

# **THE TRENDS OF LNG/CNG APPLICATION IN THE TRANSPORTATION INDUSTRY IN CHINA**

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## Executive summary

The number of natural gas vehicles (NGVs) and fuel stations has grown very strongly worldwide, especially in the Asia-Pacific region, in the past decade and continues to do so. While the Natural Gas Ships utilization are still in the initial stages, and some pilot projects are under further evaluation.

Because of the carbon reducing target and serious heavy pollution in some densely populated big cities and old norms of diesel standards adopted for ship's fuel, China needs to develop NGVs and NGS compared with other countries.

Natural gas can play a significant role in cutting vehicle carbon dioxide (CO<sub>2</sub>) emissions. Natural gas may be especially important for cutting CO<sub>2</sub> emissions from heavy-duty vehicles (HDVs), since other options such as electrification appear to be limited.

Vehicle and fuel technology for natural gas is available today and relatively affordable, particularly in comparison with other alternative fuel vehicles (AFVs).

Besides, the strong benefits cutting carbon emission, NGVs can also have other effects including: reducing noise in urban areas; diverting oil from domestic consumption to export; improving energy security; and reducing government spending on road fuel subsidies..

Natural gas can be competitive via gasoline where transmission and distribution grids are present or liquefied natural gas (LNG) terminals are available. There is often an opportunity for simultaneous gas market development and increasing NGV and VGS market share. While investments in vehicles and retrofit, and retail infrastructure can generate positive returns. Currently government support may be required to establish an NGV and NGS market. Without such support, it is unlikely to achieve self - sustaining NGV NGS markets with substantial levels.

Through the case studies, natural gas vehicle (NGV) and Natural gas ship(NGS), both from home and abroad, this report draws the following recommendations:

( 1 ) The application of NGV and NGS in the transportation sector in China should be enforced and 'Natural Gas Utilization Policy' (NGUP) should be fully implemented in the daily work.

( 2 ) NGV and NGS development plan should be made——specially the plan for

filling stations, in order to guide this industry to develop normally and orderly.

( 3 ) More incentive policies should be developed in order to encourage end-users to consume natural gas.

( 4 ) More legal standards and Related technical specifications should be completed, especially NGV and NGS manufacturing standards, retrofit standards, equipment testing standards and operation standards. Safety training for filling station operation is also necessary.

# 1. Introduction

## 1.1 Backgrounds

**Low-carbon economic development makes natural gas the focus of energy market**

During past several years, climate change and energy conservation have become and will be the worldwide issue for all countries around the world. How to handle these issues and realize sustainable development is a common topic of international society. In November 2011, the Chinese government committed support to control the emission of greenhouse gas in the 17<sup>th</sup> climate change conference in United Nations .At the same time, all other countries are seeking feasible methods to cut down greenhouse gas emissions.

Methane, the main component of natural gas, has the lowest carbon to hydrogen ratio among all hydrocarbons. This means that, compared to conventional road fuels, such as gasoline and diesel, on an energy equivalent, less carbon dioxide is released into air when it is burned.

As a result Natural gas, as a low-carbon clean energy, without any doubt, attracts the highest attention of all countries around the world. Statistics of BP energy 2012 shows the ratio of natural gas among the primary energies has been increasing constantly in recent years. Meanwhile with the deregulation for non-conventional gas in United States, the supply of natural gas will be more diversified.

In the '12th Five-Year Plan' (12<sup>th</sup> FYP), the Chinese government has set the target of ratio of natural gas among the primary energies from 4% to 7.5% by end of 2015. Natural gas applications have moved from traditional residential, commercial, and power plants to some more high efficient and cleaner sectors, such as co-generation and transportation etc. Many countries are taking this low-carbon economic development opportunity to increase and stimulate the technology of the natural gas industry and other related industry such as equipment manufacturing and technical service.

**Heavy pollution attracts social attention on PM2.5, vehicle exhaust faces mass media pressure in China**

In year 2011, continuous heavy hazy and foggy weather hit many densely populated big cities, included Beijing, Tianjing and Shanghai, during winter time, and heavy pollutions attracted social attention on particulate matter (PM2.5). According to statistics issued by Shanghai Environmental Supervision Central Of

Environmental Protection and Administration Bureau, the main contributors of PM<sub>2.5</sub> come from motor vehicles' exhaust, power plant emissions, industrial boilers, combustion of furnace and wheat straw direct burning.

According to the 'Annual Report of Motor Vehicle Emission 2012', emissions from motor vehicles have contributed the first position for each city, and among them public transportation occupied the majority. The exposure to PM alone has been estimated to cause 3.4 billion life years lost in 2005 in India, China and Europe.

Being environmentally friendly, and a cheap and safe energy source, natural gas has become more and more popular as an alternative fuel for vehicles. It has an active effect not only on the environment but also on energy savings and emission-reduction as well as on diversifying the utilization of energy.

## 1.2 Purpose of the paper --Why Natural Gas Vehicle and Natural Gas Ship?

Natural gas can play a significant role in cutting vehicle carbon dioxide (CO<sub>2</sub>) emissions, especially important for cutting CO<sub>2</sub> emissions from heavy-duty vehicles (HDVs), since other options, such as electrification, appear to be limited.

Vehicle and fuel technology for natural gas is available today and relatively affordable, particularly in comparison with other alternative fuel vehicles.

Natural Gas Vehicles (NGVs) have strong benefits including: improving air quality and reducing noise in urban areas; diverting oil from domestic consumption to export; improving energy security and reducing government spending on public transportation (inter-city public bus) subsidies.

Governments should carefully consider the role of NGVs compared to other alternative fuel vehicles, such as electric, fuel cell and biofuel vehicles, and weigh the costs and benefits of each for different modes of transportation.

Natural gas can be competitive via gas pipeline where transmission and distribution grids are present.

There is often an opportunity for simultaneous gas market development and increasing NGV market share. While investments in vehicles and retail infrastructure can generate positive returns, temporary support from government is required to establish an NGV market. Without such support, self-sustaining NGV markets are unlikely to achieve with substantial penetration levels.



### 1.3 Structure of the report

The first chapter of this report provides the background to develop NGV, low-carbon economic development and heavy air pollution are mainly driven factors for China to utilize the NGV technology.

Chapter two introduces the overall situation of NGV and NGS worldwide and some of the experiences are also introduced in this section.

Chapter three mainly focuses on the situation of NGV and NGS in China, the history of the technical development of Engine, the Original Equipment Manufacture and retail infrastructure and also the technical specification.

The last part of this report, chapter four, concludes the opportunities and challenges and difficulties for the next development of NGV and NGS.

Main findings and recommendations are summarized in the final part.

## 2. Global trend analysis of LNG/NG application in vehicle and ship industries

As a kind of clean and low emission energy, Natural Gas(NG) draws intensive attention and takes increasing share in first time energy consumption worldwide. Global NG/LNG(liquefied natural gas) production and trade are becoming more and more active as the new hotspot in oil/gas industry along with quick developing in NG equipment and related services. In the transportation industry, more and more companies and government authorities are paying extra interesting and attention to NG/LNG due to their characteristics of energy-saving and low-emission.

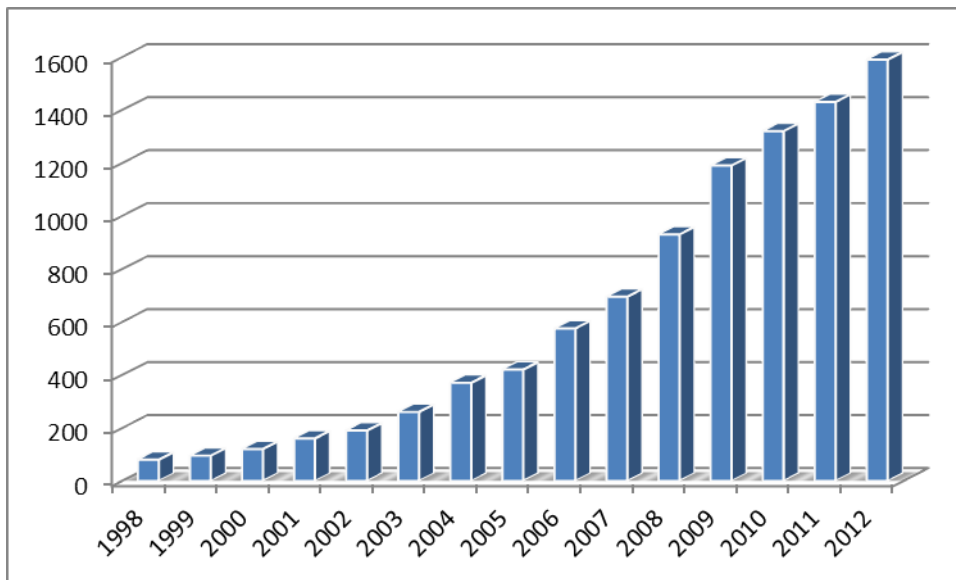
### 2.1 The current status of NGV application worldwide

The vehicle industry brings comfort and the convenience to the world as well as environmental pollution and energy shortage, so alternative energies such as electricity, NG, alcoholate, hydrogen, solar and hybrid are all under research. Up to now, electricity vehicles, hybrid vehicle, battery vehicle and hydrogen vehicle are in the initial stages with accepted low mature technology, related service and high price. To make thing worse, experts have been arguing about whether the production and treatment of electric batteries, used in electricity vehicles, is environmental-friendly or not. But all experts agree that NG vehicles have

relatively low pollution contributed to low CO<sub>2</sub> and NO<sub>x</sub> emission, compared with traditional vehicles. <sup>i</sup>

Currently NGVs are used in 84 countries with about more than 70 vehicle manufacturers investing and making NG/LNG light and heavy-duty vehicles, including Mercedes-benz, Toyota, General Motors, Volvo. According to statistics from the NGV Journal, the number of NGV soared at 30 percent annual rate in past years. Up to 2012/12, there are more than 17 million NGVs and 21000 filling stations with 24-27 billion cubic meters natural gas consumption worldwide. Following figure 1 shows the detail: trend of NGVs worldwide. Table 1 is the top 10 countries including China with most NGVs and filling stations 2012.

**Figure 1: The trend of NGVs worldwide**



**Table 1: Top 10 countries with most NGVs and filling stations 2012<sup>ii</sup>**

No	Country	Number of Vehicles (in million)	Filling station
1	Iran	3.3	3330
2	Pakistan	3.1	1851
3	Argentina	2.18	1922
4	Brazil	1.73	1789
5	India	1.5	724
6	China	1.5	2880
7	Italia	0.74	909
8	Ukrain	0.38	324
9	Columbia	0.38	692
10	Thailand	0.35	481
In total		15.16	

According to the latest Pike research, the number of NGVs will keep increasing in coming years and is estimated from 19 million in 2010 to 32 million in 2016.

## 2.2 Summary of NGV application worldwide

### 2.2.1 Promote NGV by providing tax reduction and subsidiaries

Some European countries, including Italy, Holland, Greece, France, Germany and Spain, reduce consumption tax or set special most favor tax on vehicles fuelled Compressed Natural Gas(CNG)/LNG.<sup>iii</sup>

The Italian government provides a 25% infrastructure subsidiary for each natural gas filling station and monitors strictly to maintain CNG price as quarter of gasoline and half of diesel. The French government exempts NG domestic consumption tax to stimulate NGV industry.

The Federal government of the United States issues 14 tax exempt policies along with 122 tax reduction and favor policies in 51 states to promote the NGV industry as well as posts the detailed natural gas filling station locations for customers' reference. The EPA amended regulations that make it easier to convert cars and trucks to run on natural gas.<sup>iv</sup>

In Pakistan, all imported NG equipment, vehicles and spare parts are duty-free and sales consumption tax is exempted. In Bangladesh, besides government exempts

taxes on imported equipment for filling station as well as NGVs and related spare parts, bank and leasing companies also give financial support. The Asia development bank once helped Daka city to purchase 10000 NGVs and gas cylinders.

The Thai government has cut tax rate on NGVs, engines and related spare parts from 40% to 20% then 0% . The addition, if someone modifies a NGV, government will subsidize Taibaht10000(approximately AUD400).

Generally speaking, most governments strongly support NGV application.

### 2.2.2 Lack of filling stations constraints NGV application

Compared with petroleum, there isn't a mature natural gas filling station network to meet daily gas usage in most countries. The number of natural gas filling stations is very few and many belong to private companies without public service.

## 2.3 Current statues of LNG Ship worldwide

LNG was initially used as fuel in LNG ships. In recent years, dual-fuel LNG ships have demonstrated the LNG advantages in economic and environmental aspects as ship fuel. In the same time, diesel ships generate severer and severer environmental problems especially in SOx, NOx emission. The increasing diesel price and ever stricter emission regulation issued by International Marine Organization(IMO) appeal LNG louder as an alternative of diesel.

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Till now, LNG as ship fuel has gradually been valued. BV(Bureau Veritas) thought that natural gas driven system will be one of the major contributors in future green shipping industry. Det Norske Veritas(DNV) also publicly claimed that the most efficient way is to use LNG as fuel to achieve the 30% emission reduction target by 2030 in shipping industry worldwide. <sup>vi</sup> Some Europe countries, including Denmark and Norway have been using LNG as fuel in coast guard cruisers, platform supply boats, LNG ships and roll on/roll off ships. After the first LNG-fuelled ship, which can accommodate 100 cars or 300 people, was put in service in 2000, Norway has already built an additional 28 LNG fuelled ships, mostly used in ferries and another 12 ships are in preparation. Most LNG-fuelled ships are used in Norway domestically or act as offshore supply/service ships in North Sea and Baltic Sea. Table 2 shows the LNGS figures in service or undelivered.

Table 2 LNGS in service or undelivered worldwide <sup>vii</sup>

Type	In service	Undelivered	Total
Ferry ship	16	4	20
Offshore service/supply boat	6	5	11
Coastal guard cruise	3	0	3
LNG ship	2	0	2
Roll on/roll off ship	1	2	3
General goods ship	0	1	1
Chemical ship	1	0	1
Total	29	12	41

LNG as alternative fuel in ships in Europe proves that LNG not only reduces costs but also meets the long-term environment requirements. The new regulation about emission reduction issued by IMO will push ship owners to strive to find cleaner fuel. It is estimated that LNG fuelled ships will increase 10 times in next 5 years.

## 2.4 Summary of LNGS application worldwide

There are some obstacles to promote LNG usage in ships, the first and biggest one lies on lack of LNG related infrastructure. In most ports, there isn't intact and practical supply system even if it is not difficult to supply LNG. LNG infrastructure construction and port layout needs close communication and co-operation among government authorities and companies.

Secondly, LNG fuelled ships can meet the inland river transportation requirements, but they can't meet the ocean transportation requirements. <sup>viii</sup>

The vice president from Cogen ocean shipping company, Norway, expressed that the biggest challenge to use LNG as fuel is long distance. LNG is different with diesel; it needs larger storage space, and that is a real big challenge. <sup>ix</sup>

## 3. Current situation of NGV and NGS utilization in China

### 3.1 History and future trends of NGV in China

China started the research of Gas Vehicle in 1950s, but it was not until the end of 1980s that the technology matured and converting equipment for Gas Vehicle and filling stations were imported by some Chinese companies. For a variety of reasons, NGV developed very slowly. In the past several decades with continuing effort put on researching and developing, different types of original manufactured NGV, especial light-duty vehicles were put into the market in China. Currently, those NGVs running on road are mainly CNGVs<sup>x</sup>, mainly taxis and light commercial vehicles, as well as a number of NGVs<sup>xi</sup> including buses and heavy-duty trucks are also put into operation in some cities, meanwhile the number of filling stations for NGVs has been increased very fast in recent years.

To the end of year 2012, there are more than 100 cities among 31 provinces in China that have adopted NGV as public transportation. The number of NGVs is more than 1.5 million and more than 2000 filling stations have been put into use according to statistics. In cities, where natural gas transportation and distribution pipelines are present, such as Chongqing, Urumqi, Xi'an, Lanzhou, Xining, 95% of the taxis and inter-city buses are using natural gas as fuel. LNGVs like buses and heavy-duty vehicles have been promoted in Xijiang, Inner Mongolia, Guizhou, Guangdong, Fujian, Hainan and Jiangshu. With the pressure of environmental protection, in those regions, such as South West of China and East Coast areas where there are plenty of pipeline and gas supply or imported LNG, NGVs will increase rapidly. Figure 2 shows the gas vehicle share in the motoring market.

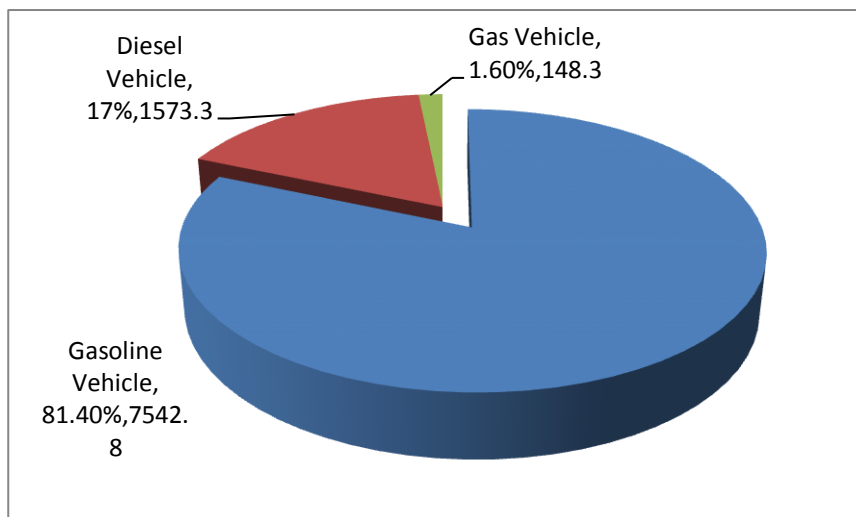


Figure 2 Number of motor vehicles classified by the fuel<sup>xi</sup>

Because of the heavy pollution and worsening environment, reducing the vehicle exhaust has become one of the main goals for some cities. In the '12<sup>th</sup> Five-Year

Plan of Transportation’, it claims clearly to “take technical actions to reduce emission and keep energy saving”. “Positive methods should be adopted to alternate the fuel used in the new environment-friendly vehicles and ships”. The plan also said: “it should set stricter high energy efficiency and low emission standard, meanwhile set tougher requirements for entering the transportation industry”. In order to eliminate those old vehicles and ships which can only meet the low standards, it was encouraged to use NGVs and buses in cities.

It is estimated that in year 2013, the number of LNGVs in China domestic market will reach as shown in Table 3.

Table 3 Number of LNGVs in China

Type of LNGV	Number (unit)		
	Year 2011	Year 2012	Year 2013
LNG passenger bus	6,000	12,000	18,000
LNG heavy-duty Vehicle	25,000	30,000	45,000

### 3.2 Summary of NGV utilization in China

Environmental protection is the original motivation for the development of NGV.

Natural gas is regarded so far as one of the cleanest energies in the world, NGV can certainly contribute to decarbonising transportation. On average, a 25% reduction in carbon dioxide emission compared with gasoline and 5% to 10% compared with diesel. Equivalent (CO<sub>2</sub>-eq) emissions can be expected on a well-to-wheel (WTW) basis when replacing gasoline by light-duty vehicles (LDVs) running on compressed natural gas (CNG). While the technology for bio-synthetic gas is not fully developed yet, biogas could provide significant quantities of a low-carbon fuel in the longer term at low or even negative greenhouse gas abatement costs. For various reasons, the potential to reduce greenhouse gas emissions make NGV or LNGV as one of the positive choices for current situation of environment protection in China. Table 4 shows the results of NGV emission compared with other fossil fuels.

Table 4 Comparison of NGV emissions with other fossil fuels

Type of pollutant	gasoline	Diesel
HC	28%	78%
CO	76%	
NOx	71%	37%
SOx	8%	11%
CO2	67%	91%

Economic advantage is the inner driven factor for the development of NGV.

One of the critical factors for NGV development strongly in China is mainly because the selling price of natural gas is cheaper than the same heat value of gasoline and diesel. This is also the reason for many local governments to issue the incentive policies to encourage NGV utilization. Price difference is showed in table 5.

Table 5 Selling price of different fuels in different cities in China  
( unit: RMB/L or cm )

Region	City	Natural gas for NGV	Gasoline (No.90)	Ratio of NG to Gasoline
SE coast	Haikou	5.06	7.63	66%
Bohai area	Beijing	4.73	7.62*	62%
Delta area	Shanghai	4.2	7.56*	56%
North-west	Urumchi	4.07	6.66	61%
South-west	Chengdu	4	6.86	58%
Middle south	Changsha	3.85	6.8	57%
North-east	Harbin	3.7	6.96	53%
Middle east	Hohhot	3.56	6.72	53%

\*The price of the gasoline is the No.93, instead of No.90.

**Diversified natural gas resources and retail infrastructures are guarantees for the development of NGV.**

Currently, China holds both the domestic pipeline natural gas resources and



imported LNG, besides conventional natural gas, China also holds a certain number of non-conventional gas, like Coal Seam Gas and Shale Gas. The Chinese government has made some plan to explore those non-conventional gases in the near future. In the '12<sup>th</sup> Five Year' period, the capacity of the natural gas supply will increase largely. It is estimated that to the end of year 2015, the total supply of natural gas will be more than  $2700 \times 10^8 \text{m}^3$ . It is the guarantee for the next development of NGV industry.

**Lack of land to construct new retail infrastructure will be barrier for further development.**

With the urbanization process in recent years, it is hard to find enough space in some big cities to build filling stations, but still more and more companies are interested in the infrastructure sectors, so filling station construction has moved forward steadily. Currently, bi-fuel oil-gas compact filling station is a new concept and new module for the NGV, but this kind of trial needs detailed research in operation, daily management and cooperations.

### 3.3 Current situation of NGS in China

According to statistics, there are over one million small-size vessels in China, 200,000 of them are inland water vessels. All of these small-size vessels are using diesel fuel. As a clean energy source, LNG produces less carbon dioxide, sulfur dioxide and other greenhouse gases than diesel during combustion, but it only take about 75% cost compared with diesel. The advantage for vessel using LNG fuel to replace diesel fuel is good for both cost and environment protection, which makes many ship-owners very concerned about LNG used as vessel fuel. Currently, considering oil pollution, exhaust emissions, diesel supply pressure and other side-effects brought by vessels, China is beginning to pay attention to the development of LNG as a vessel fuel, which should achieve coastal and inland shipping "green environmental protection". Vessel power changing to LNG will become the development trend.

Currently, the main method carried out in China is "changing diesel to LNG" for vessel fuel. This change made vessel power from a single pure diesel fuel mode to diesel and LNG fuel alternate mode. In December 2009, usage of vessel power for diesel-LNG hybrid technology project in Suqian City, Jiangsu Province was officially launched. In August 2010, "Su-Su goods 1260" freighter in the Northern section of the Grand Canal began real ship trials. In September, a hybrid diesel-LNG ship loaded with 3,000 tons sand sailed from Suqian City into Huai'an City.

March 25, 2011, Kunlun Energy Company Limited, a CNPC subsidiary, Jichai Power Plant, Wuhan Transportation Development Group and Wuhan Ship Design Transportation Development Co., Ltd. signed a cooperation framework agreement in Wuhan city on demonstration and application of LNG fuelled ships, and developing the "gasified Yangtze River strategy".

July 2, 2011, China Marine Bureau organized a research conference about alteration and inspection of inland water vessels in Wuhu City, Anhui Province, The attendees confirmed the test that made LNG as fuel for vessels and drafted the meeting memo.

Currently, some Chinese companies such as Hubei Xilan, Beijing Youlu, Guilin Xin'ao, Xinjiang Guanghui, Fujian Zhongmin have or are about to carry out the vessel fuel "oil to gas" demonstration project. (detailed information shown in table 6)

Table 6 NGS Demonstration Project <sup>xiii</sup>

NO.	Project Practice Unit	Vessel Name	Usage	Area	Project Progress
1	Beijing Youlu Corp.	Su Su cargo boat No. 1260	Transportation	Canal	Alteration has been completed and put into operation
2	HubeiXilanNatural Gas Company Ltd.	Wulun drag boat No. 302	Drag Boat	Yangze River	Alteration has been completed and put into operation
3	Kunlun Energy "gasified Yangtze River" project	8 vessels	Transportation	Inland River	Most of Alteration has been completed and some vessels has been put into operation
4	Beijing Zhongxinhenghe Investment Co., Ltd.	Changxun cargo boat No.3	Transportation	Yangze River	Trials sailing was successful, and was about to convening feasibility studies via national experts
5	Guilin Xinao Natrual Gas Co.,Ltd.	Shangshui No.34	Yacht	Li River	Alteration has been completed and put into operation
6	Xinjiang Guanghui Corp.	Fisheries enforcement No.522kW	Fisheries enforcement	East Sea	Ship redesigned and reconstructed is ongoing
7	Fujian Zhongmin Transportation Co., Ltd.	TBD	Transportation	Min River	Project feasibility study has been completed, awaiting government approval

Although it is a little late for China to develop LNG as vessel fuel, the developing speed is increasing. We believe in future, LNG can be used in more fields of vessel fuel.

### 3.4 Summary of NGS utilization in China

LNG has many advantages in use, but as a new marine power fuel, its application and promotion is still facing many problems that should be solved in future.

Firstly, the alternative cost of vessel is higher but the sailing time is too short. Although LNG storage tank volume is small, but the system is complex and layout is difficult. At the same time, installing cylindrical LNG storage tanks will lose part of the carriage space. Coupled with strict request of safety distance between safety storage tank and conveying equipment. That brought great difficulty for ship design and modification. Therefore, before the popularization of vessel for natural gas, most of the manufacturers will choose to put the modified vessels into short-haul operation according with caution and cost consideration. This led to the ship sailing time is being too short, and so cannot meet the requirements of long-distance transportation.

Secondly, in China for promoting LNG as a marine vessel fuel, the biggest obstacle is a serious lack of supporting infrastructure. The global marine fuel supply system has been established and the replenishment supply network is perfect, while the global LNG receiving terminal is only 73, most of them are in Asia, and have not established a complete and practical supply base and network. Promotion and development of LNG ships must accelerate the related supporting infrastructure investment and construction. However, LNG supporting infrastructure cost is a large initial investment, not only within the industry enterprises to actively respond to, and they must be supported by the port and related government departments.

Finally, lack of industry standards is another problem that we should face. Although China Classification Society has issued three guiding standards on the dual-fuel engines and dual fuel systems on board, it is not in line with China's actual situation in the shipping industry standards. If there are no appropriate industry standards as a reference, the dual-fuel transformation for ship will be difficult to get a wide range of promotion.

## 4. Conclusions

### 4.1 The opportunities

#### 4.1.1 Diversified and plenty supply of natural gas

Natural gas, as a low-carbon and clean energy for reducing emission, becomes the first option for many countries. In the next 5 to 10 years, the natural gas industry, especially the LNG industry will be developed strongly. During the '12<sup>th</sup>

Five Year' period, natural gas industry will enter into a large-scale development stage, average annual increase rate of natural gas supply would be 10%, imported pipeline gas and LNG terminals will be raised too. Figure 3 illustrates the natural gas resource in China in the next 5-10 years. Meanwhile the number of small-scale LNG tanks will be increased quickly. The pipeline network will be built step by step, and the trunkline will cover the whole mainland. The plentiful supply of natural gas and the natural gas grid are the best guarantees for NGV and NGS.

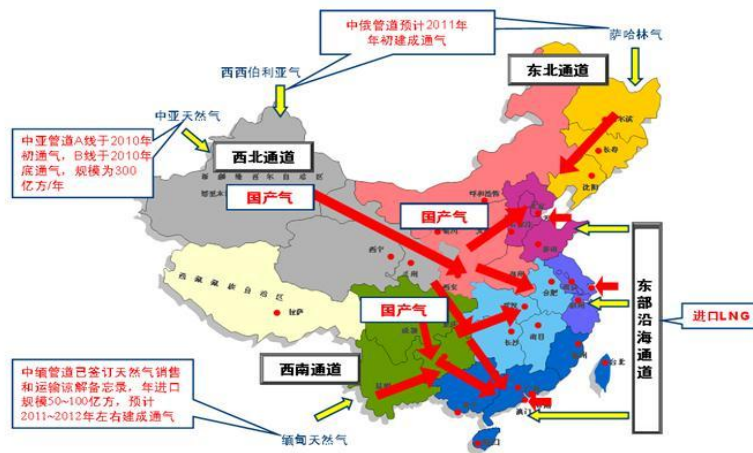


Figure 3 Natural gas resources in China in the next 5-10 years

#### 4.1.2 Technology and standards

In the past several years, the Chinese government and some of the industrial supervision departments sped up pace to make legal and technical standards for NGV and NGS. In July 2011, the National Energy Bureau issued the ‘ Technical Specification for LNGV Filling Station’( NB/T 1001-2011 ) , which is critical for the development of NGV industry and filled the blank in this field. Some other related standards are listed in the following table.

Table 7 Exiting Technical Standards Related to NGV and NGS

Serial Number	Name of Standard	Reference Number
1	Low Temperature Thermal Isolated Cylinder	GB 18442-2001
2	LNG Manufacture, Storage and Transportation	GB/T 20368-2006
3	Installation Specifications for LNGV Equipment	GB/T 20734-2006
4	Technical Specifications for LNGV	QC/T 755-2006
5	Testing Specification for LNGV	QC/T 754-2006 )
6*	Testing Indicator for Vessels Using Gas as Fuel	

\*In 2008, China Classification Society (CCS) issued 'Testing Indicator for Vessels Using Gas as Fuel', but at that moment the version only suited to LPG (Liquified Petroleum Gas) and CNG(Compressed Natural Gas). In December 2010, CCS amended the 'Indicator', LNG as gas fuel was also put into the updated version.

Regarding the gas engine and vehicle manufacturing aspects, Chinese Engine manufacturers, such as Yuchai, Weichai and Shangchai, have the technology in manufacturing the gas engine for NGVs. And automobile manufacturers, including Yutong, Zhongtong and Heavy Automobile Factories, have the production capacity of 30,000 annually.

#### 4.1.3 Environmental protection pressure

There was acid rain in 215 counties, about 46.1% among 466 counties which were monitored by the environment protection department. Among these counties, acidic rain frequency in 133 counties, namely 28.5% in total, was above 25%, and acidic rain frequency in 56 counties, namely 12% in total, over 75%. Figure 4 shows the annual changes of different acid rains in cities of China during the year 2011 -2012.

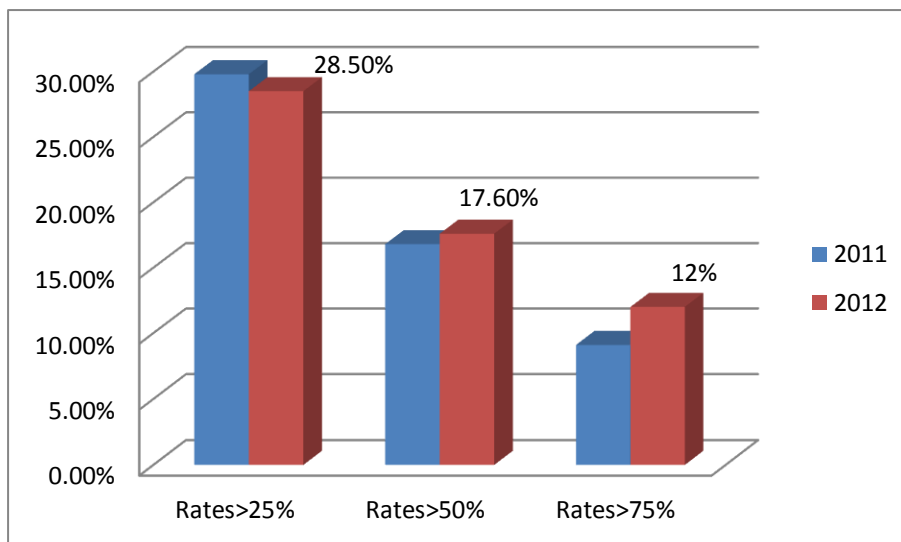


Figure 4 Annual Changes of different Acid Rains rates in cities of China 2011-2012<sup>xiv</sup>

In September 2012, the State council officially approved the 12<sup>th</sup> 5-year air pollution control plan in major areas, which covered 13 major areas, 117 cities in 19 provinces, including Beijing-Tianjin-Hebei area, Changjiang River Delta area, Pearl River area, set up target to reduce PM10,SO2,NO2,PM2.5 concentration 10%,10%,7%,5% respectively.

Equipment industrial companies, state industry and information departments, described its phase objective in 2015 in its energy-saving and new energy vehicle industry development plan as to optimize vehicles' fuel structure, alternative energy leads 10% market share in total vehicle fuels as well as 1.5 million NGVs.

State council officially issued the proposal of accelerating inland river ship transportation in January, elevating the inland river shipping development in as national strategy, targeting to set up fast, high efficient, safe, green and modern inland river shipping industry. The China national ship inspection bureau also expressed that developing, utilizing and promoting new environment-friendly energy will benefit the shipping industry.

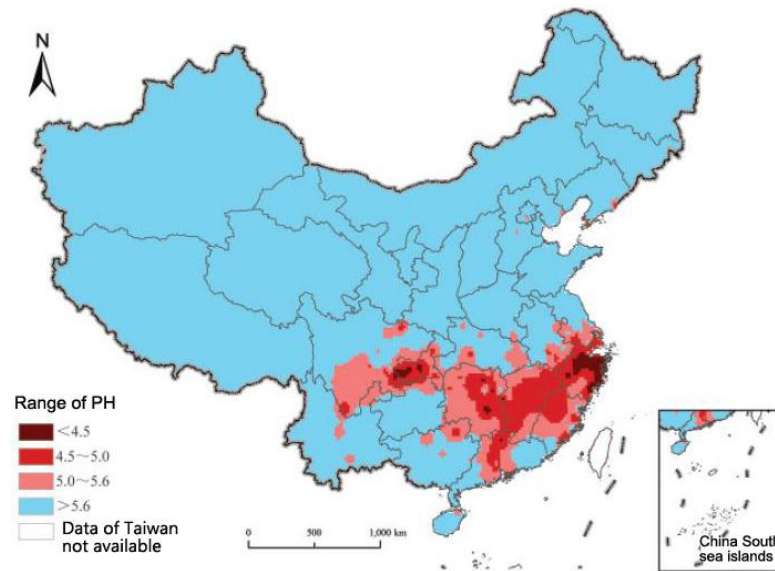


Figure 5 Annual average precipitation PH contours of China, 2012<sup>xv</sup>

#### 4.1.4 Big market potential and price edge

China became the biggest country in vehicle production and sale for the first time in 2009. It manufactured about 13.79 million vehicles and sold 13.645 million vehicles, a 48.3% and 46.2% increase respectively compared to the previous year. Total number of vehicles reached 170 million, a 9.3% increase compared to the same period in 2008. <sup>xvi</sup>

China has more than one million small-size ships including 200 thousands used in inland rivers; these ships consumed 19 million tons fuels in 2009. NG accounted for 4% in total national first time energy consumption vs 25% average worldwide. It means a huge gap and potential as well.

At the same time, according to the requirements of China national development and reform committee, gas-oil price ratio will adjust to 0.6:1 then to 0.75:1 within 2 years. NGV industry has huge market potential and sharp price edge, can lead a leapfrog development

## 4.2 The challenges or difficulties

### 4.2.1 Organization, policy implementation

In 2010, China National Developing and Reforming Committee(NDRC) issued the "Natural Gas Utilization Policy". In this policy NGV is put into the first section with priority for natural utilization. The National Transportation Department (NTD) also claimed in its "12<sup>th</sup> Five Year Plan" (FYP) to speed up modern traffic transportation industry and construct low-carbon transmission system. There are plenty of challenges and difficulties for NGV and NGS in order to utilize broadly. For example, on one hand, some regions are too eager to NGV to build too much retail infrastructure; it makes wastes resources and improper location of the fuelling stations. On the other hand, some of the local government doesn't implement the national policy, so it is hard for NGV and infrastructure to be used. In the same time, the disorder allocating natural resources and insufficient financial support from local government also leads to negative results. Therefore, a strong organization and co-operation among local government, industry associations and companies who do business in this sector is required. Only on such condition the FYP for NGV would put into practice efficiently.

### 4.2.2 Balancing Natural gas supply and demand, and filling station plan

Increasing an number of NGV and NGS means increasing of natural gas consumption in future. Government and gas supply companies need to plan carefully in advance in order to avoid a seasonal or regional shortage in future which occurred once in some areas in China in 2008.

Regarding the filling station for NGV and NGS, because of the short development time, plan for such kind of infrastructure is incomplete. With the urbanization process, it is hard to find an extra or proper land to build retail infrastructure, while along the high way some of the state-owned companies lack of intent to open its filling station for building oil/gas fuelling station. This has become one of the big obstacles and bottle-necks for the development the NGV and NGS in future, especially to inner-city and inter-city buses.

One of the indicators for measuring the development of NGV markets is the

number of vehicles per filling station. A very low number of vehicles per filling station has a negative impact on the economic sustainability of filling stations; whereas a very high ratio may imply queues forming which, in the longer term, can be detrimental to the growth of the NGV fleet. This situation is occurring in China right now. How to solve this chicken-egg problem is a challenge for the NGV industry.

Local government can play a very important role in the promotion of NGV and NGS utilization, from the economic development positive point of view, local government should support the development of NGV and NGS, co-ordinate the plan of natural gas resources and retail infrastructure, balance the benefit for each party involved in this industry, and enhance the healthy development of NGV and NGS.

#### 4.2.3 Optimizations of technology standards and supervision

A problem facing NGV and LNGS is lack of legal documents currently. Normally local government may issue some 'Red Letter' files to promote the application instead of legal documents or regulation requirements. It is not defined yet how to supervise this industry and if there are some accident or problem how to deal with these from the government point of view. The lack of approval for project, certificate, quality recognition, safety supervision and administration punishment will tangle the long term healthy and sustainable development of NGV and NGS in China.

However, a lot of national standards or technical specifications need to be amended and enforced, including specification for safety testing, cylinder testing, daily maintain for gas supplying system. All these issues are critical with increasing amount of NGVs, and also with the less identity of quality requirement of components of filling station.

## 5. Findings and recommendations

**Findings of this paper are as following :**

- The utilization of NGV and NGS has obvious positive impact for greenhouse reduction.
- NGV is one of the best and fastest ways to improve heavy pollution especially in densely populated city with high traffic intensity comparing with other alternative vehicles.
- Vehicle and fueling station technology for natural gas is available and relatively affordable in China.
- Investments in NGV and fuelling station can generate positive returns, especially in automobiles and components.



- Government support is critical in order to achieve self-sustaining NGV and NGS market, especially in retail infrastructure plan and project approval.
- Natural gas can be competitive via gas pipeline where transmission and distribution grids are present.
- There is often an opportunity for simultaneous gas market development and increasing NGV market share. While investments in vehicles and retail infrastructure can generate positive returns.
- Government support should be required to establish an NGV market. Without such support, it is unlikely to achieve self-sustaining NGV markets with substantial penetration levels.

**Though analysis the NGV and NBS situation in China, we would like give some recommendations :**

- Enhance organization to co-ordinate the development of NGV and NGS, and implement the relative policy effectively and completely.
- Enforce Industry standards and technical specifications specially the standard of retrofit for NGV and NGS.
- Enhance environment protection policies implementation, energy saving and reduce emission in transportation industry
- Make prospective plans and enforce supervision to orderly and healthy development in NGV and NGS industry

**There are some limitations in this paper:**

First, lack of transparent information. It is difficult to search the open information in China, some figures cited in this paper is hard to verify.

Second, this paper mainly focus on the trend of NGV and NGS in China, other factors, like which type of vehicle model should be considered, whether it should choose OEM or retrofit, and which kind of natural gas ,Compressed or Liquefied gas for each situation and certain region, have not be discussed for time limit. There is no one-fit-all theory or policy and technology, so who involved in this business should make some comparison before investment.

## Abbreviations and acronyms

12th FYP	12th Five-Year Plan
BV	BureauVeritas
CCS	China Classification Society
CNG	Compressed Natural Gas
CNGV	Compressed Natural Gas Vehicle
DNV	Det Norske Veritas
HDV	heavy - duty vehicle
LNGV	Liquefied Natural Gas Vehicle
LPG	Liquefied Petroline Gas
NDRC	National Developing and Reforming Committee
NGS	Natural gas ship
NGV	Natural gas vehicle
NTD	National Transportation Department
PM2.5	particulate matter

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