B-15.1.2 An International Exchange Study for Developing AIM/KOREA Model (Final Report)

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Abstract

The AIM/KOREA Model has been developed to analyze global environmental policies with local ones in Korea. Various scenarios are considered for analyzing policy options to reduce CO_2 and SO_2 emissions. AIM/KOREA CO2 module produces preliminary simulation results for the alternative scenarios of CO_2 reduction policies in Korea. The Korean Model has been developed based on the AIM end-use model, by means of reforming sectoral module structures and parameters, changing technological lists and data, and extending transport modules in order to simulate Korean energy systems. It is estimated that 18.3 million tC (tons of carbon), 13.3% of CO_2 emissions with the BaU (Business-as-Usual) scenario, can be reduced with the carbon tax and extension of payback period in 2010.

For analyzing local air pollution, the Global 2100 and AIM/KOREA SULFUR model has been used. The former is applied to evaluate relatively macro level policy measures, and the later is applied to evaluate detailed policy measures. It is estimated that SO_2 emissions increase to 5 million tons in 2020, which correspond to about three times of the base year emissions, 1.61 million tons in 1992. In order to reduce SO_2 concentration to the current Japanese level, 0.01 ppm, it is necessary to introduce desulfurization plants together with improving energy efficiencies and replacing fuels with low sulfur contents. Policy options such as sulfur tax and proper subsidy in the steel industry and residential sectors, and the low sulfur Bunker-C option in the cement industry are fund to be very effective.

Key Words Korea, global warming, carbon dioxide, sulfur dioxide, end-use model

1. Introduction

In 1992, CO_2 emission was 77.7 million tC in Korea. Korea's CO_2 emission was the 18th largest in the world, however it is projected to be the 10th largest in the world in 2010[1]. It is urgently requested to develop socio-economic and scientific response strategies to global warming in Korea.

AIM/KOREA CO2 module produces preliminary simulation results for the alternative scenarios of CO_2 reduction policies in Korea. The Korean Model has been developed based on the AIM end-use model[2,3], by means of reforming sectoral module structures and parameters, changing technological lists and data, and extending transport modules in order to simulate Korean energy systems. It is estimated that 18.3 MtC, 13.3% of CO_2 emissions with the BaU scenario, can be reduced with the carbon tax and extension of payback period in 2010.

Local air pollution problems are also very important issues in Korea just like other developing countries. If international cooperation targeting mitigation of CO_2 emissions was linked with policy measures taken by developing countries to reduce SO_x , NO_x and other pollutant emissions, it would be clearly possible to cut the costs of environment protection and provide better life conditions of those countries. For analyzing local air pollution, the Global 2100 and AIM/KOREA SULFUR models are used. The GLOBAL 2100 model analyses the overall trend of the measures using dynamic optimization method. With the AIM/KOREA SULFUR module, the countermeasures for decreasing SO_2 emissions are studied.

2. Model and Data

The AIM emission model, which integrates the technological selection model into the end-use energy demand model[4], is modified to be adopted to the Korean case. The resulting AIM/KOREA could simulate the interrelationships among the energy-saving technology selection, energy efficiency improvement, energy service demand, their related socio-economic variables and the amounts of energy consumption and CO_2 emissions.

The AIM/KOREA CO2 model is a "bottom-up" model. The energy efficiency improvement is evaluated by introducing the various energy-saving technologies and the substitutions among the technologies, taking place according to the levels of fixed costs and energy prices, are analyzed. Therefore, detailed evaluation of different CO_2 abatement options are possible in the model. Also, future energy efficiency improvement can be predicted since the technology selection behavior is integrated into the end-use energy demand model. Furthermore, this model could be extended to analyze the regional or global cases since it can be easily linked to the AIM/WORLD model. AIM/KOREA can be integrated into the "top-down" model at the final stage of modeling and the prices of technologies and the structure of the changes of energy consumption patterns are determined endogenously within the integrated model.

For analyzing local air pollution, the Global 2100 and AIM/KOREA SULFUR models are used. National Institute for Environmental Studies in Japan revised parts of Global 2100 model of Manne & Richels[5], which is adapted to Korea and used in this study. The Global 2100, which is a dynamic optimization model is effective for analyzing the restrictive factors against various policies and proposing and designing policies. Using this model, it is able to assess SO_2 measures in macro economic levels in Korea. Especially, this model makes it possible to assess investments on equipment for desulfurization, fuels with low sulfur, energy saving and changes in production processes. Also, SO_2 increase scenarios caused by economic development and growth of population and energy consumption, and a scenario reducing SO_2 concentration to 0.01 ppm, which is the Japanese standard, are studied.

The AIM/KOREA SULFUR model, revised for assessing SO_2 countermeasures in Korea was used for analyses. The AIM/KOREA SULFUR model can reflect mechanisms of energy saving and fuel substitution on the premise of setting up such detailed conditions as energy effectiveness of relevant technologies, possibilities of fuel substitution, final energy consumption, energy prices, SO_2 emission coefficients, SO_2 emissions, fixed costs, etc. The sectors to be analyzed are the steel and cement industries and the residential sector. In this study, however, we excluded desulfurization facilities from the lists of technology selection. A SO_2 emission coefficient corresponding to desulfurization was given exogenously, assuming desulfurization facilities would be installed to reach the level of the current Japanese standard.

Both models take 1992 as the base year. Global 2100 model simulates every 2 years and AIM/KOREA SULFUR model does every year up to 2020.

3. Simulation Results

3.1 Simulation Results with AIM/KOREA CO2 Model

(1) Steel industry

In the steel industry, CO_2 emissions in 1990 was 9.2 million tC, which shared 41% of those in total manufacturing industries and 16.2% of total CO_2 emissions in Korea. Three scenarios are studied. The first assumes that there would be no technological change. The second scenario assumes technological changes and the third assumes introduction of carbon tax from 1996. CO_2 emissions in 2010 with the first two scenarios would be 27.0 MtC, which is three times larger than that in 1990. The result with 20,000 Won (about 2,600 Yen) carbon tax is the same with the BaU scenario. With 200,000 Won (about 26,000 Yen) carbon tax, 0.3 MtC would be reduced in 2010.

Figure 1 shows future CO_2 emissions in the steel industry with the BaU scenario and the $400 carbon tax scenario. It is very difficult to reduce CO_2 emissions, as long as the shares of electric furnace and integrated steel mills are not changed. The only way is to reduce steel production itself, but this is not acceptable, considering the economic impact on this industry. However, if new technologies such as COREX, are utilized, it becomes possible to reduce CO_2 emissions in the steel industry. Also, efficiency improvements in each process and increasing the amount of recycling can reduce the overall CO_2 emissions in this industry.

(2) Residential sector

In the residential sector, CO_2 emission in 1990 was 14.4 MtC, which shared about 25.6 % of the total CO_2 emission in Korea. In this sector, it is found that there are many possibilities to save energy. The pattern of energy usage in this sector, heavily depends on the weather conditions in winter and summer. The main sources of energy demand in this sector are heating and hot water. Also energy efficiency improvements in lighting and other home appliances are recommended. Since the marginal costs of reducing CO_2 emissions in this sector are relatively low, compared with other options in other sectors, it is concluded that we can program feasible mitigating options in this sector. Therefore, policy measures, such as an energy labeling system, rebates, and other incentives to encourage energy saving are recommend. Another scenario assumes that the payback period for energy efficient appliances is extended to a maximum of 20 years with personal financial burdens reduced by the use of soft loans. As a result, as shown in Figure 2, it might be possible to stabilize CO_2 emissions in 2010 at the 1990 level.

(3) Transportation sector

In the transportation sector, the demand for vehicles, especially passenger cars, has increased rapidly, as per capita income has increased. It is projected that the saturation of the passenger car market will occur around 2010. Therefore, fuel substitution from carbon intensive to less intensive fuels is an important option. This option depends on how much subsidy can be used for the fixed cost of new technologies, such as hybrid and CNG cars. Policy options, such as driving restrictions, toll systems and energy price increases are considered and some of which are already implemented. Also the secondary benefits of reducing CO_2 emissions in this sector are important, since by reducing CO_2 emissions, we improve air quality, reduce congestion, and lower social costs. For example, if the driving restriction system (prohibition of driving on the days when the last digit of the vehicle license plate is the same as that of the date) is implemented nationally, then total CO_2 emission in 2010 could be reduced by 12.6% (Figure 3) while 4% reduction is possible if the system is implemented only in Seoul.

3.2 Simulation Results with Global 2100 Model

The SO_2 emissions in Korea was 1.61 million tons in 1992. The simulation set up 0.8% and 1.0% of autonomous energy efficiency improvement (AEEI) with 0.5% AEEI as the base

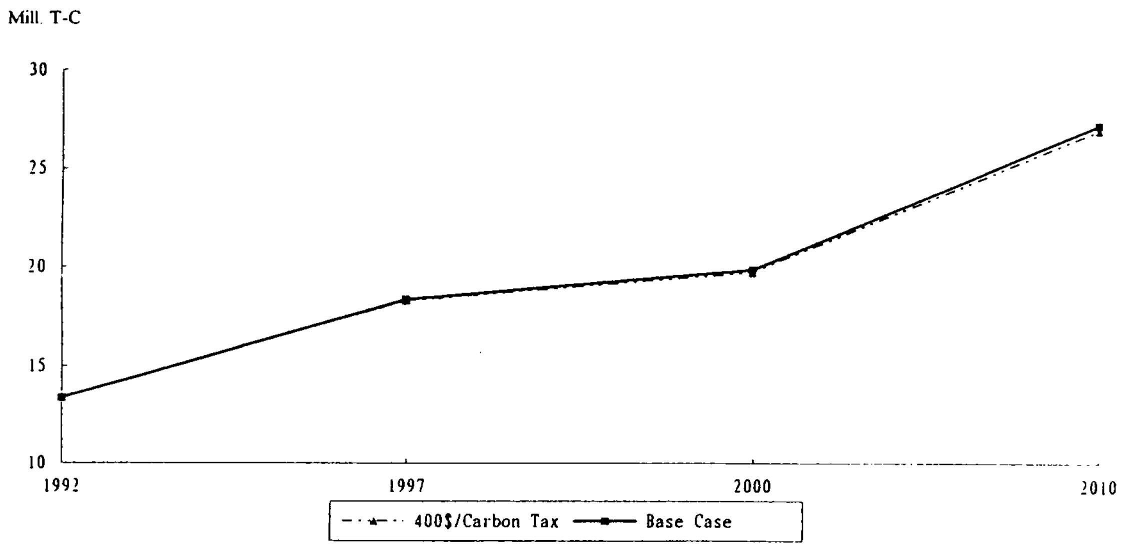

Fig. 1 CO_2 emissions based on carbon tax in the steel industry.

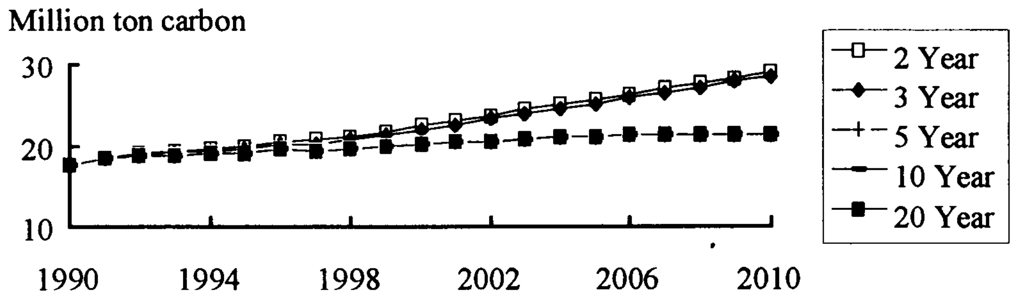

Fig. 2 CO_2 emissions base on payback periods in the residential sector.

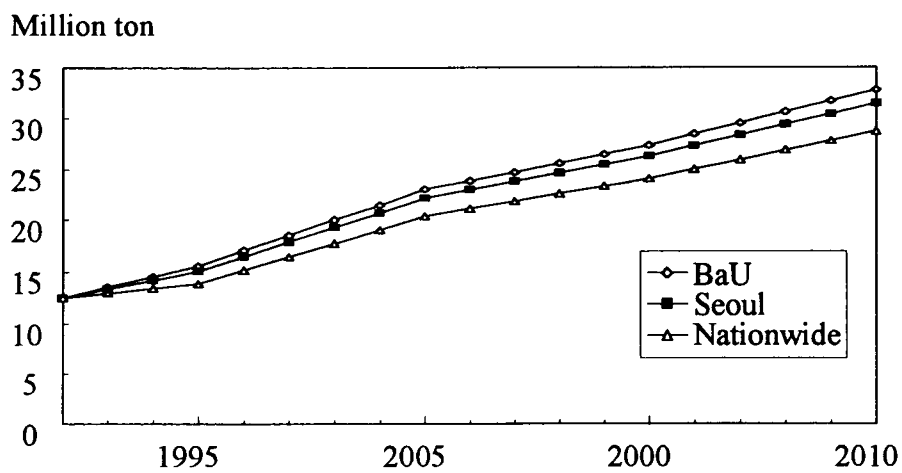

Fig. 3 CO_2 emissions based on effects of the driving restriction systems in the transportation sector.

case. Two cases are studies for SO_2 concentration; SO_2 increase and decrease cases. SO_2 emissions increase due to the increase of energy consumption with economic development and SO_2 emissions decrease to 0.44 million tons so that its concentration will decrease to 0.01 ppm. In addition, for the costs of desulfurization facilities, the scenarios of $500 and $1,000 per one ton of SO_2 reduction are used.

As a result, with fuel substitution only, it is not possible to reduce SO_2 concentration to 0.01 ppm, and the introduction of desulfurization facilities is necessary. Furthermore, even if the introduction of desulfurization facilities is delayed, the policy goal of Ministry of Environment, 0.44 million tons emissions, might be attained by year 2012 if almost all fuels would be substituted by natural gas.

3.3 Results from simulations in AIM/KOREA SULFUR Model

(1) Steel industry

The SO_2 emissions was 252 thousand tons in the steel industry sector in 1992, which was 32% of that of the whole industry sector and 16% of the total SO_2 emissions in Korea. The simulation set up 5 scenarios which are BaU scenario, scenario of sulfur tax and subsidiary introduction, scenario of electric arc increment, scenario of technology selection for independent electric power, and scenario introducing the desulfurization facilities (Figure 4).

With the BaU scenario, SO_2 emission increases to 586 thousand tons until year 2020, which is 2.3 times as much as that of 1992. Such a high increase happens because of huge amounts of steel productions. With the sulfur tax scenario, 100 thousand Won (approximately 13 thousand Yen) tax is used referring to the current tax of Norway and Sweden. No effect was appeared with the sulfur tax alone, however when the sulfur tax revenues were used as subsidiary resources for the SO_2 emissions, 51 thousand tons would be decreased as much as 8.7% of the BaU scenario. Also with the increment of electric arc furnace and the selection of independent electric power technology, it diminished respectively six thousand tons and 96 thousand tons in 2020. In addition, with introduction of desulfurization facilities as much as the Japanese level, it showed that the SO_2 emissions in 2020 reaches 59 thousand tons, one tenth of that of the BaU scenario. This SO_2 emission is equivalent to 23% of the total SO_2 emissions in 1992.

From these results, the measures such as introduction of energy saving devices and fuel substitution to reduce SO_2 in the steel industry sector, is plausible. In order to lower SO_2 emissions as little as those of Japan, it requires to import desulfurization facilities. This is because considerably many energy saving devices have already been installed in the steel manufacturing processes in Korean and there are few processes and technologies where fuels would be substituted with low sulfur fuels.

(2) Cement industry

The SO_2 emissions in cement industry in 1992 was 106 thousand tons which is about 13% of SO_2 emission of total industries and about 7% of total SO_2 emissions in Korea. The simulations set up 5 scenarios which are BaU scenario, scenario of sulfur tax and subsidiary introduction, scenario of increasing blast furnace cement, scenario of using low sulfur Bunker C, and scenario of introducing the desulfurization facilities (Figure 5). The scenario of increasing blast furnace cement accelerates the market penetration of blast furnace cement to reach 18% in year 2020, which is the current share of this type in Japan. In the BaU scenario, it is expected that the share of blast furnace cement will reach 11% in year 2020. The scenario of using low sulfur Bunker C is to use Bunker C with the 1.0% sulfur contents after 1997. The current sulfur constants in Bunker C is 4%. The other scenarios are the same as in the case of the steel industry.

In the BaU scenario, SO_2 emission increases to 219 thousand tons until year 2020, which is 2.1 times as much as that of 1992. Such a high increase happens because of huge expansion of cement productions. While, the effect from levying 100 thousand Won (approximately 13 thousand Yen) for sulfur tax and sulfur tax returns subsidiary as resources for the SO_2 emissions, decrease 6 thousand tons as much as 2.7% of the BaU scenario. Also the scenario of increasing blast cement reduces SO_2 emissions by 6 thousand tons in 2020. And the scenario of using low sulfur Bunker C does SO_2 emissions by 29 thousand tons in 2020. If the introduction of desulfurization facilities reaches the current level of Japan, the SO_2 emissions in 2020 will be 23 thousand tons, which is just 10% of BaU scenario. This amounts of SO_2 emissions is only 21% of SO_2 emissions in 1992.

These results tell us that the measures such as introduction of energy saving devices and fuel substitution to reduce SO_2 emissions in cement industry sector, is somewhat possible like in the steel industry. However, in order to lower SO_2 emissions as little as those of Japan, it requires to install desulfurization facilities in this sector, too.

(3) Residential Sector

The SO_2 emissions in residential sector in 1992 was 276 thousand tons which is about 17% of total SO_2 emissions in Korea. In this sector, we also set up the following five scenarios: BaU scenario, scenario of sulfur tax, scenario of subsidiary, scenario of rapid penetration of LNG as heating sources, and scenario of introducing the desulfurization facilities (Figure 6).

In BaU scenario, SO_2 emission decreases to 251 thousand tons in year 2020, which is 10% reduction of those in 1992. Surprisingly enough, in year 2000 the SO_2 emissions in this sector will decrease to 170 thousand tons, which is, 40% reduction of that in 1992. These results with the BaU scenario are mainly due to the rapid fuel substitution from coal to cleaner energy scenario, LNG. Since this substitution rate is much higher than the rate of energy consumption in this sector, these results can be possible. If the same sulfur tax is imposed as in the industrial sector, 69 thousand tons of SO_2 emissions will be reduced, which is different results from those in industrial sectors. Since in the residential sector, the cost of introducing new technology is cheaper, compared with in industrial sectors where 100 thousand Won sulfur tax is much lower than the cost of new technology or energy. In addition, if subsidy is provided with sulfur tax, the additional three thousand tons of SO_2 emissions are reduced. In the scenario of rapid penetration of LNG that implies there will be no LNG supply constraints, the SO_2 emissions will be 222 thousand tons in 2020. If the introduction of desulfurization facilities reaches the current level of Japan, the SO_2 emissions in 2020 will be 59 thousand tons, which is just 20% of the BaU scenario. This amounts of SO_2 emissions is only 21% of SO_2 emissions in 1992. The installment of desulfurization facilities in this sector means to install these facilities at power generation plants to supply electricity with lower sulfur to each household.

From these results, to emphasize fuel substitution for the policies to reduce SO_2 emissions in this sector seems to be effective. However, the installment of desulfurization facilities can reduce more SO_2 emissions.

5. Discussion

For further studies, we will calibrate the AIM/KOREA module. More advanced and new technology options will be introduced in each sector and the effects of these options analyzed. Further investigation into the major parameters in the AIM model will be conducted to reflect conditions in Korea. Based on the improved model, more reasonable scenarios will be set up for energy saving programs in each sector in order to derive practical policy measures. To meet this goal, the study of costs, benefits and economic impacts of each policy measure will be

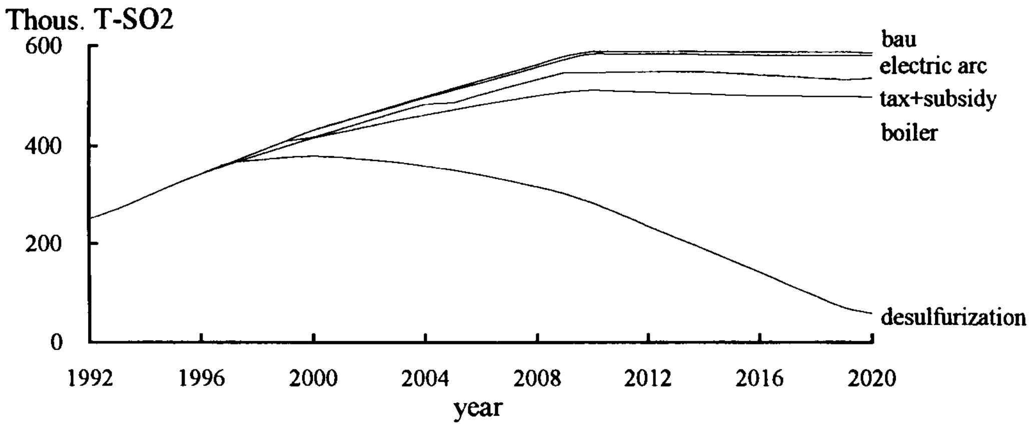

Fig. 4 SO2 emissions in the steel industry.

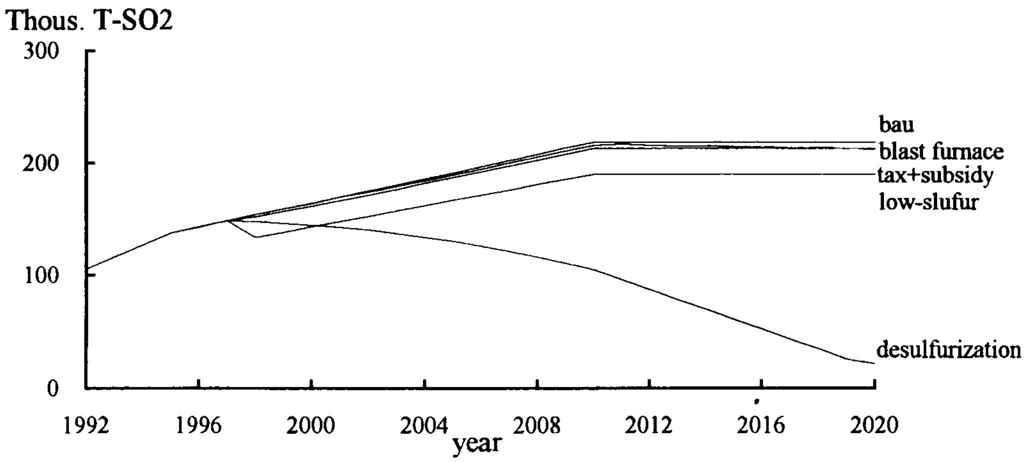

Fig. 5 SO2 emissions in the cement industry.

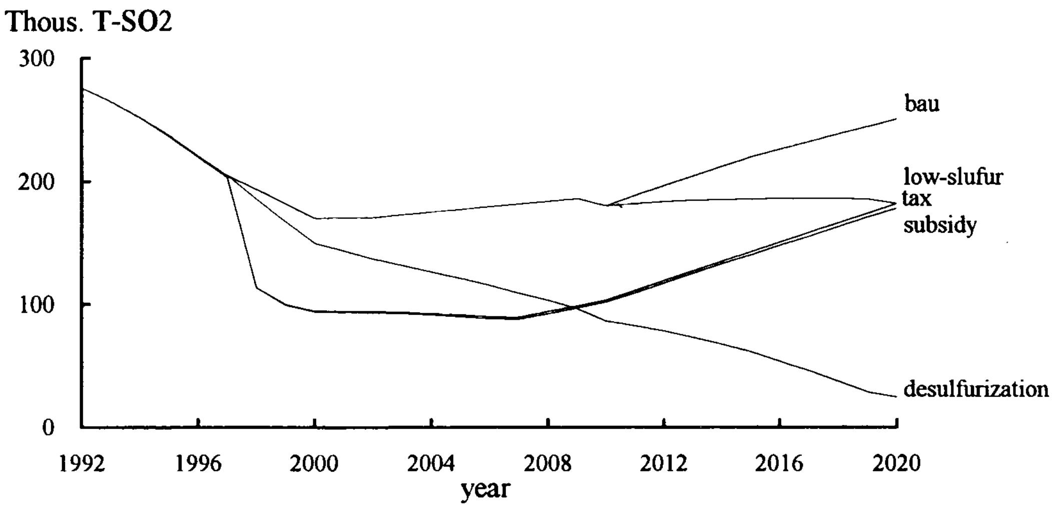

Fig. 6 SO2 emissions in the resident sector.

cautiously examined. Also, it is necessary to link the AIM model, with its bottom-up approach structure to comprehensive top-down model to integrate the overall impact of mitigating greenhouse gas emissions, within a broader policy context.

To analyze the specific measure to reduce SO_2 emissions, AIM/KOREA SULFUR Model is used for simulation. The SO_2 emission in the steel industry in 1992 was 252 thousand tons, and that in the cement industry was 106 thousand tons. The BaU scenario results show that these will be 586 thousand tons and 219 thousand tons, respectively. However, in the residential sector, SO_2 emissions in 1992 was 276 thousand tons, reducing to 251 thousand tons in 2020, due to the fuel substitution, which is 10% reduction of those in the base year.

The effects of sulfur tax and subsidy, the share increase of electric arc furnace in steel industry, the share increase of blast furnace cement industry, so on are somewhat reasonably expected, but the 0.01 ppm SO_2 concentration level can not be reached. To meet this goal, which implies that the current SO_2 emissions of 1,610 thousand tons should be reduced to 440 thousand tons, it is necessary to install desulfurization facilities.

Further researches will focus on the following topics. First of all, to incorporate the technology selection module of desulfurization facilities in AIM/KOREA SULFUR Model is necessary. Second, for the detailed analysis on the effect of lower sulfur fuels, it is needed to include energy transformation sector in AIM/KOREA SULFUR Model. Finally, we will combine AIM/KOREA CO2 and SULFUR Models to assess both policies of global warming and local air pollution.

6. References

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