Seoul's Efforts to Tackle Air Pollution
Performance and Challenges

11th Metropolis World Congress 2014

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October 9, 2014

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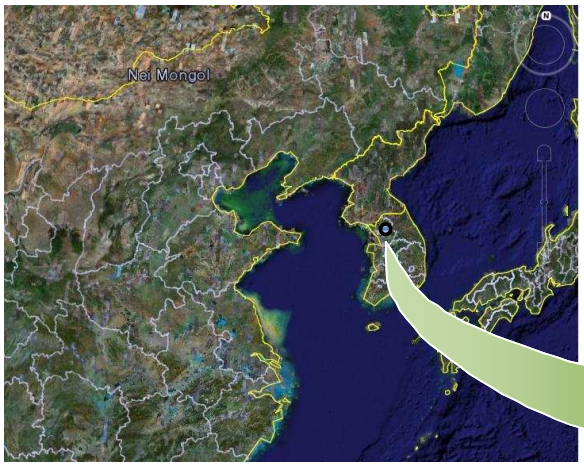
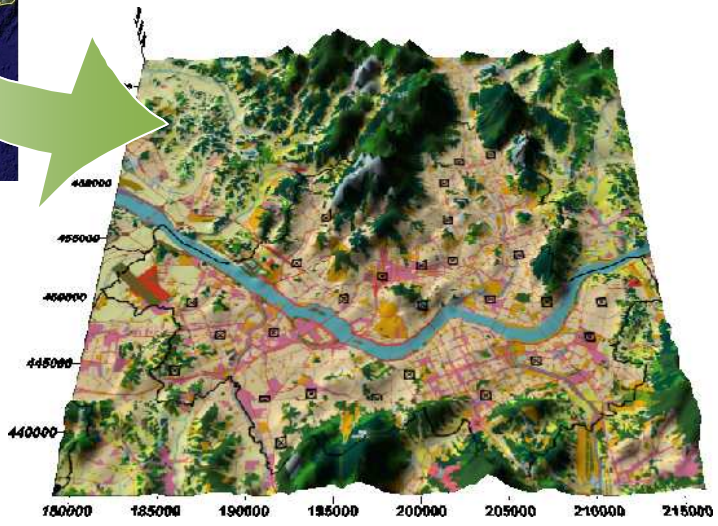
Brief Introduction of Seoul

Location and Topography



- Geographical location : Located at the east side of China with westerly wind predominant
  ➔ Air pollutants transported from overseas
- Geophysical characteristics : Surrounded by mountains from North, east and south
  ➔ Difficult to diffuse air



Average wind speed (m/s)
- Seoul (2.8), New York (4.1)
- London (3.8), Paris (3.0)

Population and Vehicles

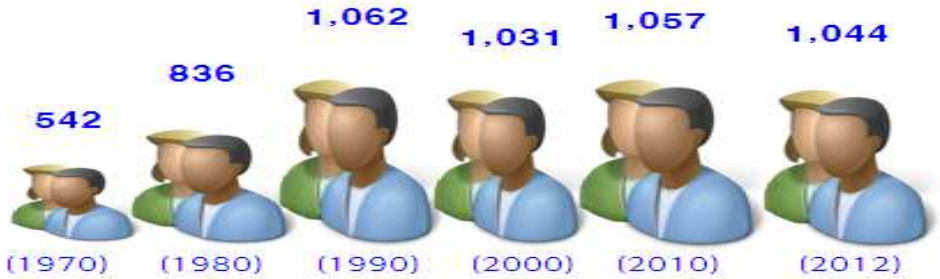
Comparison of major statistics

		Seoul	Tokyo	Berlin	Beijing	New York	Paris
Base year		2006 (2012)	2004~2006				
Area	**km^2**	605 (605)	622	892	1,368	786	763
Population	**thousand persons**	10,356 (10,442)	8,490	3,400	9,530	8,240	6,410
Population density	**persons/km^2**	17,108 (17,254)	13,650	3,799	6,996	10,483	8,401
Registered vehicles	**thousand vehicles**	2,856 (2,969)	2,205	1,428	2,461	1,856	2,142

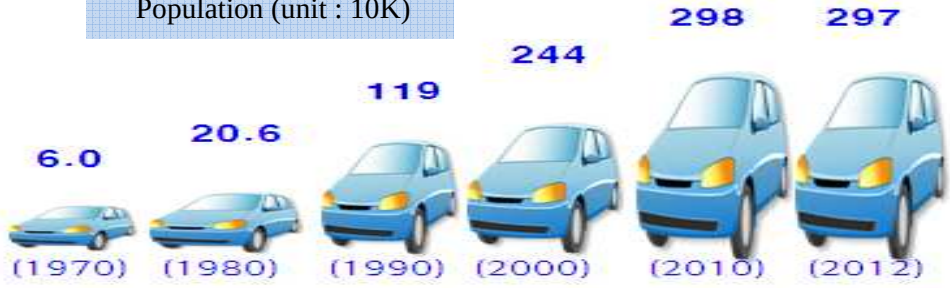
- Population density and automobile registration are larger than other international megacities.

Population and Vehicles

- Population : two times increase between 1970 and 1990
- Vehicles : 50 times increase between 1970 and 2010



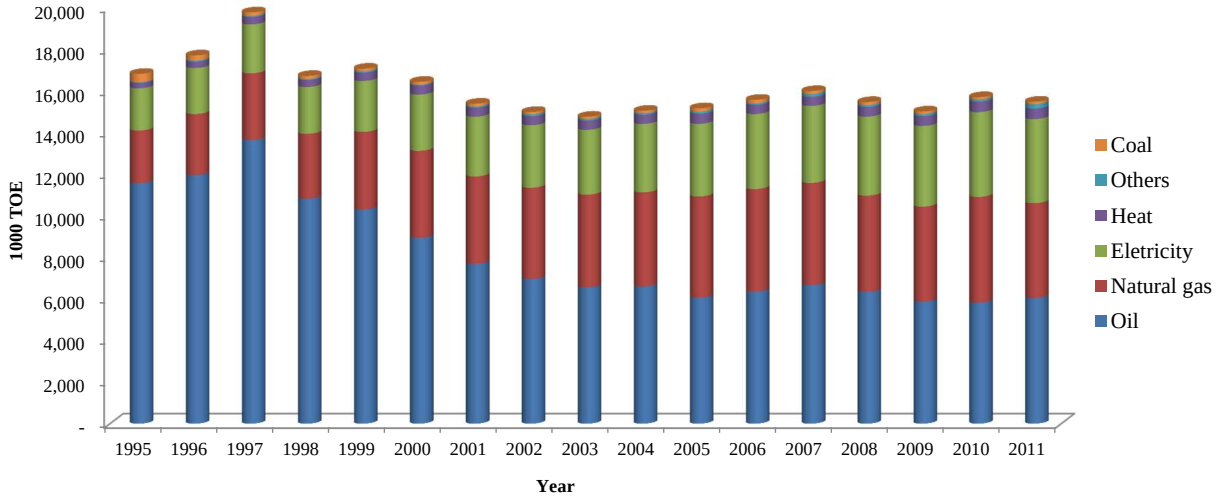
Population (unit : 10K)



Registered cars (unit :10K)

Energy Consumption

- Energy consumption
  - Not a big change of total amount of energy consumption in recent years
  - Smooth transition from less clean energy sources to more clean energy sources (from oil & coal to natural gas & electricity)



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Air Quality of Seoul : Now and Past

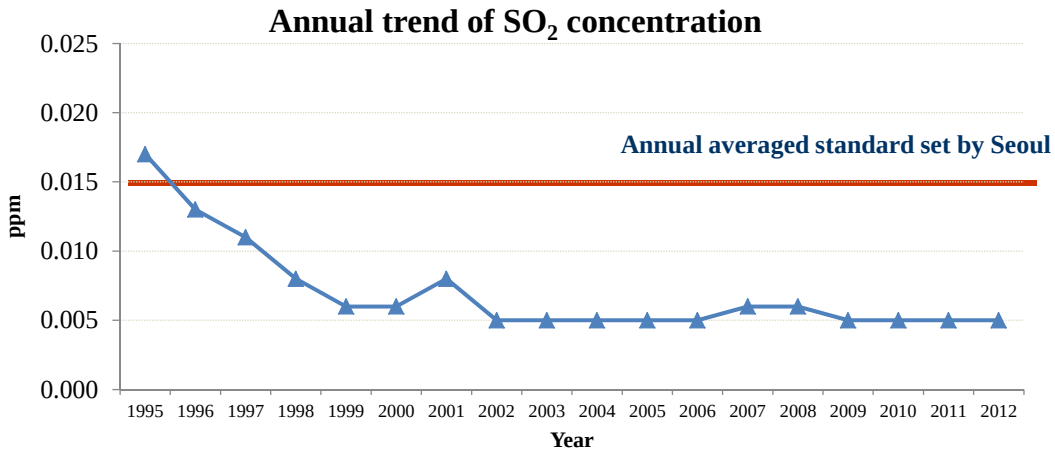
Criteria Pollutant Ambient Air Quality Standards

Comparison of air quality standards

	Averaging Time	Korea	USA	Japan	WHO guideline	EU guideline
PM10 (PM2.5) ($\mu g/m^3$)	Annual	**50(25)**	-(15)	-(15)	20(10)	40(25)
	24-hr	**100(50)**	150(35)	100(35)	50(25)	50(-)
	1-hr	-	-	200	-	-
NO_2 (ppm)	Annual	0.03	0.053	-	0.021	0.021
	24-hr	0.06	-	0.04-0.06	-	-
	1-hr	0.10	-	-	0.105	0.105
SO_2 (ppm)	Annual	0.02	0.03	-	-	-
	24-hr	0.05	0.14	0.04	0.008	0.047
	1-hr	0.15	-	0.10	-	0.13
O_3 (ppm)	8-hr	0.06	0.08	-	0.05	0.06
	1-hr	0.10	0.12	0.06	-	-
CO (ppm)	8-hr	9	9	20	8.6	8.6
	1-hr	25	35	10(day)	25.9	-
Pb* ($\mu g/m^3$)		0.5/yr	1.5 (3mon.)	-	0.5/yr	0. 5/yr

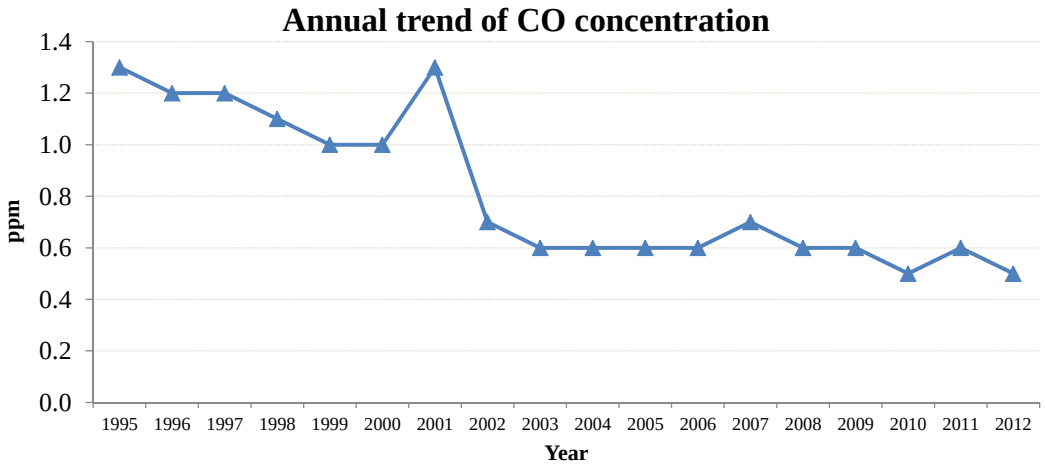
- Criteria pollutants are pollutants posing especially great threats to human health
- PM standards are higher compared to other developed countries and WHO
- PM2.5 standard in Korea is effective from 2015

Pb and SO_2 in Seoul



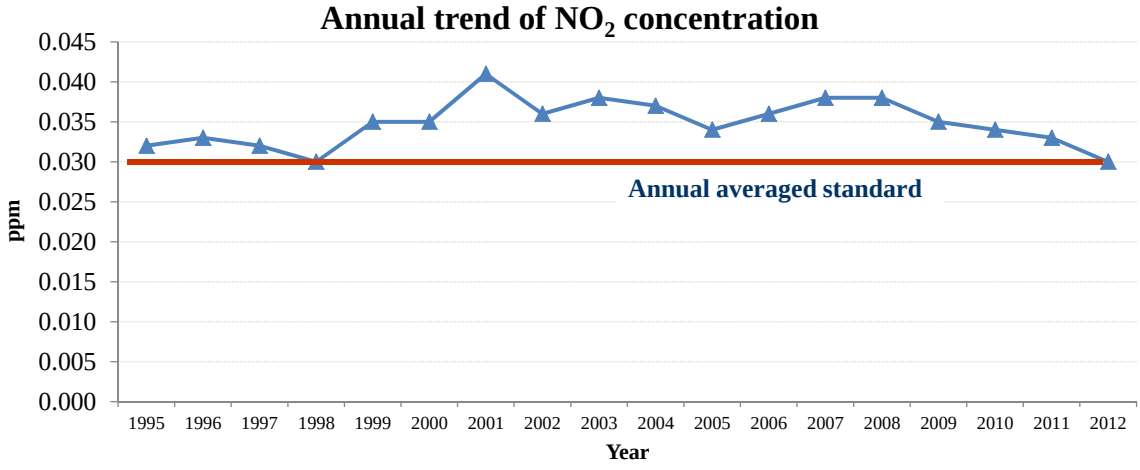
- Pb has been under the standard
  - Main sources : leaded gasoline.
  - Key measures : ban using leaded gasoline since 1986
- SO_2 has been stabilized at below the standards
  - Main sources : coal and oil combustion for heating
  - Key measures : introduce and enhance sulfur content limit in fuel since 1981 gradually, supply low-sulfur oil and LNG since 1988, and switch to cleaner heating fuel (coal→ oil → natural gas)

CO in Seoul



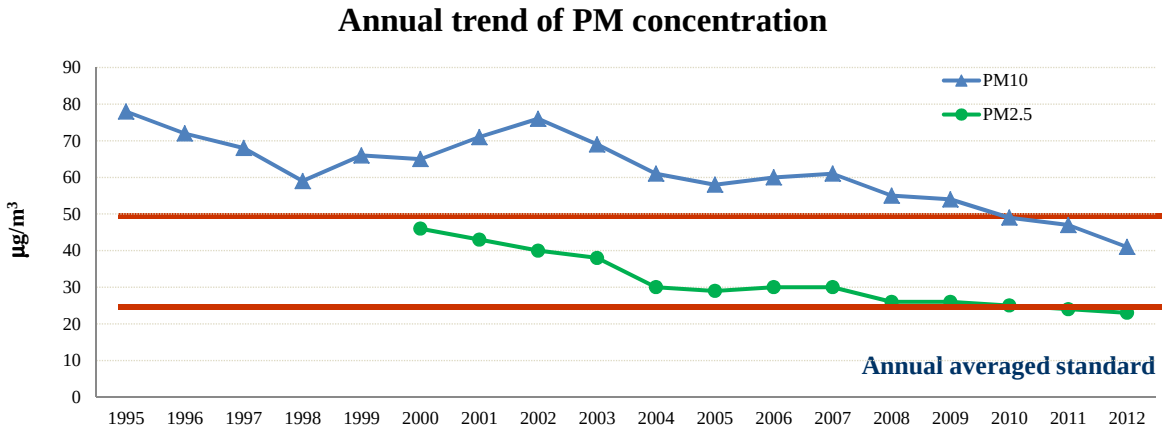
- CO has been staying at below the environmental standards
  - Main sources : fuel combustion, particularly for motor vehicle in recent years
  - Key measures : introduce and strengthen emission standards for motor vehicles since 1991, promote the use of low-emission vehicles, and switch to cleaner heating fuel (coal→ oil → natural gas)

NO_2 in Seoul



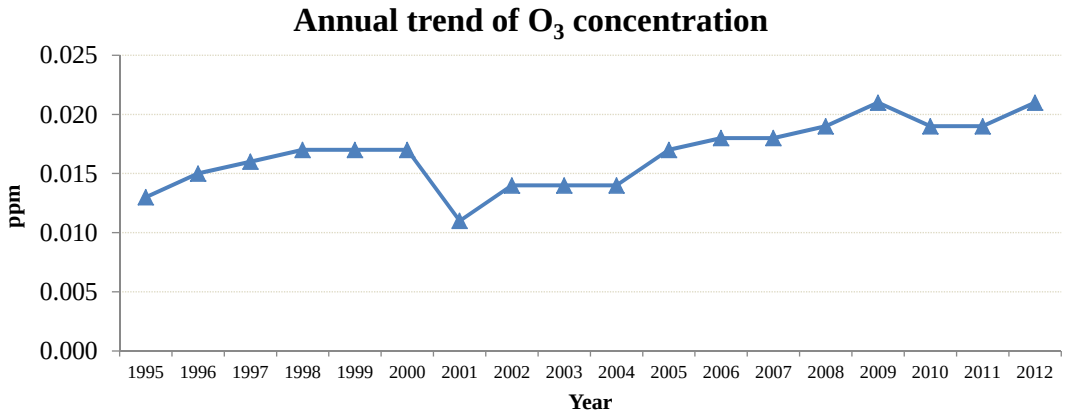
- NO_2 shows slow improvement in recent years, reaching the standard in 2012
  - Main sources : fuel combustion for vehicle and heating
  - Key measures : change to clean heating fuel (coal→ oil → natural gas), introduce and strengthen emission standards for motor vehicles since 1991, and promote the use of low-emission vehicles

PM10 and PM2.5 in Seoul



- PM is on a decreasing trend, but Seoul is still experiencing high pollution episodes
  - Main sources : fuel combustion for mobile sources (diesel cars), fugitive dust, and secondary formations
  - Key measures : change to clean heating fuel, introduce and strengthen emission standards for vehicles, promote the use of low-emission vehicles, retrofit old diesel cars with DPF or DOC, street cleaning, etc.
  - Many things are still in black box (emission inventory, source characterization and apportionment, long-range transport, etc.)

Ozone(O_3) in Seoul



- Ozone is a typical secondary pollutant, formed from photochemical reactions of NOx and VOC. During summer, depending on weather condition, Seoul is experiencing high ozone events.
  - Annual averaged concentration is on the rise.
  - But annual number of O_3 watch dates(over 120 ppb/hr) is decreasing slowly.
  - Many things are still in black box (NOx and VOC relationship, VOC emission source characterization and apportionment, biogenic contribution, long-range transport, etc.)

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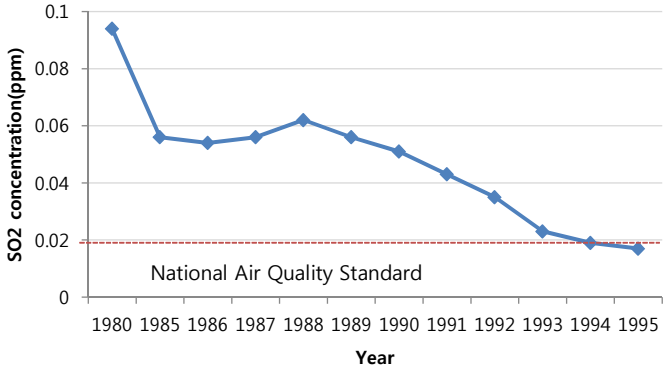
Key Actions Taken to Improve Air Quality of Seoul

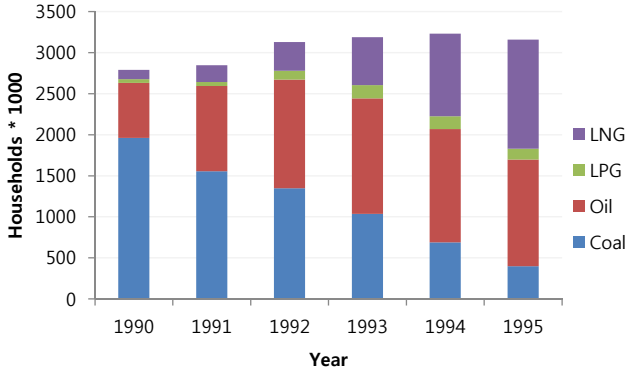
Transition to Cleaner Fuel : Key policy for SO_2 reduction

Background

- During 1970s and 1980s, SO_2 concentration in Seoul
  - 2~4 times higher than Korean National Air Quality Standard
- During 1970s and 1980s, major SO_2 emission sources
  - Fossil fuel such as coal and oils with higher sulfur content
  - Coal as major heating fuel (until 1990, 70% of households in Seoul had used coal as a heating fuel)



Annual trend of SO_2 concentration in Seoul



Annual trend of the number of households by heating fuel in Seoul

Transition to Cleaner Fuel : Key policy for SO_2 reduction

Key Policies

- Supply low-sulfur fuels
  - Implement in Seoul metropolitan area in 1981, and expand nationwide
  - Set and enhance sulfur content limits in fuels gradually

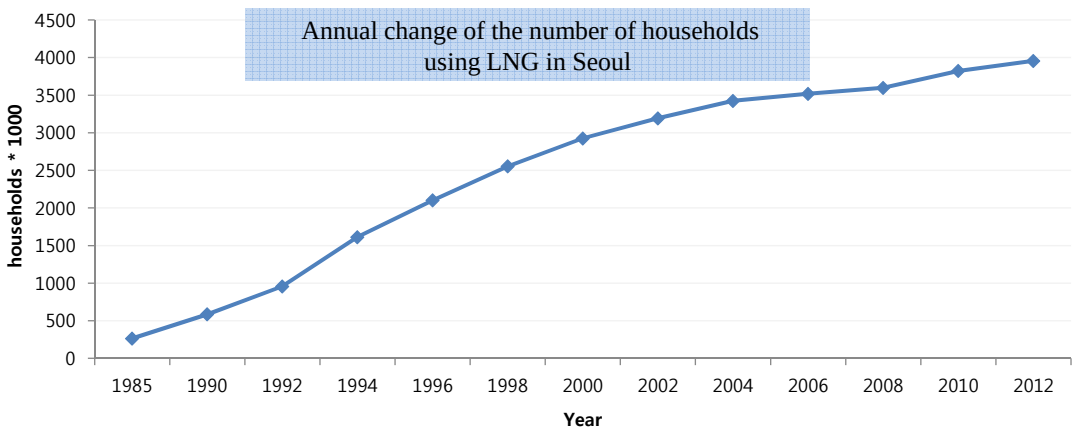
	Since 2001	Prior to 1981
Heavy oil (B-A, B-B, B-C)	Less than 0.3%	Less than 1.6%
Diesel	Less than 0.1%	Less than 0.4%

- Ban using solid fuels such as coal and wood for business facilities in Seoul metropolitan area from 1985
- Mandate the use of clean fuel (LNG)
  - Apply to large sized business facilities in 1988 and expand to small sized apartment buildings
    - Business and industry: + 2 ton boiler (1988) → + 0.2ton boiler (1994)
    - Apartments : + 115m^2 in area (1990) → + 40m^2 in area (1997)

Transition to Cleaner Fuel : Key policy for SO_2 reduction

Key Policies

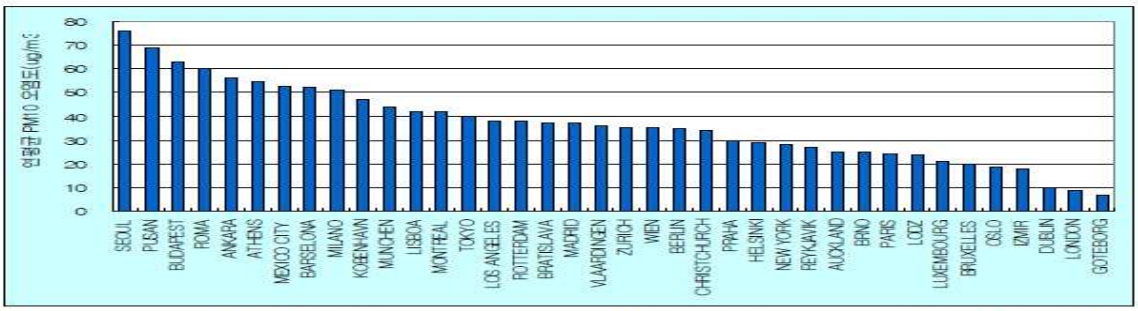
- Expand LNG supply for houses
  - Change of heating fuels : wood and coal in 1960's → Oil in 1970's → LNG in 1990's
  - LNG(city gas) supply rate for houses in Seoul was about 95% in 2012
  - Seoul Metropolitan Government launched funds to support early expansion of city gas infrastructure and to provide low-interest loans to city gas suppliers.



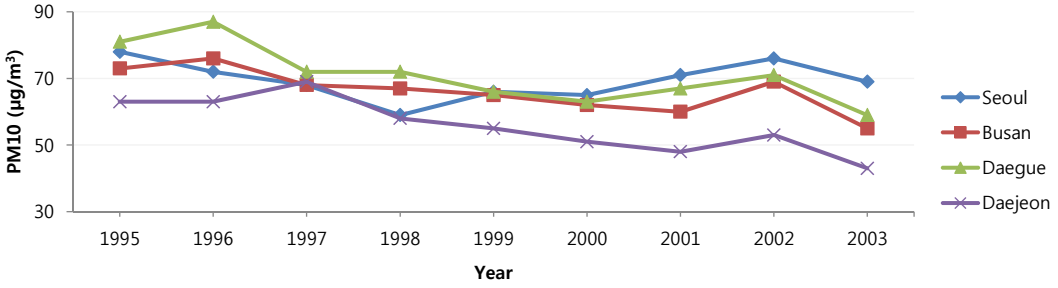
Program for In-Use Diesel Vehicles : Key policy for PM reduction

Background

- In early 2000, PM10 concentration in Seoul was the highest in OECD cities
- PM10 in Seoul was the highest in major cities in Korea



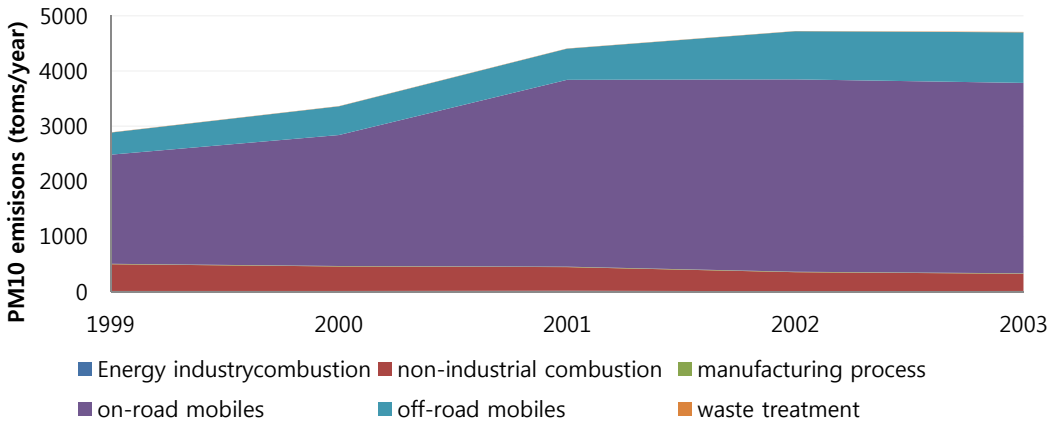
주: OECD 국가에서 제시한 'A' 그룹 도시(국가별 인구의 5~10% 점유 대도시) 전체 (38개)의 최근(주로 1998~2000년) 대기오염도를 나타냄.
자료: OECD Environmental data 2002



Program for In-Use Diesel Vehicles : Key policy for PM reduction

Background

- Rapid increase of vehicles in Seoul
  - 10 times increase of vehicles registered in Seoul between 1980 and 2000
  - On-road vehicle emissions, responsible for more than 70% of PM10 emissions in Seoul in 2003(excluding fugitive dust)
  - Gradual increase of diesel vehicles, amounting to 28% of vehicles registered in Seoul in 2004 (Diesel cars known to emit much more PM and NOx than gasoline cars)



Program for In-Use Diesel Vehicles : Key policy for PM reduction

Key Policies

- Apply stricter and more detailed vehicle emission inspection for diesel vehicles that have an expired exhaust emission warranty
- Implement emission reduction program for in-use diesel vehicles registered in Seoul metropolitan area

- Diesel vehicles that fail to emission inspection are required to install emission reduction equipment such as DPF or DOC, or retrofit with low emission engines like LPG engine, or scrap early.
- A pilot project was started in 2003, and now this program is mandatory for diesel vehicles which weigh more than 2.5tons and older than 7 years since the registration date .

  - DPF (Diesel Particulate Filter)
    - attached to large-size vehicles
    - reduce 50~70 % of PM10 emissions
    - require cleaning of filter once a year
  - DOC (Diesel Oxidation Catalyst)
    - attached to small & medium size vehicles
    - reduce about 25 % of PM10 emissions
  - Retrofit with LPG engine
    - reduce 100% PM10 emissions

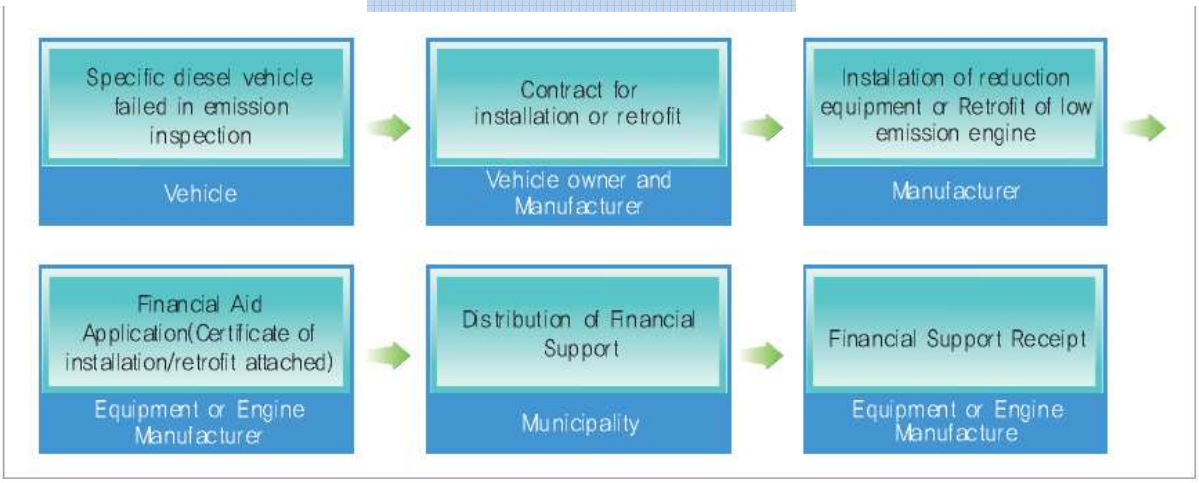
Program for In-Use Diesel Vehicles : Key policy for PM reduction

Key Policies

- Provide financial support for vehicle owners

- Seoul Metropolitan Government supports 70~80% of the expenses of the installation of equipment, retrofit of engine, or scrap

Financial support provision process



Source : Ministry of Environment, Regulations on the ex-post management and financial support for emission reduction program for specific in-use diesel vehicles, December, 2007

Program for In-Use Diesel Vehicles : Key policy for PM reduction

Key Policies

➢ Ex-post management of emission reduction equipment and LPG engine

- Manufacturer of emission reduction equipment is responsible for the submission of quarterly reports regarding installation status of equipment and engines
- 40 cleaning centers are established to clean the filter in DPF equipment
- Owner has to return equipment and engine in case of scrap or export the vehicle during the warranty period (3 years)

➢ Performance of emission reduction program in Seoul

- Install emission reduction equipment
  - 82,115 vehicles equipped with DPF and 53,054 vehicles with DOC by 2012
- Replace old diesel engine with LPG engine
  - 67,834 vehicles replaced with LPG engine by 2012
- Early scrap old-dirty diesel vehicles
  - 45,776 vehicles scrapped by 2012

Other policies against vehicles

Polices to supply cleaner cars

➢ Supply CNG vehicles

- Start pilot projects for natural gas vehicles in 1998
- Replace diesel buses and garbage trucks with CNG vehicles
  - 50 vehicles in 2000 → 10,396 vehicles in 2013
- Establish 48 CNG charging stations

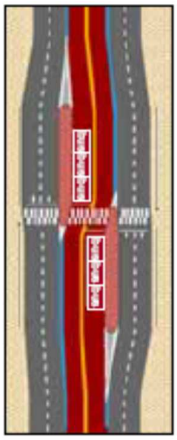
➢ Supply green cars (by 2014)

- 14 Electric buses, 334 Electric passenger cars, 352 Electric motorcycles
- 469 Electric charging stations

Other policies against vehicles

Environment-friendly traffic polices

- Reform public transportation system
  - Reorganization of bus routes
  - Integrated transfer fare system
  - IT-based high-tech management (GPS, T-Money)
- Introduce and extend exclusive median bus lane
- Weekly no-driving day program
- Car-free day campaign
- Congestion pricing
- Parking management



Other policies against point & area sources

Point sources (Business facilities)

- Enhance emission limits for large-scale business facilities
- Provide small/medium-sized facilities with low-NOx burners or boilers
  - 2,437 business facilities applied with low-NOx burners or boilers by 2013

Area sources

- Measures against fugitive dust
  - Road dust : introduce water-spraying and vacuum cleaning vehicles (37 four-seasons vacuum cleaning cars by 2013 with improved efficiency)
  - Construction dust : reinforce regular and special (March ~ May) checkups
- Measures against household boilers
  - Support boiler retrofit in houses with eco-friendly boilers
  - Low-income people, old-boilers prioritized

※ Conventional boiler's NOx emission 114ppm vs. Eco-friendly boiler's NOx emission 40ppm

- Indirect measures : Expand green zone in urban area by introducing urban agriculture and small-sized green zone projects

4

Challenges and Next Steps

Classification of air pollutants by source

Primary pollutants

- Emitted directly from sources
- SO_2, CO, Pb, Components of PM10, PM2.5, and NO_2
- Mostly certain to be improved by reducing emissions from the direct sources

Secondary pollutants

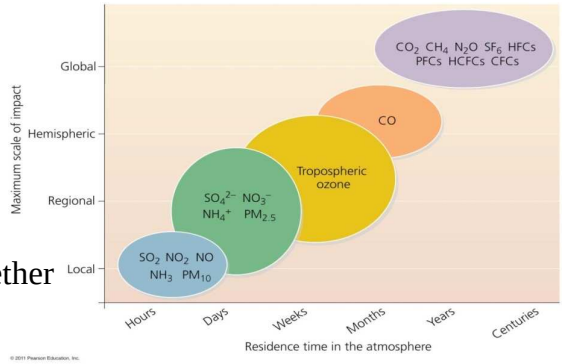
- Formed from chemical and/or physical processes such as nucleation, condensation, evaporation and coagulation in the atmosphere
- O_3, Components of PM10, PM2.5 and NO_2
  O_3 : NOx + VOC (photochemical reaction)
  NO_2 : NO + O_2
  PM10 (or PM2.5) : (SO_X, NO_X) + NH_3, VOC + OH →Mainly belong to PM2.5
- Uncertain to be improved by reducing emissions from sources of precursors (VOC, SO_X, NO_X, NH_3)

Current Situation

- Seoul is facing with issues of the secondary pollutants (PM, NO_2, and O_3), which are more difficult to control than the primary pollutants (CO, SO_2, and Pb)
- There are still many unidentified factors for the secondary pollutants
  - Emission sources and amounts
  - Formation and removal processes in the atmosphere
  - Contribution of transported pollutants from outside (trans-boundary pollutants)
  - Contribution of biogenic sources (trees, oceans, etc.)
- With increasing interest in public health, the demand for healthy air is going up
  - Increased concerns on non-criteria pollutants such as toxic chemicals as well as criteria pollutants
  - Not many known things about risks of both each pollutant and mixture of pollutants
  - On shifting directions of air pollution management from clean air to healthy air (risk-based approach)

Future Directions for Air Quality Management in Seoul

- Need to take an airshed-based approach by assessing and controlling emissions arising from local, national, and international sources.
  - Pollutants with long residence time such PM2.5, O_3 and CO can travel long-distance
  - Hard to solve with local emission management only for Seoul
  - More cooperation with neighboring cities, even countries required : monitoring and planning together



Seoul's Action

- Cooperate with Northeast Asian megacities for environment
  - Hold Northeast Asian International Seminar on air quality improvement
  - Join efforts to improve AQ with Beijing, Ulaan Bataar, etc : MOU under consideration for information sharing and personnel exchange
  - Strengthen other network in the region for environment
- Enhance activities and mutual cooperation neighboring cities
  - Conduct joint research, mutual monitoring and evaluation

Future Directions for Air Quality Management in Seoul

- Need to take an integrated multi-pollutant approach to controlling emissions of pollutants posing the most significant risks
  - Secondary pollutants are interacting each other in a complicated manner
  - Traditional approach, single-pollutant management not considering interactions with other pollutants, does not work well with the secondary pollutants any more.
  - Multi-pollutant approach, developing strategies that simultaneously meet multiple air quality targets, is the way to solve current air pollution issues.

To shift to an integrated multi-pollutant approach

- Establish a refined air quality modeling system for Seoul Metropolitan area
  - Improve uncertainty of modeling results
- Develop a reliable emission inventory
  - Modify incorrect emissions, and find unknown emission sources
- Establish an intensive monitoring system
  - Monitor various components from secondary formations, and investigate long-range transport of air pollutants, in order to understand complex characteristics of secondary pollutants