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The Application of AIM/Korea Model to Transport Sector in Seoul, Korea

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The Application of AIM/Korea Model to Transport Sector in Seoul, Korea

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Abstract

Since the population, vehicles, energy consumptions, economic activities are rising in the metropolitan area of Seoul, it is difficult for existing environmental policies and measures to mitigate air pollutions. To respond such challenges, the Ministry of Environment (MoE) of Republic of Korea (ROK) enacted the Special Act on Metropolitan Air Quality Improvement in December 2003. The Special Act will be effective from January 2005. Since we notice that the transport sector is rapidly growing in the metropolitan area of Seoul, we discuss the possible impact of this Special Act on emissions of sulfur-dioxide (SO_2), nitrogen-oxide (NOx), carbon monoxide (CO), particulate matter (PM), and carbon dioxide (CO_2) from the transport sector in Seoul. For the policy analysis, AIM (Asia-Pacific Integrated Model for Evaluating Policy Options to Reduce GHG Emission and Global Warming Impacts) Local model is used.

In this study, we analyze and assess the air pollution policies in the metropolitan area of Seoul with AIM/local model. In particular, the new legislation of the Special Act on Metropolitan Air Quality Improvement is expected to affect the whole emission profiles of air pollutants in this area with the introduction of diesel passenger cars. This paper analyzes the various policy scenarios along with projections of key determinants in the transport sector in this area. With such high emission standards and other policies and measures envisioned by the Special Act, the introduction of new vehicles equipped with advanced technologies and energy efficiency improvement will be accelerated, that will contribute to the reduction of air pollutants and CO2 emissions.

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Key word: Special Act on Metropolitan Air Quality Improvement; AIM/local model; transport

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Table of Contents

1. Introduction

The transport sector in the metropolitan area is the major source of key air pollutants, such as NOx, SO2, PM and CO, in addition to the greenhouse gas (GHG) as a direct result of increase in the energy demand. (IEA/OECD, 2001) In the case of the metropolitan area of Seoul, the primary air pollutants such as SO2, and CO have decreased remarkably since last 10 years. However, the trend of the secondary air pollutants such as NO2, PM10, and O3 has continued to increase. (Seoul Metropolitan Government 2002) One of the studies finds that 67.8% of total air pollutants in the metropolitan area of Seoul are emitted from the transport sector alone and the 45% of NOx emissions, 68% of PM and 82% of CO emissions come from this sector. (Kyunggi Development Institute, 2002; myungji univ., 2002)

The MoE of ROK considers the air quality in this area very seriously and has realized that it is difficult for existing environmental policies and measures to mitigate air pollutions. To respond this challenge, the MoE of ROK enacted the Special Act on Metropolitan Air Quality Improvement in December 2003. That will be effective from January 2005.

One of area touched in this Special Act is to allow the diesel passenger cars in Korea. Before this Special Act, the MoE of ROK has been very firm to maintain the very high level of emission standards for the diesel passenger cars, which was technically almost impossible with prevailing technology (CO: 0.5g/km, NOx: below 0.02g/km, PM: below 0.01g/km)(Korea Environment Institute, 2002). As a result, such high emission standards played the major role in creating market barriers for the diesel passenger cars in Korea. The economic issues related to the diesel passenger cars such as technology development, export, auto-industry's international competitiveness, environmental concerns, relative energy price system (gasoline versus diesel), the conflicts of interested groups have emerged in recent days with this Special Act. The environmental NGOs finally have agreed that the sales of diesel passenger cars in the metropolitan area of Seoul could be allowed on the condition that this decision would not deteriorate the existing air quality in this area, and the reasonable emission standards such as EURO-3 or EURO-4 on the diesel passenger cars would be set in due course. (Jang, 2004)

The Special Act has clear target of the air quality in the metropolitan area of Seoul to follow in line with those in major cities in developed countries within 10 years. It is necessary to examine the feasibility of this target with quantitative analysis. At the same time, the reduction of GHG emissions is another emerging global environmental concern. On February 16, 2005, the Kyoto Protocol has entered into force and therefore, the local and global environmental policy integration has become important issue. Accordingly, we analyze the air pollutions and GHG emissions from the transport sector in the metropolitan Seoul, based on several scenarios with detailed technology data in this paper. In section 2 of this paper, we briefly describe the structure and data of AIM (Asia-Pacific Integrated Model for Evaluating Policy Options to Reduce GHG Emission and Global Warming Impacts) model. In section 3, we set up scenarios up to 2030 and explain the simulation results for those scenarios. Section 4 presents the concluding remarks and policy implications.

2. Model Structure and Data

In this paper, we use AIM Local model for the analyzing air pollutions related measures in the metropolitan area of Seoul. To assess the future energy and emission projection from the transport sector, the energy service structures in this sector are examined in details.[5]

The AIM Local model is based on the AIM/Enduse model; the structure of AIM/Endue model is presented in Figure 1.

5 The AIM/Local model follows the approach of linear programming to find an optimal solution by selecting a combination of technologies with the least cost while satisfying the given constraints of fulfilling the demand and meeting the environmental targets and/or energy supply constraints in the specific region (AIM project team, 2002)

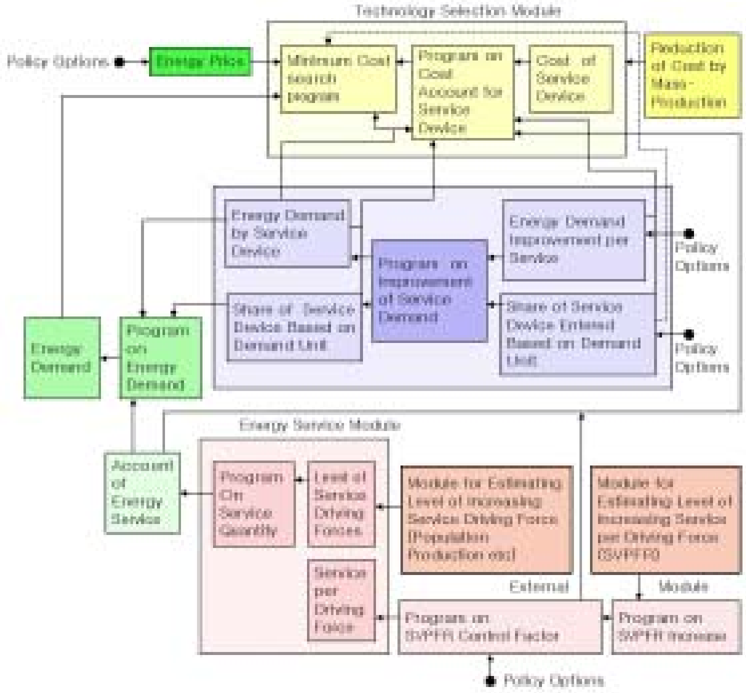

Figure 1. AIM/Enduse: Structure of Energy Demand System

Source: Morita, T., Y. Matsuoka, M. Kainuma, K. Kai, H. Harasawa and D. K. Lee, 1994, Asian-Pacific Integrated Model for Evaluating Policy Options to Reduce Greenhouse Gas Emissions and Global Warming Impacts, p.4

AIM/Endues model is a "bottom-up" model where the energy efficiency improvement is analyzed by introducing various energy-saving technologies. The substitutions among various technologies are taking place according to the changes of energy price that this model can address. Therefore, a detailed assessment of different air pollutants and CO_2 abatement measures and technology selection can be carried out using this model. This model combines the technology selection module with the energy demand module and it can simulate the energy-saving mechanism and resulting CO_2 abatement mechanism by making assumptions on energy service demand and energy-saving technologies. This model requests to derive relationships among the energy-saving technology selection, energy efficiency improvement, energy service demand, socio-economic variables, the amounts of energy consumption and various emissions. Essentially, it constitutes 3 modules. The first module deals with the energy service. For example, in case of the transport sector, it estimates the amount of energy service in terms of energy service units, such as passengers distance or freight distance under given scenarios that reflect the changes of energy consumption patterns, economic activities, lifestyles or other major economic variables. The second module deals with the energy efficiency improvement, where various programs of energy efficiency improvement can be taken into accounts. The last module is the technology selection module, in which the most cost-effective technology is selected by evaluating the comparative advantages of different energy-saving technologies.

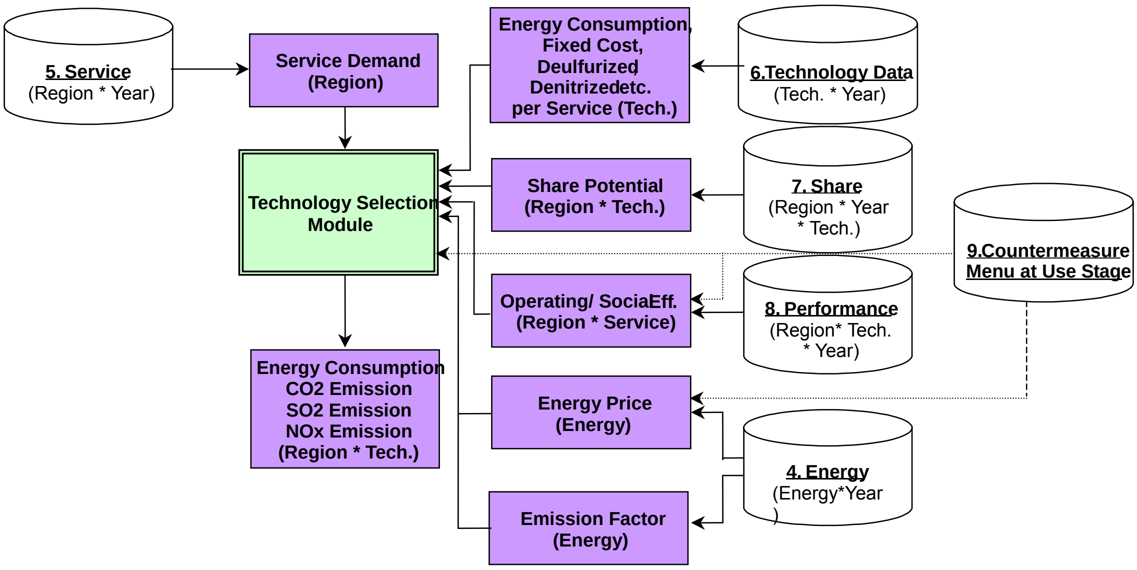

Figure 2. Structure of AIM/Local Model

Major input data for this model are energy service data, service technology data, and unit-energy consumption. For the future projection, it requires data on energy (calories) by fuel types and emission factors The energy service is defined as the physical utility by energy consumption, the unit of which depends on the types of devices that consume the energy.

In the transport sector, the energy service depends on the transport modes and such classification of mode depends on the engine size of each transport mode. In case of private passenger car, bus, and truck, the technology selection[6] is available with detailed information and data on new technologies in those transport modes.

6 One of important characteristics in AIM/local model is the availability of technology selection. The important criterion of technology selection is whether one technology used now is to be replaced by a new technology or not. Once the lifetime of a device is finished, people should decide whether a new device with an energy efficient technology, which is usually expensive will be purchased or a conventional one with old technology will be purchased. In the model, the sum of initial fixed cost of a new device and maintenance cost is compared for the technology selection.

Service technology in the transport sector deals with the data on fuel type, price, lifetime, service-requirement, and unit-energy consumption. Price is defined here as the average price of introducing a new service technology and lifetime is defined as an average lifetime of each service technology. Service-requirement means the amount of energy that each specific technology provides a service to some units or within some ranges. Unit-energy consumption implies here the amount of energy consumed for the service-requirement The types of representative vehicles are selected based on the sales of such vehicles at the base year and in previous years. Service technologies are classified as conventional, new types of passenger cars, electric cars, fuelcell car, diesel car, gasoline hybrid car and CNG vehicles. However, due to the data and technology limitations, only conventional and new types are used in this paper except passenger cars and buses with less than 15 passengers. Unit-energy consumption is calculated based on the formula shown in equation (1) with the data on total energy consumption of each service technology, registered number of vehicles, average annual mileage of each type of vehicle, and average number of passengers (freight tonnage)

$$UE_i(t) = \frac{TE_i(t)}{VP_i(t) \times VM_i(t) \times RF_i(t)} \qquad (1)$$

where, $UE_i(t)$ is the unit of energy use by service type *i* in year *t*, $TE_i(t)$ is the total energy use by service type *i* in year *t*, $VP_i(t)$ is the registered number of vehicle by service type *i* in year *t*, VM(t) is the annual average mileage of service type *i* in year *t*, and $RF_i(t)$ is average number of passengers (or average freight tonnage) by service type *i* in year *t* in pass-km/veh-km.

Emission factors are used in this paper based on various sources. In case of CO2 emissions, emission factors from Intergovernmental Panel on Climate Change (IPCC) are used. Other emission factors for pollutants such as NOx, SO2 are obtained from the emission factor data of MoE of ROK and emission standards for the newly manufactured vehicles. The emission factors depend on the progress of technologies and the targets of fuel economy of automobiles. Hence, the future emission factors reflect the trends and plans of manufacturers and MoE of ROK that are obtained from the interviews with experts and available secondary information.

Table 1. Energy Services in Transport Sector

Service	Service Technology	Fuel Type	Technology Selection
Passenger Car	1. Light Car (below 800cc)	Gasoline and LPG	O
	2. Small Car (below 1500cc)	Gasoline and LPG	O
	3. Medium Car (1500cc ~ 2000cc)	Gasoline and LPG	O
	4. Large Car (above 2000cc)	Gasoline and LPG	O
Taxi	Private	LPG	O
	Company	LPG	O
Jeep	Jeep	Diesel	O
Bus	Less than 15 passengers	Diesel and LPG	O
	Less than 35 passengers	Diesel	O
	More than 35 passengers	Diesel	O
Train	Passenger	Diesel	X
	Freight	Diesel	X
Air	Passenger	Jet oil	X
	Freight	Jet oil	X
Freight	Less than 1 ton	Diesel and LPG	O
	Less than 5 tons	Diesel	O
	More than 5 tons	Diesel	O
Subway		Electricity	X

3. Scenario Analysis

3-1. Basic Assumptions

A. Polution

Air pollution and other emissions are the by-products of the human activities(David. 2002). To analyze the future trends of air pollutions and CO2 emissions in the metropolitan area of Seoul, the population projection is the basic assumption. The population projection of the National Bureau of Statistics, ROK (2003) is used in this paper. The important characteristic of future population projection for Korea is the saturation of the population within next two to three decades and then gradual decrease in population. According to this projection, the population of Korea will reach its peak about 50.7 million people at 2023, then gradually decrease to 44.3 million people by 2050.

We finds similar trend for Seoul. Accordingly, in 2020, the population of Seoul will be around 9.5 million people, which will reach to 9.0 million people in 2030. The population of Seoul has already started to decrease from 2002. The main reason is for this is that the prevailing migration from downtown to suburb and commuting to Seoul as living in suburb (Seoul Metropolitan Government(SMG), 2000 ; SMG, 2003). The population composition is also rapidly changing in Seoul with rising share of older people due to the longer life expectancy. Similarly, the share of infant population is decreasing, and the average number of children in a household is decreasing as more females have jobs, single females are increasing.

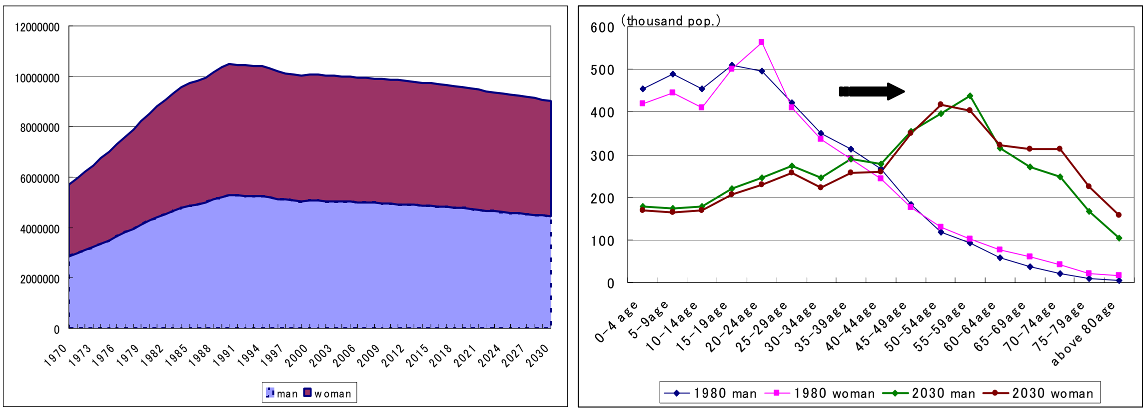

Figure 3. Population projection in Seoul (National Bureau of Statistics, ROK, 2003)

B. GRDP (Gross Regional Domestic Product)

We project GRDP for Seoul using the annual data from 1985 to 2002. Using the official regional population projection by National Bureau of Statistics, ROK, we selected the most proper model to explain the structure of regional GRDP. The Autoregressive Distributed Lag (ARDL) model is used for the projection with regressors such as population, time trend, 1998 dummy variable to reflect the financial crisis in Korea and the first order of distributed lagged variables of GRDP and population.

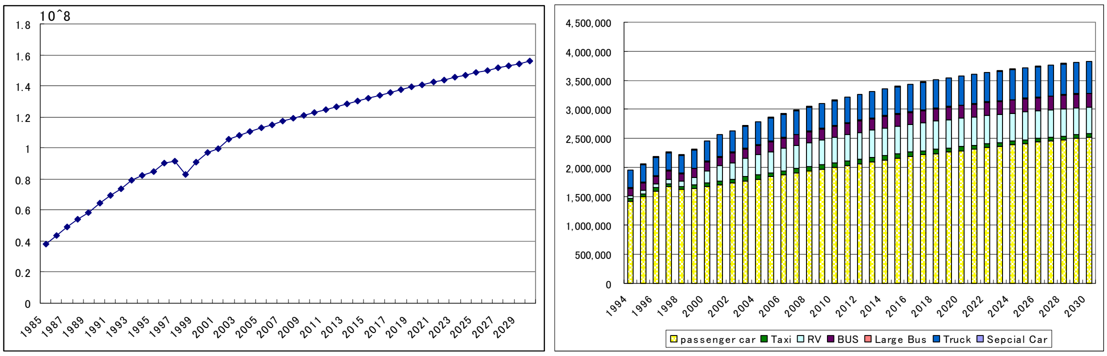

Figure 4. GRDP and Vehicle Projection in Seoul

C. Registered Number of Vehicles

We estimated the projections of vehicles by types by the regression model with Autoregressive Distributed Lag (ARDL), the regressors of which are per capita registered number of vehicle, per capita GRDP, and time trend. The projections of shares by (Types of Vehicles)×(Engine Size)×(Fuel) is estimated by Multicategory Logit Model (MLM), which can reflect the changes of market shares among competing goods. This shows that the number of registered vehicles in Seoul will almost double in 2030 from 1994, which will grow more rapidly than GRDP during the same period.

3-2. Scenario Setting

In this paper, we consider the temporal aspects of technology development of energy efficient devices and the predictability of relevant data. The base year that was chosen is 2001, considering the availability of the most updated data sets. The simulation is conducted year by year up to year 2030.[7] The following 5 scenarios are constructed to analyze impact of the environmental policies in the metropolitan Seoul area.

1) Scenario 1: (Business-As-Usual; BAU)

This scenario is based on the default data for the base year and follows past trend continues without any policy intervention. It assumes that no of variables that affect the energy consumptions, emissions.

2) Scenario 2: (BAU_IMP)

In this Scenario, the newly reinforced emission standards for vehicles are applied from 2006 over the BAU Scenario. MoE of ROK announced the detailed air pollution regulation on December 10, 2003. For example, EURO-4 Standard for diesel cars will be applied from 2006. The regulations in this new legislation are reflected in this scenario.

3) Scenario 3: (D10)

In Korea, it was decided to introduce diesel passenger cars after long debates and discussions. Therefore, it is necessary to analyze the impacts of the introduction of diesel passenger cars on air pollutions in the metropolitan area of Seoul. A recent study on ‘Demand Change of Passenger Vehicles due to the Introduction of Diesel Passenger Cars’ by Korean Auto Industry Research Institute shows that many consumers are willing to purchase diesel passenger cars. The preference for diesel passenger cars was increased from 61.6% to 70.6% among surveyed people. In this scenario we set the 10% market share of diesel passenger cars in 2030.

7. In Korea, Energy Census is conducted in every 3 years, the most recent one of which was done in 2001(Korea Energy Economics Institute, 2001). The detailed data and information on energy for AIM/KOREA model were obtained from this census.

4) Scenario 4: (H30)

According to the Special Act on Metropolitan Air Quality Improvement, it is necessary to promote low emission vehicles and it aims to introduce such vehicles in mandatory basis for central and local governments, public administrations and organizations with financial subsidies. In addition the auto-industry in Korea now is eager to develop new types of vehicles such as fuelcell cars, electric cars, gasoline-hybrid cars and CNG cars. Therefore, we set up 30% share of passenger cars with new technologies in 2030[8] in this Scenario.

5) Scenario 5: (D10H30)

In this Scenario, features of Scenario 3 (D10) and Scenario 4 (H30) are combined. We set both 10% of diesel passenger cars and 30% of new vehicles with advanced and new technologies in 2030 to figure out the joint effect of two scenarios in this case.

Table 2. Scenario Description

Scenario	Description
BAU	Business-As-Usual (BAU) Scenario
BAU_IMP	Scenario that the new emission standard is applied
D10	Scenario that diesel passenger cars will take 10 % shares in 2030
H30	Scenario that new advanced technology vehicles will take 30% shares in 2030
D10H30	(D10 + H30) Combined Scenario

3-3. Scenario Results

The results of the 5 scenarios are presented in Figure 5. In the projection of energy use, we reflect that fuel economy of diesel passenger car is 20-30% more efficient than that of conventional gasoline passenger car, which is incorporated in the technology data. In addition, we

8 According to the new vehicle demand project by Bureau of Transport in US Department of Construction & Transport, the share of fuelcell car is 9.8%, and the share of hybrid electric car is 50.1%. The share of electric car is 5.3%, and that of CNG car is 5.0% in 2030.

also considered the trend of the improvement of fuel economy in the future. We assumed that the new type of gasoline passenger car is 10% more energy efficient than the conventional one.

The simulation outputs show that D10 Scenario can reduce 4,538 Tone of Oil Equivalent (TOE) of energy in 2030 from BAU Scenario. In case of H30 Scenario, 206,740 TOE of energy cam be reduced, compared to BAU Scenario. The combined Scenario, D10H30 shows that large amount of energy can be reduced up to 222,659TOE from BAU Scenario. This simulation result shows that the implementation of the Special Act on Metropolitan Air Quality Improvement will contribute to the energy savings, as well as reduce air pollution. In case of passenger cars, the engine efficiency will improve due to the introduction of the tighter emission standards such as EURO-4 and EURO-5 from 2005. Hence, in terms of energy use, the share of passenger cars in the transport sector was 30.7%, which will decline to 24.2% in 2030.

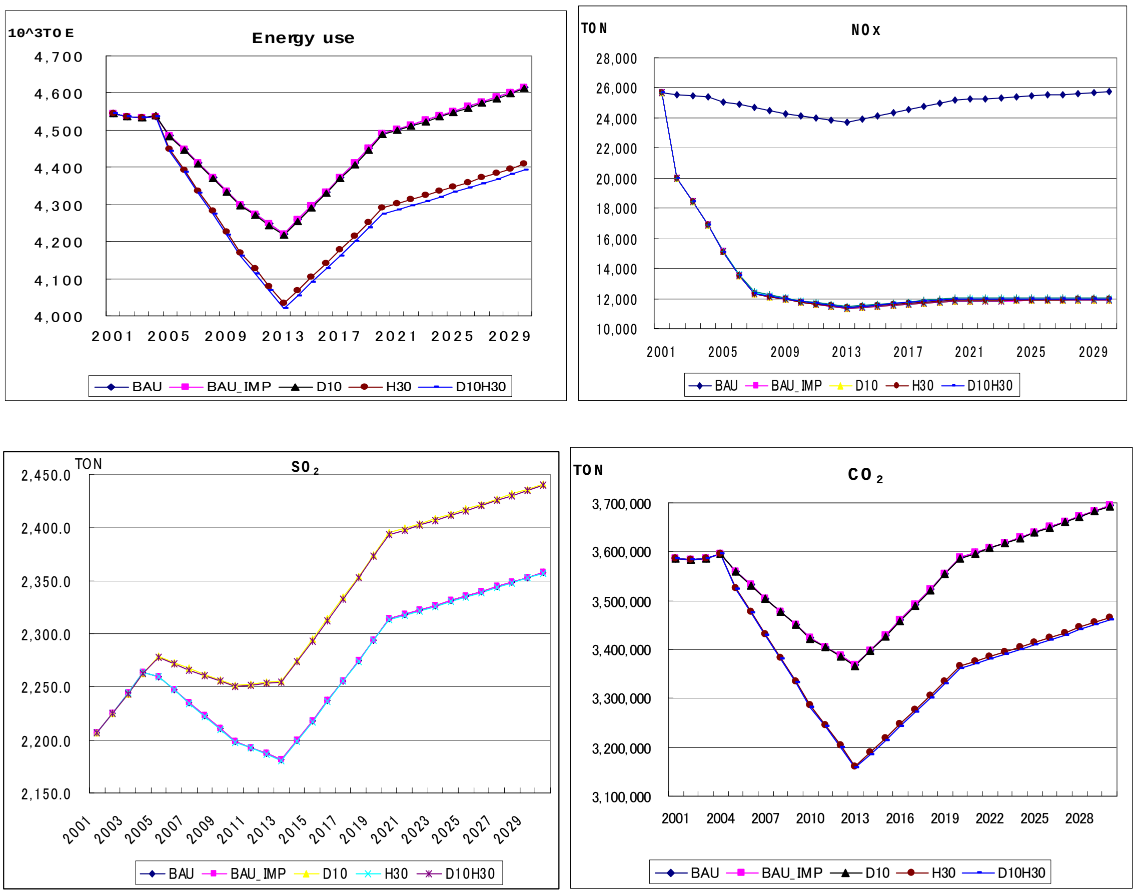

Figure 5. Energy and Emission Projects by Scenarios

In the case of NOx emissions, the maximum reductions will take place in BAU_IMP (Scenario 2) Scenarios where MOE of ROK introduces stronger emission standard. For NOx emissions, it is obvious that it will increase in the case of D10 Scenario where more diesel passenger cars are introduced in the market. If the vehicles with new advanced technologies are introduced, the effect of emission reductions depends on which types of technologies are introduced. In case of fuelcell cars, or electric cars, the emissions of air pollutants would reduce in large amount. However, we assumed that gasoline hybrid vehicle would take 50% of total vehicle with new technology in 2030, which is more realistic assumption. As a result, the potentials of NOx emission reduction with H30 Scenario are almost same as other Scenarios.

SO2 emissions will increase as diesel passenger cars are introduced. However, if new vehicles with new advanced technologies are introduced, SO2 emissions will reduce. This finding implies that environment policies to introduce lower emission vehicles through incentives and subsidies from government have potentials to offset the increase of SO2 emissions resulting from the introduction of diesel passenger cars.

In case of Scenario 2, the trends of energy efficiency improvement and other energy saving programs in the transport sector have already been reflected. Therefore, the emission reductions from other scenarios show the other impact of emission reductions without the impact of energy savings in this sector, which indicates that not much emission reduction potentials exist in other scenarios.

The current air pollution emission standards in the metropolitan area of Seoul are very high and with effective implementation of various policies and measures, which are already proposed, it is expected that the air quality in this area will improve, as well as it will effectively mitigate CO2 emissions.

In terms of CO2 emissions, the introduction of diesel passenger cars and low emission vehicles contributes to the reduction of CO2 emissions remarkably. In case of D10H30 Scenario, CO2 emissions can be reduced by 6.3% in 2030 from BAU Scenario. Hence, various policies and measures to encourage the introduction of such vehicles should be examined, including some incentive programs for the technology development of such vehicles. At the same time, it is very important for developing countries where the air pollution is an urgent policy priority to integrate policies and measures to tackle both local air pollution and global environmental issues such as GHG emissions. In this paper, we also found that the synergetic effect of mitigating both air pollutants and GHG emissions can be a feasible option with proper policy intervention.

4. Conclusion and Policy Implications

In this paper, we have analyzed and assessed the air pollution policies in the metropolitan area of Seoul with AIM/local model. Especially, the new legislation of the Special Act on Metropolitan Air Quality Improvement will affect the emission profiles of air pollutants in this area especially with the introduction of diesel passenger cars. Therefore, the various policy scenarios are analyzed with projections of key determinants in the transport sector in this area. With such high emission standards and other policies and measures, the introduction of new vehicle equipped with advanced technologies and energy efficiency improvement in this sector will be accelerated, that will contribute to the reduction of air pollutants and CO2 emissions.

It is worthwhile to note that the progress that has been made to create a system and programs for local residents to participate into the policy- making processes. While MoE of ROK prepared for the Special Act on Metropolitan Air Quality Improvement, MoE of ROK held many public hearings and meetings for the participations of local residents, NGO's and other stakeholders.

It is found that the environmental policies and measures would be shifted to more market-oriented approaches rather than the conventional 'command-and-control' type. For example, the structural change of energy tax system or the introduction of traffic congestion charges will make consumers to shift their behaviors and life styles to more environmentally friendly. This approach will provide an opportunity for people to choose their own transport modes, responding to the change of energy price, achieving the social welfare with minimum social cost at the same time. For example, among those diesel passenger cars to be introduced, if EURO-4 emissions standards are met, the special consumption tax on those vehicles could be reduced by 50%, which will result into 3% decrease of their retail sales price. Similarly, the energy tax system among different fuels could be reformed. Currently, the relative price ratio between gasoline and diesel is 100 versus 68. However, in the future, this gap will be reduced gradually. (by July 2005, 100 vs. 72, by July 2006, 100 vs. 78 and by July 2007, 100 vs. 85) Hence by year 2007, the price of diesel will be increased by 30% In addition, MoE of ROK will impose charges for the environmental improvement on diesel MoE of ROK tries various policies and measures, including legislation of special act, which is strong signal for the change of policy formation process and its targets and goals.

In this paper, we also find that the policy design, which will boost the research and development of advanced technologies in the transport sector with financial and tax incentives will contribute to the formulation of overall framework for environmentally sustainable society.

On February 16, 2005, the Kyoto Protocol, which is a multilateral agreement to mitigate GHG emissions has entered into force. As shown in this study, policies and measures for air pollution will work in mitigating GHG emissions by accelerating new technology development and its application. Therefore, comprehensive policy integration to handle both local and global environmental issues should be examined. Furthermore, environmental policies should be integrated into other key policies in the areas such as energy, technology and economy.

In addition, to transport sector, similar policy design is necessary for the point pollutant sources such as power plants, factories and buildings. Voluntary emission reduction programs such as SO2 emission trading programs among power utilities in US have been effective in the past. Therefore, the sound policy design is necessary to both mobile pollutant sources like transport sector and point pollutant sources.

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