 | NA |
| consumption | 485.2 | 518.1 | 646.3 | 867 | 882.9 | 1046 | 1111 | 1208 | 999.4 | 1123 | NA |
| Net exports/imports | 0 | 0 | 0 | 0 | 0 | 12.4 | 38.8 | 292.8 | 596.8 | 554.4 | NA |
| Proved reserves | 27622 | 31500 | 35180 | 35180 | 35180 | 58500 | 58500 | 58500 | 58500 | 58500 | 58500 |

**Source: EIA**

## 3.5 **Australia**

### Political Structure

Australia is a federation of six states and two territories (Northern Territory and Capital Territory of Canberra), each of which exercises considerable autonomy over its own affairs. The country's central affairs are run by a Cabinet which answers to a 150-member House of Representatives, elected for a term of three years. The Senate has 76 members, elected through a preferential system in 12-seat state constituencies and two-seat territorial constituencies. The territorial senators are elected for a three-year term. The state senators are elected for a six-year term, with half of the seats renewed every three years.

### International Issues

The current government has reversed the decision of its predecessor and ratified the Kyoto protocol on the environment. It is also playing a much more active role in new environmental initiatives. Nonetheless, Australia is still the world’s second largest producer of greenhouse gases per capita after the USA.

There is a dispute with East Timor over the distribution of oil and gas revenues in the Timor Sea. Australia also asserts land and maritime claims to Antarctica, which are not recognized by the USA.

## Energy Markets

The country has 30.4 trillion cubic feet (Tcf) of proven natural gas reserves and the government estimates that offshore basins may hold 130 Tcf of undeveloped reserves. Australia's energy consumption is dominated by coal, which provides most of its power generation. It is now the world's fourth largest producer of coal. A rapidly expanding economy and declining domestic oil production have led some observers to forecast an energy supply crisis in the next ten years. The government, itself, expects energy demand to rise by 50% by 2020. Australia also has approximately 40% of the world's recoverable uranium.

Source: Euromonitor International based on the World Bank Note:

Table 3.11Natural gas Australia

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 1097 | 1116 | 1159 | 1185 | 1235 | 1275 | 1308 | 1440 | 1509 | 1541 | NA |
| consumption | 751.6 | 759.1 | 797 | 841.1 | 887.7 | 916.8 | 946.1 | 949.3 | 1012 | 1038 | NA |
| Net exports/imports | 345 | 357.3 | 362 | 344.1 | 347.3 | 357.6 | 361.7 | 490.3 | 528.9 | 502.3 | NA |
| Proved reserves | 19429 | 44638 | 44638 | 44638 | 90000 | 90000 | 90000 | 29000 | 27640 | 30370 | 30000 |

**Source: EIA**

## Political Stability and Risks

Aboriginal relations pose a problem for the government. Canberra spends A$3 billion each year on aboriginal welfare. Meanwhile, large chunks of land are under the control of aboriginal communal councils. Many officials believe that the best way to bring these minorities into the economy is to grant them private title to these communal lands. The proposal is strongly opposed by others.

Australians face rather serious problems as a result of their country's ageing population. A low birth rate combined with the impending retirement of baby boomers is the source of the problem. The population aged 65 years and over will exceed 3.5 million by 2015, up from just 1.4 million in 1980. To counter these trends, the government plans a series of programmes to boost labour force participation and raise productivity.

## 3.6 **Algeria**

### Political Structure

The President is elected for a five-year term by the people. Parliament has two chambers. The National People's Assembly has 389 members, elected for a five-year term in multi-seat constituencies by proportional representation. Eight seats in the national assembly are reserved for Algerians abroad. The National Council has 144 members; 96 members elected by communal councils and 48 members appointed by the President.

### International Issues

In 2001, Algeria and the EU reached an Association Agreement after years of negotiations. Under the accord, Algeria agreed to cut tariffs on EU agricultural and industrial products over the next 10 years and the EU agreed to eliminate duties and quotas on many Algerian agricultural products. In 2005, voters approved a controversial peace plan which will pardon most militant Islamists who rose up against the army-backed regime in 1992. A series of suicide bombings in 2007 created concerns among Western countries that rely on Algeria for energy.

## Energy Markets

Algeria is considered to be under-explored although significant oil and gas discoveries have been made over the last few years. The country has 12.1 billion barrels of proven oil reserves. Energy exports have risen fourfold in the past five years and are expected to surpass US$80 billion in 2008. Algeria should see further increases in crude oil exports over the next few years, due to significant investment and the continued substitution of natural gas for oil in domestic energy consumption. Total oil production presently averages about 1.37 million barrels per day (bbl/d). The country plans to invest billions of dollars in exploration and development. Officials intend to boost crude oil production capacity to 2.0 million bbl/d by 2010.

Algeria is also estimated to have 161.7 trillion cubic feet (Tcf) of natural gas reserves (the eighth-largest in the world). The volume of recoverable natural gas potential, however, may be as high as 282.0 Tcf.

## Political Stability and Risks

Algeria continues to face serious economic, social, and political problems such as labor unrest; a large black market (possibly 20% of the country's GDP) and weakness in the non-oil economy. In 2007 and 2008, the country suffered a series of suicide attacks by Islamists affiliated with al-Qaeda. The attacks could prompt the government to boost spending on security and slow the pace of some reforms.

Roughly 70% of the population is under 30 years of age and more than a quarter are unemployed. A housing shortfall of around 1.5 million homes adds to the general dissatisfaction. Periodically, there have been protests by the country's restive Berber minority demanding greater autonomy, increased employment opportunities, and better living conditions.

Table 3.12 Natural gas Algeria

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 2604.5 | 2875.7 | 2939.6 | 2787.1 | 2798.7 | 2849.9 | 2830.5 | 3107.7 | 3079.5 | 3026.5 | NA |
| consumption | 736.3 | 752.6 | 726.1 | 721.8 | 720.8 | 724.7 | 680.9 | 802.7 | 904.1 | 928.8 | NA |
| Net exports/imports | 1868.2 | 2123.1 | 2213.5 | 2065.2 | 2077.9 | 2125.3 | 2149.6 | 2305 | 2175.4 | 2097.7 | NA |
| Proved reserves | 130,600 | 130,300 | 159,700 | 159,700 | 159,700 | 159,700 | 160,000 | 160,500 | 160,505 | 161,740 | 159,000 |

**Source: EIA**

## 3.7 **Nigeria**

### Political Structure

Nigeria, an independent member of the Commonwealth, has been ruled by civilian administrations for only nine of its 36 years of independence. Parliament has two chambers. The House of Representatives has 360 members, elected for a four year term in single-seat constituencies. The Senate has 109 members, elected for a four year term in 36 3-seat constituencies, and 1 seat in a single-seat constituency representing the Federal Capital Territory.

### International Issues

The country’s record on human rights has improved but observers constantly report abuses. Another development that worries westerners is the emergence of a severe form of Sharia (Islamic law) in the north. Both Cameroon and Nigeria claim the Bakassi peninsula, a 1,000-sq-km (400 sq m) area in the Gulf of Guinea, which is believed to contain significant oil reserves. The Nigerians have questioned Equatorial Guinea's claim of another oil field.

### Energy Markets

Nigeria has proven oil reserves of 36 billion barrels and the government expects these to rise to 40 billion barrels by 2010. New sources have been discovered in deeper waters offshore. Oil production has stagnated or even dropped slightly owing to technical problems and militant activity in the Niger Delta. The government hopes to boost oil production to 4 million bbl/d by 2010 but current levels are well below that target. Analysts estimate that US$7 billion per year will be necessary to fund exploration and development in hopes of reaching production targets. In 2009, Petrobras, the Brazilian state-owned oil company, announced planned investments of US1.9 billion in 2009-2013 in Nigeria's upstream oil and gas industry.

Nigeria’s oil industry has been poorly run for years. In 2007, it failed to remit nearly US$5.2 billion it was scheduled to pay the national treasury. The industry is the target of pipeline vandalism and armed attacks, as well as hampered by decrepit refineries. Analysts estimate that the country is losing between US$84-100 million daily due to militant activity alone.

The country has 184 trillion cubic feet of natural gas, the 7th largest in the world. The government hopes to boost earnings from natural gas exports to 50% of oil revenues by 2010. However, the government estimates that US$15 billion in private sector investments is necessary to meet this target.

**Political Stability and Risks**

Ethnic and religious violence has worsened since the country returned to democracy. Muslims fight Christians, and several of Nigeria's 250 tribes battle over land. Corruption is also widespread. An audit of the oil industry completed in 2006 revealed that €268 million in royalties and other payments went astray between 1999 and 2004.

Nigerian militants have launched repeated attacks against the country’s oil industry. Government officials estimated that the country is losing about US$100 million and 225,000 barrels of oil per day as a result of the attacks. There are fears that the movement could evolve into a “high-intensity” conflict on a par with

Chechnya and Colombia.

Table 3.13 Natural gas Nigeria

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 208.4 | 245.4 | 440 | 526.2 | 501.5 | 716.9 | 769.9 | 791.1 | 1006.5 | 1204.2 | NA |
| consumption | 208.4 | 219.3 | 237.7 | 219.3 | 224.6 | 300.5 | 329.1 | 365.9 | 385.6 | 455.6 | NA |
| Net exports/imports | 0 | 26.1 | 202.4 | 306.9 | 276.9 | 416.4 | 440.7 | 425.2 | 620.8 | 748.7 | NA |
| Proved reserves | 114852 | 124000 | 124000 | 124000 | 124000 | 124000 | 159000 | 176000 | 184660 | 181900 | 183990 |

**Source: EIA**

## 3.8 **Trinidad and Tobago**

### Political Structure

The Republic of Trinidad and Tobago is an independent member of the Commonwealth. The executive president is elected by parliament for a term of five years. Legislative power rests with the bicameral parliament, which consists of a 31-member Senate and a 41-member House of Representatives. The House is elected by universal suffrage for five years while the Senate is appointed – 16 members by the prime minister, six by the leader of the opposition and nine by the president. In Tobago, the smaller of the two islands, politics run to quite a different agenda from those of Trinidad and the political complexion is very different. Tobago has been independent from the UK since 1987 and has its own 12-member House of Assembly with some autonomous powers.

### International Issues

Barbados claims that the northern limit of Trinidad and Tobago's maritime boundary with Venezuela extends into its waters; Guyana has also expressed its intention to challenge this boundary as it may extend into its waters as well. The islands are a trans-shipment point for South American drugs destined for the US and Europe.

## Energy Markets

Trinidad and Tobago is the largest producer of oil and gas in the Caribbean. Production has been rising in recent years and is expected to continue to rise over the medium term. Crude oil reserves, at an estimated 728 million barrels, will be exhausted in less than two decades unless new reserves are found.

Proven natural gas reserves in Trinidad and Tobago are estimated to be 25.9 trillion cubic feet (Tcf). The expectation is that the continental shelf surrounding the islands contains much more, with some estimates of potential reserves reaching as high as 90 Tcf. Both natural gas and oil exploration activities continue at a fast pace. Investors spent US$2.5 billion between 2004 and 2007, with most of it going toward increasing production. Other funds will be allocated to exploration activities in the Columbus Basin, off the eastern coast.

## Political Stability and Risks

The ethnic split between Indians who support the UNC and blacks who support the PNM continues. There are also differences between the citizens of Tobago and those of Trinidad. Politicians on Tobago suggest that there is a growing disparity in social services and several would like to secede. More than one-fifth of the country's population lives in serious poverty.

The economy is slowing owing to the drop in energy prices and a slowdown in tourism. At present rates of extraction, the country's existing reserves of natural gas will be exhausted by 2020. However, analysts suspect that the continental shelf surrounding the islands contains much more. The government hopes to use its energy resources to reach the status of a developed country by 2020. There is a consensus among economists that growth will be threatened without a greater measure of diversification. Presently, natural resources provide almost 40% of government income.

Source: Passport GMID

Table 3.14 Natural gas Trinidad and Tobago

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 328.4 | 414.2 | 493.4 | 536.4 | 610.9 | 873.7 | 992 | 1069.3 | 1286.9 | 1377.3 | NA |
| consumption | 328.4 | 336.9 | 354.2 | 396.9 | 423.1 | 453.1 | 499.7 | 574.6 | 713 | 734.6 | NA |
| Net exports/imports | 0 | 77.3 | 139.1 | 139.5 | 187.9 | 420.6 | 492.3 | 494.8 | 573.9 | 639.2 | NA |
| Proved reserves | 15,916 | 18,297 | 19,770 | 21,351 | 23,450 | 23,450 | 25,887 | 25,887 | 25,880 | 18,770 | 18,770 |

**Source: EIA**

## 3.9 **Iran**

### Political Structure

Modern Iran has its foundations in the Islamic revolution led by Ayatollah Seyyed Ruhollah Khomeini. Political power rests loosely in the clerical and religious hierarchy, which exercises authority through the 86-member Assembly of Experts. The country's parliament – the Islamic Consultative Assembly or Majlis – consists of 290 members, which are popularly elected. There is also a 12-member Council of Guardians, which includes six clerical members appointed by the head of state, Supreme Leader Ayatollah Ali Khamenei. The council must approve all legislation coming from parliament and vets all would-be candidates.

### International Issues

Iran's nuclear ambitions and its reluctance to cooperate with the

International Atomic Energy Agency have soured relations with most Western countries. Several rounds of UN sanctions have been imposed, contributing to a further downturn in Iran's international trade and thwarting foreign investment. A new round of negotiations was launched in 2008.

Of all its neighbours, Iran enjoys normal relations only with Armenia. Iran has still not signed a peace pact with Iraq. Israel accuses Iran of supporting the Hamas, which is regarded by some as a terrorist organisation. Negotiations with the UAE over Abu Musa and the Tunb Islands remain stalled. Iran seized the islands in 1971 and has rejected proposals by the Gulf Co-operation Council to resolve the dispute.

Some big foreign investors are threatening to pull out of Iran, complaining that bidding is often rigged and corruption is widespread.

## Energy Markets

Iran contains an estimated 948 trillion cubic feet (Tcf) in proven natural gas reserves – the world's second largest and surpassed only by Russia. Most of these resources have not been developed. Currently, natural gas accounts for nearly half of Iran's total energy consumption, and the government plans billions of dollars worth of further investment in coming years to increase this share. Despite the fact that domestic natural gas demand (for consumption, enhanced oil recovery and petrochemicals) is growing rapidly, Iran has the potential to become a significant natural gas exporter due to its enormous reserves.

## Political Stability and Risks

Iran's economy faces some serious problems. Exporters have little chance of gaining access to world markets unless the US lifts its veto of Iran's membership of the World Trade Organisation. About one million Iranians enter the labour market each year, and it is difficult to create the necessary jobs. Since 2000, about 285,000 qualified Iranians have emigrated. Officials dole out more than US$1 billion each year in the form of soft loans to employers who hire extra workers.

Unrest among the country's ethnic minorities – particularly Azeri nationalists, Kurds and Baluchistanis – is stretching security forces.

Table 3.15 Natural gas Iran

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 1765.8 | 2041.2 | 2127.4 | 2330.8 | 2648.6 | 2860.5 | 2962.9 | 3563.3 | 3835.2 | 3951.7 | NA |
| consumption | 1827.6 | 2111.8 | 2221 | 2478.4 | 2798 | 2910 | 3020.8 | 3615.5 | 3839.1 | 3948.2 | NA |
| Net exports/imports | -61.8 | -70.6 | -93.6 | -147.6 | -149.4 | -49.4 | -57.9 | -52.3 | -3.9 | 3.5 | NA |
| Proved reserves | 810000 | 812300 | 812300 | 812300 | 812300 | 812300 | 940000 | 940000 | 971150 | 974000 | 948200 |

**Source: EIA**

## 3.10 **Calculations on distance**

As to transportation, distance plays a critical role because transportation cost dose affect the possibility of international trade, I chose 9 LNG export countries as sources for Chinese LNG import in different corners in the world, mainly big LNG export countries, I will examine which one makes economical sense from the perspective of distance.

The biggest LNG terminal in China will be Port Nantong in Jiangsu province, which situated at north side of Changjiang river mouth, and has a water depth of average minus 17 meters, thus can accommodate Q-max. I originally chose Q-max as LNG carriers to check and find out the best source from the perspective of distance. But Chinese government dose not allow foreign shipping companies transport LNG to China, that's why I chose Dapeng Moon to do my calculations.

Table 3.16 Comparisons to Peer Group　Dapeng Moon

| | Low | High | Avg. | Dapeng Moon | % Diff. to Avg. |
|---|---|---|---|---|---|
| **cu.m.** | 138,000 | 157,611 | 149,357 | **147,210** | -1.46% |
| **DWT** | 69,000 | 91,198 | 79,929 | **73,275** | -9.08% |
| **Age** | -0.75 | 2.75 | 1.11 | **0.75** | -47.55% |
| **LOA** | 277.00 | 294.60 | 287.38 | **292.30** | 1.68% |
| **Draft** | 11.00 | 13.21 | 12.04 | **11.45** | -5.17% |
| **Breadth** | 42.50 | 49.00 | 45.01 | **43.35** | -3.82% |
| **Speed** | 19.00 | 20.30 | 19.61 | **19.50** | -0.56% |
| **Fuel Consumption tpd** | 140.00 | 196.00 | 160.03 | | % |

**Source**: Clarkson

SEA SISTANCES-VOYAGE CALCULATOR is a web application that gives distances between any two ports in the world and if voyage speed given, it can work out the time needed to accomplish that voyage, and if ship costs like Heavy fuel, diesel oil, Lubricant and other fixed cost are given, it can work out total cost both at sea and in port of that voyage, between any two ports. I choose this web application to facilitate my calculations and as a tool, it is not what I design but a free application from the web: http://e-ships.net/dist.htm. See figure below.

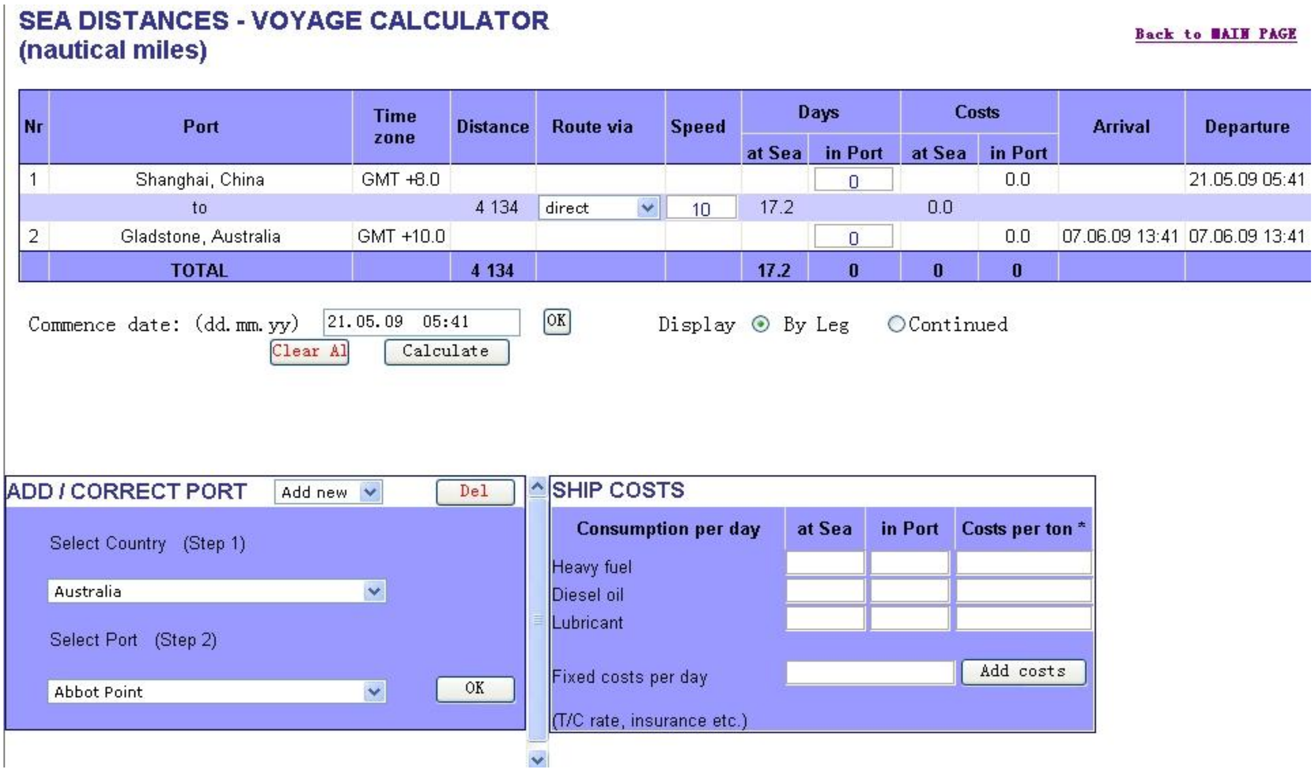


Figure 3.1Voyage Calculator

**Source**: http://e-ships.net/dist.htm

And the following table about the nine LNG sources is the results I get from that web application. To get what I want, some assumptions must be made. Dapeng Moon has a designed speed of 19.5 knots, but it won't go at the speed of 19.5, but choose to go at economic speed. And I chose speed of 16.5, about 85% of the designed speed as its economic speed, because LNG shipping has fewer requirements on time accuracy.

Table 3.17Port Shanghai to source Ports

| Port Shanghai to | Distances(Nautical miles) | Time needed Dapeng at 16.5 |
|---|---|---|
| Halul Island, Qatar | 5794 | 14.6 Days |
| Westport, Malaysia | 2447 | 6.2 Days |
| Citra Ujung Baru, Indonesia | 2612 | 6.6 Days |
| Port Said, Egypt | 7251 | 18.3 Days |
| Fremantle, Australia | 4037 | 10.2 Days |
| Port Methanier, Algeria | 8575 | 21.7 Days |
| Qua Iboe, Nigeria | 10070 | 25.4 Days |
| Tembladora, Trinidad & Tobago | 97500 | 24.6 Days |
| Kharg Island, Iran | 5972 | 15.1Days |

**Source**: Done by the Author.

As I mentioned before, LNG trade has its characteristic of long term contract, so LNG production can be can be considered as demand of LNG shipping market. That's why I chose LNG export countries as my first chapter, which can be demonstrated by the following two tables. As statistical data shows, currently, the world's production capacity of all countries export countries is 226.04 million tons per year, while the world's LNG re-gasification capacity of import countries reached 411.38 million tons per year, with Qatar as the biggest export country and Japan the biggest import country. The difference of them is 185.34 million tons per year, which supports my conclusion that LNG export capacity can be viewed as demand of LNG shipping market of the world

Table3.18 Capacity of LNG export countries

| Country | Capacity (M T/Y) | Percentage of World(%) |
|---|---|---|
| **ALL WORLD** | 226.04 | 100.00 |
| Qatar | 38.00 | 16.81 |
| Indonesia | 29.39 | 13.00 |
| Malaysia | 24.00 | 10.62 |
| Algeria | 21.95 | 9.71 |
| Nigeria | 21.15 | 9.36 |
| Australia | 19.54 | 8.64 |
| Trinidad and Tobago | 15.40 | 6.81 |
| Egypt | 12.20 | 5.40 |
| Oman | 10.30 | 4.56 |
| Russian Federation | 9.60 | 4.25 |
| Brunei | 7.20 | 3.19 |
| Abu Dhabi | 5.60 | 2.48 |
| Norway | 4.20 | 1.86 |
| Equatorial Guinea | 3.70 | 1.64 |
| Libya | 2.30 | 1.02 |
| United States (export) | 1.50 | 0.66 |

**Source:** Petroleum Economist: LNG data. http://www.petroleum-economist.com/

Table 3.19 Capacity of LNG import country

| Country | Capacity (M T/Y) | Percentage of World(%) |
|---|---|---|
| **ALL WORLD** | 411.38 | 100.00 |
| Japan | 178.04 | 43.28 |
| United States (import) | 67.90 | 16.51 |
| South Korea | 45.70 | 11.11 |
| Spain | 36.82 | 8.95 |
| India | 12.50 | 3.04 |
| France | 12.32 | 2.99 |
| Mexico | 11.00 | 2.67 |
| Turkey | 8.58 | 2.09 |
| Taiwan | 7.87 | 1.91 |
| Belgium | 7.20 | 1.75 |
| United Kingdom | 6.55 | 1.59 |
| China | 6.30 | 1.53 |
| Portugal | 4.00 | 0.97 |
| Italy | 3.50 | 0.85 |
| Greece | 1.60 | 0.39 |
| Dominican Republic | 1.00 | 0.24 |
| Puerto Rico | 0.50 | 0.12 |
| Argentina | 0.00 | 0.00 |
| Brazil | 0.00 | 0.00 |

**Source:** Petroleum Economist: LNG data. http://www.petroleum-economist.com/

**Conclusion**: From the above analysis, we can see that, Australia would be the best choice from the perspective of sea voyage, only 10 days from China, good political stability, fewest international issues, and more over, new proved natural gas reserves are continuously found and is big in volume, supported by its vast land and territory sea area, thus can enable its ability to provide LNG in the long run, while Qatar, currently the biggest LNG export country, and also ranked third of natural gas reserves, has a very close relationship with US, and is political unstable because some of the Arabian countries are irritated by its intimacy with US, and sabotage of LNG facilities happened occasionally in the past.

# Chapter 4 LNG fleet analysis

## 4.1 **World LNG fleet**

Ever since 1959, when the first LNG tanker, called Methane Pioneer, safely carried LNG from Charles, LA., to Canvey Island in United Kingdom, the commercial LNG shipping began, the development of LNG shipping is a process of development of LNG trade together with LNG carrier build-up industry, so in this chapter, I will briefly introduce the history of LNG fleet and its latest development, the LNG build-up industry and demolition market. As we know, LNG vessels will be built only after the long term transportation contract is confirmed, but it doesn't mean that it is unpredictable, and I did include a forecast of number of LNG vessel that will physically come into exist using ANFIS at the end of this chapter.

### 4.1.1 **Dominant characteristics of LNG ship building market**

First, LNG vessels delivery has a very close relationship with LNG trade, because the LNG supplier and LNG buyer usually established long term contract called SPA, in which quantity per year, LNG price and who entails the transportation etc. are stimulated in the contract. LNG vessel are built exactly according to the requirements in it, while other carriers like oil tanker, container ship are driven by supply and demand, so there are delays when the demand increase or decrease, it need some time for ships built to meet that change.

Second, since the cost of an LNG vessel is very high, so owners built a ship only when he got the long term contract, saying 25 years, so LNG vessels enjoys high occupancy rate than any other kinds of ships, few LNG vessels that are not subject to any contract will be used in short term or spot market.

Third, LNG market can bring ship owners long term and stable profits with very little competition, its routes, port of call, time schedule are pre- decided and fixed, and they never stop at port not planned, because they need special receiving facilities from the land side.

### 4.1.2 **LNG fleet development**

As I mentioned before, LNG is specially treated natural gas, so LNG transportation via vessels requires a number of high technologies, that's why LNG vessels is the most expensive ship among all kinds of ships. Since it is fund intensive industry including high risk, the development of LNG fleet can be divided into five phases with ups and downs.

The first stage began from 1950s, and ended in early period of 1970s. In this initial stage, only a few companies from Europe and America knew how to built LNG vessels because the technology barriers facing other yard around the world, they monopoly the LNG vessel market and very limited LNG vessels are delivered, so that they gained huge amount of profits. The LNG vessel market was fully controlled by sellers, owners of ship yard that can build LNG carriers.

The second stage was from the beginning of 1970s to the beginning of 1980s, during which LNG vessel building industry gained great development, because Japanese ship yard became one of active players in LNG ship building market, and brought competition into this market, meanwhile, the commercial LNG trade became booming, which expedite LNG fleet expanding, the number of LNG vessels reached 53 with capacity of 4900,000 cubic meters

The third stage began early in the 1980s and ended at the end of 1980s. During this period, the LNG vessel market experienced stagnancy, because, after the oil crisis before that, a lot of countries, exercised research on energy-saving technologies, and its applications, in the mean time, they tried to exploit new oil sources to ensure world energy security, which lead to price slump in oil price, and oil market became dominated by buyers, not suppliers. Under this circumstance, LNG production and trading almost stopped during this time span, that’s why LNG vessel delivery reduced to 22, with capacity of only 2800,000 cubic meters.

The fourth stage began is from the beginning of 1990s till 2008, another booming period of LNG ship building industry. In 1990s, except 1992 with no new delivery, the rest 9 years witnessed 44 LNG vessel increase all together, with new added capacity of 5260’000 cubic meters. After year 2000, the number of LNG vessel increased dramatically at 10 at least in a year, and it is interesting to point out that, in 2008, the LNG vessel increased by 51, almost the same amount of total number LNG vessels of the first two stages, from 1950s to 1980s which all added up as 53. See Tables below.

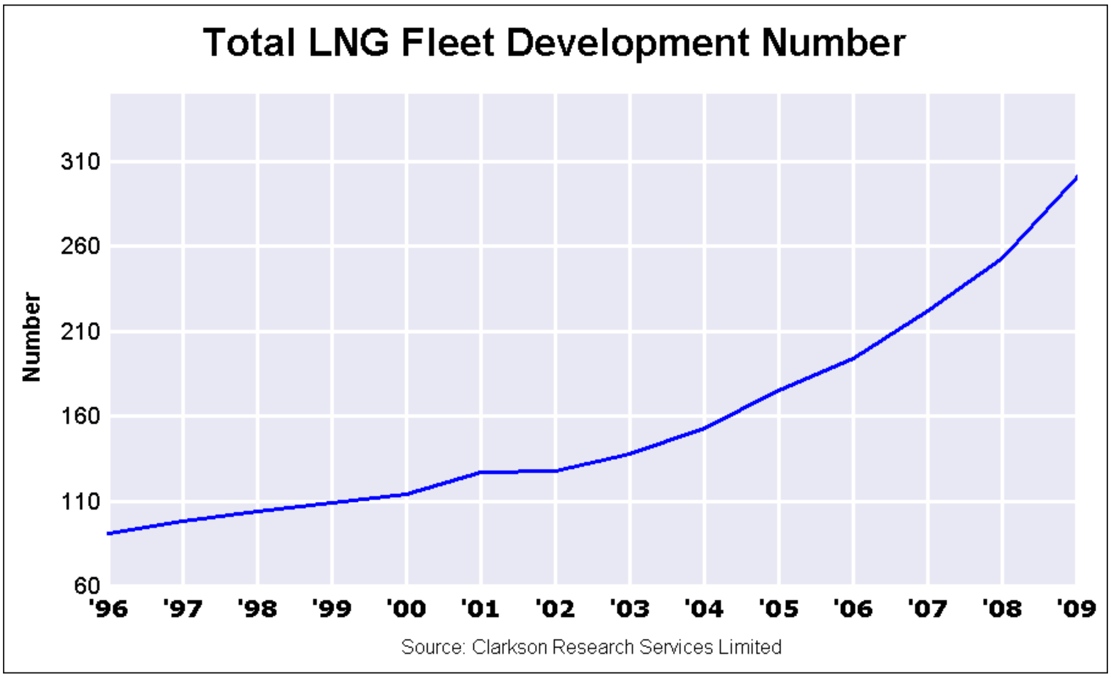


Figure 4.1LNG vessel development Number

**Source: Clarkson**

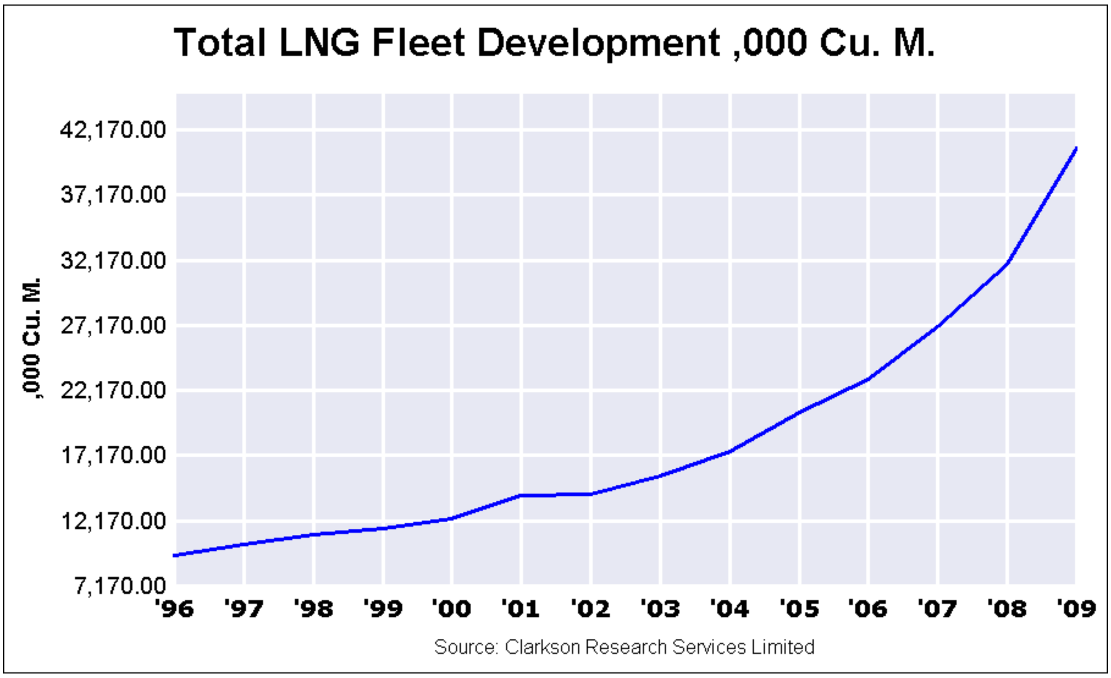


Figure 4.2 LNG vessel Development Volume

**Source: Clarkson**

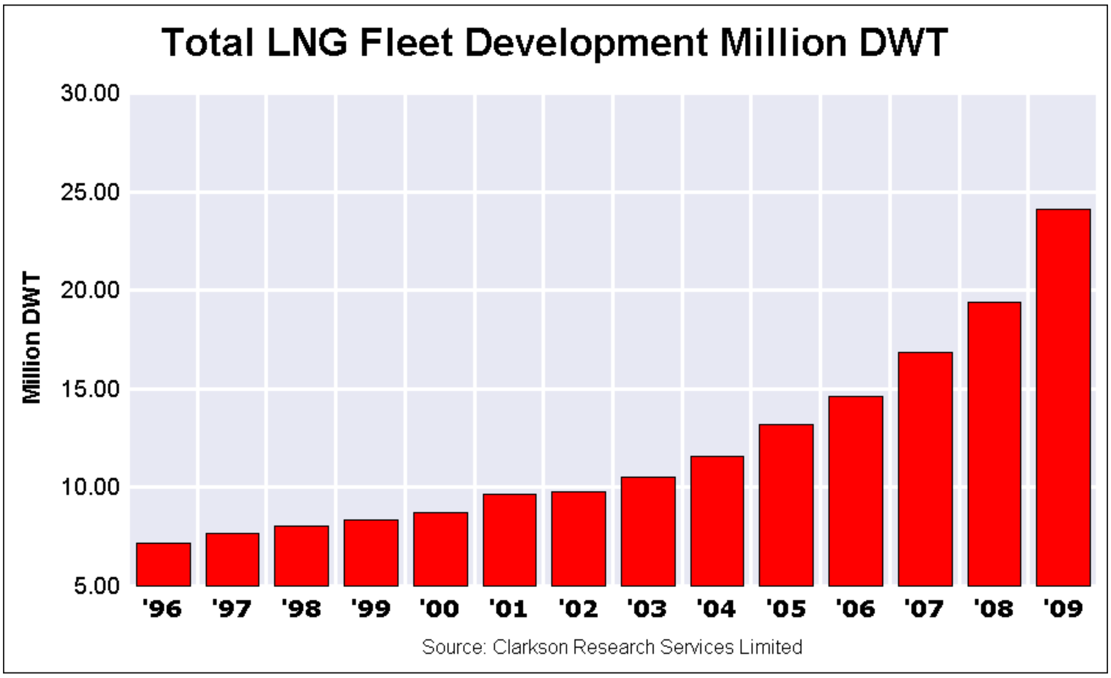


Figure 4.3 LNG vessel development Deadweight

**Source: Clarkson**

The fifth stage began in 2009, and we don't know when it will be ended. As the world experienced financial crisis in 2008, economic recession dominates in most countries, the energy demand of the whole world decreased drastically, as a result, all international trade including LNG trade experienced sluggishness again, and a lot of shipping company tries to negotiate with ship yard to cancel or delay ship delivery because of big financial difficulties they encountered, so far in 2009, there are only five LNG vessels that newly come into use, while the order book shows that there are 57 LNG vessels will be delivered in this year, with total capacity of 9,143,250 cubic meters, and the order book for next few years are as follows: 18 LNG vessels for 2010 with total capacity of 2,585,700 cubic meters, 9 for 2011 with total capacity of

1,435,700, and 2 for 2012 with total capacity of 337,400 cubic meters. And all together, the number is 86 with capacity of 13,050 cubic meters. But that doesn't mean that this will be actual delivery number for the next three years, and that's why I included predictions on LNG vessels for the next few years, and they are different from the existing order book.

### 4.1.3 **LNG vessel today**

The passed few years witnessed upsizing of vessels, especially container ship, because the economic of scale, which also apply to LNG vessels. The first LNG vessel built in 1955, Methane, only has a cargo capacity of 5550 cubic meters, and the smallest LNG vessel called Pythagore, built in 1964, has the smallest cargo capacity of 610 cubic meters, which was converted to a fish carrier then. And today, the biggest LNG vessels, called Q-max, has a cargo capacity of 266,000 cubic meters, Q-Max is 345 meters (1,130 ft) long and measures 53.8 meters (177 ft) wide and 34.7 meters (114 ft) high. It is propelled by two slow speed diesel engines, which are claimed to be more efficient and environmentally friendly than traditional steam turbines. Q-Max vessels are equipped with an on-board re-liquefaction system to handle the boil-off gas, liquefy it and return the LNG to the cargo tanks. The on-board re-liquefaction system allows a reduction of LNG losses, which produces economical and environmental benefits. Overall, it is estimated that Q-Max carriers have about 40% lower energy requirements and carbon emissions than conventional LNG carriers. The vessels are currently constructed at three shipyards in South Korea:

Hyundai Heavy Industries (HHI) at Ulsan, Samsung Heavy Industries (SHI) on Geoje Island and Daewoo Shipbuilding & Marine Engineering (DSME), also on Geoje Island. See table below.

Table 4.1 Current LNG Fleet Size

As of January 15th 2009

| Summary | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | Size Bracket | In Service | | | Building for Delivery in | | | | | | Totals |
| | | Pre-2009 | 2009 | Total | 2009 | 2010 | 2011 | 2012 | 2013 | Total | |
| Q-Max | > 250,000 cm | 4 | 0 | 4 | 8 | 2 | 0 | 0 | 0 | 10 | 14 |
| Q-Flex | 200-250,000 cm | 20 | 0 | 20 | 6 | 4 | 0 | 0 | 0 | 10 | 30 |
| Standard | 100-200,000 cm | 244 | 0 | 244 | 28 | 16 | 13 | 2 | 0 | 59 | 303 |
| Small | <100,000 cm | 30 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| Totals | | 298 | 0 | 298 | 42 | 22 | 13 | 2 | 0 | 79 | 377 |

**Source:** www.coltoncompany.com

### 4.1.4 **LNG trading routes around the world**

In 2007, the LNG trade movements are mainly from LNG production sites to the following areas: North America, S. & cent America, Europe, Asia Pacific. See figure

As to North America, let us first examine the LNG trade line, that is, trade between United States and main LNG production countries. America LNG imports in 2007 accounted for roughly 91 percent of the total imports to North America (21.82/23.99=90.95 percent), and the biggest LNG export country for US is Trinidad & Tobago, with LNG volume of 12.78 billion cubic meters, and 3.24 billion cubic meters from Egypt, 2.69 billion cubic meters from Nigeria, 2.11 billion cubic meters from Algeria, 0.52 billion cubic meters Qatar, 0.50 billion cubic meters from Equatorial Guinea, totaled as 21.82. And the other LNG import country in North America is Mexico, with 0.99 billion cubic meters from Egypt, 0.62 billion cubic meters Trinidad & Tobago, 0.56 billion cubic meters from Nigeria, totaled as 2.17.

In 2007, the S. & Cent America has very little LNG trade in volume, with Dominican Republic imports 0.36 billion cubic meters from Trinidad & Tobago and Puerto Rico imports 0.74 billion cubic meters also from Trinidad & Tobago.

When it comes to Europe, the biggest LNG import country is Spain with total volume of 24.18 billion cubic meters, or exactly, 8.33 billion cubic meters from Nigeria, 4.45 billion cubic meters from Qatar, 4.32 billion cubic meters from Algeria, 4.04 from Egypt, 2.09 billion cubic meters from Trinidad & Tobago, 0.76 billion cubic meters from Libya, 0.12 billion cubic meters from Oman, 0.07 billion cubic meters from Norway. And the second large LNG import country in Europe is France with total import volume of 12.97 billion cubic meters, 7.85 billion cubic meters from Algeria, 3.78 billion cubic meters from Nigeria, 1.21 billion cubic meters from Egypt, 0.07 billion cubic meters from Norway, and 0.06 from Trinidad & Tobago. And the third largest import country is Turkey, with total volume of 6.01 billion cubic meters, Belgium with 3.17, Italy with 2.43, Portugal with 2.31, and United Kingdom with 1.46.

As we know, Asia Pacific is the dominant LNG import market in the world, almost 66 percent of the world total (147.98/226.41=65.36 percent), in 2007, Japan was still the biggest LNG import country in Asia Pacific, with total volume of 88.82 million cubic meters, mainly from Indonesia, Malaysia, Australia, Qatar (listed in order of contributed volume), South Korea ranked number 2 with volume of 34.39 million cubic meters, mainly from Qatar, Malaysia, Oman, Indonesia. Taiwan was the third largest import country in Asia, with volume of 10.92, followed by India with 9.98 million cubic meters and China, 3.87 million cubic meters.

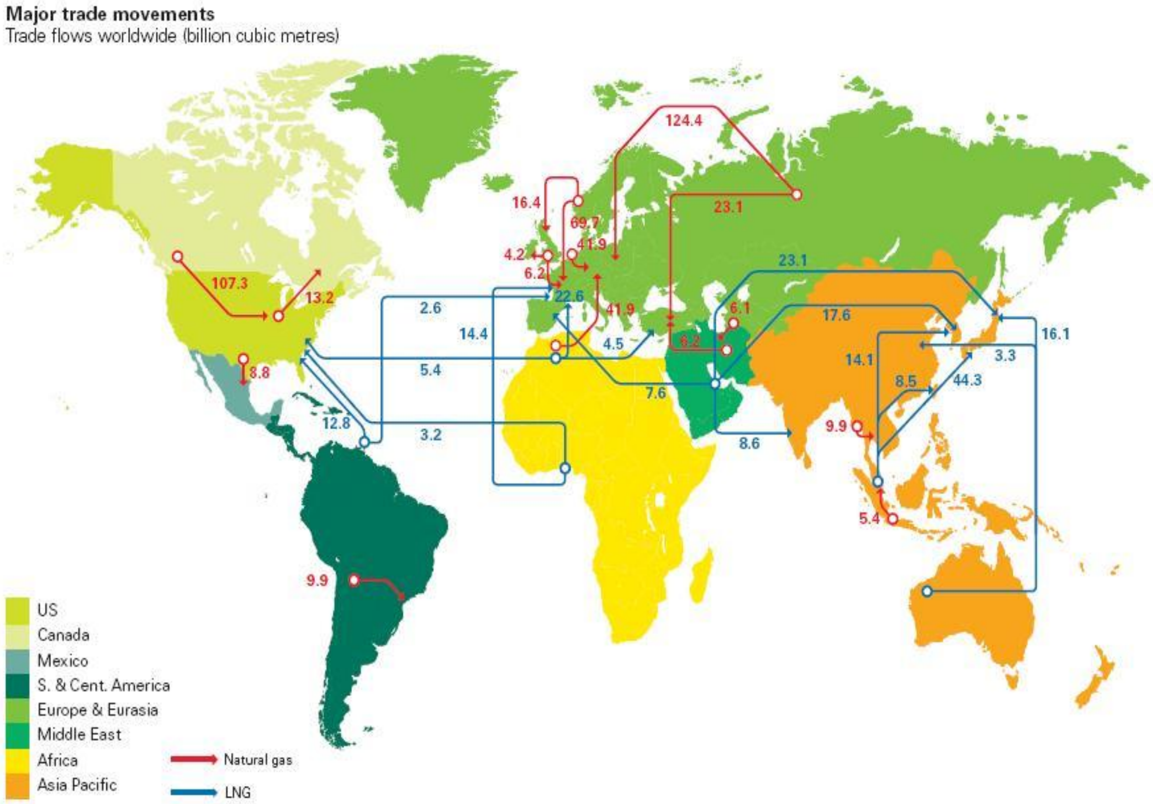


Figure 4.4 Natural Gas and LNG trade movements around the world

**Source**: petroleum economist

4.2 LNG shipbuilding market analysis

4.2.1 **LNG shipbuilding industry**

The first LNG vessel called Methane (barge) was built by Ingalls shipbuilding in 1955, with cargo capacity of only 5,550 cubic meters, and the same year it was converted to an oil barge. After that, more and more countries came into existence in LNG shipbuilding industry, United Kingdom built its first LNG vessel in 1964, followed by France, Sweden, Italy, Spain, and Norway. Germany and Belgium built their LNG ships a little bit later, in middle 1970s. From above historical events, we can see that, in early ages, America and Europe dominated the LNG carrier building industry, main shipyard like Atlantique and La Ciotat, Kvaner Masa in France and GD Quincy in America etc.. Japan introduced LNG shipbuilding technology into the country in 1980s, and built big number of LNG vessels for domestic ship owners, by middle of 1980s, shipyards like Mitsubishi, Kawasaki, Mitsui etc. dominate the LNG shipbuilding market. South Korea was another active player in LNG shipbuilding industry after 1990s, shipyards like Hyundai, Daewoo, and Samsung came into this industry one after another, and Hyundai built its first LNG vessel in 1994, also the first vessel in Korea history. Due to their innovation in LNG shipbuilding technology, shipbuilding companies in Japan and Korea forced Europe and America ship builders out of LNG shipbuilding market, and enjoy big share in LNG shipbuilding market. After year 2000, Korea ship building companies prevail in the competition with Japan, and became number one LNG shipbuilder in the world, while Japan, world's number 1 in 1990s, now ranked number 2. A lot of orders for LNG vessels from Europe go to South Korea, Europe shipbuilders only have very few orders from ship owners in Europe, what has to be pointed out is that Korea LNG ship builders has to pay France GTT about $10,000,000 patent fees as it has no its own core technology for cooling down natural gas into liquid for sea transportation.

#### 4.2.1.1 **LNG shipbuilders in South Korea**

Currently, there are 6 shipyards that build LNG vessels in Korea, Daewoo SB with LNG vessels 81 handled, Samsung H.I. with 71 handled, Hyundai H.I. with 37 handled, Hanjin H.I. with 6 handled, Hyundai Samho with 3 handled, STX Shipbuilding with 1 handled, all together 199 LNG vessels, accounted for about 51% of the world total(199/391=0.5089).

Daewoo SB built its first LNG vessel for Sk, a shipping company in Korea, in 1999, by 2009, Daewoo has handled 81 LNG vessels, and become world's number one LNG ship builder with on order book.

Samsung H.I. entered into LNG shipbuilding industry in 2000, the latest player in Korea among the three biggest LNG ship builders, and built its first LNG vessel for SK in 2000 when the vessel physically at sea, and by 2009, it has handled

71 vessels, became world's number two LNG ship builders with LNG vessels on order book.

Hyundai H.I., as the first LNG vessel builder in Korea, it built is first LNG vessel in 1994 with cargo capacity of 125,000 cubic meters. It is important to point out that Hyundai is the only LNG ship builder in the world that own two cargo systems: MOSS (This design is owned by the Norwegian company Moss Maritime) and TZM.

Hanjin H.I. built its first LNG vessel in July 2000, and has since built 6 LNG vessels till 2009, with no new orders from ship owner.

STX shipbuilding is a major international shipbuilding company headquartered in Jinhae, South Korea. It owns STX Europe, the largest shipbuilding group in Europe, and has won its first order to build a liquefied natural gas carrier. Under the deal, STX constructs a membrane type LNG vessel of 173,600 cubic meters costing $225 million for delivery by May 2010 for Stream, a joint venture between Spanish oil major Repsol and gas firm Gas Natural

#### 4.2.1.2 **LNG ship builders in Japan**

Currently, there are 9 shipyards that physically build LNG ships, Mitsubishi H.I. with 41 LNG vessels handled, Kawasaki H.I. with 29 handled, Mitsui SB 17 handled, NKK Corp. with 4 handled, Koyo Dock K.K. with 3 handled, Universal S.B. with 2 handled, Higaki Zosen with 2 handled, I.H.I. with 2 handled, Imamura Zosen with 1 handled, all add up as 101 vessels, and account for about 25% of the world's total (101/391=0.258).

Mitsubishi H.I., the biggest LNG ship builder in Japan, also can build LNG vessels using two types of cargo systems: MOSS and GTT-96, but most of their LNG vessels are built in MOSS system. By 2009, it has handled 41 LNG vessels, with LNG vessels on order book.

Kawasaki H.I. is a pioneer LNG ship builder in Japan, because it built a

LNG vessel using their owned cargo system called Kawasaki. And most of their LNG vessels are also with MOSS cargo system, has built 29 vessels till 2009 with on order book.

Mitsui SB can build LNG vessels using two cargo systems as Mitsubishi H.I., and has built vessels mostly in MOSS system, with a record of 17 vessels handled until 2009. Its order book record vessels

NKK Corp., Nippon Kōkan KK, was founded in 1912 to make products using the steel from Japan’s first steel mills. The NKK Corporation is the second largest steelmaker in Japan (after the Nippon Steel Corporation). In addition to producing a great array of finished and semi-finished steel products, the company designs and builds industrial plants, ships, and other large-scale steel structures. It built its first LNG vessel for MISC using TCM cargo system, and the cargo capacity is 18,800 cubic meters, only four LNG vessels are built till 2009.

Koyo Dock K.K. has its head office and ship yard in Mihara, Hiroshima with four ship building facilities: B.DOCK & R.DOCK No.5, B.DOCK No.1, R.DOCK No.1 and R.DOCK No.2, the maximum length is 378 meters and beam of 59 meters. In 2008, Koyo add new crane with lifting capacity of 800 tons to its number one DOCK to relieve its lack of yard area. Until 2009, it has only built one LNG vessel called Trinity Arrow, but without any new building orders on hand. Trinity Arrow is the newest LNG Carrier with membrane type built by the famous shipbuilder Imabari. The vessel has a cargo capacity of 154,900 cubic meters The vessel was built into the ship-yard of Koyo Dockyard and the owner of the beautiful LNG Carrier is Trinity Transport S.A. Trinity Arrow has a deadweight of 79,556 metric tons and gross tonnage of 108,010 metric tons. The overall length of the vessel is 289.93 meters and the length between perpendiculars is 276 meters. The other measurements of the vessel Trinity Arrow are beam of 44.70 meters, draught of 26.00 meters and draft, while fully loaded of 12.07 meters.

Universal S.B. has five shipyards: Ariaka Shipyard has two building facilities, namely, B.DOCK No.1 B.DOCK No.2, with No.1 has maximum length of 620 meters and beam of 85.4 meters, Tsu Shipyard has two facilities called B.DOCK No.1 and R.DOCK No.2, with R.DOCK has the maximum length of 500 meters and beam of 75 meters, Malzuru Shipyard has three facilities: Berth No.1 B.DOCK No.3 and R.DOCK No.2 with maximum length of 258 meters ang beam of 36.4 meters, Kelhin Ship yard has four facilities Berth No.1, R.DOCK No.1, R.DOCK No.2, R.DOCK No.3, with maximum length of 177.7 meters and beam of 35 meters, Innoshima Ship yard has three facilities, R.DOCK No.1, R.DOCK No.2, R.DOCK No.3, with maximum length of 282 and beam of 56.7.

Source: ship builders' association of Japan

I.H.I. is a famous company in Japan because it used to work out a new cargo system of its own called SPB(self supporting prismatic IMO type B), which can be used to built big vessels over 200,000 cubic meters , and built two LNG vessels for America. But they never receive any orders again till 2009. I.H.I its head office in Tokyo mainly deals in ship & offshore sales and ship repair, its Yokohama ship yard has building facilities: two B.DOCK & R.DOCKs and two F.DOCKs, with maximum length of 353.7 and beam of 56 meters, Its Kure Shipyard has three ship building facilities: two B.DOCKs and one R.DOCK, with maximum length of 508.2 meters and beam of 80 meters, its Aioi Production Workshop has four building facilities: one berth, and three R.DOCK, and its Chita Works has only one B.DOCK &R.DOCK.

#### 4.2.1.3 **LNG builders In France**

As the third biggest LNG ship builders, France has six ship yards that constructed LNG vessels, At.Ch. La Seine, France-Dunkerq., Ch.De La Ciotat, C.N.I.M., Ch. de l'Atlantique, among which Atlantique is the biggest, and have built 14 LNG vessels. But builders in France has been forced out of LNG building market by Korea and Japan, and that's why France sell its building technology to china, which has ambition to become main players in LNG ship building market.

#### 4.2.1.4 **LNG builders in China**

China's trying to built LNG vessels can ascend to 1997 in Hudong Zhonghua, shanghai China. And in 1998, China tried to contact GTT in France, and negotiated long for cooperation, in 2000, GTT and Hudong Zhonghua signed a contract for using its LNG building technology. After years of efforts, China built its first LNG vessel called Dapeng Moon, handed it over to ship owner on 3, 04, 2008. Hudong Zhonghua began to built this LNG ship on 15, 12, 2004, and spent more than 40 months to accomplish its first LNG vessel. This vessel was built for China LNG shipping with length of overall 292.30 meters, drought of 11.45 meters, beam of 43.3 meters, gross tonnage of 97,871 tons, speed of 19.50 knots using Kawasaki engine and cargo capacity of 147,210 cubic meters. Since that, Hudong Zhonghua has delivered three LNG vessels called Dapeng Moon, Dapeng Sun and Min Rong, all with cargo capacity of about 147,000 cubic meters. And the other two LNG vessels are in progress in 2009, not named, Hudong Zhonghua Shanghai H1378A, Hudong Zhonghua Shanghai H1379A. Taizhou Wuzhou Dingheng Jiangsu

Table 4.2 LNG builders by country

| Rank | Yard | Number | total# | Total | Avg Size | Unit | Age | Country |
|---|---|---|---|---|---|---|---|---|
| 1 | Gen. Dynamics | 10 | | 725,839 | 72,583 | DWT | 30 | United States |
| 2 | Newport News SB | 3 | 13 | 213,380 | 71,126 | DWT | 31 | United States |
| 3 | Kockums M/V AB | 4 | 4 | 224,116 | 56,029 | DWT | 33 | Sweden |
| 4 | Izar S.A. | 3 | | 226,636 | 75,545 | DWT | 5 | Spain |
| 5 | Izar S.A. | 2 | | 149,432 | 74,716 | DWT | 5 | Spain |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 6 | Astano S.A. | 1 | | 25,293 | 25,293 | DWT | 39 | Spain |
| 7 | Const. Nav del Norte | 1 | 7 | 69,000 | 69,000 | DWT | 1 | Spain |
| 8 | Hyundai H.I. | 37 | | 3,187,084 | 86,137 | DWT | 4 | South Korea |
| 9 | Hyundai Samho | 3 | | 246,303 | 82,101 | DWT | 0 | South Korea |
| 10 | Samsung H.I. | 71 | | 6,700,145 | 94,368 | DWT | 2 | South Korea |
| 11 | STX Shipbuild. | 1 | | 95,000 | 95,000 | DWT | -1 | South Korea |
| 12 | Daewoo SB | 81 | | 7,289,269 | 89,990 | DWT | 2 | South Korea |
| 13 | Hanjin H.I. | 6 | 199 | 463,359 | 77,226 | DWT | 7 | South Korea |
| 14 | Remontowa | 1 | 1 | 6,150 | 6,150 | DWT | 0 | Poland |
| 15 | Moss Rosenberg | 5 | | 321,321 | 64,264 | DWT | 34 | Norway |
| 16 | Moss Rosenberg | 2 | 7 | 43,729 | 21,864 | DWT | 35 | Norway |
| 17 | Shipyd. Bijlsma | 1 | 1 | 817 | 817 | DWT | 5 | Netherlands |
| 18 | I.H.I. | 2 | | 97,634 | 48,817 | DWT | 16 | Japan |
| 19 | Mitsubishi H.I. | 41 | | 3,068,507 | 74,841 | DWT | 8 | Japan |
| 20 | Higaki Zosen | 2 | | 3,561 | 1,780 | DWT | 3 | Japan |
| 21 | Imamura Zosen. | 1 | | 1,408 | 1,408 | DWT | 21 | Japan |
| 22 | Kawasaki H.I. | 29 | | 2,006,837 | 69,201 | DWT | 6 | Japan |
| 23 | Koyo Dock K.K. | 3 | | 246,000 | 82,000 | DWT | 0 | Japan |
| 24 | Mitsui SB | 17 | | 1,218,185 | 71,657 | DWT | 12 | Japan |
| 25 | NKK Corp. | 4 | | 40,028 | 10,007 | DWT | 12 | Japan |
| 26 | Universal S.B. | 2 | 101 | 79,003 | 39,501 | DWT | 1 | Japan |
| 27 | Italcantieri | 2 | | 50,794 | 25,397 | DWT | 39 | Italy |
| 28 | Sestri-Cantiere | 2 | 4 | 71,520 | 35,760 | DWT | 12 | Italy |
| 29 | H.D.W. | 2 | 2 | 137,830 | 68,915 | DWT | 32 | Germany |
| 30 | At.Ch. La Seine | 1 | | 13,400 | 13,400 | DWT | 44 | France |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 31 | France-Dunkerq. | 4 | | 283,721 | 70,930 | DWT | 29 | France |
| 32 | Ch.De La Ciotat | 3 | | 135,555 | 45,185 | DWT | 34 | France |
| 33 | C.N.I.M. | 9 | | 442,780 | 49,197 | DWT | 32 | France |
| 34 | Ch. de l'Atlantique | 14 | | 929,869 | 66,419 | DWT | 27 | France |
| 35 | Aker Yards S.A. | 3 | 34 | 187,345 | 62,448 | DWT | 2 | France |
| 36 | Kvaerner Masa | 4 | 4 | 317,000 | 79,250 | DWT | 13 | Finland |
| 37 | Hudong Zhonghua | 5 | | 365,825 | 73,165 | DWT | 0 | China P.R. |
| 38 | Taizhou Wuzhou | 6 | | 49,200 | 8,200 | DWT | -1 | China P.R. |
| 39 | Dingheng Jiangsu | 2 | 13 | 18,000 | 9,000 | DWT | -1 | China P.R. |
| 40 | Boelwerf | 1 | | 72,792 | 72,792 | DWT | 31 | Belgium |
| | | Total number | 391 | | | | | |

**Source: Clarkson**

## 4.3 **LNG demolition market**

Though a long history of LNG shipping of about 50 years, LNG vessels have the lowest records of accidents, when compared with oil tankers etc., and usually it has a very long life span at sea, of about 35 to 40 years, that's a very important reason why LNG vessel demolition market is still small. More important, LNG ship is safe, no significant accident happened at sea until now, till January 15, 2009, there are 24 LNG vessels that are out of services, among which 7 are converted to other usage and 17 went to demolition market. See tables below

Table 4.3LNG vessels out of use

| *Name of Ship* | *Operator* | *Shipbuilder* | *Year Built or Rebuilt* | *# of Voyages* | *Year With-drawn* | *Cargo Capacity (cu.m.)* | *Cargo System* | *LDT* | *$/LDT* | *Disposition* |
|---|---|---|---|---|---|---|---|---|---|---|
| Methane (barge) | Chicago Stockyards | Ingalls | 1955 | 0 | 1955 | 5,550 | Morrison | | | Converted to an oil barge |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Beauvais | Gaz de France | Atlantique | 1962 | 0 | 1962 | 640 | Mixed | | | Scrapped |
| Pythagore | Gazocean | Le Havre | 1964 | 1 | 1964 | 610 | TZM | | | Converted to a fish carrier |
| Aristotle (ex Methane Pioneer) | Stephenson, Clarke | Alabama | 1958 | 30 | 1972 | 5,000 | Morrison | | | Converted to LPG storage |
| Euclides | Gazocean | Le Havre | 1971 | 14 | 1973 | 4,000 | TZM | | | Converted to an LPG carrier |
| Sanko Ethylene Maru | Hitachi Zosen | Hitachi | 1974 | 0 | 1974 | 1,100 | Hitachi | | | Disposition unknown |
| Massachusetts (barge) | Moran Tankship | Todd Houston | 1974 | 7 | 1974 | 4,000 | Unknown | | | Converted to LPG storage |
| Sant Jordi | Unknown | Bilbao | 1975 | 0 | 1975 | 5,000 | Sener | | | Sank off Spain in 1995 |
| El Paso Columbia | El Paso Tankers | Avondale | 1979 | 0 | 1979 | 130,000 | Conch | | | Converted to OBO, scrapped in 2000 |
| El Paso Savannah | El Paso Tankers | Avondale | 1979 | 0 | 1979 | 130,000 | Conch | | | Converted to OBO, now an FPSO |
| El Paso Cove Point | El Paso Tankers | Avondale | 1979 | 0 | 1979 | 130,000 | Conch | | | Wrecked and scrapped in 1987 |
| Ben Franklin | SNTM-Hyproc | La Ciotat | 1975 | 5 | 1980 | 120,000 | TZM | | | Scrapped in 1980 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| El Paso Paul Keyser | El Paso Tankers | Dunkerque | 1976 | 12 | 1980 | 129,500 | GT | | | Scrapped in 1985 |
| El Paso Sonatrach | El Paso Tankers | Dunkerque | 1977 | 26 | 1980 | 129,500 | GT | | | Scrapped in 1985 |
| El Paso Consolidated | El Paso Tankers | Dunkerque | 1977 | 15 | 1980 | 129,500 | GT | | | Scrapped in 1987 |
| Esso Portovenere | SNAM | Italcantieri | 1971 | 335 | 1984 | 40,000 | Esso | | | Scrapped in 1984 |
| Methane Progress | British Gas | Harland & Wolff | 1964 | 467 | 1992 | 27,400 | Conch | | | Scrapped in 1992 |
| Methane Princess | British Gas | Vickers-Armstrong | 1964 | 500+ | 1998 | 27,400 | Conch | | | Scrapped in 1998 |
| Havfru | BW Gas | Moss Verft | 1973 | | 7-May | 29,388 | Moss | 11,192 | 550 | Scrapped in 2007 |
| Laieta | Maritima del Norte | Astano | 1970 | | 8-Jun | 40,000 | Esso | 14,481 | 940 | Scrapped in 2008 |
| Cinderella | TMT Co. Ltd. | Le Trait | 1965 | | 8-Jul | 25,500 | Worms | 11,353 | 775 | Scrapped in 2008 |
| Charm Junior | TMT Co. Ltd. | Atlantique | 1971 | | 8-Jul | 50,000 | TZ Mk. 1 | 14,162 | | Scrapped in 2008 |
| Century | BW Gas | Moss Verft | 1974 | | 8-Nov | 29,588 | Moss | 11,192 | | Scrapped in 2008 |

**Source**: Peter G. Noble . Texas Section – SNAME, Feb 10th. 2009

**Conclusion**: From the above analysis, we can reach the conclusion that LNG shipping capacity has an excess over the LNG shipping demand, because until recently, the number of world's LNG vessels reached 391, and more important LNG vessels has long life span and very few accidents, which also ensure that the excess of shipping capacity last for long. As China became the most active player in LNG shipping builder industry and its ambition to dominate this market, there will be more and more LNG vessels come into existence in China, at the end of 2009, the number of LNG vessels would be 13. So shipping price of LNG will witness further decrease. (Also see tables below)

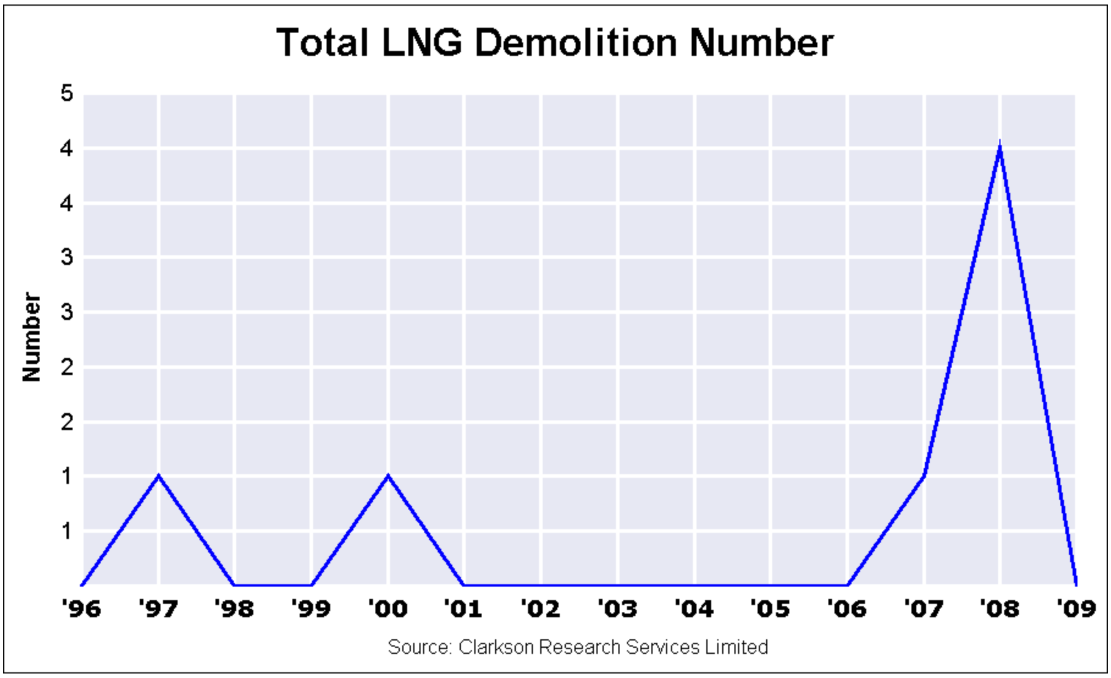


Figure 4.5 LNG Demolition Number

**Source: Clarkson**

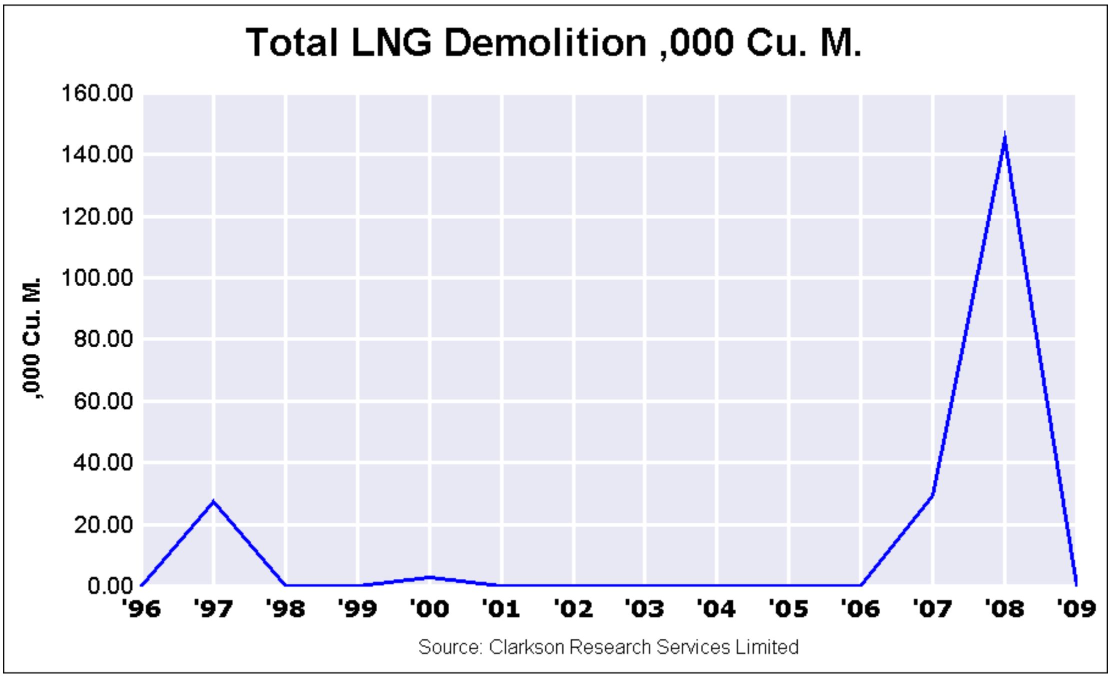


Figure 4.6 LNG Demolition Capacity

**Source: Clarkson**

# Chapter 5 LNG demand in China

As we know, china's rapid economical growth was at the expense of high energy consume rates, so the energy demand in China is huge, especially for clean energy like natural gas. But natural gas production is lagged behind when compared with economic performance, the gap between remains big for years, and that gap is the gauge for LNG import volume or exactly, LNG demand in China. In this Chapter, I will do some forecast based on historical data and analysis.

## 5.1 **Natural gas in China**

### 5.1.1 **Natural gas reserves in China**

According to the newest appraisal of oil and natural gas resources in China, China has abundant natural gas resources with an estimated reserves of 35.03 trillion cubic meters or 1237 Tcf, among which 22.03 trillion cubic meters or 776.9 Tcf are minable, mainly in nine basins as follows: Tarim Basin, Sichuan, ordos Basin, East China Sea, Qaidam Basin, Songliao Plain, Yinggehai in Hainan province, southeast Guangxi province, Bohai Bay Basin. And big natural gas field with reserves of over 100 billion cubic meters are found, namely, Sugeli, Daniudi, Puguang, Zizhou-Qingjian, Xushen etc.. That's really a huge leap when compared with years before 2009. (See table)

Table 5.1 Natural gas China

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 821.6 | 889.3 | 962.3 | 1070.4 | 1152.7 | 1211.3 | 1439.4 | 1762.9 | 2066.6 | 2446.3 | NA |
| consumption | 724.7 | 782.4 | 902.4 | 974.2 | 1061.3 | 1143.4 | 1350.3 | 1654.5 | 1993.5 | 2490.1 | NA |
| Net exports/imports | 96.9 | 107 | 95.3 | 96.2 | 91.4 | 67.9 | 89.1 | 108.4 | 73.1 | -43.4 | NA |
| Proved reserve | 41000 | 48300 | 48300 | 48300 | 48300 | 53325 | 53325 | 53325 | 53325 | 80000 | 80000 |

**Source**: EIA

It is forecasted that, before the year 2030, new proved reserves will increase at a high rate, at about 450 billion cubic meters. And the production also will increase fast, with 100 billion cubic meters in 2010, nearly 200 billion cubic meters in 2020, and 250 billion in 2030.

Table 5.2Main natural gas reserves China

| | middle China | west China | Adjacent sea |
|---|---|---|---|
| Volume(Tcm) | 10.11 | 11.6 | 10 |
| Percentage | 28.86% | 33.12% | 23.13% |

**Source:** Journal of West Oil College.

### 5.1.2 **Natural gas demand in China**

Despite new findings of natural gas in China, gas demand in China jumped dramatically in the past few years, because increased rate of GDP of China, above 10 percent for a few years. But domestic natural gas production in present, which mainly in west part of China, cannot meet the huge demand. On the other hand, price of natural gas on international market keep going up before 2009, import of natural gas from foreign countries thus are limited because domestic price are much lower than international market.

To ease the situation, Chinese government framed policies on natural gas use to prevent, so called, unreasonable or unwanted usage of natural gas in certain sector or industry. These policies aimed to reduce fast growth of natural gas demand and better balance the demand and supply. Due to low price of natural gas in China, natural gas consuming structure is not very reasonable, the percentage of natural gas consuming in chemical industry is too high, especially in those low value-added, short chained industry like fertilizer production, methanol production etc., this phenomena prevails around the natural gas production site in most natural gas production provinces. Using of natural gas falls into four categories in China, namely, residential, industrial, electricity, and chemical. And Chinese government also defined four kinds of usage according to their priorities. The kind with first priority include residential like cooking, public facilities such as government, canteen, school, restaurant, hotel, offices, LNG vehicles etc.. The second kind is called permitted use, like central air conditioning, usage of natural gas instead of oil or LPG in industries like construction materials, textile, oil chemistry, metal industry etc., and LNG generated electricity for peak shaving. The third is called constrained usage like natural gas electricity plant in less important areas, LNG for ammonia synthesis. The fourth kind is called forbidden usage, for example, electricity generating in areas like Sanxi, Mongolia, Shanxi, Anhui, in which coal is abundantly available.

From above mentioned limits in use, we can see that the gap between demand and production in China are increasing, though not urgent as before, besides pipeline gas, LNG is a way to overcome the problem, but high price of LNG, compared with domestic gas, will prevent LNG use in big scale, only a few less price sensitive areas or industry will witness the increase in using of LNG, like coastal cities that esteem environment, industries that attach importance to quality not cost such as porcelain manufacture, and industries with oil to fuel its growth, which is higher in price than gas.

## 5.2 **Analysis of gas gap in China**

### 5.2.1 **Potential of gas use per capita**

China was among those countries who first use natural gas in the world, but natural gas use remains of small proportion of the whole energy consuming from the beginning, at about 2.5% in production, and 2.35% in consuming, averaged from 1978 to 2006(see table). Over 70% of energy demand is from coal. But natural gas consuming in developed countries take a big proportion of the whole energy demand, about 30%. In 2007, United States consumed 23058 billion cubic feet, UK consumed 3217.2 billion cubic feet, and Japan, 3542.2, but China only 2490.1. (see table below), and the population of the four countries are as follows: China 1338612968, USA 307212123, Japan 127078679, UK 61113205, if see below natural gas consuming per capita of the four countries.

Table 5.3Peer comparison of gas consuming in 2007

| | China | USA | Japan | UK |
|---|---|---|---|---|
| Gas consumed | 2490.1 | 23058 | 3542.2 | 3217.2 |
| Population | 1338612968 | 307212123 | 127078679 | 61113205 |
| per capita bcf | 1.86021E-06 | 7.50556E-05 | 2.7874E-05 | 5.26433E-05 |
| per capita cf | 1860.209082 | 75055.63184 | 27874.07 | 52643.28716 |
| per capita cm | 52.67526149 | 2125.339067 | 789.30586 | 1490.692065 |

**Source**: Done by Author

From the above calculation, we can see that, in 2007, China consumed 52.7 cubic meters of gas per capita, USA 2125.3, Japan 789.3, UK 1490.7, there is huge gap between china and developed countries, if China consumes 39358.3 cubic feet or

1468.45 cubic meters per capita, average of USA, Japan, and UK, the demand of natural gas in China will be 52685.5 billion cubic feet, though it is not practical for China to consume that much in near future, but it is a gauge, in a sense, of potential of LNG demand in China, a gap of about 50195.4 billion cubic feet of natural gas in 2007.

Table 5.4 Total Production of Energy and Its Composition

| Year | Total Energy Production (10 000 tons of SCE) | As Percentage of Total Energy Production | | | |
|---|---|---|---|---|---|
| | | Coal | Crude Oil | Natural Gas | Hydro-power, Nuclear Power, Wind Power |
| 1978 | 62770.0 | 70.3 | 23.7 | 2.9 | 3.1 |
| 1980 | 63735.0 | 69.4 | 23.8 | 3.0 | 3.8 |
| 1985 | 85546.0 | 72.8 | 20.9 | 2.0 | 4.3 |
| 1990 | 103922.0 | 74.2 | 19.0 | 2.0 | 4.8 |
| 1991 | 104844.0 | 74.1 | 19.2 | 2.0 | 4.7 |
| 1992 | 107256.0 | 74.3 | 18.9 | 2.0 | 4.8 |
| 1993 | 111059.0 | 74.0 | 18.7 | 2.0 | 5.3 |
| 1994 | 118729.0 | 74.6 | 17.6 | 1.9 | 5.9 |
| 1995 | 129034.0 | 75.3 | 16.6 | 1.9 | 6.2 |
| 1996 | 132616.0 | 75.2 | 17.0 | 2.0 | 5.8 |
| 1997 | 132410.0 | 74.1 | 17.3 | 2.1 | 6.5 |
| 1998 | 124250.0 | 71.9 | 18.5 | 2.5 | 7.1 |
| 1999 | 125934.8 | 72.6 | 18.2 | 2.7 | 6.6 |
| 2000 | 128977.9 | 72.0 | 18.1 | 2.8 | 7.2 |
| 2001 | 137445.4 | 71.8 | 17.0 | 2.9 | 8.2 |

| | | | | | |
|---|---|---|---|---|---|
| 2002 | 143809.8 | 72.3 | 16.6 | 3.0 | 8.1 |
| 2003 | 163841.5 | 75.1 | 14.8 | 2.8 | 7.3 |
| 2004 | 187341.2 | 76.0 | 13.4 | 2.9 | 7.7 |
| 2005 | 205876.0 | 76.5 | 12.6 | 3.2 | 7.7 |
| 2006 | 221056.0 | 76.7 | 11.9 | 3.5 | 7.9 |
| average | | | | 2.5 | |

**Source**: China Statistical Yearbook

Table 5.5 Total Consumption of Energy and Its Composition

| Year | Total Energy Consumption (10 000 tons of SCE) | As Percentage of Total Energy Consumption | | | |
|---|---|---|---|---|---|
| | | Coal | Crude Oil | Natural Gas | Hydro-power, Nuclear Power, Wind Power |
| 1978 | 57144.0 | 70.7 | 22.7 | 3.2 | 3.4 |
| 1980 | 60275.0 | 72.2 | 20.7 | 3.1 | 4.0 |
| 1985 | 76682.0 | 75.8 | 17.1 | 2.2 | 4.9 |
| 1990 | 98703.0 | 76.2 | 16.6 | 2.1 | 5.1 |
| 1991 | 103783.0 | 76.1 | 17.1 | 2.0 | 4.8 |
| 1992 | 109170.0 | 75.7 | 17.5 | 1.9 | 4.9 |
| 1993 | 115993.0 | 74.7 | 18.2 | 1.9 | 5.2 |
| 1994 | 122737.0 | 75.0 | 17.4 | 1.9 | 5.7 |
| 1995 | 131176.0 | 74.6 | 17.5 | 1.8 | 6.1 |
| 1996 | 138948.0 | 74.7 | 18.0 | 1.8 | 5.5 |
| 1997 | 137798.0 | 71.7 | 20.4 | 1.7 | 6.2 |

| | | | | | |
|---|---|---|---|---|---|
| 1998 | 132214.0 | 69.6 | 21.5 | 2.2 | 6.7 |
| 1999 | 133831.0 | 69.1 | 22.6 | 2.1 | 6.2 |
| 2000 | 138552.6 | 67.8 | 23.2 | 2.4 | 6.7 |
| 2001 | 143199.2 | 66.7 | 22.9 | 2.6 | 7.9 |
| 2002 | 151797.3 | 66.3 | 23.4 | 2.6 | 7.7 |
| 2003 | 174990.3 | 68.4 | 22.2 | 2.6 | 6.8 |
| 2004 | 203226.7 | 68.0 | 22.3 | 2.6 | 7.1 |
| 2005 | 224682.0 | 69.1 | 21.0 | 2.8 | 7.1 |
| 2006 | 246270.0 | 69.4 | 20.4 | 3.0 | 7.2 |
| Average | | | | 2.35 | |

**Source**: China Statistical Yearbook

Table 5.6 Natural gas America

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 19024 | 18832.2 | 19182 | 19616 | 18928 | 19099 | 18591 | 18051 | 18476 | 19278 | NA |
| consumption | 22246 | 22405 | 23333 | 22239 | 23007 | 22277 | 22389 | 22011 | 21653 | 23058 | NA |
| Net exports/imports | -2993 | -3423 | -3538 | -3604 | -3499 | -3264 | -3405 | -3612 | -3462 | -3780 | NA |
| Proved reserves | 2E+05 | 164041 | 2E+05 | 177427 | 183460 | 186946 | 189044 | 192513 | 204385 | 211085 | 237726 |

**Source: EIA**

Table 5.7 Natural gas UK

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 3144 | 3486 | 3826 | 3689.4 | 3658 | 3632 | 3389 | 3099 | 2819 | 2553.3 | NA |
| consumption | 3072 | 3259 | 3373 | 3338 | 3379 | 3359 | 3478 | 3357 | 3202 | 3217.2 | NA |
| Net exports/impor | 72 | 227.1 | 452.4 | 351.4 | 279 | 273.7 | -88.3 | -258 | -384 | -663.9 | NA |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ts | | | | | | | | | | | |
| Proved reserves | 26839 | 27016 | 26663 | 26839 | 25956 | 24600 | 22200 | 20800 | 18750 | 17000 | 14550 |

**Source: EIA**

Table 5.8 Natural gas Japan

| Billion cubic feet | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 197.9 | 201.2 | 205.2 | 193.2 | 218.7 | 184.8 | 181.1 | 178.6 | 173.9 | 131.7 | NA |
| consumption | 2676 | 2818 | 2914 | 2902.4 | 3100 | 3100 | 3074 | 3081 | 3247 | 3542.2 | NA |
| Net exports/imports | -2462 | -2576 | -2678 | -2691 | -2720 | -2894 | -2863 | -2858 | -3130 | -3377 | NA |
| Proved reserves | 1386 | 1380 | 1414 | 1414 | 1414 | 1400 | 1400 | 1400 | 1400 | 1400 | 738 |

**Source: EIA**

### 5.2.2 **Potential of gas use by sector**

In 2006, China has a total final consumption of gas of 1560816, with consumption in industry of 692323, transport of 2826, residential of 399494, Commercial and Public Services of 129615, and non-energy use of 336558. Gas are mainly consumed in industry and residential, about 44% of the total are used in industry like chemicals, and 26% are used in residential. See table below. But in Japan, that of gas in industry only takes up 20%, and residential of about 11%, most of their imported LNG are consumed in power plant, about 61% of the total gas consumed. And most power plant in China are fueled with coal, the problem is that

China now face severe environmental problems, because of that dirty energy resource. If China uses natural gas to fuel power plant to avoid pollution problems, then the demand will increase big enough, LNG demand huge.

Table 5.9 Gas consume by sector 2006

| | Gas Consumed | Share of the total |
|---|---|---|
| Industry | 692323 | 0.443564776 |
| Transport | 2826 | 0.001810591 |
| Residential | 399494 | 0.255952015 |
| Commercial and Public Services | 129615 | 0.083043101 |
| Agriculture / Forestry | 0 | 0 |
| Fishing | 0 | 0 |
| Other Non-Specified | 0 | 0 |
| Non-Energy Use | 336558 | 0.215629517 |
| Total Final Consumption | 1560816 | |

**Source: EIA**

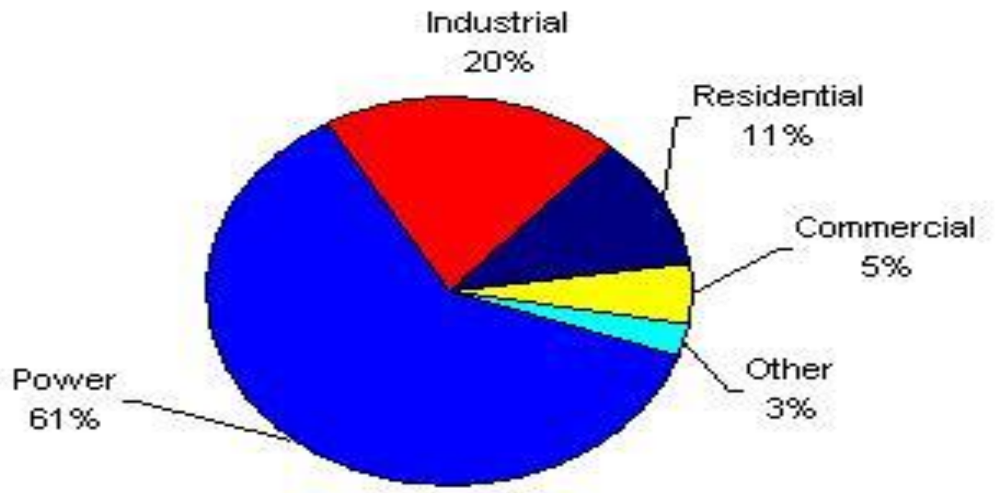


Figure 5.1 LNG consumptions by sector Japan

Source: Facts Global Energy Gas Insights March 2008.

Table 5.10 Natural Gas in China, 2006

| | |
|---|---|
| *Unit:TJ - on a gross calorific value basis* | |
| Production | 2279526 |
| From Other Sources | 0 |
| Imports | 36984 |
| Exports | -112822 |
| International Marine Bunkers | 0 |
| Stock Changes | 0 |
| **Domestic Supply** | **2203688** |
| Transfers | |
| Statistical Differences | -28276 |
| **Total Transformation** | **229212** |
| Electricity Plants | 146225 |
| CHP Plants | 0 |
| Heat Plants | 82987 |
| Petroleum Refineries | 0 |
| Other Transformation | 0 |
| **Energy Sector** | **335164** |
| Distribution Losses | 50221 |
| **Total Final Consumption** | **1560816** |
| Industry | 692323 |

| | |
|---|---|
| Transport | 2826 |
| Residential | 399494 |
| Commercial and Public Services | 129615 |
| Agriculture / Forestry | 0 |
| Fishing | 0 |
| Other Non-Specified | 0 |
| Non-Energy Use | 336558 |
| *- of which Petrochemical Feedstocks* | |

Source: IEA

## 5.3 **Quantitative forecast of Gas gap in China**

### 5.3.1 **Introduction of ANFIS: Artificial Neuro-Fuzzy Inference Systems**

As its name indicates, ANFIS is a forecast method that combines two different systems, Neuro network and Fuzzy logic, thus has strong points of the two methods and avoids their constraints in mean time. ANFIS are a class of adaptive networks that are functionally equivalent to fuzzy inference systems based on Sugeno e Tsukamoto fuzzy models(S-T models), using a hybrid learning algorithm，it is also called model-free estimator because it has no need of specific model and model description like traditional forecast method. Neuro network uses learning method of Black-Box, which means that the relation between the inputs and outputs cannot be displayed, while the Fuzzy logic is based on a easily understood way of IF-THEN, but it needs experts to manipulate.

S-T model assumes that the fuzzy inference system has two inputs *x* and *y*, and one output *z*, and a first-order Sugeno fuzzy model has rules as follows:

Rule1:

If x is A1 and y is B1, then f1 = p1x + q1y + r1

Rule2:

If x is A2 and y is B2, then f2 = p2x + q2y + r2

ANFIS has different Architectures as follows:

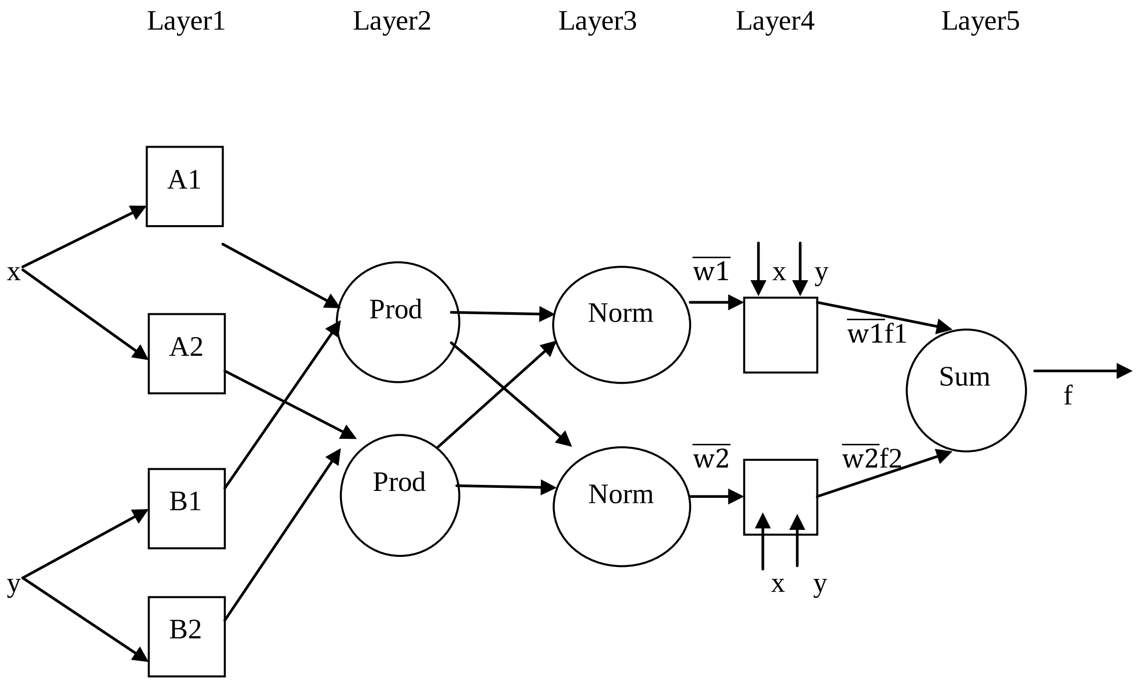


Figure 5.2 AFNIS structure

Layer 1

$O_{l,i}$ is the output of the ith node of the layer l.

Every node i in this layer is an adaptive node with a node function

$O_{1,i} = \mu A_i(x)$ for i = 1, 2, or

$O_{1,i} = \mu B_{i-2}(x)$ for i = 3, 4

x (or y) is the input node i and $A_i$ (or $B_{i-2}$) is a linguistic label associated with this node

Therefore $O_{1,i}$ is the membership grade of a fuzzy set ($A_1$,$A_2$,$B_1$,$B_2$).

Typical membership function:

$$\mu_A(x) = \frac{1}{1+\left|\frac{x-ci}{ai}\right|^{2bi}}$$

$a_i$, $b_i$ , $c_i$ is the parameter set.

Parameters are referred to as premise parameters.

Layer 2

Every node in this layer is a fixed node labeled Prod.

The output is the product of all the incoming signals.

$O_{2,i} = w_i = \mu A_i(x) \cdot \mu B_i(y)$, i = 1, 2

Each node represents the fire strength of the rule

Any other T-norm operator that perform the AND operator can be used

Layer 3

Every node in this layer is a fixed node labeled Norm.

The ith node calculates the ratio of the ith rulet's firing strength to the sum of all rulet's firing strengths.

$O_{3,i} = \overline{w}_i = \frac{wi}{w1+w2}$, i=1,2

Layer 4

Outputs are called normalized firing strengths.

Every node i in this layer is an adaptive node with a node function:

$O_{4,1} = w_i f_i = w_i(px + q_i y + r_i)$

$w_i$ is the normalized firing strenght from layer 3.

$\{p_i, q_i, r_i\}$ is the parameter set of this node.

These are referred to as consequent parameters.

Layer 5

The single node in this layer is a fixed node labeled sum, which computes the overall output as the summation of all incoming signals:

$Overall\ output = O_{5,1} = \sum_i \overline{w_i}\, f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}$

There are other structures:

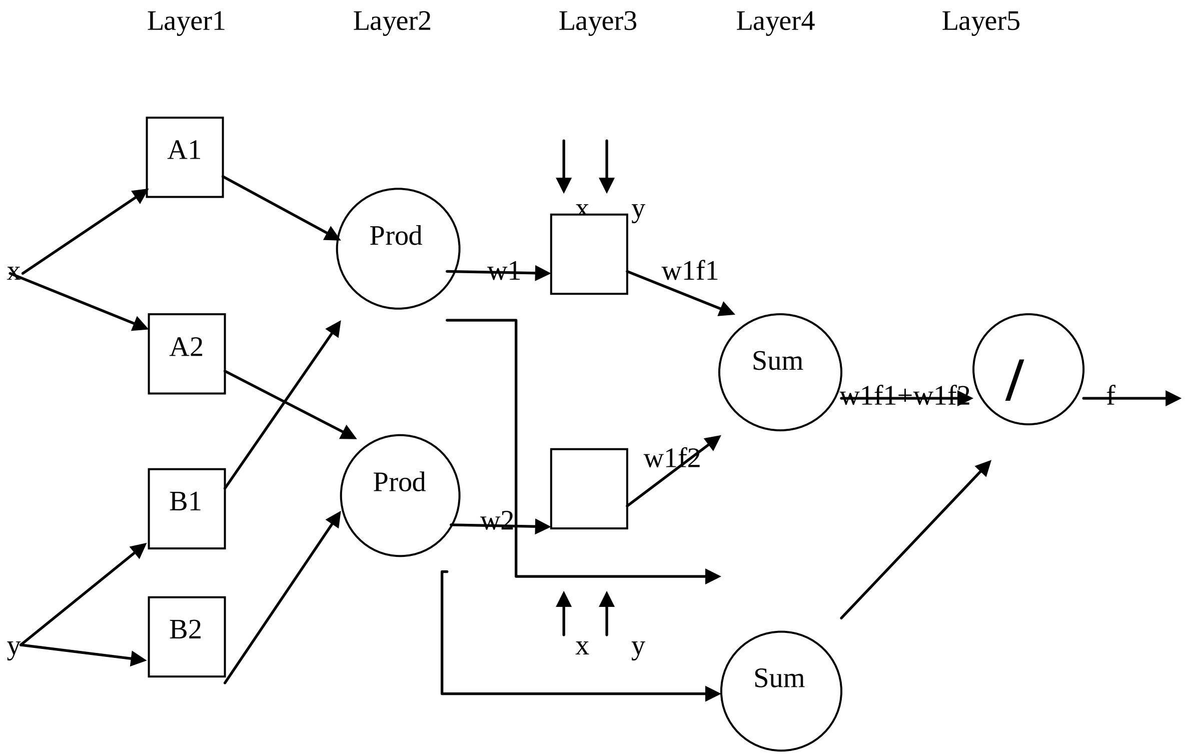


Figure 5.3 ANFIS alternative structure

Hybrid learning algorithm

The ANFIS can be trained by a hybrid learning algorithm.

In the forward pass the algorithm uses least-squares method to identify the consequent parameters on the layer 4.

In the backward pass the errors are propagated backward and the premise parameters are updated by gradient descent.

Table 5.11 Two passes in the hybrid learning algorithm for ANFIS

| | Forward Pass | Backward Pass |
|---|---|---|
| Premise Parameters | Fixed | Gradient Descent |

| Consequent Parameters | Least-squares estimator | Fixed |
|---|---|---|
| Signals | Node outputs | Error signals |

Command anfisedit.

It is possible to use the command line interface or m-file programs.

There are functions to generate, train, test and use these systems.

See figure below

Applying:

Initializing

Training

Testing

Using

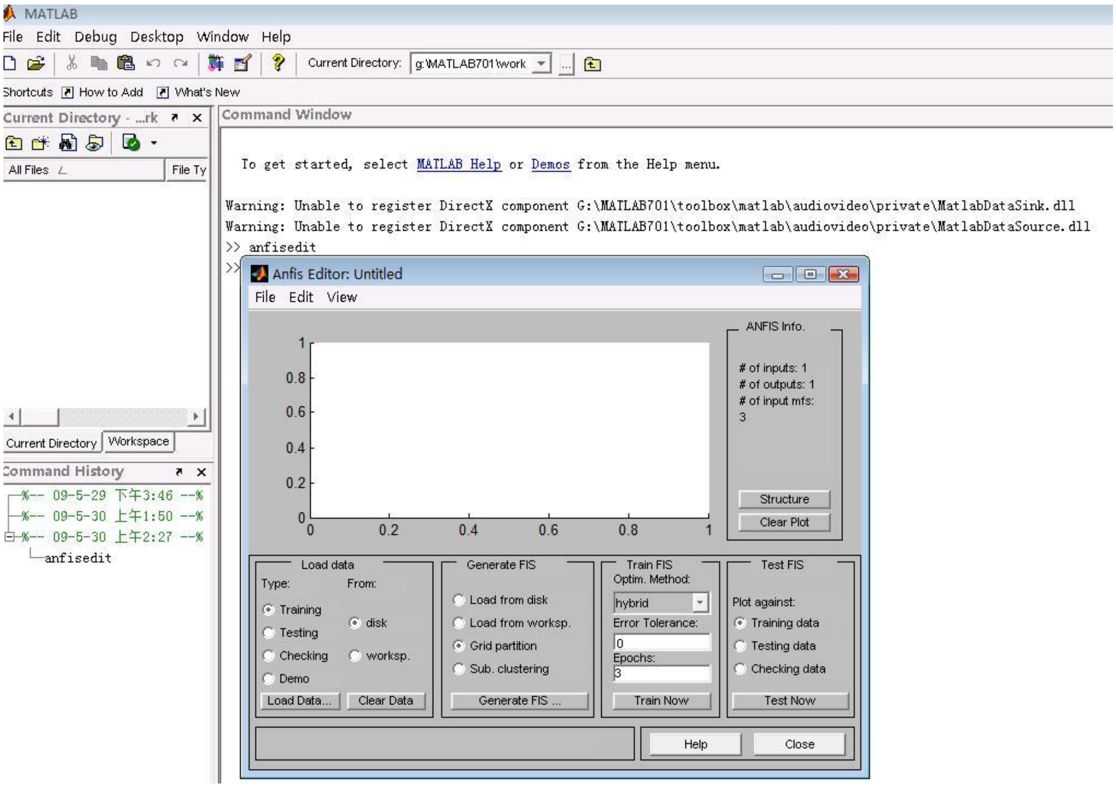


Figure 5.4 ANFIS editor

### 5.3.2 **Influential factors of Natural gas**

Since the title of my thesis is LNG shipping market analysis, I should find data of LNG import, but China only begin to import LNG in 2006, so it is very hard to forecast using data record of only two years, that's why I choose natural gas production and consumption to do my prediction, the difference between which are presumed as LNG demand in China.

As I mentioned above, natural gas is consumed mainly in industry, residential, other none energy use, and most people in cities have facilities to use natural gas, So I choose the GDP and number of people in cities as important criteria. It is forecasted by Chinese Academy of Social Sciences that the GDP growth rate will be surely be 9% or above, and I made the assumption that GDP growth rate will be maintained at 9% till 2015. Till the end of 2006, the urban population of China was 577 million, and the urbanization rate of population will be at 0.8% the following 10 to 20 years.

Table 5.12 Natural gas China

| Bcf | **1981** | **1982** | **1983** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** |
|---|---|---|---|---|---|---|---|---|---|---|
| NG production | 450 | 381 | 431 | 438 | 457 | 484 | 494.3 | 490.9 | 505 | 508 |
| NG consumption | 450 | 381 | 431 | 438 | 457 | 484 | 494.3 | 503.3 | 505 | 494.4 |
| net export | NA | NA | NA | NA | NA | NA | NA | NA | NA | 13.6 |
| proved reserves | 24500 | 24400 | 29800 | 30300 | 30900 | 30000 | 30000 | 30700 | 31700 | 35300 |

| | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** |
|---|---|---|---|---|---|---|---|---|---|---|
| NG production | 526 | 533.3 | 558.3 | 588.7 | 601.4 | 711.8 | 801.3 | 821.6 | 889.3 | 962.3 |
| NG consumption | 511.3 | 516.8 | 541 | 569.9 | 581.5 | 646 | 697.3 | 724.7 | 782.4 | 902.4 |
| net export | 14.7 | 16.5 | 17.4 | 18.8 | 19.9 | 65.8 | 104 | 96.9 | 107 | 95.3 |
| proved reserves | 35300 | 35400 | 49400 | 59000 | 59000 | 59000 | 41357 | 41000 | 48300 | 48300 |

| | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NG production | 1070 | 1152.7 | 1211 | 1439.4 | 1762.9 | 2066.6 | 2446.3 | NA |
| NG consumption | 974.2 | 1061.3 | 1143 | 1350.3 | 1654.5 | 1993.5 | 2490.1 | NA |
| net export | 96.2 | 91.4 | 67.9 | 89.1 | 108.4 | 73.1 | -43.4 | NA |
| proved reserves | 48300 | 48300 | 53325 | 53325 | 53325 | 53325 | 80000 | 80000 |

**Source: EIA**

After training, the FIS achieved average relative error of below 3%, which satisfy the requirement of forecast. See table 33.

Table 5.13 Natural gas production and prediction

| Bcf | **1981** | **1982** | **1983** | **1984** | **1985** | **1986** | **1987** | **1988** | **1989** | **1990** |
|---|---|---|---|---|---|---|---|---|---|---|
| Actual production | 450 | 381 | 431 | 438 | 457 | 484 | 494.3 | 490.9 | 505 | 508 |
| pridicted production | 463 | 392 | 419 | 441 | 456 | 477 | 498 | 476 | 493 | 517 |
| relative error | **2.95%** | **3%** | **2.78%** | **0.70%** | **1.20%** | **1.45%** | **0.65%** | **3.10%** | **2.43%** | **1.72%** |

| | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** |
|---|---|---|---|---|---|---|---|---|---|---|
| Actual production | 526 | 533.3 | 558.3 | 588.7 | 601.4 | 711.8 | 801.3 | 821.6 | 889.3 | 962.3 |
| pridicted production | 535 | 523 | 563 | 603 | 616 | 700 | 804 | 826 | 889 | 965 |
| relative error | 1.73% | 2.12% | 0.89% | 2.45% | 2.44% | 1.67% | 0.34% | 0.58% | 0.01% | 0.29% |

| | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** |
|---|---|---|---|---|---|---|---|---|
| Actual | 1070 | 1152.7 | 1211 | 1439 | 1762.9 | 2066.6 | 2446.3 | NA |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| production | | | | | | | |
| pridicted production | 1077 | 1161 | 1202 | 1459 | 1766 | 2062 | 2444 |
| relative error | 0.69% | 0.72% | 1.76% | 1.33% | 0.17% | 0.20% | 1.10% |

### 5.3.4 **Forecasting**

The following are predictions of both production and consumption from the trained ANFIS for 2010 to 2015 since the data for 2008 is not valuable, and 2009 has passed half.

Table 5.14 Predictions for 2010 to 2015 natural gas

| Billion cubic feet | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** |
|---|---|---|---|---|---|---|
| production | 2987.4 | 3219.9 | 3452.3 | 3685 | 3917.2 | 4149.7 |
| consumption | 3007.5 | 3254.7 | 3502 | 3749 | 3996.6 | 4243.8 |
| difference | 20.071 | 34.893 | 49.714 | 64.54 | 79.357 | 94.179 |

**Conclusion**: From the above prediction, we can see that there will be a gap of 94 billion cubic feet between natural gas production and consumption, which is a gauge for LNG import in China. After doing all the analysis and calculations, we can see that, in the long run, especially when compared with America, LNG demand in China is huge, about a gap of 50195.4 billion cubic feet of natural gas in 2007. But from the results of ANFIS forecast, the natural gas gap or LNG demand is going to change moderately year by year, only 94 million cubic feet in 2015, because LNG price is still higher than natural gas in China, which prevented LNG demand from drastic increase, only in coastal cities, there will be demand of LNG, and China has established about 11 LNG receiving terminal along its coast line with an total capacity of 56.8 million tons per year, already a big excess than the actual LNG demand, so Chinese government should reduce the approval of new LNG receiving terminal, moreover, China was presumed as poor natural gas country, but from the latest report, China is a country with abundant natural gas reserves, which also prevent LNG demand from drastic increase in near future.

## Chapter 6 Conclusion

LNG shipping market experienced drastic change from 2008 to 2009, so does the LNG price. Prices have fallen mainly for three reasons: economic recession; new LNG export projects are being commissioned; and US producers find large commercial resources of gas. In Asia, spot LNG is selling in buyers' market for about $4.60/m Btu, almost 47% discount to that of crude oil. By mid-May, the near-month contract was trading at just under $4.50/'000 cf at Henry Hub. That’s why western countries try to stimulate LNG demand in countries like China and India etc. to pull up the price of LNG

Meanwhile rapid growth in LNG trade has led to major investment in new buildings. LNG may currently be one of the fastest growing sectors of world shipping with fleet capacity to grow by almost a third in 2008, yet LNG production has not grown as quickly as expected. Production and carrying capacity are not balanced, so the shipping price of LNG falls as the LNG price.

As I mentioned in the goals and points of the thesis, financial crisis also brought opportunities for LNG industry in China, decrease of LNG price and LNG shipping price is a good chance for Chinese company to capture LNG market that used to be dominated by developed countries, China should actively take part in competition with developed countries for future energy security, but what should be pointed out is that, in the short run, LNG demand won’t rocket up, but in the long run, the demand is going to be huge, so China have to develop its LNG market at slow pace, step by step, and grasp this market gradually but firmly, to meet the future demand synchronously.

**References:**

1 Ruben Tavares, David A. Ashuckian, P. E.,2007 FINAL NATURAL GAS MARKET ASSESSMENT, 12, 2007.

2 Kaoru YAMAGUCHI, Keii CHO, Natural Gas in China, 8, 2003.

3 Karen Schneider, Lindsay Fairhead, Christopher Short, THE ASIA PACIFIC LNG MARKET: issues and outlook, Commonwealth of Australia 2004.

4 Kazuya FUJIME, Japan, LNG Market and Price Formation in East Asia, 4,2002.

5 Eugenio Fco. Sánchez-Úbeda, Ana Berzosa, Modeling and forecasting industrial end-use natural gas consumption, 3, 2007.

5 Chu Liangyong, Ship type Evaluation for LNG Transportation of China. 2, 2000.

7 Gao Feng, A Study on Sea Transportation of China's LNG import projects, 3, 2000.

8 Ding Pengkai, Wavelet Analysis forecasting in bulk market, 6, 2007.

9 OWeixing, Fleet Planning for a LNG company in south china, 6, 2007.

10 Haizong, A study on LNG shipping market development in china, 6, 2004.

11 XuPing, Study on forecasting BFI based on wavelet analysis and neural network, 12, 2005.

12 Gligo S. Tomanovic, Predictions in dry bulk carrier fleet's market in view of Jugooceanija shipping company's fleet development, 6, 2000.

13 Liu Yongsheng, A study on international bulk market, 5, 2007.

14 Zhang Honglin, Study on forecast model of international bulk shipping market, 3, 2002.

15 Sun Jun, Analysis of international dry-bulk shipping market and study on the managerial counter-measures, 3, 2007.

16 J.S.R. Jang, IEEE Trans. Systems, Man, Cybernetics, ANFIS:

Adaptive-Network-Based Fuzzy Inference System，23(5/6):665-685, 1993.
17 J.S.R. Jang and C.-T.Sun, Proceedings of the IEEE Neuro-Fuzzy Modeling and Control, 83(3):378-406
18 Bonissone, Badami, Chiang, Khedkar, Marcelle, Schutten, Proceedings of the IEEE Industrial Applications of Fuzzy Logic at General Electric, 83(3):450-465
19 J.S.R. Jang and N. Gulley, Natick, MA: The MathWorks Inc. The Fuzzy Logic Toolbox for use with MATLAB, 1995