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T Assessment of the Impact of Energy Transformation Accompanying Decarbonization on 2050 Air Quality

Yusuke Yasukawa Ran Hayashi Yoshiaki Yamadaya Tazuko Morikawa Masamitsu Hayasaki Hiroyuki Yamada

Kotaro Tanaka Shinichiro Okayama Yoshiaki Shibata Hiroe Watanabe Toru Kidokoro

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Global efforts to reduce greenhouse gas emissions are accelerating. In Japan, the "7th Strategic Energy Plan" (cabinet-approved in February 2025) aims for carbon neutrality (CN) by 2050, with renewables providing 40–50% of the energy mix by 2040. Such energy transformations significantly alter the emission patterns of atmospheric pollutants. Our previous study based on the 5th Plan (80% reduction goal) predicted that achieving the 60 ppb O_3 standard by 2050 would be difficult. Since mobile sources still account for 40–60% of urban NOx emissions, evaluating shifting vehicle contributions alongside stationary source reductions is crucial.In this study, we conducted air quality simulations for 2050 based on the 7th Plan to evaluate O_3, NOx, and $PM_{2.5}$ levels, comparing them with results from the 5th Plan. Additionally, sensitivity analyses were performed to quantify the specific impact of vehicle emissions on ambient pollutant concentrations.The emission data for combustion-derived atmospheric pollutants in 2050, based on the 7th Strategic Energy Plan used in this study, were estimated under the assumption that emissions of other combustion-related pollutants change in conjunction with carbon dioxide CO_2 emissions. The pollutants estimated in this study include NOx, SOx, VOC, and $PM_{2.5}$, as well as NH3 and CO.

Fig. 1 shows the sensitivities of O_3, NOx, and $PM_{2.5}$ concentrations to vehicle emissions, respectively. Regarding O_3, positive sensitivities were observed in some cities while negative sensitivities were seen in others during the spring season. This variation is likely due to the geographical distribution of chemical regimes; urban areas are generally NOx-saturated (VOC-limited), whereas suburban areas tend to be NOx-limited. Furthermore, the significant impact of NOx emitted from vehicle exhaust on atmospheric chemistry contributes to these regional differences.For NOx concentrations, an increase was observed at many evaluation sites in the current study. Although the vehicle emission amounts were consistent with our previous study, it was initially expected that the sensitivity of NOx to vehicle emissions would decrease. However, the results showed no significant difference compared to the previous findings. As for $PM_{2.5}$, the sensitivity to vehicle emissions tended to be lower than those of O_3 and NOx in both spring and summer.

Based on our previous air quality simulations for Japan in 2050 using the 5th Strategic Energy Plan, we newly estimated emissions of various atmospheric pollutants from stationary sources according to the 7th Strategic Energy Plan. Additionally, a sensitivity analysis of vehicle exhaust emissions to ambient pollutant concentrations was performed. The results indicated that for O_3, both positive and negative sensitivities existed in various regions during the spring season under both the 5th and 7th Strategic Energy Plans. In contrast, positive sensitivities were observed in most regions during the summer. Regarding the sensitivities of NOx and $PM_{2.5}$ to vehicle emissions, no significant changes were identified between the two scenarios.

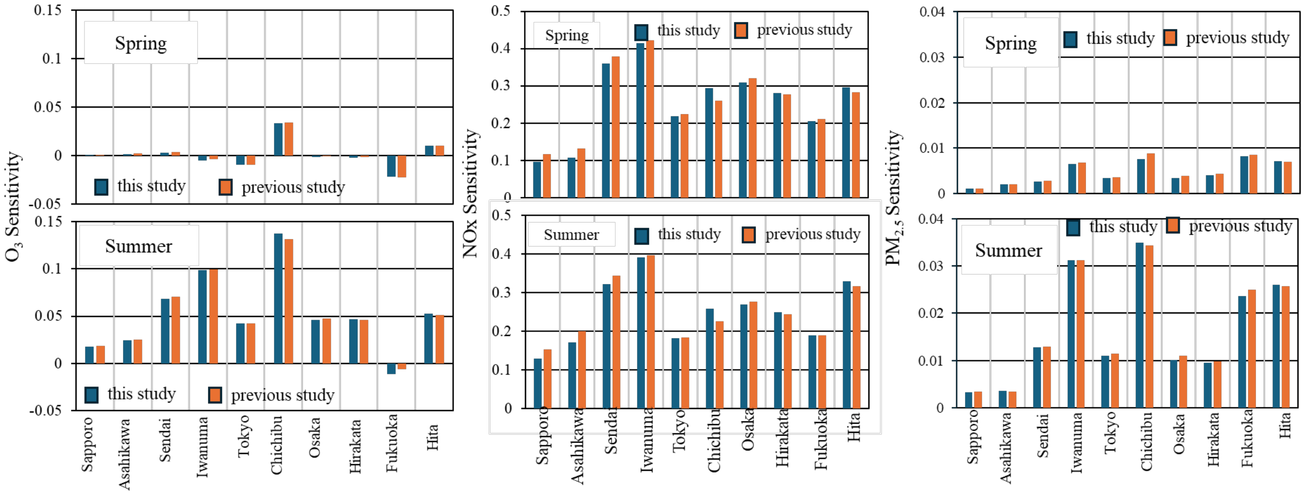

Fig1. Sensitivity of vehicle emissions for ambient O3, NOx, PM2.5 concentrations with the 5th and 7th energy plan.