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Environmental Policies for Fuel Switching

1. Introduction

Fossil fuels such as coal, oil and gas have been indispensable commodities for the economy since long ago. Electricity, which is essential to daily life, is mostly generated from these fossil fuels. Fuels for automobiles such as gasoline, diesel oil and gas are also fossil fuels. Steam and heat required for industrial activities are also largely produced from these fossil fuels. In fact, large part of all energy sources, that are crucial to economic activities in households, transportation and industry, comes from fossil fuels.

However, among various fossil fuels, coal and oil are basically composed of carbon and contain a large quantity of impurities. Therefore, no matter how high their combustion efficiency may be, air pollutants, including particulate matters(PM), sulfur dioxide(SO_2) and nitrogen dioxide(NO_2), and global warming substances such as carbon dioxide(CO_2) are emitted during the process of combustion. On the other hand, although such gases like liquefied natural gas (LNG) and liquefied petroleum gas (LPG) are fossil fuels, their components are different from those of oil and coal and their contents of impurities are lower. Naturally, in the process of combustion, they emit much less air pollutants and global warming substances than coal and oil.

Korea has achieved rapid economic growth since the 1970s, mainly driven by heavy and chemical industries. However, because the nation primarily relied on coal and oil as its energy sources, it suffered from air pollution triggered by SO_2 and PM. Particularly nearby industrial complexes and in metropolitan cities, pollution by SO_2 has worsened and was the cause of

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widespread air pollution damage such as respiratory diseases.

Recognizing that such situation cannot be neglected any longer, the government began to adopt strong policies of fuel switching since the mid-1980s. They include: sulfur content standard system, which sets the maximum permissible level of sulfuric contents in fuel and allows the production and supply of fuels that meet the requirement only; solid fuel banning system, which mandates the banning of solid fuels including bituminous coals in designated areas; and mandatory use of clean fuels, such as LNG, in energy consuming facilities that exceed a fixed scale and are located in the regions designated as environmentally sound areas.

Introduction of such direct restriction schemes have made significant contributions to improving the air quality in urban and industrial complex areas. However, the concentrations of SO_2 and PM were still higher than the level recommended by the World Health Organization (WHO). Moreover, as the automobile supply rate continued to increase rapidly in urban areas, automobiles emerged as a major source of air pollution. In fact, buses and trucks mainly use diesel oil, which emits much higher air pollutants than gasoline.

In order to tackle these problems, the government launched the Natural Gas Vehicle Supply Program starting in 2000. With this program, about 20,000 diesel-powered city buses will be replaced to natural gas buses in large cities throughout the nation by 2007. There is also a plan to replace about 800 diesel-powered garbage trucks with natural gas garbage trucks nationwide by 2010. The plan will expand to replace school buses and airport shuttle buses.

The policy to operate natural gas vehicles, which was launched in 2000, marked an important turning point of Korea's fuel switching initiative. In order to promote the usage of natural gas vehicles, the government provides subsidies for the vehicle operators to compensate for the price gap between diesel oil vehicles and natural gas vehicles. This has served as a momentum for Korea's fuel switching policy to shift away from the direct restrictions to a system that utilizes economic incentives.

In order for the government's fuel switching policy to succeed, consumers should not experience any loss caused by the policy change, but gain full motivation to switch fuels. The most sensitive factor in motivating consumers to switch fuels is the relative price of fuels. In case of the transportation sector, if diesel oil price were much lower than the price of LPG, consumers would not prefer LPG vehicles unless a special subsidy for using LPG is provided. In order to address these problems, the government is drafting a plan to restructure the relative prices of gasoline, diesel oil and LPG with underlying strategies to raise the relative price of diesel oil.

Despite such efforts, the air quality in the Seoul capital region is still unsatisfactory. High population density coupled with the growing automobile supply rate has resulted in a rapid increase in energy consumption and, accordingly, the absolute emission amount of air pollutants shows a gradual incline. This offsets the improvement of energy consumption efficiency and the air pollution improvement effects from fuel switching.

In order to resolve this issue, the government plans to introduce the Total Air Pollution Load (TAPL) Management System targeting SO_2, PM and NOx in the industrial sector in the capital area beginning in 2007. With this measure, the Ministry of Environment allocates the maximum emission load per each pollutant and companies are required to comply with the allocated limit. In addition, Emission Trading will be introduced for companies with exceeded pollution load to purchase emission permits from those with surplus emission allowance.

As described above, the fuel switching policy in Korea has taken the course of shifting from the direct restriction system of 1980s to an economic incentive system since the early 2000s. In the text below, the background, detailed features and achievements of the fuel switching policies adopted to date will be reviewed with the special focus on direct restrictive actions and the policy to promote greater supply of natural gas vehicles. In addition, although adjustment of fuel prices and the total air pollution load management system are also significant measures for effective fuel switching, the details and achievements of these will not be explored deeply, since they are yet to be introduced in Korea.

2. Details and current status of fuel switching policy measures

A. Direct restrictive actions

As part of the fuel switching policies, three direct restrictive regulations - sulfur content standard system, solid fuel banning system and mandatory use of clean fuels - are currently in effect in Korea. Among them, the sulfur content standard system was the first to be introduced in 1981. Since the introduction of this regulation, the pollution level of SO_2 in urban areas has improved by a certain degree. However, it was unsuccessful in improving Korea's air quality status to a level recommended by the World Health Organization (WHO) or to the levels of the world's major cities. Emission level per national land area, which can be used as an indicator for air capacity, marks higher than that of major developed countries. In addition, absolute amount of energy consumption was high and its consumption increased sharply. In other words, this regulation alone was insufficient to reduce SO_2 and PM to the desired level in urban areas. In order to overcome such limitation, solid fuel banning system was introduced in 1985 to supplement the sulfur content standard system.

The adoption of these two regulations has significantly reduced the levels of SO_2 and PM pollution in urban areas. By the late 1980s, however, it was realized that pollution could not be reduced to a satisfactory level only through these two regulations. Large apartment complexes using bunker C-oil in central heating systems and large-scale energy consuming facilities for power generation and district heating have been gradually built in the vicinities of urban areas, and pollutants emitted from these sites posed serious threats to the air quality of urban areas. Recognizing the seriousness of such situation, the government introduced a regulation requiring the mandatory use of clean fuels in 1988 as part of the efforts to improve the level of pollution from SO_2 and PM in urban areas.

The details of these direct restrictive measures are described below.

1) Sulfur content standard system

The sulfur content standard system sets the maximum allowance level of sulfur contents in diesel oil and bunker C-oil and to guide fuel producers to produce and supply products within the maximum allowance level, mainly in order to fundamentally reduce SO_2 emission generated from fuel burning. The legal basis of this system is included in the Article 26 of the Air Quality Preservation Act, Article 34 of the Enforcement Decree of the same act, and the Ministry of Environment Notice No. 2002-52 (revised on April 8, 2002) "A Notice on the Use of Clean Fuel".

This system was first introduced in Seoul in 1981. At this time, sulfur content standards were set at 0.4% for diesel oil and 1.6% for bunker C-oil. Just prior to the introduction of this system, the annual SO_2 pollution level in Seoul was 94ppb, which was more than four times higher than the level recommended by WHO (19ppb). As a result, the nation was faced with soaring

<Table 1> Sulfur Content Standard of Fuels

		enforcement period		
		until '97.6.30	'97.7.1- 2001.6.30	after 2001.7
oil	heavy oil (bunker-A bunker-B bunker-C)	below 1.0%	below 0.5% below 1.0%	below 0.3% below 0.5% below 1.0%
	diesel, kerosene	below 0.1%		
	LSWR	below 0.3%		
coal	bituminous	below 0.7%	below 0.5%	below 0.3%
	anthracite	below 0.7%	below 0.5%	below 0.5%

SOURCE: MINISTRY OF ENVIRONMENT, KOREA

concerns toward serious damages inflicted by air pollution. For instance, in the case of London Smog that caused enormous air pollution damage, the pollution level of SO_2 was over 100ppb. Together with PM, SO_2 was a primary culprit of acid rain. Therefore, in order to reduce air pollution, which was severe enough to raise serious concerns, a measure that would fundamentally reduce the emission of SO_2 was urgently called for. The sulfur content standard system was an initiative launched as a part of such efforts.

Since the introduction of the sulfur content standard system, its standards and governing regions have been raised and expanded. As of the end of December 2003, bunker C-oil (including LSWR) supplied must have less than 0.3% sulfur content and used in a total 20 areas including Seoul, six metropolitan cities and 13 cities/ counties such as Suwon. Bunker C-oil (including LSWR) supplied in 56 cities/counties, including Daejeon and Gwangju, must contain less than 0.5% sulfur content. In the rest of the nation, excluding areas restricted to supply and use less than 0.3% and 0.5% bunker C-oil, bunker C-oil with less than 1.0% sulfur contents is required. In the case of diesel oil, as of the end of December 2002, the system requires the supply and use of 0.1% diesel oil throughout the nation.

Under this system, the sulfur content of fuels is restricted to a certain limit. Therefore, emissions at the consumption stage are essentially reduced independent of consumption conditions such as consumer behavior or the efficiency of consuming devices. On the other hand, additional facility investments and desulfurized fuel, which leads to product price increase, are required to reduce sulfur contents. Therefore, if sulfur content standards are tightened, consumers end up using fuel that are more expensive than in the past and will pay more for fuel. However, use of fuel under the past standard is allowed when optimal prevention facilities are set up or when it is recognized that emission of SO_2 can be controlled to a level lower than the tightened standard by setting up prevention facilities. In addition, according to the Non-Low Sulfur Oil Fuel Approval System (Air Quality Preservation Act Article 35 and Enforcement Decree of the same Act Article 60-2), consumers are guaranteed the discretionary right to choose whichever is advantageous to them between using expensive low sulfur oil or using fuels other than low sulfur oil, provided that they establish prevention facilities. The number of companies that obtained approval for the use of non-low sulfur oil fuels totaled 239 as of the end of November 2000.

2) Solid fuel banning system

The Solid Fuel Banning System designates areas that exceed or is likely to exceed environment standards and bans the energy using facilities in the area from using solid fuels such as coal, cokes, and inflammable wastes to prevent air pollution caused by the use of solid fuels. The legal basis of this system is included in the Article 27 of the Air Quality Preservation Act, Article 36 of the Enforcement Decree of the same Act, and the Notice on the Use of Clean Fuel (Ministry of Environment Notice No. 2002-52). Since the first oil crisis in 1973, the use of coal was highly recommended as a part of the efforts to diversify the sources of energy. As a consequence, the use of coal increased in large cities including the capital region and, as its side effect, air pollution emerged as a serious issue. For instance, in the case of Seoul in 1984, the SO_2 concentration was 66ppb, which was over three times higher than the level recommended by WHO. In the case of Seoul in 1986, PM pollution level was very high at 183㎍/㎥, which was causing serious problems such as poor visibility and respiratory symptoms.

Therefore, in order to address such serious situation, the Solid Fuel Banning System was introduced in 1985. To be more specific, beginning in 1985, areas where air pollution was serious, such as the capital area and large cities, were designated as areas where the use of solid fuel was prohibited. Since its initial introduction, the system continued to expand the prohibited areas. As of the end of December 2003, 20 areas were required to ban the use of solid fuels, including Seoul, six major metropolitan areas and 13 cities/counties surrounding the capital area.

According to Article 36, Clause 2 of the Enforcement Decree of the Air Quality Preservation Act, facilities within areas where solid fuel is prohibited may use solid fuels if they belong to one of the following: melting furnace facilities in foundry or iron mills, firing facilities for cement and limestone, waste treatment facilities that use energy produced from wastes and facilities that are recognized to emit pollutants lower than emission standards although solid fuels are used with approvals, and thermal power plants recognized to use fuels other than clean fuels. As of the end of 2000, a total of 55 companies have obtained approvals to use solid fuels in such areas.

3) Mandatory use of clean fuel

In the case of large city areas such as the Seoul metropolitan area, the overall air quality has not improved significantly or, in fact, worsened despite the introduction of direct restrictions such as controlling the use of solid fuels. In the case of major cities, in particular, SO_2 pollution has worsened even since the mid-1980s when the sulfur content standard system and the solid fuel banning system were fully implemented. In fact, pollution levels in these cities were higher than those of major cities in developed countries. The

<Table 2> Areas under Mandatory Use of Clean Fuel

	1988	1991	1993	1998	1999	after 2000
Areas	Seoul	Incheon, 13 cities in Kyungki province were added	Busan, Daegu were added	12 cities such as Ulsan, Gwangju, Daejon were added	6 cities such as Gimhae, Gumi, Pohang were added	-
Facilities	power plant, boilers	power plant, boilers, apartment complexes				

main reason for this was that while the use of the highly polluting bunker C-oil or coal has grown sharply in power generation facilities and large housing complexes, the development of technology to effectively reduce emission by the use of this type of fuel was delayed. As the level of air pollution became aggravated, smog and poor visibility in urban areas were often observed and the number of people suffering from respiratory symptoms increased. As a result, developing fundamental measures to improve the air quality in urban areas emerged as an urgent task.

Therefore, as an initiative to improve the air quality of urban areas beginning in 1988, it became mandatory for power generation, heating and business facilities located in urban areas that exceeded a certain size to use cleaner fuels such as LNG in order to essentially reduce the emission of air pollutants including SO_2. The legal basis of this system is included in the Article 27 of the Air Quality Preservation Act, Article 37 of the Enforcement Decree of the same Act, and Ministry of Environment Notice No. 2002-52 (Notice on the Use of Clean Fuel). Since its initial introduction, the system has gradually increased the designated areas and facilities subject to the mandatory use of cleaner fuels. As of the end of December 2003, a total of 37 cities across the nation were subject to mandatory use. Facilities subject to the regulation include apartment buildings with central heating systems, district heating facilities, business-purpose boilers (excluding industrial-purpose boilers), and power generation facilities.

However, with a view of lowering industrial fuel expenses, there has been a tendency to exempt work sites from the mandatory use of clean fuels when they sign a voluntary agreement or set up optimal prevention facilities, in particular by power generation facilities.

B. Natural gas vehicle supply program

As long as fossil fuels such as gasoline and diesel oil are used as automobile fuels, the problem of vehicle exhaust pollution is inevitable no matter how excellent reduction technology may become or no matter how new policies are proven effective. Pollutants are emitted in the process of combustion because of the substance of the fuels themselves. In this perspective, relatively clean natural gas, when used as automobile fuel in replacement of existing fossil fuels, may make notable contributions in improving air quality. The vehicle exhaust pollutants will be fundamentally reduced because the fuel itself is cleaner.

In addition to direct restriction measures described above, the government has been initiating a policy to supply natural gas vehicles since 2000 in order to fundamentally reduce vehicle exhaust pollution. Its necessities are summarized below.

First, the conventional air quality preservation schemes including direct fuel switching policies alone were limited in improving urban air quality. Although technology to curb the gas emission is further developing on a daily basis, the unending supply of automobiles outweighs such improvement. With the rise in incomes, automobiles have become a daily necessity. Therefore, controlling the pace of automobile supply through pricing policies such as increasing the tax rate or fuel prices reveal limitations. In addition, in the case of privately owned cars, fuel price increase or demand management measures showed some efficacy in controlling their driving mileages. However, in case of city buses, controlling their operation is fundamentally impossible. The necessity of running city buses may be reduced through restructuring efforts such as working-at-home and expansion of subways. However, the restructuring efforts would require a significant period of time. Due to these reasons, it has been realized that fuel switching (from diesel oil to CNG) was the most effective means to fundamentally reduce city bus emissions.

Second, natural gas vehicles were proven to have relatively high stability as well as environment-friendliness. Natural gas reserves are abundant. It is a clean energy of which price is relatively low compared to other fuels. The energy efficiency of natural gas is higher than those of other fuels. Its risk of explosion is also low and natural gas vehicles emit remarkably less of nearly all kinds of air pollutants than vehicles powered by gasoline or diesel oil.

When solely considering the environmental aspect, zero emission vehicles that run on electricity, solar heat, and hydrogen are most ideal. However, the profitability of zero emission automobiles is currently very low; it is expected to take longer than ten years to effectively commercialize them. Therefore, natural gas vehicles are drawing keen attention of the globe as a sound alternative that is environment-friendly, stable and profitable.

Third, in order to prepare for the 2002 World Cup, increasing the supply of natural gas vehicles became a critical action to be taken. The host cities in Korea were experiencing serious air pollution problems compared to major cities in Japan, a co-host nation. For instance, in the case of PM, Seoul and Busan both marked 68 ul/㎥ , which was significantly higher than the levels in Yokohama (30 ul/㎥) and Osaka (37 ul/㎥). However, in the case of major host cities, automobiles, diesel vehicles in particular, accounted for about 70-80% of all pollutant emission. The existing policies were not enough to tackle the ever-worsening air pollution problems caused by automobiles. As described earlier, a fundamental approach of replacing fuel with cleaner fuel is most effective in addressing air pollution in the short term. At that time, it was estimated that if large diesel oil vehicles in Seoul such as city buses are replaced with CNG vehicles, air pollution in Seoul could see an improvement of over 20%.

Lastly, given that the supply of natural gas vehicles becomes active, substantial contribution is expected in increasing the exports of related equipment and technology. Natural gas vehicles are actively supplied in many countries all over the world, including Japan, China and Thailand in Asia. In the Convention on Climate Change and the strategies for sustainable development of the UN, the supply of natural gas vehicles is stressed as one of the major strategies in the transportation sector. Therefore, demand for natural gas vehicles is likely to rise considerably worldwide. As a result of continual investments in technology development for natural gas vehicles, Korea is now able to manufacture the vehicles on its own. In fact, its technology and price competitiveness are acclaimed to be better than those of foreign countries. There is a great potential for natural gas vehicles to become a major export item. However, the exploration of overseas markets and expansion of exports would be possible only when demand in the domestic market continues to rise and investment is made to develop relevant technologies. Due to the uncertainty of overseas demand, it would be difficult to guarantee the profitability of producers and, accordingly, major market exploration and technology development investments are unlikely to be achieved without a stable demand in the Korean market. In other words, in order to tap overseas markets for natural gas vehicles - whose increase in demand is highly expected globally - and to expand their exports, it is necessary to promote domestic supply and operation of natural gas vehicles.

The basic infrastructure that is required for supplying natural gas vehicles includes a reliable network for natural gas supply, refueling stations and natural gas vehicles. The natural gas supply network is necessary for the stable supply of natural gas vehicles. However, in order to provide natural gas as cooking fuel, Korea had already installed an extensive network of natural gas pipes (underground) in most urban areas throughout the nation by the mid-1990s. Therefore, if refueling stations are introduced at sites where the pipes are accessible, natural gas can be supplied at low cost without additional cost of installing the pipes.

In regards to refueling stations, various laws and regulations have been revised to ease the restriction on their opening in downtown areas and overall technology to secure stability has been developed. Therefore, once the location and budget are secured, the construction of refueling stations will proceed with no major barriers. For instance, relevant laws and regulations that were revised to allow the opening of refueling stations in downtown areas are as follows: The amendment of the enforcement order of the Construction Act allows refueling stations to be set up at city bus depots. The revision of a notice by the Ministry of Commerce, Industry and Energy eased the standard safety distance around the refueling station from 10 meters to 5 meters. By revising the ordinance of local governments, refueling stations can be set up at public parking lots. Also, the Law on the Designation and Management of Green Belts was amended to allow the setting up of refueling stations within green belt areas. In addition, considering that an up-front investment for setting up refueling stations is excessively high and poses a huge financial burden on refueling station operators, an up-front investment of about 700 million won will be facilitated as a long-term, low-interest loan. Then, electricity for refueling stations will be charged at the industrial rate, which is about 30% cheaper than the regular rate. In order to assure the profitability of station operators, the wholesale price of natural gas for transportation purposes will be set at 3 won/㎥, which is lower than the price of industrial purpose gas.

In the case of natural gas buses, the G-7 project (national environment technology development project) has been initiated from 1990 to 1997 and domestic development stage has been completed. A pilot project involving four CNG buses and two refueling stations was undertaken successfully in Incheon and Ansan from July 1998. However, as of 2001, a natural gas bus was priced at about 31 million won more than a regular diesel oil bus and bus operators may have been reluctant to switching to natural gas buses because of the greater financial burden. However, the government and local authorities subsidized 22.5 million won per bus to compensate for the difference and the remaining was preserved through subsidies on fuel price differentials, exemption of value-added and acquisition taxes on the purchase of natural gas buses and exemption from environment improvement charges levied on diesel-powered buses.

The government plans to replace 20,000 city buses that operate across urban areas with natural gas buses while installing 400 refueling stations by 2007. In addition, the plan is to replace 800 garbage trucks with natural gas vehicles in major cities nationwide by 2010. The plan will expand to replace school buses and airport shuttle buses.

In order to achieve these goals, as described above, the government is initiating various supportive measures. Some typical examples include the adjustment of the relative price of fuels, subsidies for the difference in bus purchasing prices, long-term loans for setting up refueling stations and other tax breaks in order to assure an appropriate margin to bus operators and refueling station operators.

Supported by the government's firm commitment, the project to supply natural gas vehicles is making stable progress. However, the supply of natural gas buses and natural gas garbage trucks has come in slightly lower than the target planned for 2004. This is due to a delay in the construction of refueling stations, which is the most basic infrastructure, because of the issues involving site selections. However, as shown in <Table 3>, constructions of refueling stations have been nearly completed as against the plan as of the end of November 2004. Therefore, natural gas buses and natural gas garbage trucks are expected to be supplied more rapidly.

3. Achievements and limitations of the fuel switching policy

A. Achievements

1) Air quality

LNG was introduced in full scale in Korea in 1986. Although the sulfur content standard system was adopted in 1981, it aimed at improving fuel quality rather than replacing fuels. Therefore, it was in 1984, when the use of solid fuels was banned, that efforts to replace fuels to improve air quality began in earnest. In 1984, however, LNG had not supplied yet. Even if fuel replacement efforts were pursued, they were a phase of mainly replacing coal with bunker C-oil. In other words, it was in 1988 when the mandatory use of clean fuels - including LNG - was promoted , at a full scale. Since then, LNG has been used for power generation, heating and cooking. Beginning in 2000, its use was expanded to the transportation sector and its share in primary energy consumption grew sharply. As of the end of 2001, LNG accounted for 10.5% of primary energy consumption.

LPG, another clean fuel, has been used primarily in the transportation sector such as in taxis and recreational vehicles as well as for cooking. Recently, however, cooking fuel in large-scale housing complexes has been switched to LNG. As a result, the share of LPG as a cooking fuel dropped drastically and its share in primary energy consumption has stayed at a 4% level.

Nevertheless, thanks to an increase in LNG consumption, the share of clean fuels such as LPG and LNG is gradually increasing in total energy consumption. The growing share of gas

<Table 3> Natural gas vehicle Supply

		2004	2007
natural gas bus	target	7,400	20,000
	result	5,816	
natural gas garbage truck	target	93	800
	result	41	
refueling station	target	183	400
	result	168	

SOURCE: MINISTRY OF ENVIRONMENT, KOREA

<Table 4> Share of primary energy consumption by energy sources (unit: %)

	coal	oil	LPG	LNG	others[1]	total
1980	30.1	60.1	1.0	0.0	8.8	100.0
1985	39.1	45.6	2.6	0.0	12.7	100.0
1990	26.2	49.9	3.9	3.2	16.8	100.0
1995	18.7	58.1	4.4	6.1	12.7	100.0
2001	23.0	46.3	4.4	10.5	15.8	100.0

1) Hydro, nuclear and renewable energy, etc.
SOURCE: KOREA ENERGY ECONOMICS INSTITUTE, YEARBOOK OF ENERGY STATISTICS, 2002

consumption has resulted in a declining share of fossil fuel consumption such as coal and oil, creating a positive effect on air quality improvement. Although the same amount of energy is consumed, the emission of pollutants from gas is significantly less than that from coal or oil. The details of air quality improvement achieved by switching to gas fuels are described below.

The sulfur content standard system is a measure designed to reduce SO_2 emission among a number of air pollutants. The regulations restricting the use of solid fuels and requiring the compulsory use of clean fuels do not intend to reduce particular pollutants. However, they are actions effective in curbing the level of sulfurous acid gas and PM ultimately. For instance, in the case of power generation purposes, the positive effect can be easily confirmed by comparing the emission factors of major pollutants such as SO_2, CO, HC, NO_2, and PM by the use of bunker C-oil or bituminous coal vs LNG. Among various fuels, bunker C-oil or bituminous coal was compared against LNG because these three are the major fuels used to generate power and the main fuel for power generation switched from bituminous coal to bunker C-oil and then from bunker C-oil to LNG.

As shown in <Table 5>, according to emission factors converted on the basis of calories, in the case of power generation purposes, bunker C-oil emits less pollutants in every category, except for HC, than bituminous coal does. In particular, it emits about 10 times less PM than coal, but the difference was not so distinctive in the case of other pollutants. Compared with bunker C-oil and bituminous coal, LNG emits SO_2 480 times less and 1,152 times less, respectively. In the case of PM, the emission is 34 times less and 8,328 times less. Meanwhile, the emission of other pollutants except SO_2 and PM did not vary greatly among these three types of fuels.

<Table 5> Emission factors of air pollutants by energy sources(power generation)

		SO_2	CO	HC	NO_2	PM
EPA(US) emission factors	B-C oil	19S	0.6	0.09	8.0	1.25S+0.38
	bituminous coal	19S	0.635	0.015	9	6.5
	LNG	0.02	0.792	0.034	10.894	0.035
converted emission factors (calory- based)	B-C oil(A)	0.960	0.060	0.009	0.808	0.102
	bituminous coal(B)	2.303	0.096	0.002	1.364	0.985
	LNG(C)	0.002	0.061	0.003	0.838	0.003
A/C		480	0.984	3	0.964	34
B/A		2.399	1.6	0.222	1.688	9.657
B/C		1,151.5	1.573	0.667	1.628	328.3

1) S is sulfur content.
2) EPA emission factor: B-C oil kg/kl, bituminous coal and LNG kg/ton
converted emission factor: oll units are kg/kcal

In regard to the natural gas vehicle supply project, which switches fuels from diesel oil to natural gas, it contributes to fundamentally reducing the emission of every pollutant. As shown in <Table 6>, a bus running on regular diesel oil emits a large quantity of PM and SO_2. However, a natural gas bus does not emit such pollutants at all. In addition, the emissions of NO_2, HC and CO were notably less in natural gas buses than in conventional diesel buses. This is because natural gas has less impurities than diesel oil and its constituents themselves are cleaner.

<Table 6> Emission factors of air pollutants by vehicle types (unit: g/kwh)

	diesel bus			natural gas bus	
	conventional	low-emission			
	emission factor (g/kwh)	emission factor (g/kwh)	decreasing rate(%)	emission factor (g/kwh)	decreasing rate (%)
PM	0.40	0.02	95	0.00	100
SO_2	0.31	0.00	100	0.00	100
NOx	7.20	3.50	51	2.64	63
HC	0.96	0.46	52	0.15	84
CO	3.92	1.50	62	1.59	59

SOURCE: MINISTRY OF ENVIRONMENT, KOREA

Therefore, based on these facts, it can be seen that fuel switching policies in Korea have focused mainly on reducing the emission of SO_2 and PM. In fact, it is indirectly proven through available data that they had contributed greatly in curbing the emissions of SO_2 and PM (Refer to <Table 7>).

When fuel consumption and pollutant emissions

<Table 7> Emission of air pollutants by sector (unit: 1,000 ton, %, 1,000TOE)

		total	SO_2	NO_2	PM	CO	HC	energy consumption
total	'91	4,866.9	1,597.8	878.4	431.3	1,759.5	199.9	83,803
	'00	3,565.2	955.3	1,118.3	239.1	1,106.1	146.4	150,108
	increasing rate	-26.7	-40.2	27.3	-44.6	-37.1	-26.8	79.1
non-transportation sector	'91	2,960.2	1,397.3	432.3	352.0	712.2	66.4	67,647
	'00	1,488.4	634.5	602.5	154.2	89	8.2	119,163
	increasing rate	-49.7	-54.6	39.4	-56.2	-87.5	-87.7	76.2
transportation sector	'91	2,005.9	200.5	446.1	79.3	1,047.9	133.5	16,156
	'00	2,073.9	317.8	515.8	85.0	1,017.1	138.2	30,945
	increasing rate	3.4	58.5	15.6	7.2	-2.9	3.5	91.5

SOURCE: MINISTRY OF ENVIRONMENT, KOREA for 1991 and 2000 are compared, total emissions of five pollutants including SO_2 have been reduced by about 26.7% although fuel consumption has increased by 79.1%. Total emissions of pollutants have declined despite a 27.3% rise in the emissions of NO_2 in the same period because the emissions of other pollutants such as SO_2 and PM had all dropped. In particular, in the same period, the emissions of SO_2 and PM have decreased by 40.2% and 44.6%, respectively.

A similar phenomenon is observed in the pollution trend of major pollutants such as SO_2, and PM. That is, in all major cities, the concentrations of SO_2 and PM have significantly improved after the introduction of the direct restriction measures. In Seoul in particular, pollution by SO_2 was 0.094ppm in 1980 when sulfur content standards were not applied. However, it has drastically dropped to 0.005ppm in 2001 (<Table 8>). In the case of PM(TSP), it has decreased from 175ug/m3 in 1987, which was shortly before the mandatory use of clean fuels, to 85ug/m3 in 1996 (<Table 9>).

<Table 8> Trend of SO2 concentration according to application of sulfur content standard in major cities

(unit: ppm)

	date of enforcement	before application		after application	
		year	concentration	year	concentration
Seoul	'81. 7. 1	1980	0.094	2001	0.005
Busan	'84. 7. 1	1981	0.061	2001	0.008
Daegu	'84. 7. 1	1981	0.046	2001	0.008
Incheon	'82. 2. 1	1981	0.043	2001	0.007
Ulsan	'81. 7. 1	1981	0.057	2001	0.012

SOURCE: MINISTRY OF ENVIRONMENT, KOREA

<Table 9> Trend of PM(TSP) concentration according to application of mandatory use of clean fuels in major cities

(unit: ug/㎥)

	date of enforcement	before application		after application	
		year	concentration	year	concentration
Seoul	1988	1987	175	1996	85
Busan	1993	1992	113	1996	85
Daegu	1993	1992	119	1996	75
Incheon	1991	1990	170	1996	86

SOURCE: MINISTRY OF ENVIRONMENT, KOREA

As described above, a decrease in the emissions and pollution of major air pollutants since the late 1980s is largely attributable to the direct restrictions of fuel switching policies. Direct restrictions are compulsory measures that can reduce the emissions of pollutants at their source. Therefore, once these types of schemes are taken, the emissions of pollutants per energy consumption unit diminish automatically regardless of other economic changes. For instance, if sulfur content standards are tightened, the emission of SO_2 will decline in proportion to the level mandated by tightened regulation and this proportionate reduction is not affected by the efficiency of energy consuming devices or operation of prevention facilities at all. Therefore, direct restrictions are the most reliable means in achieving pollutant emission reduction goals. However, the effects of emission restriction systems are variable and highly influenced by how systematically emission permissible standards are managed and operated. In the case of permissible emission standard systems, some people may avoid running prevention facilities in order to save the facility operating costs. Therefore, in the case of direct restrictions, the implementation itself guarantees the reduction of emission. However, the adoption of emission restriction systems does not assure an emission reduction effect.

This is well illustrated by the fact that while fuel consumption has increased by 79% in a decade since 1991, the emissions of air pollutants have declined by 27%.

2) Climate Change

As reviewed above, fuel switching policies, direct restrictions in particular, are one of the most effective means for reducing air pollution emissions. As the sulfur content standard system forces the reduction of the sulfur content of fuel, the emissions of SO_2 released in the combustion process fundamentally diminish. As for the solid fuel banning system, fuel is switched from coal, a fuel emitting the largest amount of pollutants, to bunker C-oil or the clean fuel, LNG. Although fuel is consumed to generate the same amount of heat, pollutant emissions are less. In the case of the mandatory use of clean fuel system, coal or bunker C-oil are all replaced with LNG and pollutant emissions are fundamentally reduced.

The question is whether such fuel switching policies can contribute in curbing the greenhouse gas emission just as they contributed significantly in reducing the emissions of air pollutants. If the answer is yes; the next question would be how much reduction can they contribute.

First of all, whether each policy measure truly contributed to reducing the emission of greenhouse gas was reviewed. In the case of sulfur content standard system, according to its concept, it would not contribute to the reduction of greenhouse gas emission. As stated above, the sulfur content standard system sets the limit of sulfur content in fuels, and only the fuels meeting such requirements are supplied and consumed. Therefore, this is a program designed and introduced to essentially reduce SO_2 generated in the combustion process and, in its concept, not relevant to decreasing the emissions of other air pollutants or carbon dioxide. However, a technical review is required to examine whether improving fuel quality by lowering the sulfur content would result in the reduction of CO_2 emissions. Nevertheless, its contribution is not likely to be significant.

On the other hand, the regulation banning the use of solid fuels, the mandatory use of clean fuel, and the natural gas vehicle supply project, may contribute greatly when these systems are applied properly. When the use of solid fuels is prohibited, due to the nature of the current fuel supply-demand structure, bituminous coal will be mostly replaced with bunker C-oil or LNG. In addition, when the use of clean fuels becomes mandatory, fuels will be switched from bituminous coal or bunker C-oil to LNG. Then, in the case of the natural gas vehicle supply project, diesel oil will be replaced with LNG. According to IPCC as shown in <Table 10>, carbon emission factor is highest in bituminous coal and lowest in LNG. The emission factor of bituminous coal is 1.21 and 1.66 times higher than those of bunker C-oil and LNG,

<Table 10> IPCC emission factor of carbon

(unit: ton C/toe)

	emission factor	LNG = 1
bituminous coal	1.059	1.66
B-C oil	0.875	1.37
diesel	0.837	1.31
LPG	0.713	1.12
LNG	0.637	1.00

SOURCE: IPCC

respectively. Also, the emission factor of bunker C-oil is 1.37 times higher than that of LNG and the emission factor of diesel oil for transportation use is 1.31 times higher than that of LNG. Therefore, assuming that only fuels are replaced while all other conditions remain the same, less greenhouse gases will be emitted when bunker C-oil is used in lieu of bituminous coal, when LNG is used in the place of bunker C-oil and when LNG is used rather than diesel oil.

Here, it is assumed that all other conditions remain the same, which means that fuel currently in use will be actually replaced under fuel restrictions and fuel consumption will stay the same on the calory basis. The condition that fuel consumption would be the same on the basis of calories is a pre-requisite for a comparison under equal conditions and would not be a problem. However, whether fuel will be actually replaced under fuel restrictions is very significant in terms of reducing greenhouse gas.

As described earlier, facilities or areas subject to the regulations banning the use of solid fuel and a system requiring the mandatory use of cleaner fuels may still be exempted from these regulations when they meet certain conditions. In short, they would be allowed to use solid fuels and non-clean fuels. Facilities exempted from the regulation banning the use of solid fuels include melting furnace facilities in foundries or iron mills, firing facilities for cement and limestone, waste treatment facilities that use energy produced from wastes and facilities that are recognized to emit pollutants lower than emission standards although solid fuels are used and approved to use solid fuels, and thermal power plants recognized to use fuels other than cleaner fuels. In addition, facilities that are allowed to use non-clean fuels include power plants, district heating facilities and heating supply facilities of less than a certain size that are recognized to have a huge impact on the supply and demand of clean fuels because their fuel consumption is excessively high or have high air pollution reduction impact from energy-saving. In fact, in the case of the solid fuel banning system, 55 companies have been exempted as of the end of 2000. In other words, they have been allowed to use bituminous coal, a solid fuel.

Indeed, companies recognized as exceptions include a number of companies with high energy-saving effects such as district heating facilities. High energy-saving effect translates into high impact on fundamental reduction of greenhouse gas emissions. Despite, a large number of companies will continue to use existing fuels. Although they may have strong competence in reducing air pollutants, as long as existing fuels are used as they are, it would not have a direct impact on reducing greenhouse gas. In conclusion, although direct restrictions such as a regulation banning the use of solid fuels and a system that mandates the compulsory use of clean fuels are adopted, all applicable areas and facilities would not necessarily contribute to the reduction of greenhouse gas emission. Therefore, if greenhouse gas reduction is calculated for entire areas and facilities not taking into account the exceptions, the outcome would over-state the reduction effect.

B. Limitations and issues

1) Sulfur content standard system

Some argue that the sulfur content standard system is an additional regulation when the emission of sulfur dioxides is restricted through a permissible emission standard system. However, the sulfur content standard system controls the fuel quality. It is different in nature from the mandatory use of a clean fuel system that restricts the right to choose a fuel type. In other words, a switch to fuels that are not subject to sulfur content standards or fuels that are subject to the standards, that are favorable to operators is assured. In addition, in the case of controlling fuel quality, fuels other than low sulfur oil are legally assured when optimal prevention facilities are set up or when prevention facilities are sufficient to meet an emission concentration level equivalent to a level measured when optimal prevention facilities are set up or low sulfur oil is used. For instance, in the case of coal, the sulfur content standard is applied only in areas where the use of solid fuels is banned. If applicable facilities in this area are recognized to meet permissible emission requirements, the use of solid fuels is allowed. In addition, if a company approved for the use of solid fuels sets up desulfurization emission facilities, it would be exempted from the sulfur content standards. If the company installs optimal prevention facilities, emission charges will be exempted. If a facility is less than a certain size and meets permissible emission requirements, emission charges will be exempted. Therefore, companies may choose whichever option that is beneficial for them, between complying with the sulfur content standards and being exempted from the standards by setting up prevention facilities that meet the permissible emission requirements. It would be reasonable to understand the sulfur content standard system as a policy mix instead of an additional, redundant restriction. However, being exempted from the sulfur content standards requires an administrative procedure of obtaining an approval from the Ministry of Environment. This should be understood as an inevitable step that needs to be tolerated in order to preserve the air quality.

2) Solid fuel banning system

There is controversy over the adoption of a regulation to ban the use of solid fuels with the reasoning that this policy seems overly stringent. The main point of the argument is that since the emission is controlled through permissible emission standards, they should be adequate as long as they are properly implemented; while fundamentally banning the use of certain fuels is an excessive restriction and inefficiently raises the fuel expenses of operators. In fact, if permissible emission standards are set at a level that can fully meet environmental requirements for all pollutants and if emission control is thoroughly implemented and managed, banning the use of solid fuels in addition to emission restrictions may be an overlapping restriction.

However, the permissible emission standards are not set at an appropriate level to meet environmental requirements in reality. This is because prevention technology matching the environmental requirements has not yet been developed or even if the technology is developed, it is realistically impossible to set the permissible emission standards matching the requirements if the technology installation and operational expenses are excessively high. In addition, if pollutants that are emitted in particularly high volume from the use of solid fuels are not subject to emission restrictions, an emission restriction alone would not be enough to control these pollutants (i.e., NO_2). Therefore, due to such limitations of permissible emission standard systems, additional actions such as banning the use of solid fuels, which supplement the weak points of emission restrictions, are unavoidable to satisfy environment standards. It would be better to recognize its existence as an alternative policy mix like the sulfur content standard system.

In addition, even under the solid fuel banning system, the use of solid fuels is allowed when it is recognized that permissible emission standards can be complied with. Accordingly, companies can choose the option most advantageous to them by comparing the sum of solid fuel expense, prevention facility installation, the operational expenses against the sum of expenses for using other types of fuels, and prevention facility installation and operation expenses. Usually, when solid fuels are used, fuel expense is less but prevention facility-related cost is higher. In the end, a final approval criterion for the use of solid fuel is not the nature of the type of fuel but whether permissible emission standards are met.

3) Mandatory use of clean fuel

The mandatory use of clean fuels is one of the very effective means in terms of execution and management because while it does not require high implementation cost, it always generates fundamental and captive effects on air quality improvement. However, from the perspective of the party being regulated, this system may possibly be a cause for deteriorating business profitability as it artificially restricts a user's choice of fuel. In other words, this system may trigger a rise in fuel expenses of consumers or companies and a weakening of their price competitiveness. This is because bunker C-oil and low sulfur waxy residue (LSWR), whose prices are relatively cheaper than the price of LNG since the social cost of air pollution is not reflected in the fuel prices, cannot be used. Moreover, if non-clean fuels are used but state-of-art air pollution prevention facilities are built to meet permissible emission standards or achieve air quality improvement effects equivalent to using cleaner fuels, and the total cost of this option is less than using clean fuels, it may be beneficial to every one to allow the use of non-clean fuels. However, under the compulsory system that mandates the use of clean fuel, such a possibility is fundamentally ruled out. In certain cases (although the chance of their materialization may be very slim), this system may trigger a distortion of a fuel consumption structure and lower the efficiency of resource allocation.

In areas where the use of clean fuels is mandatory, according to the Air Quality Preservation Act, Enforcement Decree Article 37-3, power plants, district heating facilities and heating supply facilities of less than a certain size that are recognized to have a significant impact on the supply and demand of cleaner fuels because their fuel consumption is excessively high or have a high air pollution reduction impact from energy-saving are exceptionally allowed to use non-clean fuels. However, exceptions are allowed only in special cases and they require the final approval of the Minister of Environment for the use of non-clean fuels. In fact, such complex requirements serve as grounds for criticism that the system requiring the mandatory use of clean fuel is excessive.

Therefore, due to such clear advantages and disadvantages of the mandatory use of clean fuels, evaluation of this system seems to depend on one's value judgment or a choice between environmental quality and profitability. In other words, since permissible emission standards will be inevitably set taking account of the current economic and technical circumstances, permissible emission standard systems have a limitation that they cannot be the only means of air quality preservation. On the other hand, there is the realistic limitation that fuel cannot be restricted excessively without regard for the profitability of business operators, which are the basis of the economy. Therefore, in the case of the mandatory use of clean fuels, it would be desirable to achieve harmonization instead of making one extreme choice.

4) Natural gas vehicle supply project

Without government support to bus operators and refueling station operators, the natural gas bus project will face massive problems and obstacles. Uncertainty of the market in the early phases of business and doubts about business profitability may be the most critical problems. Expected problems may be summarized into following types.

First, excessively high price of natural gas buses will place significant financial pressure on bus operators. When diesel buses are replaced with CNG buses, benefits to bus operators mostly come from savings in fuel expense. Therefore, if the fuel savings are not sufficient enough, bus operators will not be willing to switch to natural gas vehicles at their own expense. The government addressed this issue by subsidizing the entire differential in the purchasing prices of natural gas vehicles and diesel oil vehicles. At the same time, a certain portion of the differential between diesel oil expense and natural gas expense is also subsidized.

Second, the expenditure for setting up a refueling station, which is essential for the supply of natural gas buses, is excessively high, requiring about 700 million won per station that refuels 50 buses per day. As long as an adequate level of margin is guaranteed so that refueling station operators are assured of recovering initial facility investments within an acceptable period, the high upfront facility investment would not be a major issue. Those who can maintain capital until investment is recovered will enter the refueling business and, as a result, they will generate profits in the long run. However, the price of natural gas for transportation has a direct impact upon the profitability of natural gas bus operations. If a high level of margin is guaranteed to increase the profitability of refueling station operators, fuel expense will be a great burden to CNG bus operators. Therefore, the adequate margin to refueling station operators will be inevitably set in consideration of the profitability of CNG bus operators. Consequently, if the adequate margin of refueling operators is set at a level not fully reflecting the initial facility investment, the opening of refueling stations may become passive and, in turn, the natural gas bus project is likely to remain stagnant. The government overcame this issue by facilitating a loan to refueling station operators for the entire amount required for setting up the stations.

Lastly, securing sites for refueling stations may be challenging. Some typical factors that impede the establishments of refueling stations include lack of relevant laws & regulations and the NIMBY syndrome. Currently, the School Health Act stipulates that in order to set up a refueling station within 200 meters of a school perimeter, it needs to be deliberated by the School Environment Sanitation and Cleanup Committee. In Busan, establishment of a refueling station has been delayed considerably because the School Environment Sanitation and Cleanup Committee has voted against the station after deliberating the site. In addition, Regulations on Housing Construction Standards and Others (an enforcement decree by Ministry of Construction and Transportation) requires that when a refueling station is set up, there should be a 50-meter safety distance from the protection facilities (playgrounds and child care facilities, etc) of apartment buildings. Accordingly, in Seoul, there was an instance when construction of a refueling station was put on hold because of this regulation. These bottlenecks were mostly resolved through ceaseless discussions between relevant authorities.

Nonetheless, the greatest obstacle still remaining to setting up refueling stations is the NIMBY syndrome. Out of the concern over possible casualties from an explosion or a drop in land price if a natural gas refueling station is built nearby, a strong NYMBY syndrome that establishment of refueling stations cannot be permitted in their own neighborhoods is widespread. In fact, natural gas is a clean fuel, which is far safer than LPG, and emits extremely small amount of pollutants. Regular households use natural gas every day for cooking. A natural gas refueling station would not be particularly more dangerous than gas facilities for households. Nevertheless, the NIMBY syndrome is still rampant because of the lack of public awareness on natural gas. This is a task that needs to be ultimately addressed in order to push the project through.

4. Conclusion

In the 1980s, fuel switching policies were launched in full scale to preserve air quality in Korea. Since the adoption of the sulfur content standard system in 1981, the solid fuel banning system and mandatory use of clean fuels were introduced in 1984 and 1988, respectively, and are still in effect to date. Although these systems allow certain exceptions to allow flexibility in their application, it is true that they have a significant impact on improving air quality, as they are essentially direct restriction measures. This is well proven by the fact that the current concentrations of SO_2 and PM in major cities are distinctively lower than as measured in the 1980s.

However, these approaches have a number of limitations, making the notable improvements in air quality in urban areas unlikely. Direct restriction approaches, such as regulating the right to choose fuels, have been a target of controversy over the issues of redundancy and higher fuel expenses. Above all, the rapidly increasing automobile supply shifted the main source of pollution in large cities from the industrial sector to the transportation sector. Therefore, past fuel switching policies that focused on industrial facilities began showing limitations in improving the air quality of large cities.

In order to address such problems, the government developed a long-term plan to replace city buses and garbage trucks with natural gas vehicles in urban areas beginning in 2000. To encourage the active participation of operators, the government is offering incentives such as subsidies for vehicle purchases and fuel price differential. In particular, in order to clearly motivate consumers and operators to switch fuels and to buy into market participation, the government seeks to restructure the relative prices of fuels in the direction of lowering the relative price of clean fuels as against competing fuels. In other words, the energy price structure will be shifting to an environment-friendly one by internalizing air pollution damage caused by fuel consumption to fuel prices.

In addition, beginning in 2007, a total air pollution load management system and an emission trading system on SO_2, NO_2 and PM will be adopted in the capital area. Annual emission cap will be allocated by each of these pollutants and industries will be strictly required to emit within the set limits. The party emitting the pollutants can decide on the energy type to be used and whether to install prevention facilities provided that they comply with the allocated emission load. In other words, once this total air pollution load management system is in place, there would no need for the conventional direct restrictions.

Until the total air pollution load management system is rolled out for the entire nation, the government plans to further supplement the weaknesses of direct restrictions by encouraging autonomous environment management or voluntary agreements. Companies that develop investment and implementation plans that can significantly reduce emissions and sign a voluntary agreement with the government based on the plan will be exempted from direct restrictions, including the mandatory use of clean fuels and the ban on the use of solid fuels.

As described, in promoting the fuel switching initiatives, the government plans to shift from a direct restrictive approach of the 1980s to an economic incentive system through proactive utilization of subsidies, financial and taxation supports, environment taxes, as well as total pollution load control and emission trading.