7. Low-Emission Vehicle Program

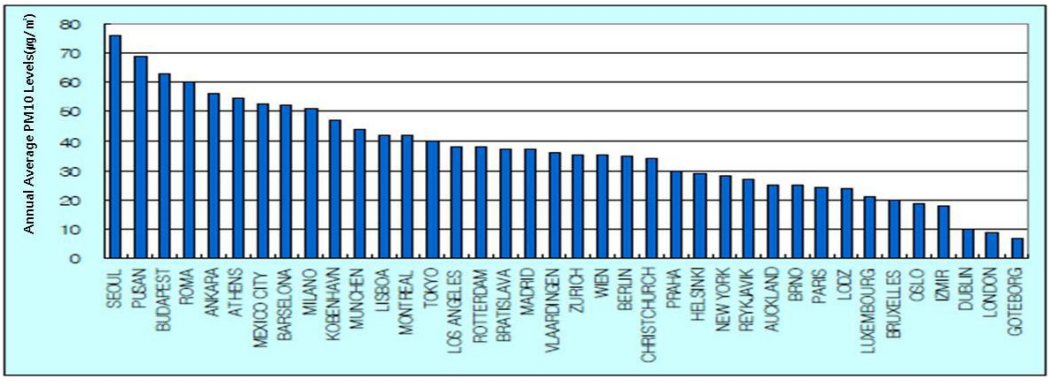
Writer : Seoul Institute Dr. Yu-Jin Choi
Policy Area: Environment

Background

Into the 1990s, air pollution surfaced as a social issue, especially in large cities where people were taking a greater interest in finding fundamental solutions to the deterioration of air quality caused by the prevalence of vehicles.

According to a 2002 OECD report, Seoul' s fine particle (PM10) level between 1998 and 2000 was the worst of all OECD member large cities: 2 to 3 times higher than London or Paris. Within South Korea, Seoul was higher than other Korean cities such as Busan, Daegu, and Daejeon.

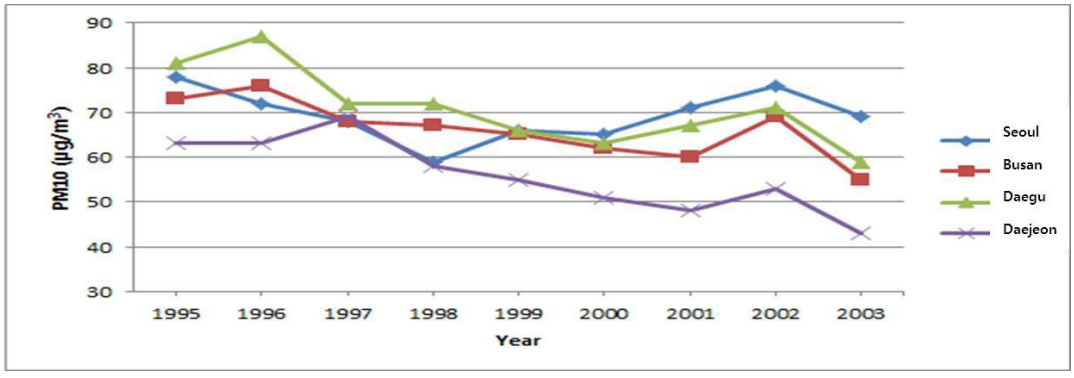
Figure 1 - Annual Fine Particle (PM10) Averages in Large Cities of OECD Countries



Note: Displays air pollution levels of recent years (mainly 1998 – 2000) in all 38 "A Group" cities (large cities with 5 – 10% of the national population) in OECD countries
Source: OECD Environmental data 2002

Source: Ministry of Environment, 2011, Interim Evaluation & Study of the Low Emissions Program for Diesel Vehicles Operating in the Capital Area.

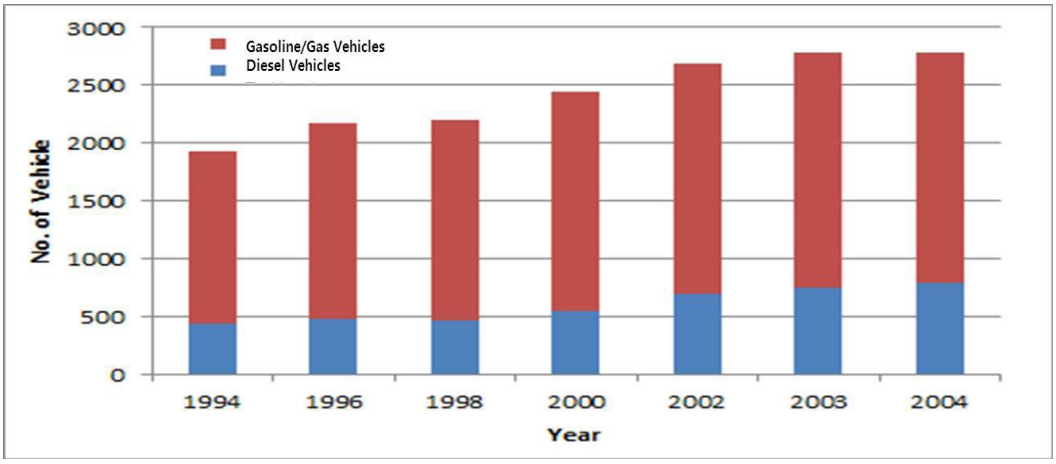
Figure 2 - Annual Fine Particle (PM10) Averages of Seoul & Other Korean Cities



Source: Ministry of Environment, 2005, Annual Report: Air Quality & Environment (2004).

At the time, the number of vehicles registered in Seoul was growing by 10% or more each year, owing to the rapid industrialization and growth in income. In 1980, there were 200,000 vehicles in the city, but by 2000, this had risen more than 10 times to 2.4 million vehicles, ever worsening the pollution. Diesel-powered vehicles particularly – known to have better mileage than gasoline-driven vehicles and less expensive in terms of fuel due to industry and energy policies – steadily grew. In 2004, 28% of the registered vehicles in Seoul were diesel-powered.

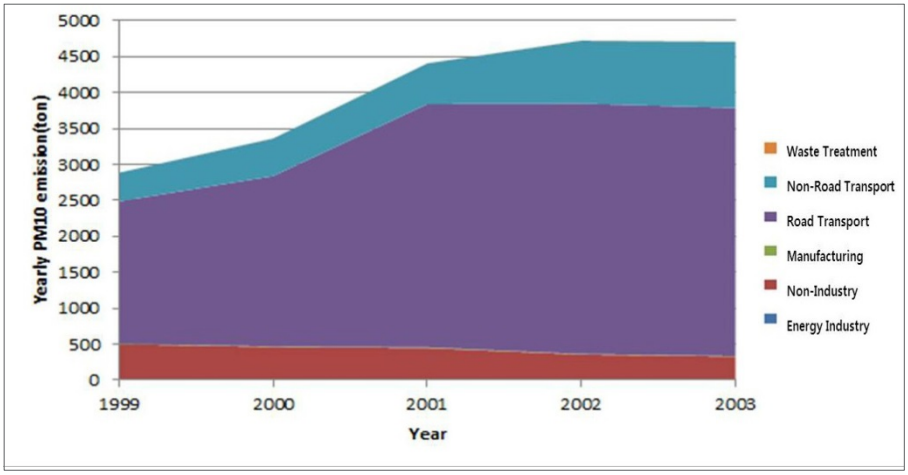
Figure 3 - Number of Registered Vehicles in Seoul by Fuel Type



Source: Seoul Metropolitan Government, 2013, Seoul' s Environment, Environment White Paper 2012.

Due to their method of fuel combustion, diesel engines produce finer particles than gasoline engines, and diesel vehicles were targeted as one of the major sources of fine particles. Considering the Euro 4 standards (reinforced emission requirements for manufactured vehicles) were introduced in South Korea in 2006, it can be assumed that diesel vehicles manufactured according to the previous emission standards added significantly to the emission of fine particles in Seoul.

Figure 4 - PM10 Emission Levels in Seoul by Emission Source



Source: National Institute of Environmental Research, 2005, National Level of Air Pollutant Emissions.

People began demanding that the environment should be made more pleasant for the upcoming 2002 World Cup. Accordingly, studies were conducted and policies adopted on the use of zero- or low-emission vehicles. As mentioned above, discussions were held on encouraging lower emissions from diesel-powered buses, trucks and other vehicles, and relevant programs were implemented.

Programs in the City of Seoul included replacing diesel city buses with CNG-powered buses and reducing emissions from older medium and heavy duty trucks and other vehicles.

Program Summary

Distribution of CNG City Buses

Introduction

In the US and other countries, governments, research institutes, organizations and automobile manufacturers studied alcohol fuels (e.g., ethanol, methanol), LPG, natural gas, electricity and hydrogen in attempts to replace conventional gasoline fuels. The technology however was not yet sufficiently advanced for electricity and hydrogen to be commercially available. On the other hand, alcohol, LPG and natural gas were deemed more practical in the mid- to long-term, with natural gas considered the next alternative fuel due to its stability, long-term supply, economics, and low environmental impact.

Natural gas produces fewer pollutants than gasoline or diesel, and is generally deemed safe, less likely than other fuels to lead to fire or fuel tank explosion, and lower in toxicity. Sufficient supplies could be secured with relative ease, estimated to last approximately 250 years (on the condition that a 100% switch to natural gas was made and was used at the same rate as oil consumption in 1989).

Natural gas was also more affordable than oil, and due to lower emissions than diesel or gasoline, the government decided to develop and encourage the use of CNG vehicles. From 2000, a policy supporting CNG buses was actively pursued to improve the air quality in Seoul and other large Korean cities.

Assistance Policies & Systems

Assistance Policies

- Subsidies/loans to cover the difference in price over diesel buses
- Assistance with installation of fuel stations: KRW 700 million per station in the form of long-term loans or subsidies from the national coffers
- Loans/subsidies from the national and city budgets; tax exemptions; fuel price regulation
  - Exemption from VAT, acquisition tax, and environment improvement charges
  - Exemption from corporate tax for the costs of fuel station construction
  - Natural gas price to be kept at a certain level below diesel prices to allow for additional profit
  - City Gas industrial electricity rates to apply to power bills for fuel stations installed/operated by bus companies to allow those companies to benefit

Special Assistance to Promote CNG Buses in Seoul before the 2002 World Cup

- Temporary, conditional assistance for those that stopped using their vehicles ahead of the World Cup, until May 2002 (one month prior to the World Cup opening)
- Subsidy of up to KRW 8.5 million: KRW 300,000 per month per bus for those operators who gave up their diesel vehicles (1994 or newer) and switched to natural gas during "the period of early termination."

Special Plan to Promote the Introduction of CNG Buses in Seoul after the 2002 World Cup

- Laid the legal and institutional framework for expanded use of CNG city buses
  - Permission for fuel stations at the bus company garage, parking lots, and development-prohibited areas
  - Relaxed distance requirements for CNG fuel stations from residential apartments, places of business, etc.

Timeline in Seoul

- 1999: Pilot CNG city bus project
  - Outcome: 15 CNG buses, 3 fuel stations installed
  - Assistance: full amount loan for fuel stations; loan/subsidy to cover price difference over diesel buses
  - Program cost: national budget (KRW 2.1 billion) + city budget (KRW 2.1 billion)
- 2000: Program launched in earnest
  - Outcome: 480 CNG buses, 13 fuel stations installed
  - Program cost: national budget (KRW 8.9 billion) + city budget (KRW 10.9 billion)

- 2000 –
  - 46 fuel stations to be installed by 2010
  - Town buses, cleaning vehicles, etc. to be included in the CNG vehicle replacement program
  - Assistance with replacement to be funded on a 50:50 basis from national and city budgets; assistance according to car type, displacement, tonnage, etc.

Table 1 - Replacement Assistance by Vehicle Type (2014)

	City Bus	Town Bus	Chartered Bus	Public Bus	Cleaning Vehicle
Subsidy/ KRW 1,000 (50:50 national/ city budget)	18,500	16,000	18,500	18,500	27,000: 5 ton 42,000: 11 ton

Figure 5 - CNG Fuel Station

Table 2 - CNG Vehicle Distribution in Seoul (2013)

	Total	Natural Gas Vehicle Distribution (No. of Vehicles)					
		Until 2008	2009	2010	2011	2012	2013
Total	10,376	6,147	1,757	1,173	590	467	242
City Buses	8,750	5,414	1,396	1,044	396	332	168
Town Buses	1,049	487	214	85	100	100	63
Cleaning Vehicles	523	246	147	44	48	27	11
Tour Buses, etc.	54				46	8	
Program cost (KRW 1 million)	350,996	215,158	49,818	37,636	19,328	16,326	12,716

Low Emission Devices for Older Diesel Vehicles

Introduction

The capital area, which includes Seoul, Incheon, and Gyeonggi-do, is affected by the same atmosphere. To improve air quality, the Special Act on the Improvement of Air & Environment for Seoul Metropolitan Area was enacted in December 2003. The aim of this Special Act was to improve the air to the OECD city average of PM10 40 $\mu g/m^3$ and NO2 to 22 ppm, to enable visibility of the Incheon coastline from Nam Mountain on a clear day. Investment of KRW 4 trillion was planned, which would include funding from the national coffers and local governments, over the 10 years from 2005 to 2014. Some 90% of the total budget for the low emissions program for older diesel vehicles was targeted to bring down the emission.

Target & Procedure

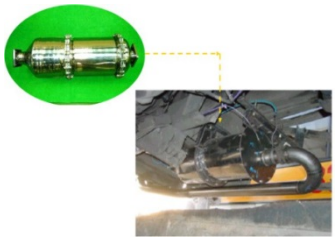
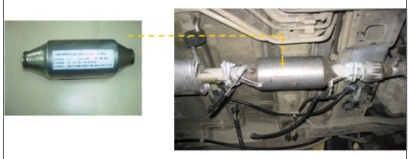
Of the diesel vehicles (excluding compact and passenger cars) registered in the metropolitan Seoul area, any vehicle that outlived the warranty period for particulate matters as stipulated in the Clean Air Conservation Act was prescribed as a "Particular Diesel Vehicle", to which emission requirements were strengthened.

Particular Diesel Vehicles could be used only once they satisfied the emission requirements in a complete test; if not, one of the following had to be chosen: retesting; installation of diesel particulate filters (DPF, p-DPF, DOC); engine retrofit for zero emissions; or removal of that vehicle from use.

For those vehicles choosing to add a diesel particulate filter, their smoke concentration had to meet the filter conditions; if not, the vehicle had to go through maintenance and testing until the concentration level met the conditions. Those vehicles that were to be terminated early need to have the smoke concentration come within the scope of the emission requirements of the operating vehicle.

Generally, medium to heavy duty vehicles need DPFs (Diesel Particulate Filters); medium-sized vehicles need p-DPFs (Partial Diesel Particulate Filters) or retrofit for zero emissions (LPG engine). For small vehicles, DOCs (Diesel Oxidation Catalyst) or retrofit for zero emissions (LPG engine) were necessary until 2009, with DOCs replaced by small p-DPFs from 2010 on.

Figure 6 - Types of Low Emission Devices for Older Diesel Vehicles

		
DPF	DOC	LPG Engine Retrofit
Traps and burns gas emissions with exhaust gas heat or other heat source (Emissions reduced by 80%)	Reduces gas emissions by pushing them through a catalyst-coated filter (Emissions reduced by 25%)	Diesel engine replaced with an LPG engine (Emissions reduced by 100%)

Support & Benefits

For those vehicles fitted with filters or retrofitted with zero-emission engines, 70 – 95% of the expenses were financed from the national and city budgets. As for early termination of Particular Diesel Vehicles, assistance was provided to eligible vehicles within an 80% range of the vehicle's residual cost within limits set by vehicle type.

Of this financial assistance, a portion for maintenance and management was deposited with the Korean Association for Automotive Environment. The device manufacturers would carry out maintenance, submit supporting documentation, and claim the costs, after which the Association was to verify the documentation and reimburse the manufacturer. For DPFs, the cost of maintenance covered by the Association included KRW 300,000 for annual cleaning and KRW 10,000 for call monitoring for the duration of the 3-year warranty. Those vehicles that participated in the low emissions program were given benefits such as exemption from environment improvement charges and the complete test. After filters were installed or the vehicle retrofitted, the vehicles had to be operated for a minimum of 2 years.

Follow-up after Fitting of Low Emission Devices

Follow-up is the most important factor in reducing diesel vehicle emissions. The City of Seoul was fully aware of this importance at the start of its low emissions program. It encouraged device manufacturers and formed its own follow-up inspection team to check filter operation on vehicles. Those vehicles that did not pass a performance test were required to improve the device, or remove the device if necessary.

Vehicles fitted with a filter could be serviced free of charge by the device manufacturers for the duration of a 3-year warranty. Vehicles fitted with DPFs could have their filters cleaned free of charge once a year at one of the 40 cleaning centers in the capital area, if the device continued to perform properly.

Except for accidents, force majeure, fire, theft, or inoperability, the vehicles must be in operation for at least 2 additional years. When the vehicles are taken out of use, the filtering devices must be returned to the Korean Association for Automotive Environment. Unless it was unforeseen or unavoidable, devices were not to be

removed during the mandatory 2 years of operation. Otherwise, all financial assistance had to be returned. This also applied if the devices were not returned to the Association.

Each device manufacturer has an after-sales customer service center and cleaning center that address device issues, complaints, and the need for improvements. Upon encountering a difference of opinion between the vehicle owner and the manufacturer during the after-sales servicing process, the City of Seoul intervenes to mediate.

The city also has its own inspection team that checks DPF performance. When the team finds any fitted device that emits 10% or more exhaust gas, the manufacturer is required to remove the device and return the subsidy.

In most cases, a DPF is proven to underperform and then removed because the vehicle in question did not meet the required conditions during its operation; in some other cases, the underperformance was caused by inadequate follow-up by the manufacturer and/or maintenance by the vehicle owner. Theoretically, a DPF reduces emissions by 80% or more. Even after the device is fitted, the vehicle owner should do his or her part to maintain this emissions reduction. When the device is removed, the benefits are also canceled. Owners are then subject to the environment improvement charge and mandatory emissions inspections, while the manufacturer is required to return the subsidy.

Timeline

Pilot Program

- 2003: Pilot program for LPG engine retrofit
  - Outcome: 135 vehicles (130 cleaning vehicles for public use, 5 vans for public use)
  - Assistance: full cost
  - Program cost: 50:50 by the City of Seoul and LPG Vehicle Distribution Council
- 2004: Pilot low emission program for diesel vehicles in operation
  - Outcome: 880 vehicles (vehicles for public use and city buses)
  - 280 vehicles (DPF); 150 vehicles (DOC); 450 vehicles (LPG retrofit)
  - Assistance: full cost
  - Program cost: DPF (100% from the national budget), DOC and LPG retrofit (50:50 from the national and city budgets)

Main Program

- 2005
  - Outcome: 12,130 vehicles
  - 7,789 vehicles (DPF); 1,490 vehicles (DOC); 2,814 vehicles (LPG retrofit); 37 vehicles (early termination)
  - Assistance: full cost

- Program cost: 50:50 from the national and city budgets

• 2006 –

- Assistance: 70 – 95% of the device cost
- Program cost: 50:50 from the national and city budgets

Mandatory Implementation

• 2008

- Target: Particular Diesel Vehicles that are 3.5 tons or heavier in total weight and 7 years or older
- Assistance: 70 – 95% of the device cost
- Program cost: 50:50 from the national and city budgets

• 2009

- Target: Particular Diesel Vehicles that are 2.5 tons or heavier in total weight and 7 years or older
- Assistance: 70 – 95% of the device cost
- Program cost: 50:50 from the national and city budgets

Table 8 - Low Emission Program Performance (2003 – 2013)

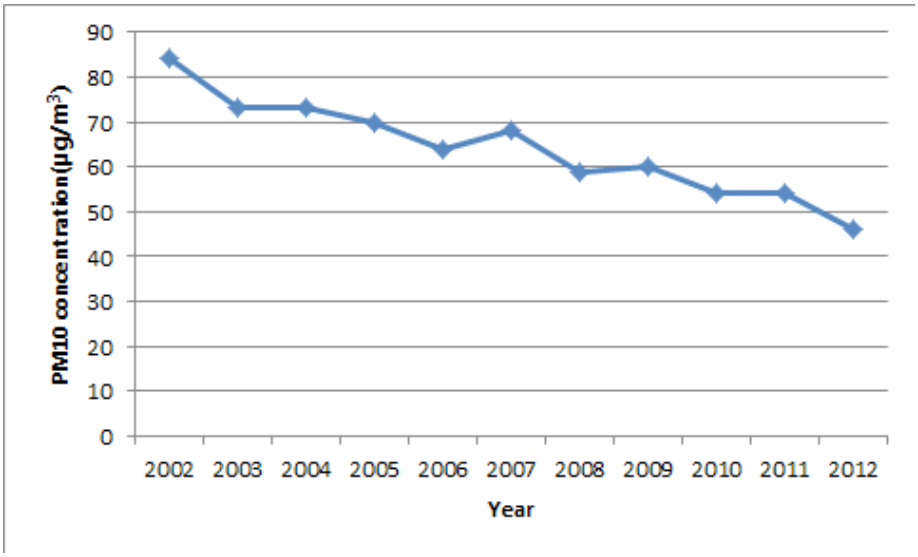
	Low Emission Program Outcome (No. of Vehicles)										
	Total	2003 – 2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Executed Amount (KRW 100 million)	7,351	41	720	1,189	1,262	948	893	800	570	472	456
(City budget)	-3,654	0	-360	-594	-631	-474	-446	-400	-285	-236	-228
Total (No. of Vehicles)	265,591	1,015	12,130	39,038	54,291	36,099	34,866	30,825	24,114	16,401	16,812
LPG Retrofit	68,111	585	2,814	8,714	14,285	16,452	14,027	7,922	2,074	961	277
Device/ Filter	142,907	430	9,279	29,715	34,201	9,796	11,709	17,461	14,961	7,617	7,738
Early Termination	54,573	-	37	609	5,805	9,851	9,130	5,442	7,079	7,823	8,797

Outcome & Implications

Benefits

Since the low emissions program was initiated in 2000, PM10 emissions from automobiles have decreased by 4 – 22% in Seoul. The PM10 levels measured at Seoul' s roadside air quality monitoring network have steadily dropped since 2005, reaching 46μg/㎥ in 2012. This is even lower than the annual average standard of 50μg/㎥; air quality has been improved beyond the standard, not just at general air quality monitoring stations (41μg/㎥ as of 2012), but also at roadside. Moreover, the number of days when the density is higher than 100 ㎍/㎥ has decreased, while low-density days have increased. Pollution from fine particles is gradually lessening. In addition, the number of vehicles reported by people for serious emissions has fallen considerably. While the low emissions program is not the sole contributor to these improvements, it remains one of the largest.

Figure 7 - PM10 Levels at Seoul Roadsides



Source: Seoul Metropolitan Government, 2013, Evaluation Report on the Air Quality in Seoul in 2012.

Challenges

The low emissions program carried out so far has aimed to reduce fine particle levels. While it has proven effective to a certain extent in reducing such emissions, Seoul' s nitrogen dioxide (NO_2) level remains above environmental standards and is not showing visible signs of improvement. Considering that a substantial percentage of NOx is produced by diesel vehicles, the low emissions program should focus on NOx as well as fine particles. The City of Seoul therefore launched a pilot project for PM-NOx filter devices to be installed on 44 older construction vehicles and heavy duty trucks in 2013. Should effectiveness be verified, the program will be pursued in earnest from 2015.

Figure 8 - PM-NOx Device on Bus: Before & After

Working principle: A DPF is attached to the exhaust vent pipe to reduce the fine particle emissions while injecting ammonia at the back to turn NOx into N_2 and H_2O and removing nitrogen compounds.

The city is also considering expanding the use of environmentally-friendly CNG hybrid buses which are highly fuel-efficient, cutting fuel consumption by 34.5% over regular CNG buses and saving approximately KRW 108 million in fuel over a 9-year operational period. Hybrid models were also found to emit 30% less in air pollutants. The city expects to introduce a "priority subsidy" and other incentives towards the purchase of hybrid buses.

References

· Ministry of Environment, 2011, Interim Evaluation & Study of the Low Emissions Program for Diesel Vehicles Operating in the Capital Area.

· Ministry of Environment, 2005, Annual Report: Air Quality & the Environment (2004).

· Seoul Metropolitan Government, 2013, Seoul' s Environment, Environment White Paper 2012.

· Seoul Metropolitan Government Press Release, April 7, 2014, All Seoul City Buses Replaced with CNG Buses".

· National Institute of Environmental Research, 2005, National Level of Air Pollutant Emissions.

· Seoul Metropolitan Government, 2013, Evaluation of Air Quality in Seoul in 2012.

· Kim Un-su, 2002, Financial Assistance to Promote Use of CNG City Buses & Distribution, The Seoul Institute.

· Ministry of Environment, 2012, Feasibility Study on CNB Bus Distribution Policies Based on Environmental & Economic Analy- sis of Diesel & CNG Buses, Korea Environment Institute.