Development of Green Strategies of Developing Countries in East Asia

| Project Report 2011-03-05 |

Environment Knowledge Sharing Program

Promotion of Natural Gas Vehicle in Korea

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Foreword

Green growth or green economy is being recognized as the new growth paradigm in the 21st century. Governments of Korea, China and Japan are making every effort to sustain economic growth while at the same time ensuring climatic and environmental sustainability.

Air pollution in densely populated metropolitan areas is emerging as a major environmental problem, especially in developing countries where environmental regulations are relatively lax and nonexistent. Sources for air pollutants vary but various studies show correlation of the degradation of air quality in the metropolitan areas and the increase of mobile sources, particularly motor vehicles. Epidemiological studies suggest that emissions of carbon monoxides, nitrogen oxides, particulate matter and other pollutants from motor vehicles can have serious health impacts and death.

Similar to any developing economies, Korea was not an exemption to air pollution problems. Increasing number of vehicles led to worsening of air quality in Seoul Metropolitan area. On top of such environmental problems, increases of energy prices and the international concerns for Greenhouse Gas emissions led to the development of environmentally friendly vehicles such as the Natural Gas Vehicles (NGV).

This paper introduces the background for promotion the distribution of NGV vehicles and reviews various programs for the distribution of NGV vehicles in Korea, current technological status of NGV and proposes the direction for international cooperation of NGVs. The paper is aimed for the use of policy makers and stakeholders in developing countries faced with the air pollution challenges and energy scarcity issues caused by motor vehicles. Although all countries differ in its environment and conditions, the paper can be consulted as a case study to understand how Korea has implemented the NGV distribution program to overcome air quality issues. I hope that this report will provide useful information to not just the policy makers and stakeholders in developing countries but to all readers concerned about the NGV.

In writing this paper, KEI would like to acknowledge Korea Association for Natural Gas Vehicles (KANGV, www.kangv.org) for their contribution,

disclosures, credits, and other information in their pursue to promote natural gas vehicles. This paper would not have been possible without the work of KANGV whose resources are cited throughout.

December, 2011
LEE Byung-Wook
President,
Korea Environment Institute

Abstract

In the beginning of year 2000, the quality of air in the metropolitan area including Seoul was in seriously bad condition. The concentration of fine particles exceeded the national environmental standard of sharp increase in the concentration of ozone. The situation at that time was the worst among the major cities of OECD countries. The causes for the drastic worsening of air quality in the metropolitan area was mainly due to increased numbers of automobiles, i.e. heavy-duty vehicles, recreational vehicles, diesel passenger cars, etc. The increase of the number of overall vehicles on the road in Korea has become a significant source of air pollution and in particular, diesel vehicles emit large amount of particulate matter (PM_{10}) and nitrogen oxide (NOx). These pollutants can lead to serious damage to human health with studies that suggested 9,641 people per year died prematurely due to fine particles in Seoul (Institute for Environmental Research, Yonsei University, 2000). With such significant impact on the air quality and to human health, diesel buses are being replaced by NGVs (natural gas vehicles).

Pilot projects for NGVs started in 1998 and as of December 2010 total of 8,383 buses and 431 garbage trucks in Seoul have been introduced. Currently, 85.6% of the nation's total number of registered buses (30,359) is NGV buses. In order to increase the demand for natural gas buses, financial incentives and tax benefits are being offered for the purchase of vehicles, or for the installation and operation of natural gas stations. As of December 2010, there are a total of 153 natural gas charging stations.

The NGV distribution project is deemed to be one of the successful environmental policies. It significantly contributed to the improvement of the atmospheric environment in the nation's major cities. In the case of the Seoul Metropolitan Area in particular, air quality has improved remarkably as a result of the NGV distribution project. For instance, as an environmental effect of CNG buses, fine particle (PM10) concentration in Seoul was reduced from 65$\mu g/m^3$ in 2000 to 47$\mu g/m^3$ in 2010. Furthermore, the environmental improvement benefit resulting from the natural gas bus was estimated to be KRW 1.643 trillion and the net economic benefit was estimated to be KRW 1.271 trillion.

According to the data on the world NGV distribution prospect announced by the World NGV Association, the number of globally distributed NGVs was 5.4 million at the end of 2006 and is expected to reach 65 million in 2020. The Ministry of Environment in Korea and various other organizations are making efforts to share the experience of the natural gas vehicle promotion program and to cooperate with other countries in introducing NGVs and relevant equipments. Korea's export for NGV was concentrated on Asian countries where the distribution of NGV started, and export grew explosively from USD 22.2 million in 2004 to USD 33 million and USD 189 million in 2008. In addition, more than 7,740 jobs - 4,280 jobs in the manufacturing sector, 960 jobs in R&D, 1,180 jobs for service and office workers, and 780 jobs in charging stations - were created in 2008 thanks to such export. With such positive influence environmental, economically and socially, NGVs are expected to expand further to help improve the air quality and diversify the energy sources.

Keywords: Green Growth, Natural Gas Vehicles, Air Pollution, Air Quality

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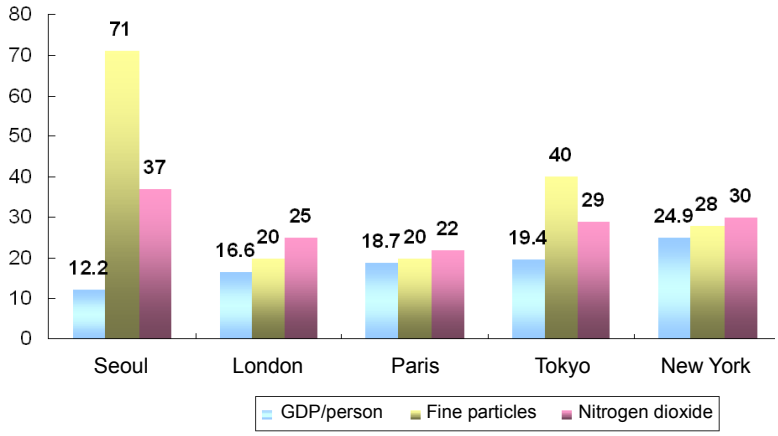
1.1 Current status of the atmospheric environment of Seoul Metropolitan Area

In the beginning of year 2000, the quality of air in the metropolitan area including Seoul was in seriously bad condition. The concentration of fine particles was between 65 and 70 ㎍/㎥, which exceeded the national environmental standard of 50㎍/㎥; even Ozone Watch was on a sharp increase. The situation at that time was the worst among the major cities of OECD countries. Air pollution is likely to result in more frequent occurrences of heart and respiratory diseases, inevitably worsening damage to human health. Research related air pollution indicated the number of people who die prematurely due to pollution from fine particles to be over 9,000 per year.



Source: Clear Environment Division, Seoul City Government

<Figure 1-1> Comparison of contamination degree of Seoul vs. other major global cities

The Seoul Metropolitan Area had relatively higher level of contamination compared to other domestic cities and 90% of Ozone Watch issued and exceeded by 99% and 60% the national environmental standards for nitrogen dioxide and fine particles, respectively. The worsening air pollution also resulted in a decrease in the annual average visibility range; the visibility range for Seoul (12.6 km in 1996→ 10.9 km in 2000) was 40% lower than those for other industrial cities such as Ulsan (16 km) and Daegu (13.9 km).

<Table 1-1> Comparison of air pollution between the metropolitan area and non-metropolitan area (2001)

	NO_2(ppb)	O_3		PM_{10}($\mu g/m^3$)
		Number of times the standard was exceeded	Ozone Watch issued	
Metropolitan area	31	394	24	67
Non-metropolitan area	22	390	5	53

Source: Annual Report of Air Quality in Korea 2009 (Ministry of Environment, 2010)

According to a research on the damage to human health resulting from air pollution, the number of people who died prematurely due to fine particles was estimated to be 9,641 per year in Seoul (Institute for Environmental Research, Yonsei University, 2000). The ratio of the number of people who died prematurely to the number of people exposed to air pollution was 0.09% in Korea; this was higher than that of industrialized nations such as France, which recorded 0.05 ~ 0.07%. Some research results showed that increased fine particles and ozone would lead to increased number of deaths due to strokes by as much as 1.5% and 2.9%, respectively (joint research performed by Harvard University and a research institute of a university in Korea). US's EPA (Environment Protection Agency) announced some time ago that the number of people who died prematurely due to air pollution was thrice the

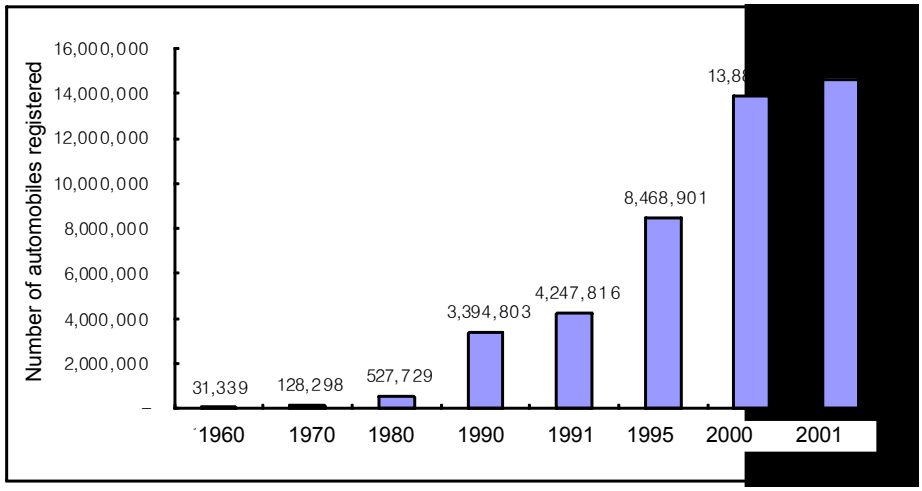
number of people killed in traffic accidents

When air pollution gets severer, the environment does not serve its function of purifying the pollutants; thus resulting in the degradation in the quality of life and wielding a negative effect on production activities and consequently obstructing national competitiveness. As of 2000, the cost of social damage resulting from air pollution was estimated to have reached KRW 10.8 trillion per year.

1.2 Cause of worsening air pollution in the metropolitan area

46% of the nation's population lives in the metropolitan area, which accounts for a mere 12% of the nation's total land area, yet the population density in the metropolitan area reached 1,858 persons/㎢. This is 4 times the nation's average population density (473 persons/㎢) and 65 times the population density of the USA (28 persons/㎢). Between 1990 and 2000, the population of the Seoul Metropolitan Area increased by 20% from 18.34 million to 21.91 million. About 50% of the automobiles registered in Korea were registered in the metropolitan area; about 50% of the automobiles registered in the metropolitan area were registered in Seoul, representing only 0.6% of the total land area of Korea. The permissible air discharge standard has been tightened, but it became meaningless due to the drastic increase in the source of pollution. A typical example was the diesel heavy-duty vehicle. The permissible discharge standard for fine particles for the heavy-duty vehicle was reinforced by 64% from 11.0g/㎞ in 1996 to 7.0g/㎞ in 2000. Note, however, that the effect of reinforcement of the standard was reduced by the 310% increase in the number of heavy-duty vehicles. In addition, the number of RVs (Recreational Vehicle) increased considerably around that time, resulting in a drastic increase in pollutants discharge. The number of diesel RVs increased by about 350% from 135k in 1995 to 477k in 2000. Diesel passenger cars are generally known to discharge 1.8 times more NOx than gasoline cars. The increased number of older cars is another cause

of air pollution. The ratio of the number of 10-year old and above cars to the total number of cars was less than 1.0% in 1994, only to increase to 5.1% in 2000 simply because of the drastic increase in car distribution among consumers; hence the further worsening of air pollution.



Source: 2002 Annual Transportation Safety Report (Ministry of Construction and Transportation, 2002)

<Figure 1-2> Increase trend for automobiles registered for ownership

Energy consumption in the metropolitan area was 18,000 TOE in 1990, increasing by more than 200% to 36,000 TOE in 2000. Transportation and power generation increased by 230% and 570%, respectively, which are considerably bigger increases compared to other sectors. Except fugitive dusts, most of the air pollutants come from energy consumption; this means that increased energy consumption would lead to the increased discharge of air pollutants.

<Table 1-2> Increase trend in energy consumption for each sector (TOE)

Items	'90	'95	2000
Total	17,902(100%)	35,691(100%)	36,215(100%)
Heating	7,192(40.2%)	11,938(33.4%)	11,806(32.6%)
Industry	4,598(25.7%)	5,041(14.1%)	6,174(17.0%)
Transportation	**4,835(27.0%)**	**9,897(27.7%)**	**10,981(30.3%)**
Power generation	1,277(7.1%)	8,815(24.7%)	7,254(20.0%)

Source: 2000 Energy Survey

In addition, the social cost of environmental contamination was not properly reflected on the price of energy. Specifically, in an effort to stabilize prices and to protect industries, diesel and heavy oil -- which discharge more air pollutants -- were priced relatively lower. The rate of gasoline to diesel was 100:56 in Korea, whereas average of OECD countries was 100:88; this suggests that diesel was cheaper in Korea than in most OECD countries. As a result, the use of diesel, which discharged a lot of air pollutants even though it was cheaper than gasoline, increased considerably.

Lastly, air pollution is generally affected not only by the amount of air pollutants discharged but also by topographical and meteorological factors. The metropolitan area particularly Seoul is located in a basin where air is not supposed to be well dispersed. Furthermore, the northeastern part of China is located to the west where a lot of pollutants are discharged; thus aggravating the air pollution in the metropolitan area in spring when pollutants from China can easily travel to Korea.

1.3 Basis of introducing the NGV vehicles created

1.3.1 Worsening air pollution

The environmental contamination problems that have gotten severer in the 20th century gave rise to serious matters such as conflict between countries due to pollutants crossing borders, destroyed tropical rainforests, global warming resulting from the use of fossil fuel, destroyed ozone layer due to

the use of Freon gas, desertification, nuclear problems, etc. In particular, the carbon dioxide (CO_2) generated when fossil fuel such as coal or oil is burned causes the Greenhouse Effect wherein radiant energy being discharged to the atmosphere is absorbed and discharged again to the surface of the earth. Accordingly, with the global temperature rising gradually in the latter half of the 20th century, abnormal weather condition such as sea level rise and El Niño, etc., occurred. Therefore, each and every country in the world is exploring various measures to address the global environmental problem.

1.3.2 UNFCCC and Kyoto Protocol

The United Nations Conference on Environment and Development was held in Rio de Janeiro, Brazil from June 3 to June 14, 1992 under the slogan "Healthy Globe, and rich future." In the Conference, more than 150 nations chose to sign, and more than 50 nations became member states. Subsequently, the United Nations Framework Convention on Climate Change (UNFCCC) officially took effect on March 21, 1994. In addition, in the 3rd General Convention meeting for participating nations held in Kyoto, Japan, the Kyoto Protocol for the reduction of discharge gas was adopted; industrialized nations such as the USA, Japan, and EU and system-implementing nations such as Eastern European countries and old Soviet Union, etc., decided to reduce the discharge gas by an average of 5.2% compared to the discharge level of 1990. The 4th general meeting held in Buenos Aires, Argentina in November 1998 was attended by 169 nations. In this meeting, the Kyoto Mechanism such as Clean Development System[1], Co-implementation[2], Emission Trading[3], etc., was introduced and adopted.

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[1] Clean Development Mechanism wherein an industrialized nation building a discharge reduction facility in a developing country is deemed a reduction of gas in the industrialized nation to utilize the market function for obligatory reduction.

[2] Joint implementation wherein -- depending on efforts such as technology transfer between industrialized nations -- reduction result can be acknowledged.

[3] Emission trading system wherein a country whose greenhouse gas -- such as carbon dioxide -- was reduced below a permissible discharge level can trade the difference between the permissible level and the actual discharge level with another country.

1.3.3 Oil crisis and energy price increase

Oil has been the most important energy source for mankind since World War II. Due to the rarity and uneven regional distribution of oil, producers' cartels such as powerful Oil Major and OPEC were created, wielding strong influences in the international community. Under the circumstances, there were two different oil crises that resulted in skyrocketing oil prices due to political conflicts in the Middle East, the core region for world oil production and export. The Korean economy did suffer during the 1st oil crisis, but the impact was not that big compared to other economies; it was badly damaged during the 2nd oil crisis, however. The reason for this was that the heavy and chemical industries-based policy for economic expansion had been emphasized by the government since the 1st oil crisis. Thereafter, the international oil price has been increasing steadily, and the age of USD 100 per barrel of oil is expected to come soon. The government, as part of actions to respond to such increase in oil price and for national security purposes (in particular, the transportation sector depends heavily on oil) as well, has been trying to establish countermeasures such as domestic oil price stabilization and adjustment of demand and supply through the development of alternative energy (natural gas, methanol, hydrogen, electricity, solar light, fuel battery, wind power generation, etc.) and efficient management of energy resources.

1.3.4 Global automobile industry's new trend of environment-friendliness

The Kyoto Protocol that took effect as well as the two oil crises gave rise to many issues to the automobile industry, which uses fossil fuel as the main power source. Countries worldwide are implementing various regulations in the automobile industry based on the Climate Change Convention and the Tokyo Protocol, and these regulations are being intensified. Since many countries are introducing and implementing various energy-related policies to prepare for the depletion of oil given limited reserves and to preserve the

global environment such as fuel economy regulation and diversification of energy sources, etc., automobile manufacturers are voluntarily leading greenhouse gas emission reduction through various research efforts and technology developments; under such circumstances, the relatively cheap natural gas is becoming more and more popular as a next-generation energy through which some of the environmental problems could possibly be solved.

|Chapter 2 . Program for promoting the distribution of NGV|

2.1 NGV: current status and future prospect

2.1.1 Background for the creation of NGV

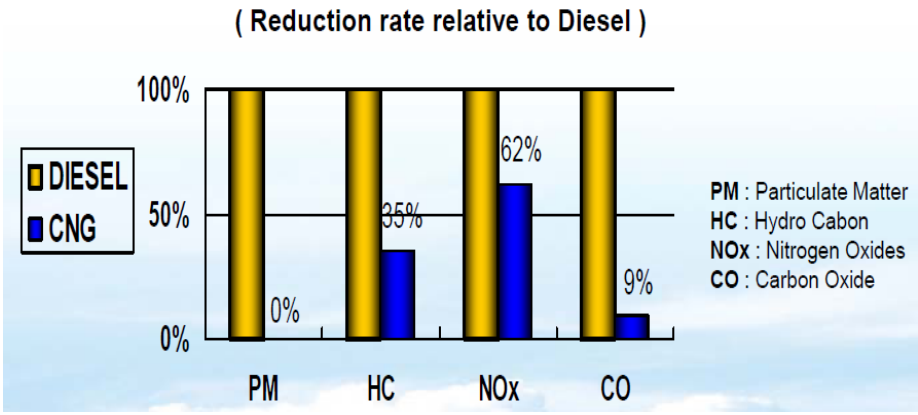
At the start of the 1990s, air pollution became a social issue especially in large cities, and it became necessary to establish various measures to deal with and solve fundamentally the air pollution problems resulting from automobiles particularly large diesel vehicles. At that time, the catalyst devices designed to purify exhaust gas from vehicles were attached to the vehicles; thus helping reduce smoke to a certain degree. According to an analysis result indicating that a fundamental solution would be required and the public opinion that the World Cup scheduled for 2002 would have to be held in a more comfortable environment, however, several research studies were launched as to the development and distribution of cleaner vehicles that discharge very little or no pollutants.

Governments of major countries including the USA, research institutes, various organizations, and automobile manufacturers - in an effort to substitute the existing oil fuel - had been performing several research studies on alcohol fuel such as ethanol and methanol, LPG and natural gas, electric and hydrogen energy, etc. Nonetheless, the conclusion reached at that time was that the electric and hydrogen energy would have to be researched on a long-term basis given the technological level available at the time. Therefore, alcohol, LPG, and natural gas fuels, which were viewed as more appropriate mid-short term alternative fuels for automobiles, seemed more promising. Vehicles using natural gas as fuel produce fewer pollutants than vehicles using gasoline or diesel; furthermore, carbon dioxide (CO_2) causing global warming is reduced by as much as 30% and 15% if and when natural gas is used as automotive fuel compared to vehicles using gasoline and diesel, respectively; thus suggesting the excellence of natural gas in terms of

environmental aspect.

In addition, according to a safety evaluation, it was also safer than other types of fuel in terms of fire hazard, explosion hazard of fuel vessel and toxicity, etc. In terms of availability to supply, assuming 100% of world oil consumption was substituted with natural gas in 1989, the estimated world reserves of natural gas would be able to supply for a period of 250 years, which is a relatively longer period of time. It was economical as well as affordable compared to the existing oil energy. For these reasons, vehicles using natural gas were driven all over the world, with the number increasing sharply due to the ease of modification of vehicles and/or technological development. Accordingly, the government of Korea also determined that natural gas was the most suitable automotive fuel given the expected UN Convention for preventing global warming, evenly distributed and operated vehicles all over the world using natural gas as alternative automotive fuel, energy security, and need to respond to reinforced regulation in industrialized nations such as the USA with regard to exhaust gas; it finally decided to implement the development project for natural gas vehicles in 1991 ~ 1997 as part of the G-7 Project[4]. Such decision by the government was based on its judgment that the development and distribution of CNG (Compressed Natural Gas) vehicles producing fewer pollutants than diesel or even gasoline vehicles were urgently required given the fact that pollutants produced by large diesel vehicles representing only 6% of the total number of vehicles accounted for some 50% of the total pollutants produced by automobiles. The government further decided to replace inter-city diesel buses - which had higher operation frequency and exhausted much smoke - with natural gas buses for city environment improvement.

[4]) This is a project designed to secure the technological level of industrialized nations based on the Leading Technology Development Plan established in June 1992. A total of 11 areas were selected, and KRW 357.3 billion was invested (government: KRW 180.9 bil.; private sector: KRW 176.4 bil.) from 1992 to 2001. Intellectual property right application and registration (928 cases) and license agreements (157 cases) were realized as a result.



Source: Data released in the "CNG vehicle distribution policy" (Environmental Transportation Division, Ministry of Environment, 2007)

<Figure 2-1> Pollutant reduction rate of CNG vehicle compared to diesel vehicle

As a result of replacing with natural gas buses, air pollutants discharged from automobiles such as fine particles (2000/65㎍/㎥→2010/47㎍/㎥), sulfurous acid gas, etc., were reduced considerably; thus creating an atmospheric environment improvement effect. In addition to the CNG buses that replaced diesel buses, LNG (Liquefied Natural Gas) vehicles for exhaust gas reduction and energy saving, HCNG vehicles wherein 20~30% of hydrogen is added to CNG, and hybrid electric vehicles wherein gasoline and electricity or natural gas and electricity are used together are also manufactured and sold or are under development.

BOX 2-1. Characteristics of natural gas

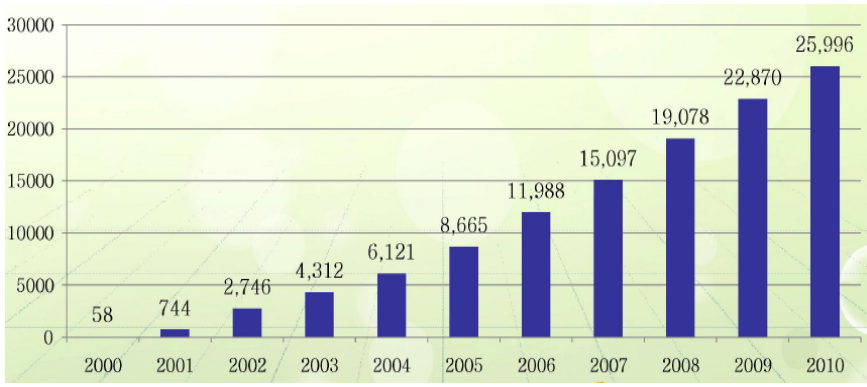
The natural gas normally found and extracted on the seabed or from oil fields is a mixture of low-grade hydrocarbon. The main component is methane (CH4), and it is flammable gas. Unlike fossil fuel, which is concentrated on one region such as the Middle East, natural gas is evenly distributed worldwide with huge deposits and is viewed as a good oil alternative that can be supplied on a stable, long-term basis. Since impurities such as fine particles and sulfur, etc., are removed from natural gas when it is liquefied, almost no substance consisting of particles is generated when burned. In addition, it is lighter than air and is dispersed into the atmosphere quickly when leaked (specific gravity: 0.6). It is deemed safer than other types of fuel since both LFL (lower limit of fuel concentration in the air that can be burned) (about 4.45%) and spontaneous ignition temperature are higher compared to other types of fuel.

Natural gas vehicles are divided into 2 types depending on the fuel storage method. One is CNG vehicle, which uses gas compressed with about 200 atmospheric pressure and stored in a high-pressure gas vessel, and the other is LNG vehicle, which uses gas liquefied at –162℃ and stored in a vacuum insulated vessel. CNG vehicles have been mainly used so far, but LNG vehicles were developed lately, and commercialization will be ready soon. In case of the CNG vehicle, the distance that can be driven with the same volume of fuel is one fourth the distance of LNG vehicles due to the lower energy density. In other words, LNG vehicles can be driven three times farther with the same volume of fuel.

2.1.2 Distribution status of NGV

In Korea, the government invested a total of KRW 13 billion from 1991 to 1997 as part of the G-7 Project for development of the Natural Gas Vehicle (NGV) for the purpose of applying to inter-city buses. From July 1998 to December 1999, 4 inter-city natural gas buses were operated in Incheon City and Ansan City, Gyeonggi-do as trial operation, whose result was successful since it drew favorable responses from citizens due to comfortable ride and zero smoke produced. As the 2002 World Cup neared, 3,000 inter-city diesel buses in Seoul, 6 Metropolitan Cities, and Suwon from among 10 World Cup host cities where air pollution was relatively worse were replaced with natural gas buses. Thereafter, the state and local governments gradually replaced diesel buses with natural gas buses. As of the end of 2010, 25,996 natural gas buses and 898 natural gas garbage trucks are operated in large

cities[5]. For the NGV distribution status, the distribution started to increase sharply in 2005; as of the end of 2010, 85.6% of 30,359 as the total number of registered buses in the nation were natural gas buses (for 7 metropolitan cities, the rate of distribution is almost 95%). The government -- to promote the distribution of CNG buses for city environment improvement -- has provided KRW 380.3 billion for financial assistance in the purchase of CNG buses (2000~2010) aside from providing KRW 212.6 billion in funds (2000~2010) to assist in the installation of gas-charging stations. The government plans to replace all inter-city buses in the nation with CNG buses by 2014.



Source: Trend in the policy implementation for NGV distribution (Environmental Transportation Division, Ministry of Environment, 2011)

<Figure 2-2> Distribution status of NGV per year

The types of vehicle dealt with in the NGV distribution policy are inter-city buses and garbage trucks, and the distribution of CNG buses in Seoul, Incheon, and Gyeonggi-do accounted for 56.3% of the total number of CNG buses in the nation; thus implying that CNG buses are mostly distributed in the Seoul Metropolitan Area.

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[5] The Ministry of Environment started to supply CNG buses in 2000, and the 2002 Korea-Japan World Cup was a good motivation to intensify the distribution of CNG buses. The natural gas-related technology was also improved, with natural gas garbage truck, school bus, commuter bus and airport bus, and city-to-city bus introduced in 2003, 2004, and 2005, respectively.

<Table 2-1> Regional distribution status of NGV

Item	Total	Seoul	Busan	Dae gu	In cheon	Gwang ju	Dae jeon	Ul san	Gyeong gi	Gang won	Choongnam /buk	Jeonnam /buk	Gyeongnam /buk
Bus	25,996	8,383	1,606	1,546	2,310	992	910	641	5,939	281	682	1,142	1,564
Garbage Trucks	898	431	32	70	15	4	8	7	77	15	26	112	101

Source: Internal data of the Ministry of Environment (as of the end of December 2010)

In the case of natural gas-charging station, there are 153 fixed stations in the nation as of the end of December 2010 with 386 chargers available, whereas 96 mobile charging vehicles[6] are under operation.

<Table 2-2> Current status of natural gas-charging stations

Fixed station		Mobile station		Mother station (M/S)	Total (fixed+mobile+m/s)	Number of NGVs (pieces)
Station	Charger	Station	T/T			
153	386	15	96	2	170	25,834

Source: Korea NGV Association (as of the end of December 2010)

<Table 2-3> Natural-gas charging station status per year (accumulated)

Item	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Fixed station (station)	4 (7)	28 (55)	36 (89)	43 (116)	63 (170)	77 (212)	78 (226)	87 (247)	94 (261)	142 (363)	153 (386)
Mobile station (station)	-	-	48 (96)	41 (96)	32 (81)	31 (85)	31 (85)	34 (85)	34 (85)	17 (82)	15 (96)

Note: Mobile station provided beginning 2002
Source: Ministry of Environment, "NGV distribution statistics"

[6] If the city gas supply network is not available, or a fixed station cannot be constructed due to slow sales and/or a small number of chargers required, the mobile charging vehicle is used.

2.2 Current status of systems to promote the distribution of NGV

2.2.1 Creation of distribution condition

To establish the conditions for distributing NGV, the Ministry of Environment started to review the appropriateness of the distribution, safety of the vehicle, revision of related laws and systems, etc., in March 1997. For that purpose, a public hearing was held in July 1997 with related ministries, related persons from the automobile and gas business industries; Korea NGV Association, a private sector organization voluntarily participated in by experts from fields such as automobile, high-pressure vessel, and gas business industries, was established in August 1997. In addition, the Ministry of Environment, in consultation with other related ministries, made preparations for the revision of the related Acts and subordinate statutes and support systems for the distribution of NGV.

As an effort to improve specifications and systems related to NGV, the ministry, along with Korea Gas Safety Corporation and Korea Environment Institute, compared and reviewed laws and regulations related to NGV of many different countries and revised provisions related to NGV in the High-Pressure Gas Safety Control Act, Automobile Management Act, and Clean Air Conservation Act as the most basic Acts from among those for the manufacture of NGV.

<Table 2-4> Revision of Acts related to NGV

Related acts	Ministry	Date	Major contents	Remarks
Automobile Management Act	Ministry of Land Transportation and Maritime Affairs	Aug. 25, 1997	Rules concerning automobile safety standard: Automobile type approval -Before revision: Gasoline, diesel, LPG fuel -After revision: Gaseous fuel such as NGV added, All liquid fuels including alcohol	Ordinance #116
High-Pressure Gas Safety Control Act	Ministry of Knowledge Economy	Jan. 10, 1998	CNG vehicle -Installation of gas-charging station, Technical standard for fuel vessel system and inspection, etc.: Safety distance -Standard for fuel device structure	Public Notice 1998-35 (May 8, 1998)
Clean Air Conservation Act	Ministry of Environment	Feb. 21, 1998	Setting the permissible discharge standard for ultra low emission vehicles such as NGV ※ For automobiles built after 2000, permissible discharge standard reinforced to the level of industrialized nations	Ordinance #38

Source: 10-year history of NGV distribution (Korea NGV Association, 2011)

In addition, to distribute NGV, the revision of related Acts and installation of infrastructure for the supply of fuel such as charging station and gas supply network, etc., have to be made at the same time. This is called "NGV Chain"; for its effective organization, the 「All-in-one project」 wherein several tasks in many different areas were driven at the same time was led by Korea Gas Corporation with support from the Energy Resources Technology Development Support Center of the Ministry of Knowledge Economy; projects such as the 「method of improving specifications and systems related to the CNG vehicle」, 「Development of package-type CNG charging system」, and 「Research as to the database construction for the characteristics of gas per site of production」 were jointly researched by related companies and academic circles.

<Table 2-5> Current status of NGV-related R&D

Item	Status
Charging station	Development of package-type CNG charging device (Jun. '96 ~ May '99) - Korea Gas Corp., Hyosung Heavy Industries, Seoul National University of Science and Technology
	Development of composite CNG charging system (Aug. '98 ~ Aug. 2000) - Korea Gas Corp., Hyundai Space and Aircraft, Sehwa Gas Equipment, Hansung University
	Development of package-type CNG charging system - Development of medium- and large-sized CNG charger for charging 50 buses per day (Jun. '96 ~ Feb. '99) - Korea Gas Corp., Hyosung Heavy Indus
System improvement	Methods of improving CNG vehicle-related specifications and systems - NGV-related Acts, systems to promote the distribution and drafting of technical specifications for related parts (Jun. '96 ~ Aug. '98) - Korea Gas Corp., Korea Gas Safety Corp., Korea Environment Institute
Combustion characteristics	Research on database construction for natural gas combustion characteristics per production site - Research on the combustion characteristics depending on the differences in the physical properties of natural gas per production site (Jun. '96 ~ Aug. '98) - Korea Gas Corp., Korea University, Korea Institute of Energy Research

Source: 10-year history of NGV distribution (Korea NGV Association, 2011)

While driving research on the development of NGV, the Ministry of Environment had a kickoff event for 「Low Emission Vehicle Test-Operation」 in October 1996 jointly with the three big automobile manufacturers in Korea. Under the campaign, three units each of Kia Sportage, Hyundai Accent, and Daewoo Ciero were test-operated at the Ministry of Environment, Korea Gas Safety Corporation, Ansan City government, and Korea Gas Corporation under the supervision of Korea Gas Corporation for the purpose of checking and identifying various problems and improvements based on the actual operation of the vehicles. As a result of analysis on the test operation, no special problems were found. In addition, based on the judgment that diesel inter-city buses and large trucks needed to be modified to NGV to reduce air pollution in large cities, the Ministry of Environment had consultations with Korea Gas Corporation, automobile

manufacturers (Hyundai, Daewoo) and inter-city bus business operators (Samhwan in Incheon, Kyungwon in Ansan) and decided to perform test operation in Incheon and Ansan using 4 CNG buses (two each city). The result of the test operation was successful since the buses produced no smoke and the citizens showed favorable response due to comfortable ride.

2.2.2 Establishing support systems

As seen through the test operation, vehicles using natural gas as fuel had several advantages such as natural gas as excellent alternative fuel, significantly reduced air pollution, and possible export of domestic NGV to overseas markets, which had grown sharply. Under the circumstances, the Ministry of Environment decided to replace diesel buses - which had higher operation frequency and produced much smoke - with CNG buses. From year 2000, the step-by-step replacement of inter-city buses (about 20,000 buses) in the Seoul Metropolitan Area and other metropolitan cities in the nation started. Note, however, that a CNG bus at that time cost KRW 25 million more than a diesel bus; building a charging station would cost more than KRW 700 million. This meant that the private sector's voluntary distribution of CNG buses was impossible.

Accordingly, bus business operators argued that they could not drive CNG bus business without financial assistance from the government as necessary for purchasing CNG buses. Nonetheless, the government's position as to the request of bus business operators was not so positive since it was impossible to shoulder the costs incurred by the operators due to limited funds. The government worked out a compromise and agreed to shoulder part of the cost required, with the rest to be settled through tax incentive. Internal consultation among different ministries of the government ensued to work out the tax incentive.

BOX 2-2. Government efforts made to distribute NG characteristics

CNG bus, a completely new type of vehicle, required the establishment of safety standards for the vehicle and charging station; for structures, etc., many different provisions of various regulations had to be reviewed. Originally, the Ministry of Environment developed NGV as part of the G-7 Project for the development of a new-generation vehicle technology jointly with the Ministry of Knowledge Economy and the Ministry of Education, Science, and Technology. Due to the uncertainty of the success of distribution, however, ministries other than the Ministry of Environment had little interest after the development of technology. As a matter of fact, some government ministries that were aggressive in the beginning almost gave up the project.

Under the circumstances, the Ministry of Environment led and drove the project, but it was difficult to get the cooperation of the other ministries of the government. The Ministry of Environment first prepared the legal basis for the distribution of CNG buses by amending the Clean Air Conservation Act in April 1999 and created a Task Force Team for consultation among different ministries. Detailed business progress was included in the daily report to the minister. The basic philosophy in the business process was persuasion and mutual consultation, but administrative proceedings were held depending on the cases, or some issues were resolved in a compulsory manner through the Office for Government Policy Coordination. Basically, the Ministry of Environment proposed that, for the price difference compensation between a CNG bus and a diesel bus, KRW 22.5 million would be granted by the state (50% from national funds) and local (50%) governments (current full-size bus: KRW 18.5 million/mid-sized bus: KRW 16 million), with the rest to be compensated through the waiving of acquisition tax and environmental improvement charges and difference in prices between diesel and CNG (difference of KRW 115 maintained: currently KRW 69). For support on the installation and operation of charging stations, it proposed that the installation cost (KRW 700 million per station) be funded in full by the government at a low interest rate (repayment in 10 years with 5-year grace period). In addition, various incentives and assistances were proposed and given, such as the application of cheaper rate (industrial rate) to the electric bill of the charging stations, exemption from corporate income tax for facility investment on the station, granting of subsidies for initial loss due to slow sales after the installation of the station, etc., to distribute CNG vehicles.

2.2.3 Major policies for NGV distribution

The government has been preparing the policy basis for the distribution of NGV such as the establishment of the tax system and financial support policies for promoting NGV distribution and constructing charging stations and amendment of related Acts for deregulation in charging station sites. The

NGV distribution policies implemented by the state and local governments include: (i) policies concerning the purchase and operation of CNG buses; (ii) policies concerning the installation and operation of gas-charging stations, and; (iii) policies related to NGV gas fuel vessels.

Policies concerning the purchase and operation of CNG buses

When a CNG bus is purchased, the difference in price between a diesel bus and a CNG bus is subsidized since the CNG bus is relatively expensive. Initially, the subsidy was granted to CNG inter-city buses only; later, however, garbage trucks, airport buses, city-to-city buses, and school buses were also included.

<Table 2-6> Current status of support policies on CNG bus purchase and operation

Date	Key contents of legally implemented support
Apr. 99	Legal basis prepared for the distribution of natural gas (Amendment of the Clean Air Conservation Act)
Aug. 99	Exemption from VAT and acquisition tax on CNG bus (Amendment of the Restriction of Special Taxation Act)
Jan. 2000	Subsidy granted for NGV distribution (Establishment of Business Processing Guideline for NGV distribution subsidy)
2001~2006	Import duties for the major imported parts used for bus manufacture waived (Enforcement Rule of the Customs Act amended)
Dec. 2002	Charging station construction permitted in any and all areas except exclusive residential areas (Establishment of the National Land Planning and Utilization Act)
Dec. 2002	Making the distribution of cleaner vehicle an obligation (Amendment of the Clean Air Conservation Act)
Mar. 2003	Garbage trucks and village buses included in the subsidy grant list (Amendment of the subsidy business processing guideline)
Dec. 2003	Making the purchase of cleaner vehicle by producers and purchasers an obligation (Establishment of the Special Act on the Improvement of Air and Environment for the Seoul Metropolitan Area)
2004~2006	Airport buses, commuter buses, school buses, and city-to-city buses included in the subsidy grant list

Source: Evaluation of NGV distribution performance and research on the vitalization method of distribution (Ministry of Environment, 2007)

<Table 2-7> Details of subsidy granted when NGV is purchased

<table>
<tr><th colspan="2">Item</th><th>Details</th></tr>
<tr><td rowspan="4">Financial support</td><td>When CNG bus and garbage truck are purchased</td><td>Cost of purchase subsidized when NGV is purchased
-Natural gas bus
<table>
<tr><th>Item</th><th>2000~2008</th><th>2009~Present</th></tr>
<tr><td>Full-size bus (engine displacement: more than 11,000 cc)</td><td rowspan="2">KRW 22.5 mil./bus</td><td>KRW 18.5 mil./bus</td></tr>
<tr><td>Mid-size bus (less than 11,000 cc)</td><td>KRW 16 mil./bus</td></tr>
</table>
Note) Until 2008, KRW 22.5 mil./bus subsidized for natural gas bus
-Natural gas garbage truck
<table>
<tr><th>Item</th><th>2000~2008</th><th>2009~Present</th></tr>
<tr><td>11-ton class</td><td>KRW 60 mil./truck</td><td>KRW 42 mil./truck</td></tr>
<tr><td>5-ton class</td><td>KRW 30 mil./truck</td><td>KRW 27 mil./truck</td></tr>
</table>
CNG hybrid bus: KRW 40 mil./bus (implemented beginning 2011)
The subsidy can be granted again when new NGV is purchased again after an old NGV to which subsidy was granted is disused</td></tr>
<tr><td>Supporting the cost of fuel</td><td>Only if the difference between diesel (l) and natural gas is KRW 69 or less, the corresponding difference is compensated.</td></tr>
<tr><td>Supporting empty car operation</td><td>If a charging station is farther than 4 km or more, the amount of loss is compensated for up to maximum of 22 ㎞.</td></tr>
<tr><td>Supporting the cost of mobile charging</td><td>The difference in costs of fuel between fixed station and mobile station is compensated.</td></tr>
<tr><td rowspan="2">Support in taxation system</td><td>Exemption from VAT and acquisition tax</td><td>KRW 9 mil. VAT and KRW 3 mil. acquisition tax waived per bus</td></tr>
<tr><td>Exemption from environmental improvement charge</td><td>About KRW 1.66 mil. per vehicle</td></tr>
</table>

In addition, in case a person who purchased a natural gas vehicle with subsidy granted for the purchase intends to export the vehicle overseas within 5 years of purchase, the subsidy granted shall be collected as follows by taking into account the period of domestic operation:

<Table 2-8> Rate of collection of subsidy per domestic operation agency (%)

Item	Within 1 year	Within 2 years	Within 3 years	Within 4 years	Within 5 years
Within 6 months	100	80	60	40	20
Within 12 months	90	70	50	30	10

Policies concerning the installation and operation of gas-charging stations

Support policies related to natural gas-charging stations that supply fuel to natural gas vehicles consist of economic support for the stations and policies on the standard of the facilities. Acts related to the installation and operation of the stations (controlling ministry) include the Clean Air Conservation Act (Ministry of Environment), High-Pressure Gas Safety Control Act (Ministry of Knowledge Economy), National Land Planning and Utilization Act (Ministry of Land Transportation and Maritime Affairs), School Health Act (Ministry of Education, Science, and Technology), Rules on Firefighting Technology Standard (Ministry of Public Administration and Security), Safety Control of Dangerous Substances Act (Ministry of Public Administration and Security), etc. The Act on the standard for gas-charging facilities, which was revised to support the installation and operation of a natural gas-charging station, is also under operation. Since natural gas is high-pressure flammable gas, technical and facility-related standards related to the safety of the gas are set forth clearly and systematically.

<Table 2-9> Current status of laws and regulations related to the technical standard for charging station facilities

Date	Major contents of support in applicable laws
Apr. 99	Installation of charging station in the inter-city bus terminal (downtown) permitted (Revision of Enforcement Decree of the Building Act)
Jan. 2000	Easing of requirement regarding the safety distance from the boundary of the charging station 10m→5m (Revision of related public notice from the Ministry of Knowledge Economy)
Mar. 2000	Installation of charging stations in parking space managed by municipalities permitted by municipal ordinances (Revision of Ordinance of Seoul City Government)
Jul. 2000	Installation of charging stations permitted in development-restricted areas (Establishment of Enforcement Decree of the Act on Special Measures for the Designation and Management of Development Restriction Zones)
Jun. 2001	Reduction of safety control personnel, 4 persons → 3 persons (Amendment of Enforcement Decree of the High-Pressure Gas Safety Control Act)
Apr. 2001	Easing of requirement regarding the safety distance from apartment houses, etc., when protection wall is installed, 50m→25m (Revision of Regulation on house construction, etc.)
Sep. 2001	Reduction of development damage charges rate by 10 to 20% when parking lots or charging stations are installed in development-restricted areas (Amendment of Enforcement Decree of the Act on Special Measures for the Designation and Management of Development Restriction Zones)
Sept. 2002	Installation of charging station permitted in distribution business facilities zone (Amendment of rule on city planning facility standard, etc.)

Source: Evaluation of NGV distribution performance and research on the vitalization method of distribution (Ministry of Environment, 2007)

The government's policies for economic support include exemption from corporate income tax, application of cheaper electricity rate (industrial), funding for the cost of installation and application of prime interest rate, and shouldering of part of the fuel and operation cost when a natural gas-charging station is constructed and operated such as 10 ~ 20% reduction in development damage charges.

<Table 2-10> Details of funds for CNG charging station construction and subsidy for operation of station

Item		Detail
Financial support	CNG station construction	Fund available with long-term loan at low interest rate -Fixed: KRW 700 mil./station, Mobile station: KRW 200 mil./station -15 years (5 years of which serve as grace period), floating rate applied
	Station operation expense support	Subsidy for initial loss granted for both fixed and mobile stations -In case daily charging capacity is 100 vehicles, if 31 or fewer cars buy gas, subsidy is granted (For capacity of 50, subsidy is granted if 22 or fewer cars buy gas.)
Support by taxation system	Exemption of income tax	3% income tax waived for investment in installation of station
	Application of cheaper rate for electricity used (industrial)	Application of industrial rate (30% lower) to electricity used in the station
	Reduction of development damage charges	10 ~ 20% reduction in development damage charges resulting from the installation of the station

BOX 2-3. Areas for installation of charging stations need to be secured multilaterally

If it is not easy to find and secure the area for constructing a charging station, there is a need to use multilateral methods that include the creation of bus terminal areas managed by municipalities. Otherwise the area for charging station may be secured in advance when city planning is established and industrial complex is created. In the case of a privately owned car port, it is normally located in the vicinity of residential areas in the city center and is small and narrow in size, and it is not a good place to construct a charging station. In the worst case, local residents may require that the private car port be relocated. Therefore, constructing a charging station in a privately owned car port is not advisable due to the technical and social conditions. To secure the area for charging station smoothly, multilateral methods need to be driven aggressively such as securing the charging station area by including the gas charging station plan into the city plan or residential area development plan in advance based on prior consultation among government ministries and/or municipalities.

Policies related to NGV fuel vessels

Policies related to gas fuel vessels used for domestic NGV have 4 different standards for the manufacture and inspection of the vessels, and they are operated with codes. The gas fuel vessels used in NGV are divided into jointless vessel and composite vessel. The jointless vessel is made of one-piece metal without weld zone, and the composite vessel consists of liner designed to maintain airtightness and fiber-reinforced plastic for reinforcement purposes. In addition, the composite vessel is divided into metal liner composite vessel and plastic liner composite vessel depending on the material of the liner. Hoop wrap vessel is one type of composite vessel wherein the body of the metal liner composite vessel is reinforced with fiber, whereas full wrap vessel is another type wherein the whole vessel is reinforced with fiber. Generally, in terms of weight, the jointless vessel is the heaviest. The lightest one is the plastic liner composite vessel, and the metal liner composite vessel is in between. The standard for jointless vessel was established in February 1999 as part of the High-Pressure Gas Safety Control Act; according to the standard, the materials that could be used include carbon steel, manganese steel, chrome-molybdenum steel, stainless steel, and aluminum alloy only; the minimum thickness standard for the body was also determined in the standard. In July 2007, the steel liner composite material vessel system and test standard for CNG vehicles were established as a guideline. Thereafter, the composite vessel for CNG vehicle fuel was publicly announced. Nowadays, any and all vessels including Type 4 wherein composite material is reinforced on the non-metallic material liner are managed and operated with Codes.

<Table 2-11> CNG vehicle vessel standard of foreign countries

Type	ANSI	ISO	Domestic standard
Type 1	Metal	Metal	Jointless vessel for CNG vehicle fuel (public notice)
Type 2	Metallic liner for 125% of the pressure in use + composite material (full wrap/hoop wrap)	Metallic liner + composite material (hoop wrap)	Steel liner composite material vessel manufacture and test standard for CNG vehicle (guideline)
Type 3	Metallic liner+composite material (full wrap/hoop wrap)	Metallic liner+composite material (full wrap)	Composite vessel for CNG vehicle fuel (public notice)
Type 4	Non-metallic liner+composite material	Non-metallic liner+composite material	

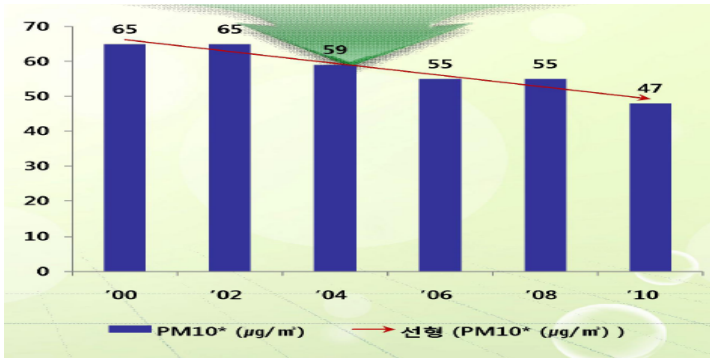
Source: Evaluation of NGV distribution performance and research on the vitalization method of distribution (Ministry of Environment, 2007)

BOX 3-1. Policy direction for Korea's CNG vessel

It is safer for the CNG fuel tank to be mounted on the roof top of a bus instead of underneath. This is because the breakage hazard increases if it is installed underneath a bus. In Korea in particular where a lot of deicing salt is used in winter to remove snow, even the corrosion hazard also increases. Checking and managing the fuel tank are more advantageous if mounted on the roof top, because it is safer to passengers in the highly unlikely event of explosion of the tank. In other words, the direction of explosion is to be upward. Still, the problem with the tank mounted on the roof top is that a bus is likely to overturn if speed is not reduced for a curve due to the lost weight balance. Under the circumstances, fuel tanks whose weight is reduced are being considered for roof top mounting in Korea. Type I and II vessels are metallic -- made of steel or aluminum -- and they are economical, but heavy. On the other hand, Types III and IV are much lighter in weight (about half of Type I and II) since carbon fiber covers the liner, but they are more expensive than Types I and II (2.5 ~ 3 times more expensive). The government is planning to switch gradually to Types III and IV, which are more stable in the future.

2.3 Environmental and economic effects of distribution of NGV

The NGV distribution project that was started is deemed a successful policy both in name and reality since the number of CNG buses reached 10,000 at the end of May 2006 and further increased to 25,996 at the end of 2010. Currently, 85.6% of the nation's total number of registered buses (30,359) is CNG buses. First of all, it significantly contributed to the improvement of the atmospheric environment in the nation's major cities. In the case of the Seoul Metropolitan Area in particular, air quality has improved remarkably as a result of the NGV distribution project (since 2000). For instance, as an environmental effect of CNG buses, fine particle (PM10) concentration in Seoul was reduced from 65㎍/㎥ in 2000 to 47㎍/㎥ in 2010.



Source: Trend in NGV distribution policy (Ministry of Environment, 2011)

<Figure 2-3> Changes in fine particle concentration (PM10) per year (Seoul City)

Analysis was performed to compare the air pollutants discharged per output power from diesel bus and natural gas bus that are currently operated; the result showed that the discharge per output power (g/kWh) for each air pollutant from the natural gas bus was 8.89 ~ 10%, 27.7 ~ 43.1%, 49.2 ~ 74.8%, and 0% discharge from diesel bus for CO, NMHC, NOx, and PM, respectively.

<Table 2-12> Comparison of permissible discharge standard vs. the test result when discharge per output power is certified

Item		Test result for exhaust (discharge) gas				Certification/ Year of test
		CO (g/kwh)	NMHC (g/kwh)	NOx (g/kwh)	PM (g/kwh)	
CNG bus	Permissible standard	0.400	0.200	3.500	-	2002
	A company	0.105	0.121	3.190	-	2006
	B company	0.007	0.109	2.277	-	
Diesel bus	Permissible standard	2.100	0.660	5.000	0.100	2002
	A company	1.181	0.437	4.267	0.098	2006
	B company	0.070	0.253	4.626	0.068	

Source: Evaluation of NGV distribution performance and research on the vitalization method of distribution (Ministry of Environment, 2007)

To analyze the environmental and economic effects created as a result of NGV, pollutants discharged by diesel bus and CNG bus were calculated based on the formula to calculate the pollutant discharge coefficient provided by the National Institute of Environmental Research. Change in air pollutants discharge resulting from the operation of natural gas bus for the period 2000 ~ 2008 was estimated; as a result, discharge from natural gas bus compared to diesel bus was found to have been reduced by as much as 4,037 tons, 101,424 tons, and 42, 486 tons for PM, NOx, and CO, respectively, for 10 years; in the case of HC, however, it increased by 56,100 tons for the same period.

<Table 2-13> Increase in each air pollutant from natural gas bus compared to diesel bus (Kg)

Air pollutant	PM	NOx	HC	CO
Change in discharge	4,037,471	101,424,377	-56,100,671	42,486,980

Note: "-" means that discharge increased.
Source: Evaluation of performance of NGV distribution and research on the reasonable methods of stable distribution (Ministry of Environment, 2009)

For the calculation of social cost, analysis was made by referring to the data from UNEP and EC with regard to the social cost per air pollutant. For CO for which no data was provided by EC, values as presented by UNEP and KAIST were applied. In addition, since natural gas distribution was implemented starting 2000, the environmental improvement benefit was also calculated based on the constant market price of 2000. The marginal cost of EC was deemed to have reflected better the condition in Korea than the marginal social cost of UNEP; based on the EC marginal cost, the environmental improvement benefit resulting from the natural gas bus was estimated to be KRW 1.643 trillion 53 million.

<Table 2-14> Estimation of the environmental improvement benefit for each air pollutant resulting from natural gas distribution

(unit: KRW mil.)

Pollutant	When UNEP marginal cost is applied	When EC marginal cost is applied
PM	80,998	1,322,085
NOx	623,123	355,101
HC	-332,969	-98,211
CO	216,694	64,078
Total	587,846	1,643,053

Source: Evaluation of performance of NGV distribution and research on the reasonable methods of stable distribution (Ministry of Environment, 2009)

Among the Cost-Benefit Analysis methods, the Net Present Value method was applied as social cost-benefit analysis for economic evaluation. In terms of expenditure, government payment with regard to the distribution of natural gas buses is estimated to be KRW 327,293 million based on 10 years' service life of the natural gas bus, including the previous payment for the natural gas buses and charging stations for the period 2000 ~ 2008 as well as additional payment made in the future. The following table shows the details of payment per year:

<Table 2-15> Government expenditure with regard to natural gas distribution policy (as of the end of 2008)

(unit: KRW mil.)

Item	2000	2001	2002	2003	2004	2005	2006	2007	2008	total
Subsidy for purchase of vehicle	12,375	11,014	14,959	30,390	35,817	36,333	43,124	26,771	55,600	266,383
Difference in interest rates for national funds lent for stations	583	1,176	6,320	2,861	2,965	2,194	2,113	3,170	2,113	23,495
Exemption from acquisition tax and registration tax	53	631	1,842	1,441	1,664	2,340	3,057	2,860	3,662	17,550
Waiving of environmental improvement charges	197	2,332	6,807	5,324	6,151	8,650	11,298	10,571	13,535	64,865
Subtotal	13,208	15,153	29,928	40,016	46,597	49,517	59,592	43,372	74,910	372,293

Note: 1) In case of subsidy for vehicle purchase, the amount also included the subsidy for garbage trucks in addition to natural gas buses; therefore, the subsidy granted to garbage trucks (KRW 27 mil. for 5-ton truck, KRW 42 mil. for 11-ton truck) was subtracted from the total amount of subsidy granted for vehicle purchase per year as prepared by the Ministry of Environment when conversion was made.

2) In case of national funds lent for charging stations, it was converted based on the net present value of 2000 on the condition that the difference between the market interest rate (5.84%) and the interest rate for national funds is repaid in 10 years with 5-year grace period.

Source: Evaluation of performance of NGV distribution and research on the reasonable methods of stable distribution (Ministry of Environment, 2009)

The environmental improvement benefit and economic cost-benefit for government expenditure incurred were estimated based on the natural gas bus distribution policy by applying EC's marginal social cost resulting from air pollutants, which is deemed more appropriate for the conditions in Korea up to year 2017 when the useful lives of the natural gas buses that had been distributed until 2008 are to expire; the net economic benefit was estimated to be KRW 1.2707 trillion. The following table shows the details of benefits, cost, and economic benefits per year:

<Table 2-16> Analysis on the economic efficiency of the natural gas bus distribution policy

(unit: KRW mil.)

Items		2000	2001	2002	2003	2004	2005	2006	2007	2008	total
Environmental improvement benefit per year (based on EC)		4,966	67,773	197,281	159,183	201,487	258,330	329,128	321,259	103,647	1,643,053
Cost	Subsidy for vehicle purchase	12,375	11,014	14,959	30,390	35,817	36,333	43,124	26,771	55,600	266,383
	Difference in interests for national funds lent for stations	583	1,176	6,320	2,861	2,965	2,194	2,113	3,170	2,113	23,495
	Exemption from acquisition tax and registration tax	53	631	1,842	1,441	1,664	2,340	3,057	2,860	3,662	17,550
	Waiving of environmental improvement charges	197	2,332	6,807	5,324	6,151	8,650	11,298	10,571	13,535	64,865
	Subtotal	13,208	15,153	29,928	40,016	46,597	49,517	59,592	43,372	74,910	372,293
Economic benefit		-8,242	52,620	167,353	119,167	154,890	208,813	269,536	277,887	28,737	1,270,760

Source: Evaluation of performance of NGV distribution and research on the reasonable methods of stable distribution (Ministry of Environment, 2009)

The economic effect of natural gas is that the total investment such as subsidy for the purchase of vehicles, funds lent for charging stations, exemption from acquisition and registration taxes, and waiving of environmental improvement charges was KRW 372.3 billion, whereas the environmental improvement benefit was KRW 1.643 trillion. Therefore, the net benefit was KRW 1.271 trillion.

On the other hand, the number of NGV-related companies belonging to the Korea NGV Association was 56 as of September 2009, whose business lines were largely parts manufacturing, facilities, transportation/operation of gas-charging stations, etc. According to the result of a survey conducted by the Korea NGV Association, the total export sales amount related to NGV of a

total of 14 companies reached USD 189,164,380 in 2008. In case of gas-charging stations, there were 118 stations (305 chargers) in the nation as of 2008, and the estimated number of employees hired by the stations was 655.

BOX 2-4. Government intervention and support required when NGVs are introduced

Since it is impossible to maximize social welfare through the private sector due to various market failure factors, the government should compensate the net social marginal benefit through intervention in the market as part of the internalization of social benefit of air pollution reduction. In other words, government support such as subsidies granted is required so that the NGV distribution policy may be driven on the condition that private balance and social balance with regard to the air pollutants reduction policy coincide.

|Chapter 3 . Current technological status of NGV in Korea|

3.1 Classification of natural gas engine technology

Natural gas whose main component is methane (CH4) is called clean fuel since its carbon content is significantly low compared to existing fuels such as gasoline (C8H18) and diesel (C17H36). In addition, natural gas has virtually no impurities such as dusts and sulfur, etc. Furthermore, since natural gas is an anti-knock-type fuel (highly resistant to knocking or abnormal combustion) with high octane rating (RON≒130), it will help improve heat efficiency and output power as well thanks to increased compression ratio. With natural gas, ultra lean burn is enabled due to the expanded lean limit when stratified combustion is induced since it offers wider limit of inflammability on combustion. Therefore, natural gas is deemed an excellent fuel in terms of exhaustion performance, engine durability, superior safety, and excellent adaptability to the internal combustion engine.

Natural gas is evenly distributed all over the world. It was accessed for energy saving and utilization of alternative energy in an effort to overcome the oil crisis starting 1970. Beginning 1990, however, it was mainly developed for the purpose of preventing air pollution resulting from automobile increase in large cities by using its cleanness and to reduce exhaust gas from diesel vehicles.

Initially, natural gas engine was developed as Bi-Fuel type designed for mounting on passenger cars with gasoline engine wherein natural gas could also be used along with gasoline. This type of engine helped solve the problem of shortage of natural gas supply infrastructure in the initial stage of NGV distribution. In addition, dual-fuel-type engine wherein diesel fuel and natural gas fuel were used together at the same time was also available. With this engine, pilot-injected diesel during engine startup and driving was used as a source of ignition. Today, however, dedicated natural gas engines wherein only natural gas is used as fuel are mainly used. The dedicated

natural gas engine has proven to be useful in improving both output power performance and exhaust performance by fully utilizing the cleanness and unique combustion characteristics of natural gas. The advantage of the natural gas engine is that both gasoline and diesel engines can be modified to a natural gas engine. In case a gasoline engine is modified to a natural gas engine, the structure of the gasoline engine can be used in the natural gas engine as is except the fuel supply device. If a diesel engine is modified to a natural gas engine, however, the problem is that the existing compression ratio does not allow compression ignition by the self-ignition temperature of natural gas. Therefore, a pre-mixer should be installed, and the compression ignition should also be modified to the ignition method by using spark plugs as in gasoline engine; this means that the fuel supply system such as injection pump and injection nozzle, etc., in the diesel engine should be changed. The fuel system and control system need to be changed as well.

The table below shows the details of development in the fuel supply system in the combustion chamber for the performance improvement of natural gas engine. Currently, both 2nd- and 3rd-generation technologies are being applied to natural gas buses in Korea. In the future, the development of 4th-generation technology and higher is required for the further improvement of performance.

<Table 3-1> Current status of natural gas engine technology

Item	Major contents
1st-generation technology	The 1st generation is of the suction tube type in the initial stage. Compressed natural gas supplied from the fuel tank passes through the mixer, which is a mixing device, and then supplied to the suction tube. the carburetor used in the gasoline engine and mixer type in the LPG engine are of the suction tube type as well. The mixer-type fuel system is the system that corresponds to the carburetor of the gasoline vehicle engine wherein high-pressure fuel in the fuel tank is reduced to the atmospheric pressure and mixed with the mixer. V ehicles using this technology are mainly distributed in Latin America and Southeast Asia, but most of the engine types are open mixer roof wherein official fuel efficiency can be fully controlled or feedback mixer wherein electronic control is added due to economic condition and technology level that falls behind. These types of engines have lower output power performance compared to gasoline engine, and exhaust gas is not fully controlled.
2nd-generation technology	In this type, the fuel supply device is installed in the suction tube. This is Single-Point Injection wherein fuel is injected by electronic control to the area around the suction tube or throttle valve using injector or solenoid valve, etc. This is called the TBI (Throttle Body Injection) type in the gasoline engine. The current systems distributed in Korea are Woodward's system and TBI type with relatively better control performance; the amount of fuel supplied to the fuel chamber is adjusted by a metering valve consisting of several injectors combined, and fuel is supplied in front of the throttle body.
3rd-generation technology	This is a multi-point injection type (MPI) wherein fuel is injected to each engine cylinder through injectors installed in the suction tube and supplied to the suction manifold. CNG vehicles modified in domestic CNG buses and garbage trucks controlled by the Ministry of Environment are using the 3rd-generation technology. Before fuel enters into the combustion chamber through each cylinder, the amount of fuel is controlled by each injector installed in the suction manifold. In other words, it is a fuel injection system wherein the amount of fuel is controlled per cylinder.
4th-generation technology	This is the type wherein fuel is directly injected into the cylinder. The injector is installed in each combustion chamber, and fuel is directly injected into the combustion chamber. This is similar to GDI (Gasoline Direct Injection) of the gasoline engine and CRDI (Common Rail Direct Injection) of the diesel engine.

Source: 10-year history of natural gas vehicle distribution (Korea NGV Association, 2011)

3.2 Technology development trend for Korea's NGV

The G-7 Project implemented in the 1990s by the Ministry of Environment, Ministry of Education, Science, and Technology, Ministry of Knowledge Economy, etc., with regard to NGV engine development was a typical government policy to support the technology and localization of NGV engine, gas-charging station facilities and vessel, etc.

<Table 3-2> Current status of research conducted with regard to NGV development (1990s)

Ministry concerned	Project	Research agency	Period of research	Details of research
Ministry of Environment	CNG dual-fuel device development (G7)	Motor Vehicle Emission Research Lab, MOTONIC Corporation	1992.11~1994.10	CNG dual-fuel device development and test using actual vehicle
	Technology to convert diesel engine into CNG engine (G7)	Daewoo Heavy Industries, MOTONIC Corporation	1995.11~1998.10	Large CNG vehicle combustion device development
Ministry of Education, Science, and Technology	Development of natural gas dual fuel supply system (specially designated research)	Korea Institute of Machinery and Materials, Kia Motors, MOTONIC Corporation	1991.8~1994.7	Development of garbage truck wherein CNG can be used together with other type of fuel, engine test and test using actual vehicle
Ministry of Knowledge Economy	Design technology for high-efficiency CNG engine (G7)	Daewoo Motors, MOTONIC Corporation	1992.12~1997.10	Development of CNG passenger car and test using actual vehicle
	Development of CNG injection device for diesel engine (specially designated research)	Doowon, KAIST	1993.12~1994.11	Development of fuel injection device and ECU by changing the diesel inter-city bus to CNG bus

Source: Final report for CNG vehicle-related standard and methods of improvement (Ministry of Knowledge Economy, 1998)

In Korea, research studies mostly concentrate on the direct injection-type CNG engine. First, Daewoo Bus Company Limited conducted research on the direct injection-type CNG engine combustion and characteristics of exhaust gas through changed injection timing by changing the 1,900 cc engine to a visualization engine. The result of the research showed that the injection angle tended to decrease and the penetration length tended to increase with increasing injection pressure. The direct injection-type CNG engine provided improved output power as volume efficiency increased and the combustion limit significantly increased through the stratification effect and increased flow velocity in the cylinder. In addition, unburned hydrocarbon and nitrogen oxide were reduced in lean burn condition due to the improved combustion limit. The Korea Institute of Energy Research conducted research on the performance characteristics of the natural gas engine depending on the engine RPM, excess air factor, and ignition timing by changing the compression ratio of 1,439cc 4-cylinder natural gas engine to 9:1, 10:1, and 11:1 and comparing with a gasoline engine with the same compression ratio. According to the research result, output power improved, and fuel consumption ratio decreased as the compression ratio increased. In CNG engine, very little CO was discharged, and HC discharge was similar to the discharge from a gasoline engine but tended to decrease under lean burn condition. NOx discharge concentration was higher than that of gasoline engine. The heat efficiency of the CNG engine was improved compared to that of a gasoline engine, improving further as the compression ratio increased.

The Korea Institute of Machinery and Materials conducted a review on the supercharging and change of compression ratio for the improvement of output power for natural gas engine. It found out through the review that supercharging was more effective in the engine operation scope than the change of compression ratio for the improvement of engine output power and efficiency. NOx discharge from the natural gas engine was similar to that from other existing types of engine when the compression ratio increased but about twice as high in case of supercharging. The result seems to suggest the need

to select appropriate supercharging level depending on the engine operation scope. According to research conducted by Sungkyunkwan University, in case of large direct injection-type CNG engine, the maximum value of lean burn appeared at air fuel equivalent ratio of around 1.5 with injection rate of 10% when injection was made by the auxiliary injection port; the knock limit compression ratio was 11.5.

In the comparison of the direct injection-type CNG engine and suction tube injection-type CNG engine with supercharging in each case, output power and heat efficiency of the direct injection type increased with increased heat supply, but NOx discharge was higher overall; thus indicating that an additional device to reduce NOx was required even though the lean burn limit was expanded. In addition, research studies are being conducted as to the development of a HCNG engine wherein natural gas and hydrogen are mixed for combustion and CNG-hybrid vehicle wherein hybrid technology is utilized.

3.3 Technological trend for NGV engine modification

Unlike the technology with which a natural gas engine is designed and built by automobile manufacturers, the modification technology for NGV is the technology with which engines of automobiles that are operated are changed to NGV engines. The engine types that can be modified are gasoline and diesel engines. In changing a gasoline vehicle to NGV, the technology and system to be applied vary depending on the level of exhaust gas and performance of the vehicle in question. In most cases, the 1st- or 2nd-generation NGV engine system is used for modification mainly for modification cost saving rather than vehicle performance. The problem with such trend includes lower output power compared to gasoline engine and slower response even though it gives better fuel efficiency. If and when the 1st- or 2nd-system generation of NGV modification technology is applied to a

gasoline vehicle wherein the MPI type is used, backfire may occur, and exhaust gas may worsen compared to gasoline engine. For this reason, the use of the 3rd-generation NGV modification technology using the MPI type is expanded in some developing countries; due to the relatively higher cost, however, the distribution pace is not that fast. The modification of diesel engine is complicated and costly compared to that of gasoline engine. Nevertheless, governments of many different countries are providing financial assistance since the modified diesel engine produces a relatively smaller amount of fine particles, nitrogen oxides, CO, etc., even though the modification involves a lot of manual works such as the modification of cylinder head, piston machining, installation of injector, etc. Korea has a very high level of diesel engine modification technology.

The NGV modification market and technology help facilitate the manufacture of NGV by automobile manufacturers, and they also contribute greatly to the establishment of gas-charging station infrastructure. In other words, the establishment of gas-charging station infrastructure is highly encouraged due to natural gas demand created by modified NGV that can be built at a lower cost than the cost of manufacturing NGV. The modification market tends to grow in its early stage when gas-charging station infrastructure is not highly available, based on the review of the international trend in NGV modification technology and market. If and when the gas supply system is fully established, with the charging station infrastructure construction distributed above a certain level per country, however, then the stage wherein automobile manufacturers design, manufacture, and sell OEM NGV follows. Thereafter, the modification market disappears drastically, and the market is transferred to the system under which automobile manufacturers build and supply NGV. This is the most typical trend in the NGV modification market and technology.

3.4 Distribution of NGV through the modification business

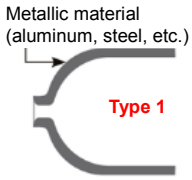
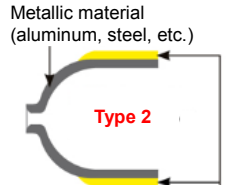
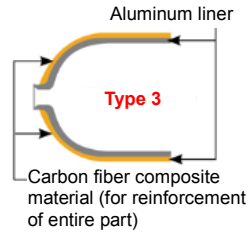
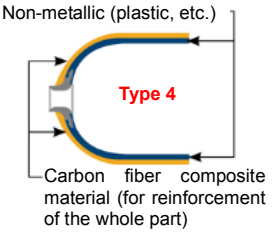
Certification cost saving and cost reduction could be expected, and quality improvement resulting from mass production and joint monitoring among different manufacturers could be enabled if the products manufactured by domestic manufacturers are jointly used by each manufacturer. Even though projects for NGV engine development, etc., such as G-7 were put into practice starting from the early and middle part of the 1990s by government ministries such as the Ministry of Knowledge Economy as well as vehicle manufacturers, it was not until 2000 that the distribution of NGVs actually started. The distribution business started as part of preparations for the 2002 Korea-Japan World Cup and particularly with natural gas buses. In the early stage of the NGV distribution business, however, cooperation among the different ministries of the government was not so smooth, related regulations were not streamlined in a timely manner, development of NGV and various parts was delayed, and construction of natural gas-charging stations was slowed down mainly by excessive regulation.

For economic reasons in most cases, it was impossible to replace any and all vehicles operated in a region or a country with cleaner vehicles at a time. Therefore, it was more appropriate to replace some highly marketable vehicles with the vehicles manufactured by makers and to modify the rest of the vehicles by using modification business operators in the after-sales service market. In most cases, the development of NGV modification technology encourages automobile manufacturers to introduce the manufacture of NGV. In other words, the distribution of NGV is promoted by a modified NGV that can be built at a lower cost than the cost for a complete NGV; thus creating a potential market for NGV as well as providing the impetus for the construction of gas-charging stations.

3.5 Trend in natural gas vessel technology

The CNG vessels used in Korea's CNG vehicles are divided into 4 types depending on the materials in use and methods of reinforcement. Types 3 and 4 are called ultra-light composite material CNG vessel. The ultra-light composite material CNG vessel is a tank wherein the gas-containing aluminum or plastic liner is reinforced with carbon fiber composite material longitudinally and in the circumferential direction. It is more than two times lighter than the existing metallic vessel, with superior durability due to its fatigue-resistant characteristics. Nonetheless, it is expensive compared to the metallic vessel considering the high cost of the fiber carbon used as reinforcement material. Even though the use of ultra-light vessel is increasing for the improvement of vehicle performance, the worldwide share of the ultra-light vessel is still small. In Korea, Types 1 and 2 are distributed, but Types 1, 2, and 3 are used in the modification market. Italy's Faber vessels were imported for use before the development of the domestic vessel. Type 4 has been developed and sold in the CNG vehicle and modified vehicle market, but sales are still sluggish due to the high selling price.

<Table 3-3> Current status of CNG vessel

Item	Details	
Type 1 (CNG-1)	As a metallic vessel made of steel or aluminum, it is designed to endure pressure load only by metallic material without structural reinforcement using composite material. The problem with this type of vessel is that it is heavy due to the increased thickness of the wall to endure high pressure.	
Type 2 (CNG-2)	Type 1 vessel is reinforced with fiber carbon or glass fiber wound in the circumferential direction to reduce the weight by reducing the thickness of the wall of cylinder. The fiber carbon or glass fiber is made by impregnating resin onto the metallic liner made of steel or aluminum. This type of vessel weighs slightly less than Type 1, but the weight reduction is not significant since the wall of the dome part at both ends of the vessel should be thicker than other parts because the liner should endure part of the vessel pressure load. In addition, reinforcement using composite material is only made to the body part in the circumferential direction rather than longitudinally; therefore, longitudinal breakage may occur.	
Type 3 (CNG-3)	This is the vessel wherein fiber carbon, aramid fiber, or glass fiber made by impregnating epoxy or unsaturated polyester resin onto thin metallic liner made of steel or aluminum is wound in the circumferential direction and longitudinally for reinforcement. The metallic liner is supposed to not to endure the load or endure just a small part of it.	
Type 4 (CNG-4)	This is the vessel wherein fiber carbon or glass fiber made by impregnating resin onto non-metallic liner made of nylon or high-density polyethylene (HDPE) used to make the vessel lighter is wound in the circumferential direction and longitudinally for reinforcement; the non-metallic liner is supposed to not to endure the load but to prevent gas leak.	

Source: Evaluation of NGV distribution performance and methods of vitalizing distribution (Ministry of Environment, 2007)

3-6. Technological level of NGV development and policy trend in Korea as well as overseas

The global technological level of CNG engine development is currently advanced, and even the domestic technology is as advanced as that of industrialized nations. CNG vehicles have been favored for their environment-friendliness owing to the significantly lowered discharge of air pollutants compared to the conventional diesel engine, but the environmentally dominant position of CNG vehicles has been weakened recently by the development of super clean diesel engine; thus leading to the development of the development technology of cleaner engine such as HCNG.

The next-generation natural gas vehicle (HCNG automobile) uses natural gas mixed with 20~30% hydrogen as fuel. This type of mixed fuel produces reduced nitrogen oxide while improving efficiency. For this reason, it is expected to be fully compliant with EURO 6 and to lead the hydrogen economy. In reality, the HCNG vehicle produces 0.4g/kWh of nitrogen oxide - representing 80% reduction compared to conventional vehicles - and 0.01g/kWh of fine particles for a 50% reduction. With regard to HCNG vehicle-related technology, research studies are conducted aggressively in Korea. One typical example of such efforts is that Doosan Infracore, a Korean firm that concluded a technical cooperation agreement with CTI in the USA in 2008, is participating in the ongoing test operation in the USA. Currently, the Korea Institute of Machinery and Materials, together with Doosan Infracore, is conducting "a feasibility study on the commercialization of the HCNG inter-city bus engine to meet and respond to EURO 6," whereas Korea Gas Corporation and Korea Gas Safety Corporation are conducting "a feasibility study on NCNG infrastructure construction using the CNG-charging station."

In the case of the LNG-diesel dual-fuel vehicle developed in Korea recently, the Ministry of Land Transportation and Maritime Affairs -- to cultivate the domestic energy industry -- discourages the use of fossil fuel and realizes green growth by maximizing energy efficiency; it decided to grant a KRW 20 million subsidy per vehicle if and when a large cargo truck using diesel fuel is

changed to LNG-diesel mixed combustion. Korea Gas Corporation has been designated as the agency responsible for overall supervision and control, and it is leading a pilot project for evaluation. The government's decision was based on the development and test operation of a 13L dual-fuel engine that proceeded from 2006 to 2007, and the 13L project is deemed to have given rise to various government policies supporting the modification businesses and led related encouraging technology development efforts for several industries.

In addition, the Korean Ministry of Environment, following the introduction of the next-generation natural gas bus, CNG hybrid bus[7], on January 25, 2011, announced that it would drive the pilot distribution business[8] of CNG hybrid bus -- which produces significantly reduced air pollutants and greenhouse gases -- mainly for the operation of inter-city buses in the Seoul Metropolitan Area. With the CNG hybrid bus, it is possible to minimize fuel consumption through the combination of engine, electric battery, and motor and electronic control device. The power produced by engine startup can be saved in the battery as electricity, with additional power transferred as the motor runs when the bus starts to move or in case of acceleration. Because of this, fuel efficiency can be improved greatly, whereas exhaust gas and greenhouse gases can be reduced by more than 24% compared to conventional natural gas buses. In other words, it is environmentally superior and economically efficient since greenhouse gases are reduced by 56 tons compared to diesel and 33 tons compared to CNG only per year.

[7]) In case of the CNG hybrid bus, most of the major parts such as electric motor, battery, etc., were developed using domestic technology alone, and such is expected to contribute to the enhancement of national competitiveness.

[8]) Due to the implementation of the Framework Act on Low Carbon, Green Growth, Korea is required to reduce greenhouse gases by as much as 30% compared to BAU by 2020; the introduction and operation of CNG hybrid bus, a low carbon-type natural gas bus, are driven as a pilot distribution business for the reduction of greenhouse gases in the transportation sector in Korea.

<Table 3-4> Environmental and economic effect on CNG hybrid bus

(based on 100,000km driving per year)

Type of vehicle	Field fuel efficiency	Annual fuel consumption	Annual cost of fuel	Annual production of greenhouse gases
	Diesel: km/ℓ CNG: km/Nm³	Diesel (ℓ) CNG (Nm³)	(KRW)	CO2 (ton)
Diesel bus	1.7	58,824	94,236,048	160
CNG bus	1.6	62,500	53,093,750	137
CNG hybrid bus	2.1	47,619	40,452,340	104
Change compared to CNG bus	30% improvement	24% saving	24% saving	24% saving

※ Fuel efficiency for CNG and HYBRID vehicles is a field value based on a self-survey of Hyundai Motor Company.

※ Based on low-floor bus, may vary depending on the type of vehicle, operation section, and operation conditions

※ Diesel: KRW 1,602/ℓ; CNG: KRW 849.5/Nm³ (as of Jan. 1, 2011)

Source: Internal data of the Ministry of Environment (2011)

Under the pilot distribution business of CNG hybrid buses, national funds are allocated to the initial 30 buses that need to be replaced due to the expiration of their useful lives from among the natural gas buses operated in the Seoul Metropolitan Area. The Ministry of Environment plans to replace all inter-city buses in the nation with CNG hybrid buses stage by stage. From the long-term perspective, the technological development and distribution of HCNG (hydrogen-natural gas) hybrid bus are to be promoted for the enhancement of environmental benefit of CNG buses.

3-7. Direction of application of next-generation technology

Euro-6 as set forth by the European Parliament shall apply to the vehicle with total weight of 2,610kg or more, with the permissible level of NOx discharge to be reduced to 0.4g/kWh for an 80% reduction compared to Euro-5 with PM to 0.01g/kWh. For fine particles and nitrogen oxide, ESC (European Stationary Cycle) and ETC (European Transient Cycle) tests standard currently apply. This means that Euro-6 has gotten even closer to the 2010

commercial vehicle regulation implemented by the US's EPA. The exhaust gas regulation of the USA, which took effect in 2010, provides for permissible discharge levels of 0.27g/kWh and 0.013g/kWh for NOx and PM, respectively.

Accordingly, many different countries of the world including Korea seem to put emphasis on improved fuel efficiency, heat efficiency, and reduction of exhaust gas while developing NGV.

<Table 3-5> EU regulation on exhaust gas from medium- and large-sized diesel engines

Item	Time of application	CO (g/kWh)	HC (g/kWh	NOx (g/kWh	PM (g/kWh	smoke (g/kWh
Euro 1	1992	4.5	1.1	8.0	0.36	-
Euro 2	1998.10	4.0	1.1	7.0	0.15	-
Euro 3	2000.10	2.1	0.66	5.0	0.10	0.8
Euro 4	2005.10	1.5	0.46	3.5	0.02	0.5
Euro 5	2008.10	1.5	0.46	2.0	0.02	0.5
Euro 6	2013.01	1.5	0.13	0.4	0.01	-

|Chapter 4 . Direction of international cooperation of Korea for natural gas vehicle|

4.1 Trend and prospect for NGV distribution in the overseas market

The number of countries where natural gas is produced or used due to high oil price and need for the introduction of clean alternative energy resulting from climate change are rapidly increasing nowadays. The number of NGVs that are distributed and currently operated in the world is approximately 12.5 million; in most of the countries, subsidies and tax exemption are granted to promote the purchase and operation of NGV; thus expanding the market share. As of October 2010, 94% of the NGVs that are globally distributed are passenger cars, and they are mostly seen in Asia and US. In Asia, Pakistan, Iran, India, and China are active whereas, Korea and Japan have 26,000 and 39,000 vehicles, respectively.

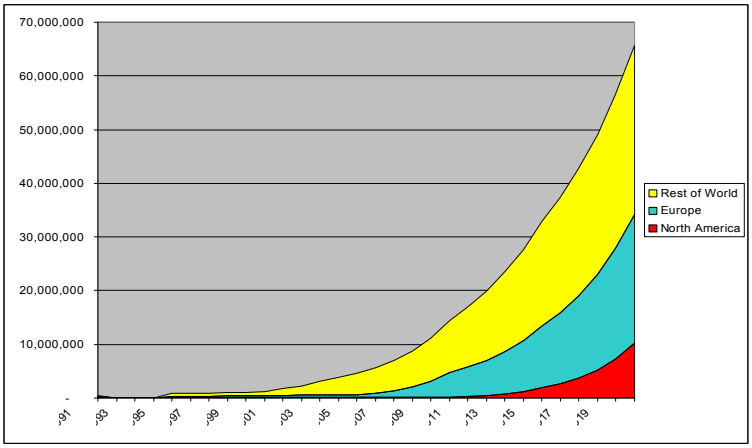
<Table 4-1> Distribution status of world NGVs (as of October 2010)

Region	Subtotal	Passenger car	Medium-sized vehicle, bus	Large-sized vehicle, truck	Others	Charging station
Asia	6,206,061	5,810,330	230,478	84,104	81,149	8,624
Eurasia	207,743	161,021	12,720	32,026	1,976	580
Africa	129,260	126,578	1,224	712	746	134
Europe	1,096,224	886,494	130,888	77,787	1,055	2,931
America	4,083,875	4,060,395	13,820	9,660	0	4,696
North America	115,177	99,037	11,240	2,500	2,400	920
Total	11,838,340	11,143,855	400,370	206,789	87,326	17,885

* Eurasia: Armenia, Georgia, Turkey, Russia

Until 1980, small and medium-sized natural gas vehicles had been distributed in countries where natural gas was produced; nowadays, however, technology for large-sized natural gas vehicles such as bus are developed and distributed to reduce air pollution in large cities. Many different countries are trying to replace with cleaner vehicles producing fewer pollutants while continuously developing the technology to reduce exhaust gas.

According to the data on the world NGV distribution prospect announced by the World NGV Association, the number of globally distributed NGVs was 5.4 million at the end of 2006 and is expected to reach 65 million in 2020. Based on 2010's 12 million, 65 million NGVs as estimated for 2020 seem highly likely. According to the data prepared based on information from each country with regard to the distribution prospect and plan, it can be concluded that the world NGV market is growing very fast. So far, CNG vehicles have been distributed in most cases, but LNG vehicles are also expected to increase in the future.

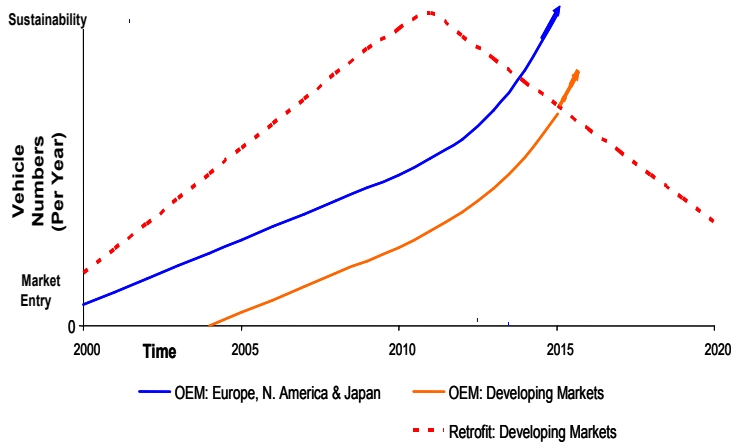


Source: IANGV

<Figure 4-1> Prospect for world NGV distribution

As mentioned earlier, the present situation is that gasoline vehicles are mostly changed to CNG vehicles in the case of developing countries and

BRICs, and there is a need to create a scenario as to how to achieve a certain level of distribution of NGV based on the manufacture of NGV and modification to NGV. Figure 4-2 shows that the modification market was bigger than the manufacturing market as of 2006, but the latter is expected to grow in the future through technological development. Based on such prospect for distribution, if the overseas market size for LNG vehicles is deemed 1% of the total NGV, the number of LNG vehicles in the world market is expected to reach approximately 0.65 million in 2020.



<Figure 4-2> NGV prospect for OEM and modification market

4.2 Growth of related domestic industries

The Ministry of Environment, to drive the continuous distribution of NGV and to promote the introduction of excellent domestic NGV technology in the overseas market, decided to reinforce its support activities. Korea's export for NGV was concentrated on Asian countries where the distribution of NGV started, and export grew explosively from USD 22.2 million in 2004 to USD 33 million and USD 189 million in 2008. In addition, more than 7,740 jobs - 4,280 jobs in the manufacturing sector, 960 jobs in R&D, 1,180 jobs for service and office workers, and 780 jobs in charging stations - were created in 2008 thanks

to such export. Given the high penetration of NGV into the Korean market, experiences obtained from the operation of NGV, and relatively superior NGV technology, Korea now exports NGV and related parts to 14 countries overseas including Asian countries such as Malaysia and Indonesia, South American countries such as Columbia and Chile, and African countries such as Egypt. Initially, export items included charging station equipment such as compressor and storage vessel, but the CNG engine and finished CNG buses were included in the export items beginning 2006. In 2007, all 50 inter-city buses in Putrajaya, a new administrative capital city of Malaysia, were replaced with Daewoo CNG buses; this which was a major performance feat in Korea's export of CNG.

4.3 International cooperation and globalization

The domestic natural gas bus distribution policy became the subject of benchmarking by Southeast Asia countries that are facing issues such as skyrocketing oil price and increased regulatory oversight for environmental protection as well as production of natural gas in their own countries. In particular, the Korea-Singapore Natural Gas Vehicle road show was held in Singapore, which was deemed an environmentally advanced nation. Korea also concluded an MOU with Singapore for NGV policy and technological cooperation in February 2005, thereby establishing a foothold to enter the Southeast Asian market. Malaysia also dispatched a delegation of 19 officials consisting of those from the government and from oil companies such as Petronas and Shell to Korea in July 2005, visiting the Ministry of Environment to take part in the presentation on Korea's NGV distribution policy and automobile and parts manufacturers for the factory tour. In addition, the Ministry of Environment organized the 「Joint Organization to drive NGV export」consisting of the government, Korea Gas Corporation, Asia-Pacific NGV Association, Hyundai Motor Company, Daewoo Bus, Kwangshin Machine Industry, etc., in March, 2005 under the supervision of Korea NGV

Association and aggressively provided support for export through the provision of information and technological cooperation with Indonesia, Vietnam, and Malaysia, which were visited by the ministry in June 2006. In November 2006, joint consultation was made as to the NGV distribution policy during the meeting between the ministers of environment of Korea and Egypt.

In addition, the NGV distribution policy and technological cooperation business were adopted as part of the businesses set forth in its Annex in the 2006 Korea-ASEAN FTA Economic Cooperation Conference; accordingly, the NGV forum and technological cooperation business have been implemented since 2008. Furthermore, the Ministry also promoted and encouraged the cultivation of knowledge for people related to the industry-academe association for natural gas by providing education for professionals on the NGV policies of Korea and overseas as well as vehicle maintenance through the Gangwon-do and Korea NGV Association. Along with those activities mentioned, the Ministry also enabled many foreign countries to have interest in Korea's NGV distribution policy and related technology by actively participating in various international events held on a yearly basis and publicizing NGV distribution policy and introducing the NGV technologies of Korea. In addition, as part of the subsequent businesses of the Korea-ASEAN economic cooperation, the Ministry provided invitation training related to NGV policy and technology for government officials of ASEAN countries to implement the basic agreements in the FTA; to maintain the human network established through the invitation training in 2010 for government officials from ASEAN countries (Vietnam, Philippines, and Indonesia) and to expand the mutual exchange of opinions between the government and industrial sector, domestic invitation training was provided on global NGV on October 10 ~ 15, 2011.

BOX 4-1. Korea-ASEAN NGV forum and technological cooperation business

The world natural gas vehicle market is growing fast, with 12.5 million vehicles currently being operated; more than half of them are operated in Asian countries. Since most Asian countries especially those in Southeast Asia are producing natural gas in their own countries, they are particularly interested in using the natural gas produced as transportation fuel, and their potential growth seems limitless. At that time, the government of Korea was in the process of negotiating FTA with ASEAN countries, and the NGV distribution policy and technological cooperation project were proposed and adopted as part of businesses in the Annex in the second meeting of the Korea-ASEAN economic cooperation conference in November 2006. Thereafter, the NGV distribution policy and technology training for technological cooperation between Korea and ASEAN countries were proposed. As a result, the first Korea-ASEAN NGV forum was held in July 2008. Initially, the program focused on visiting the target country for strategy meeting, seminar, exhibition, and technical tours to related agencies. Starting in 2010, the program was divided into three categories: technology/policy/export cooperation business, NGV invitation training, and NGV forum. Such activities are typical examples of the efforts made by the Korean government to realize technology transfer and policy cooperation through the active exchange of NGV-related industry between Korea and ASEAN countries following the FTA. Through these activities, Korea has emerged as a leading country in the NGV sector and brought economic benefit to developing countries in Southeast Asia by laying the foundation based on which NGV distribution expansion and vitalization can be enabled in ASEAN countries such as Myanmar, Indonesia, Vietnam, and Thailand, which are oil and natural gas-producing nations but pay enormous energy cost due to an inefficient energy consumption structure. In addition, the expanded distribution of environment-friendly vehicles that is in perfect accord with the Korean government's policy basis of "green growth" also contributes to the growth and development of the related domestic industry such as export increase and job creation, etc.

<Korea-ASEAN NGV forum and technological cooperation status>

Item	Date	Place
1st Korea-ASEAN NGV Forum	2008.7.2~4	Bangkok, Thailand
2nd Korea-ASEAN NGV Forum	2008.11.27~29	Manila, Philippines
3rd Korea-ASEAN NGV Forum	2009.5.27~29	Jakarta, Indonesia
4th Korea-ASEAN NGV Forum	2009.11.4~6	Hochiminh, Vietnam
5th Korea-ASEAN NGV Forum	2010.4.26~30	Seoul, South Korea (planning to provide technology training)
6th Korea-ASEAN NGV Forum	2010.7.13~15	Yangon City, Myanmar

In the case of Uzbekistan, Korea Gas Corporation and Uzbekistan's UNG concluded an MOU for DMC & CNG technological cooperation in 2008. When the Assistant Prime Minister of Uzbekistan visited Korea in December 2009, an agreement to drive the business was reached, with the MOU and HOA (Head of Agreement) concluded in January 2010 among Korea Gas Corporation, UNG, and KOLON to stipulate specific matters related to driving the CNG business. Korea Gas Corporation and KOLON were to construct and operate gas-charging stations for natural gas vehicles in the major cities of Uzbekistan including Tashkent and in the main transportation line network. Last January, a company for investment purposes was established for the CNG-charging business and vessel manufacturing, and a joint investment firm was created in Uzbekistan.

In addition, the 7th Global-Korea NGV Forum was held in Tashkent, Uzbekistan on November 9 ~ 11, 2010; the forum seeks to expand the countries with which Korea maintains NGV policy cooperation -- mostly ASEAN countries -- to Central Asia and further to the whole world to cultivate and develop the NGV industry and diversify the overseas export market. In addition, the government officials in charge of the environment, energy, and transportation of Kazakhstan, Uzbekistan, and Russia were invited to Korea from March 28 to April 1, 2011 as part of the 2011 Global-Korea NGV Policy and Technical Program, and a program through which Korea’s policy and technology for natural gas vehicles could be shared among those officials was provided.

BOX 4-2. Market potential, fuel efficiency, government's positive will

Uzbekistan is deemed to have CNG market potential, high fuel efficiency, good pipeline condition, and strong will of the government working on its favor to drive the business. Compared to other countries where the CNG business is vitalized, Uzbekistan lags behind more or less in terms of CNG infrastructure and government subsidy, etc.; in terms of price competitiveness and strong, positive, policy-based will of the government, however, it has very good business condition. In addition, the natural gas price is one third ~ one fourth the price of gasoline, and domestic demand for gas is bigger than that for oil. Specifically, natural gas production reached 60 billion m3 in 2007 alone, and 75% of the production was consumed in the domestic market. Therefore, recovering the investment cost relatively sooner -- compared to other countries in Uzbekistan where the CNG price is one third ~ one fourth the price of gasoline and diesel and one half the price of LPG -- is deemed necessary.

As for Kazakhstan, the Global-Korea NGV forum wherein about 80 people related to the natural gas vehicles of both countries took part was held in Almaty on June 14 ~ 16, 2011. Consisting of policy seminar, exhibition, strategy meeting, technical tour, etc., the event was attended by 20 officials from Kazakhstan ranging from the ministry of environment and Almaty city government to national gas company and by about 60 officials from Korea ranging from the Ministry of Environment, Korea Gas Corporation, modification business operators, and gas station facility company to city gas company. In addition to the seminar, the participants also visited the CNG-charging station and natural gas bus business operators for the technical tour. Exhibition activities were held by charging facility companies, vehicle modification business operators, and vessel makers.

ANGVA and IANGV EXPO

BOX 4-3. ANGVA and IANGV EXPO

In 2009, the 3rd ANGVA Donghae EXPO was held in Donghae-si, Gangwon-do, and active business talks were enabled among people related to the event and buyers from all over the world. It provided a good opportunity wherein world class experts in the NGV industry had discussions on the relevant knowledge and visitors saw and experienced the exhibited products and parts on their own. The 13th Biennial NGV Global Conference and Exhibition is scheduled to be held in Chuncheon-si, Gangwon-do on October 9 ~ 11, 2012, with 5,000 visitors from 60 countries expected to participate. Korea's natural gas vehicle market will further develop through the event.

In the future, projects and businesses are to be developed to establish NGV infrastructure and to expand NGV distribution in a partner country using the Official Development Assistance (ODA); such will be used as foundation for achieving the greenhouse gas reduction target of Korea in the CDM (Clean Development Mechanism) business. In addition, the experiences obtained through Korea's successful NGV distribution policy and excellent technological powers are to be shared with developing countries such as Central Asian countries and ASEAN countries.

|Chapter 5 . Evaluation and implication|

Nowadays, the distribution of NGV is being expanded in many countries worldwide as part of efforts to reduce air pollution in large cities; several countries including the USA and Canada as well as each country in Europe, Japan, etc., grant subsidies and provide tax incentive for NGV and gas-charging station through applicable laws or new programs to vitalize the distribution of NGV.

Korea also started the NGV distribution business in 2000 in an effort to improve the quality of air. Specifically, the business was started to replace the diesel inter-city buses operated in cities with CNG buses. As of the end of December 2010, 25,996 buses and 898 garbage trucks were distributed, which contributed to air quality improvement in cities whose air pollutants were significantly reduced compared to diesel buses. Of course, feasibility study and subsequent analysis were performed as to the introduction of CNG buses. First, evaluation was made through economic efficiency analysis as to whether the introduction of CNG buses was to be socially beneficial, and profitability analysis was carried out from the bus business operator's viewpoint based on the conclusion as to the social benefit. Government policy-based support was enabled based on those analyses. Based on government support, the CNG bus distribution business has been growing steadily for the last 10 years. The number of registered CNG buses exceeded 20,000 already, and 7,740 jobs had been created until 2008. The economic effect of export reached USD 189 million. In addition, with the whole world facing difficulties in transportation and logistics due to oil price increase, the distribution of NGV is expected to expand further to help improve the air quality and diversify the energy sources.

In connection with the expansion of NGV distribution, the Ministry of Environment plans to replace the inter-city buses operated in the Seoul Metropolitan Area with CNG hybrid buses, through which air pollutants and greenhouse gases can be reduced significantly since it is expected to be

launched on January 25, 2011 following the distribution of CNG buses. This will greatly help improve fuel efficiency compared to the existing CNG buses, with exhaust gas and greenhouse gases forecast to be reduced by more than 24%. In addition, the LNG vehicle can be operated in a longer operation route compared to the CNG bus and may be a good alternative to the CNG bus, which could not replace the diesel buses on a longer operation route. The LNG vehicle also uses natural gas as main fuel just as CNG vehicle does, so the air quality improvement effect will be greater if LNG vehicles are distributed.

Currently, a pilot business wherein LNG vehicles are operated is underway, and a feasibility study is being conducted as to a plan under which LNG vehicles are distributed step-by-step while maintaining complementary relations with the CNG vehicle. Depending on the result of the study, the necessary budget is to be secured after consultation with related agencies as to LNG-charging station installation, etc., is completed. Note, however, that there are many different issues to be resolved such as the establishment of infrastructure for the installation of LNG-charging stations, need to grant subsidy from national funds, unburned gas discharge into the atmosphere, etc.

In terms of the reinforcement of the permissible discharge of air pollutants, the permissible level will be further reinforced in EURO-5 and EURO-6; since the regulation on methane (CH4) discharged from natural gas only applies as well, technological development efforts for NGV such as clean diesel vehicle should continue.

Safety is also very important in utilizing natural gas. Accidents related to natural gas may become fatal accidents. Therefore, periodic inspection on the gas-charging station as well as the NGVs being operated is critical. In addition, the user needs to pay attention to the safe use of infrastructure established in connection with natural gas and NGV; safety devices should also be provided.

The government recently announced the Framework Act on Low-Carbon, Green Growth to minimize climate change and environmental damage as much as possible by saving energy and natural resources, to secure a new

growth engine through clean energy and research and development related to green technology, and to create new jobs and realize growth based on which the economy and environment are in harmony. Since the Act mainly deals with how to reduce reliance on fossil fuel using clean energy, natural gas and NGV are in agreement with the direction presented by the government through the Act. Natural gas, which is environment-friendly, is evenly and globally distributed, and can be used as new renewable energy, seems to be the optimum tool to respond to the challenge facing us.

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