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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%
oil	diesel, kerosene	below 0.1%		
oil	LSWR	below 0.3%		
coal	bituminous	below 0.7%	below 0.5%	below 0.3%
coal	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 schemes are taken, the emissions of per energy consumption unit automatically regardless of other e changes. For instance, if sulfur standards are tightened, the emissio will decline in proportion to t mandated by tightened regulation proportionate reduction is not affect efficiency of energy consuming d operation of prevention faciliti Therefore, direct restrictions are reliable means in achieving pollutant reduction goals. However, the e emission restriction systems are var highly influenced by how syster emission permissible standards are and operated. In the case of per emission standard systems, some pe avoid running prevention facilities ir save the facility operating costs. The the case of direct restrictic implementation itself guarantees the of emission. However, the ado emission restriction systems does not emission reduction effect.

This is well illustrated by the fact that consumption has increased by 79% in since 1991, the emissions of air pollu declined by 27%.

2) Climate Change

As reviewed above, fuel switching direct restrictions in particular, are c most effective means for reducing air emissions. As the sulfur content standa forces the reduction of the sulfur conte the emissions of SO_2 released in the c process fundamentally diminish. As fo fuel banning system, fuel is switched a fuel emitting the largest amount of to bunker C-oil or the clean fuel, LNG fuel is consumed to generate the same heat, pollutant emissions are less. In t the mandatory use of clean fuel syster