

# Effect of the Seoul Metropolitan Area Air Quality Policy on the Reduction of Emissions in Mobile Sources

**Effect of the Seoul Metropolitan Area Air Quality Policy on the Reduction of Emissions in Mobile Sources**  
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**Introduction & Objectives**  
 Due to the acceleration of industrialization and urbanization, various policies are implemented for the improvement of air environment in urban country. In particular, as social interest in air quality has increased recently in Korea, various air pollution management policies have been planned, such as the Comprehensive Plan for Fine Dust Management and the Regional Management System for Fine Dust. As a result, there is a growing demand for analyzing the effectiveness of policies by accurately calculating the amount of emissions cuts caused by policies. However, in the case of road transport pollution sources, domestic research is insufficient due to the

**Emissions Reduction Effect by Policy**  
 Based on the plan for changing the basic plan for air pollution management in the metropolitan area, the amount of air pollution emissions reduction in the road transport pollution source was calculated (Figure 2). A total of seven air pollutants were targeted, including CO, NO<sub>x</sub>, SO<sub>x</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, and SO<sub>2</sub>, and the emissions reduction of CO, SO<sub>x</sub> and SO<sub>2</sub> were calculated only in two in three policies, as the overall policy evaluation effects were analyzed centering on CO, PM<sub>10</sub> and VSS. First, emissions reduction was calculated in accordance with the target vehicle type, fuel, tier and policy, and then the largest reduction with significant reduction were derived. If the vehicle subject to the policy is Tier 1, the emissions reduction was the largest among all air pollutants, with a total of 208.1 Gg for CO, 7.2 Gg for PM<sub>10</sub> and 3.2 Gg for SO<sub>2</sub> from 2021 to 2024. Next, NO<sub>x</sub>, PM<sub>2.5</sub> and SO<sub>2</sub> were respectively not calculated as the second highest reduction in the CO2 pollution vehicle operation restriction, DPP amendment and hybrid vehicle supply policies, and a total of 40,750 Gg, 2,360 Gg and 4,320 Gg were reduced. In other words, it can be

**Emissions Reduction Effect by Case**  
 The results of comparing the total emissions reduction by scenario are as follows (Figure 3). Scenario C has the largest reduction in all air pollutants and Scenario A has the lowest reduction. For the policy period of 2021-2024, CO<sub>2</sub> 15,300 Gg in Scenario A, 81,300 Gg in Scenario B, and 380,500 Gg in Scenario C were expected to reduce emissions by 6% higher than Scenario A, 20% higher than Scenario C and 20% higher than Scenario B. For PM<sub>10</sub>, emissions of 2,100 Gg in Scenario A, 3,200 Gg in Scenario B, and 3,820 Gg in Scenario C were observed to be reduced by 23% compared to Scenario A, 23% lower in Scenario C and 11% higher than Scenario B. Finally, VSS was expected to reduce emissions by 2,800 Gg in Scenario A, 3,800 Gg in Scenario B, and 5,320 Gg in Scenario C. That is, scenario B is expected to be 32% higher than scenario A, and scenario C is expected to be 32% higher than scenario B and 15% higher than scenario A. This suggests that the application of the policy from the transport vehicles over the multi-year has a significant reduction effect, and indicates the need to consider extending the old vehicles to Euro 5.

**Summary & Future Works**  
 This study analyzed the effect of reducing emissions of road transport pollutants in the Seoul metropolitan area due to the application of air quality policy. In the case of the effect of reducing emissions by policy overall, the amount of emissions cuts in policies to strengthen the management of emissions of vehicles in operation was high. Among them, from 2021 to 2024, CO<sub>2</sub> (Euro 1 target) to Euro 5 (Euro 4 target) CO<sub>2</sub> was calculated to have the highest emissions reduction, while PM<sub>10</sub> was 1.1 (Euro 1 target) to 1.8 (Euro 4 target) CO<sub>2</sub> and VSS was estimated to be 3.4 (Euro 1 target) to 5.1 (Euro 4 target) CO<sub>2</sub>. In addition, the difference in total emissions cuts from 2021 to 2024 was not 2300 Gg for CO<sub>2</sub>, 200 Gg for PM<sub>10</sub> and 120 Gg for VSS when the vehicle policy was Euro 2 model year and Euro 4 model year, suggesting that consideration of the vehicle model year.

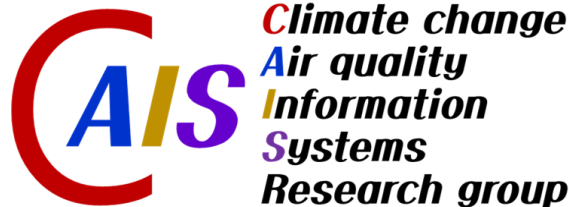
**Data & Methodology**  
 In this study the method for calculating emissions reduction in the road transport sector that is strengthened air quality policy was reconstructed by increasing the emissions calculation logic from (MIRA) scenarios for the (MIRA) (Emission Cut, and Air Pollution Interaction, and (Spring)) Activity Emission factor, Plate parameter, and Control efficiency were used to calculate the amount of air pollution emissions reduction, and the overall methodology is as follows.

**Reference**

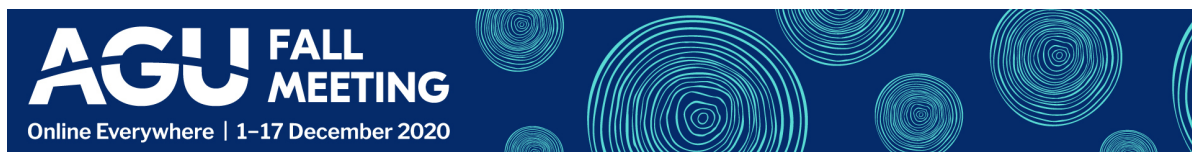
ABSTRACT CONTACT AUTHOR PRINT GET POSTER

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PRESENTED AT:



# I . INTRODUCTION & OBJECTIVES

As the amount of air pollutant emissions increased due to the acceleration of industrialization and urbanization, various policies are implemented for the improvement of the air quality in South Korea. As social interest in high PM<sub>2.5</sub> concentration has been increased, more stringent air pollution management policies have been implemented, such as the Comprehensive Plan for Fine Particle Management and the Seasonal Policy for Fine Particle Management. As a result, there is a growing demands for analyzing the effectiveness of policy measures by accurately estimating the amounts of emission reduction. The emissions reduction estimation, however, have not been estimated accurately due to the complexity of activity data, high uncertainty of emission factors, and/or limited control technology application information, especially in Seoul Metropolitan Area(SMA), the capitol region of South Korea.

The Seoul Metropolitan Area(SMA) is an area where air pollution and human damage are aggravated due to high population density. Currently, the total population of South Korea is about 52 million, with the SMA's total population of 26 million, accounting for 50 percent of the nation's population. Also, the total number of cars registered in the SMA is about 11 million, accounting for 44 percent of the country. For fine particle improvement, 2.7 billion US dollars will be spent from 2015 to 2024 in the SMA, of which 75 percent will be spent on the emission control of mobile sources pollutants.

**Therefore, The purpose of this study is to:**

- Estimate the emissions reductions on mobile sources by the current fine particle improvement policy
- Analyze the effect of applying policy measures to the most polluted vehicles first
- Analyze the effects expanding the target of the early retirement policy from pre Euro-3 to pre Euro-4

## II. RESEARCH FRAMEWORK



Figure 1. Target location

: Seoul Metropolitan Area (SMA)

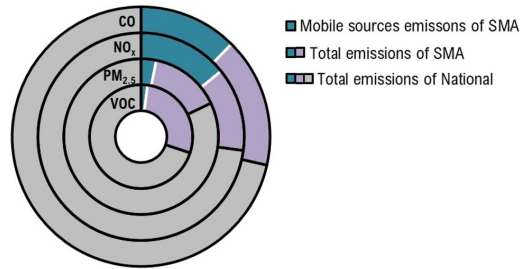


Figure 2. Mobile sources emissions ratio

As shown in Figure 1, the areas subject to this study were set as Seoul Metropolitan Area. Annual NO<sub>x</sub>, PM<sub>2.5</sub> and VOC emissions in the Seoul metropolitan area are 322.9 Gg/yr, 16.4 Gg/yr and 314.9 Gg/yr, respectively, accounting for 27%, 18%, and 30%, respectively of entire country(NIER, 2017).

In 2019, the population of the SMA is 50 percent of South Korea's total population, which are vulnerable to the air pollution induced diseases. In addition, NO<sub>x</sub> and PM<sub>2.5</sub> emitted from mobile sources accounted for 52% and 18% of the metropolitan area's emissions, which were determined to be of the highest importance to SMA air environment policy. The detail emission ratios of SMA and mobile sources are shown in Figure 2.

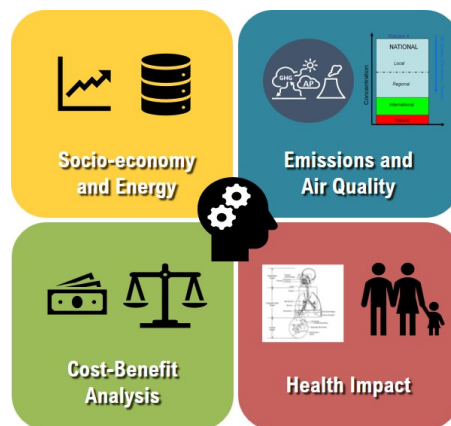


Figure 3. GUIDE / MICS-PM model

(GUIDE, GHGs and air pollutants Unified Information Design System for Environment; Woo et al., 2019) / (MICS-PM, Multi-information Convergence System for fine particle Policy Management; Woo et al., 2020)

The framework for calculating reductions by policy measures is the GUIDE / MICS-PM model, developed by this research team(Figure 3). This model was developed based on South Korean data and is an integrated management decision-making system that links the optimal energy-activity mitigation model of greenhouse gas and air pollutants, and the follow-up air pollutant reduction model based on the current air pollution policies.

### III. DATA & METHODOLOGY

In this study, the emissions reduction calculation methodologies in the GUIDE/MICS-PM framework were used to estimate emission reductions in the mobile source sector. Activity, emission factor, rule penetration, and control efficiency were used to calculate the amount of air pollutant emission reduction, and the overall methodology is as follows.

$$R_{L,F,S,P} = Em_{L,S} \times RP_{L,S,P} \times CE_{F,S,P}$$

$R_{L,F,S,P}$ : Reduction of emissions when applying P-policy to S-type vehicles with F-fuel in L-region

$Em_{L,S}$ : Emissions of S-type policy targets in the L-region

$RP_{L,S,P}$ : Rule Penetration, P-policy rule penetration for S-type vehicles with F-fuel in L-region

$CE_{F,S,P}$ : Control Efficiency, P-Policy Control Efficiency of S-type vehicles with F-fuel

Since the policies of this study are implemented between years 2015 and 2024, BAU emissions over the period were utilized for the purpose of calculating relatively accurate emissions reductions. Based on the 2015 emissions of CAPSS, the national emission inventory, the emissions were predicted until 2024, using energy and non-energy activities, such as coal/oil/gas use, industrial production, and waste. The calculation method of rule penetration and control efficiency is as shown in Table 1, and in the case of control efficiency, the calculation method of policies with and without control technology are different. The definition of reduction scenarios (i.e. cases) to be used in our analysis are shown in Table 2.

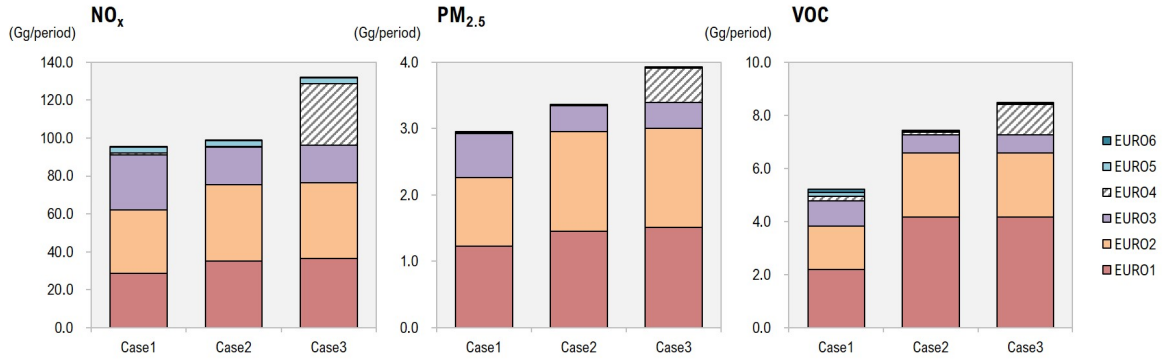
**Table 1. Calculation method by factors**

Factor	Policy type	Method of calculation
Control Efficiency	Technology-based policy	Use technology control efficiency as policy reduction efficiency
	Non-technical policy / System-based policy	$CE = 1 - (EF_c^* / EF_{uc}^{**})$ * $EF_c$ : Controlled Emission Factor ** $EF_{uc}$ : Uncontrolled Emission Factor
Rule Penetration	All policy	$RP = Em_{L,F,S}^* / Em_{L,S}^{**}$ * $Em_{L,F,S}$ : Emissions before policy application of S-type with F-fuel in L-area ** $Em_{L,S}$ : Emissions of S-type policy targets in the L-region

**Table 2. Definition of cases**

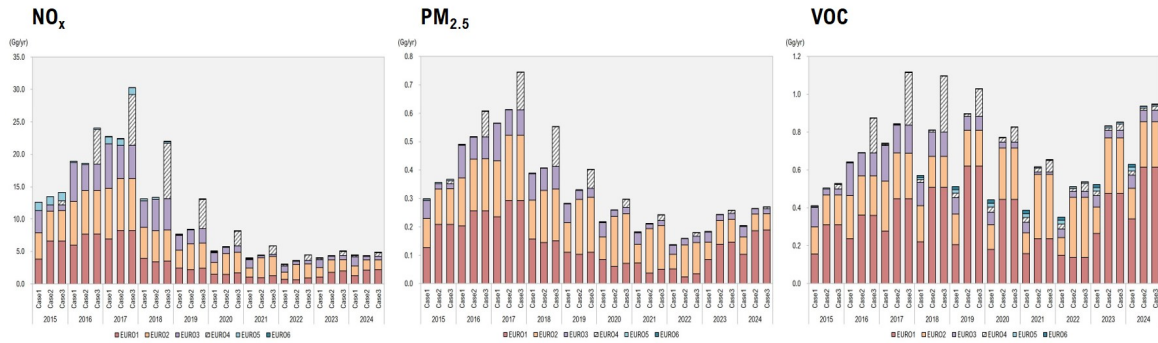
Case	Definition		
	Common application	Changing application order of policy measures	Measures to old operating vehicles
Case 1	- Based on the plan for changing the 2nd basic plan for air environment management in the Seoul metropolitan area	Equal allocation for all Euro	Euro1 ~ Euro3
Case 2	- Based on the number of registered cars of CAPSS 2015	Applying policy measures to the most polluted vehicles first(i,e, from Euro1)	Euro1 ~ Euro3
Case 3	- Preferential application from policies with large emission reductions	Same as above	Euro1 ~ Euro4

# IV. RESULTS ( I )

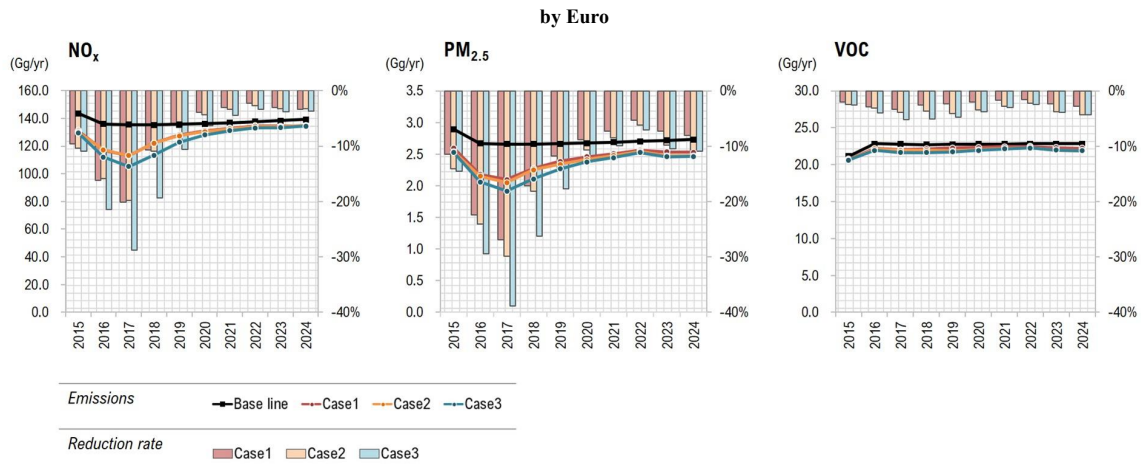


**Figure 4. Total reduction of emissions by Euro**  
(period : 2015 ~ 2024)

The total emission reductions by Euro are shown in Figure 4. In Case1, 2 and 3, NO<sub>x</sub> reduction amounts are 95.7 Gg/yr, 98.6 Gg/yr, 131.8 Gg/yr, respectively, and PM<sub>2.5</sub> decreased 2.9 Gg/yr, 3.4 Gg/yr and 3.9 Gg/yr, respectively. VOC reductions are 5.2 Gg/yr, 7.4 Gg/yr and 8.5 Gg/yr, respectively, showing the highest reduction in Case3 for all pollutants. For NO<sub>x</sub> and PM<sub>2.5</sub>, the effect of old vehicles (pre-Euro4) in operation was greater than the applying policy measures to the most polluted vehicles first policy (apply Euro1 first). This means that the measures to old vehicles in operation targeting NO<sub>x</sub> and PM<sub>2.5</sub>, including early retirement, DPF attachment, and SCR attachment, will have a significant reduction effect when extended to Euro4 vehicles, suggesting that the current policies for old vehicles need to be considered for extending to pre-Euro4. On the other hand, in the case of VOC, the reduction effect indicated that the most polluted vehicles first was greater effects. This suggests that the current policies for old cars are mainly effective to NO<sub>x</sub> and PM<sub>2.5</sub>, whereas change the most polluted vehicles first measures, such as supplying eco-friendly cars, are more effective to VOC.



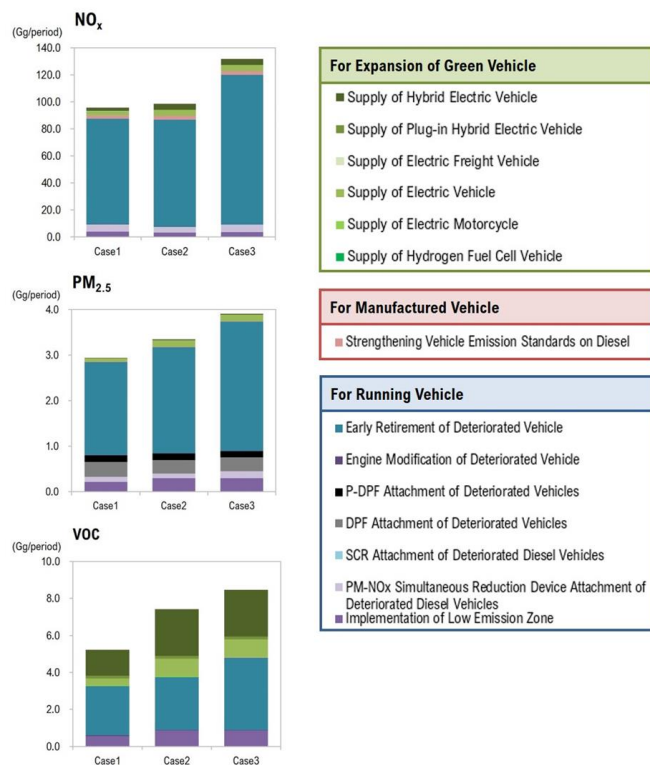
**Figure 5. Annual reduction of NO<sub>x</sub>, PM<sub>2.5</sub>, VOC**



**Figure 6. Annual emissions and annual reduction rate by Case**

The annual emission reductions and reduction rate are as follows Figure 5 and Figure 6. Overall, the 2017 reduction was the highest in all air pollutants and cases. It was judged that the policy volume was the highest in the year, and that the policy applied from 2015 had an impact. It is noteworthy that Case3, which expanded the target of old vehicles to pre-Euro4, shows a significant increase in emission reductions compared to Case2. In 2018, when the biggest difference occurs, Case3 cuts were calculated to be 65% higher for NO<sub>x</sub>, 36% higher for PM<sub>2.5</sub> and 35% higher for VOC than Case2.

## IV. RESULTS (II)



**Figure 7. Total reduction of emissions by policy**

(period : 2015 ~ 2024)

The total emission reductions by policy are shown in Figure 7. The policy of early retirement of old vehicles is the strongest policy, accounting for 81%, 80% and 84% of the reduction in NO<sub>x</sub> emissions in cases 1, 2 and 3, respectively. It also led cuts of 69%, 70% and 72% , respectively for PM<sub>2.5</sub>, and 51%, 38% and 46%, respectively for VOC. In particular, the amounts of cuts in Case3 due to early retirement policy alone increased by 40% for NO<sub>x</sub>, 22% for PM<sub>2.5</sub> and 37% for VOC compared to Case2. This is a cut-off effect that can be obtained by expanding the policy of early retirement of old vehicles to pre-Euro4, which explains the high reductions in Case3.

In addition, the reduction of Case2 with the policy volume preferential allocated from Euro1 was calculated to be higher than Case1 with the same policy volume allocated to all Euro. VOC reduction in the Case 2 was calculated to be 42% higher than Case1, and only the green vehicle expansion policy increased by 88%, which resulted in a significant reduction in VOC emissions. On the other hand, NO<sub>x</sub> and PM<sub>2.5</sub> were only 3% and 14% higher than Case1.

## V. CONCLUSION & FUTURE WORKS

In this study, we summarized our finding as follows:

- Assuming that the current policy will be applied until 2024, the total reduction rate in the SMA from 2015 to 2024 is 7% for NO<sub>x</sub>, 11% for PM<sub>2.5</sub> and 2% for VOC.
- In Case 1, where the current policy is assumed to be maintained, the NO<sub>x</sub> was reduced by 7%, PM<sub>2.5</sub> by 11%, and VOC by 2%. In addition, in case 2, where the policy was applied from the most polluted vehicles first, NO<sub>x</sub> was reduced by 7%, PM<sub>2.5</sub> by 12%, and VOC by 3%. Finally, in Case 3, which was based on Case 2, but expanded the definition of old vehicles to before Euro 4, reducing NO<sub>x</sub> 10%, PM<sub>2.5</sub> 14%, and VOC 4%, was reduced to be the most of the three cases.
- Considerations need to be made to expand the current policy measures of old vehicles from pre-Euro3 to pre-Euro4, to increase reduction amounts for PM<sub>2.5</sub> and NO<sub>x</sub>.
- Applying measures to the most polluted vehicles first method are more effective to the eco-friendly car policy which help reducing VOC emissions.

Our study has several limitation which need to be improved in the future.

- It is necessary to have the vehicle model year information to effectively implement the atmospheric environment policy
- The year-by year BAU emissions used in this study were not reflected emission reductions from the previous year. Therefore, the remaining emissions after applying reductions may have been somewhat over-calculated. Future studies will consider BAU emissions modified in accordance with reduction of previous policy measures.



# AUTHOR INFORMATION

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# ABSTRACT

The Seoul Metropolitan Area(SMA) is one of largest megacities in the world and the most important area in managing air pollution in Korea as well. Due to its densely populated cars and people, fine particle pollution in the metro area has been a big pollution issue for decades. The mobile sources have the greatest impact on air pollution in the SMA, accounting for more than 52% and 18% of annual  $\text{NO}_x$  and  $\text{PM}_{2.5}$  emissions, respectively. Various policies have been set to reduce the mobile source emissions. Stringent air quality improvement plans, such as the 'Seoul metropolitan Air quality Improvement Plan(SAIP)' and the 'Comprehensive Plan for Fine Particles Management(CPFPM)', were ambitiously set to control the emissions, including vehicle emissions. The policy measures like the early retirement of old vehicles and banning the operation for dirty vehicles were also announced. The actual ambient air pollution level, however, has not been improved much compared to the big efforts put into the anti-pollution policies. The concentration of  $\text{NO}_2$  and  $\text{PM}_{2.5}$  in Seoul was 0.032ppm and  $23\mu\text{g}/\text{m}^3$  in 2015, respectively, which remain similar level of 0.028 ppm and  $23\mu\text{g}/\text{m}^3$ , respectively, in 2018. To make substantial improvement, we first need to analyze emissions reductions from the policies and control technologies accurately, to ensure air quality policies were being implemented properly. In this study, the emission reductions for mobile sources were estimated using the proposed reduction methodologies in the SAIP to understand quantitative effects of mobile source control policies. The expected amount of emissions reduction by the policy measure was calculated by multiplying the designated BAU emissions, policy penetration rate, and the control efficiency. The emission factor, Vehicle Kilometers Traveled(VKT) and deterioration factor were also used for this process. Accurate and specific reduction estimates were derived by considering the model year of the vehicle which represents degradations and applied regulations for each vehicle. Amount of emission reduction by control measures and their impacts on the air quality will be discussed at the conference.

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