

Air Qualities in 2050, What it is like, carbon neutral society?

- Impact Analysis of Automobile Tailpipe and Non-Tailpipe Emissions-

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Situations of ambient air quality in 2050 have been simulated according to National strategies published from 2018 to achieve preventing global warming. In this study, emissions from automobiles were revised according to recent estimation by the Ministry of Economy, Trade and Industry (METI), Japan, and the Japan Automobile Manufacturers Association (JAMA). Adding to estimate ambient NO_x, O₃, and PM_{2.5} situations, sensitivity analysis of exhaust and non-exhaust emissions from automobiles for those species were conducted. Specifically, the market penetration ratio of passenger Battery Electric Vehicles (BEVs) was updated from 50% in previous frameworks to 20% in accordance with JAMA's latest projections. Additionally, operational changes including road traffic flow improvements for heavy-duty diesel vehicles were incorporated, alongside updated emission factors for non-tailpipe wear sources—increasing tire wear emissions by 1.0% to reflect heavier vehicle weights while reducing brake wear emissions for BEVs by 70% due to regenerative braking. Air quality simulations were performed using the Community Multiscale Air Quality (CMAQ) modeling system ver. 5.3.2 coupled with WRF ver. 3.8.1 for spring and summer target periods in 2050.

The sensitivity analysis revealed distinct atmospheric response mechanisms across the evaluated pollutant species. For ground-level ozone (O₃), sensitivity was heavily dominated by tailpipe emissions, exhibiting high positive sensitivities across all locations during summer. This behavior is driven by enhanced biogenic volatile organic compound (BVOC) emissions under high temperatures, combined with a structural transition toward a NO_x-limited regime resulting from substantial overall reductions in NO_x emissions by 2050. In contrast, slight negative sensitivities were observed in select urban centers during spring, reflecting a weakened titration effect under a VOC-limited condition. Tailpipe emissions also overwhelmingly controlled NO_x concentrations, demonstrating strong positive sensitivities regardless of season or region. Conversely, PM_{2.5} exhibited a contrasting response: its sensitivity was overwhelmingly dominated by non-tailpipe sources (tire and brake wear), with particularly high sensitivities observed during spring and in major metropolitan areas such as Tokyo and Fukuoka.

These results indicate that effective reduction strategies in 2050 depend on the target pollutant. While reducing tailpipe emissions remains effective for O₃ and NO_x under future NO_x-limited conditions, controlling non-tailpipe wear emissions is essential for reducing PM_{2.5} concentrations.

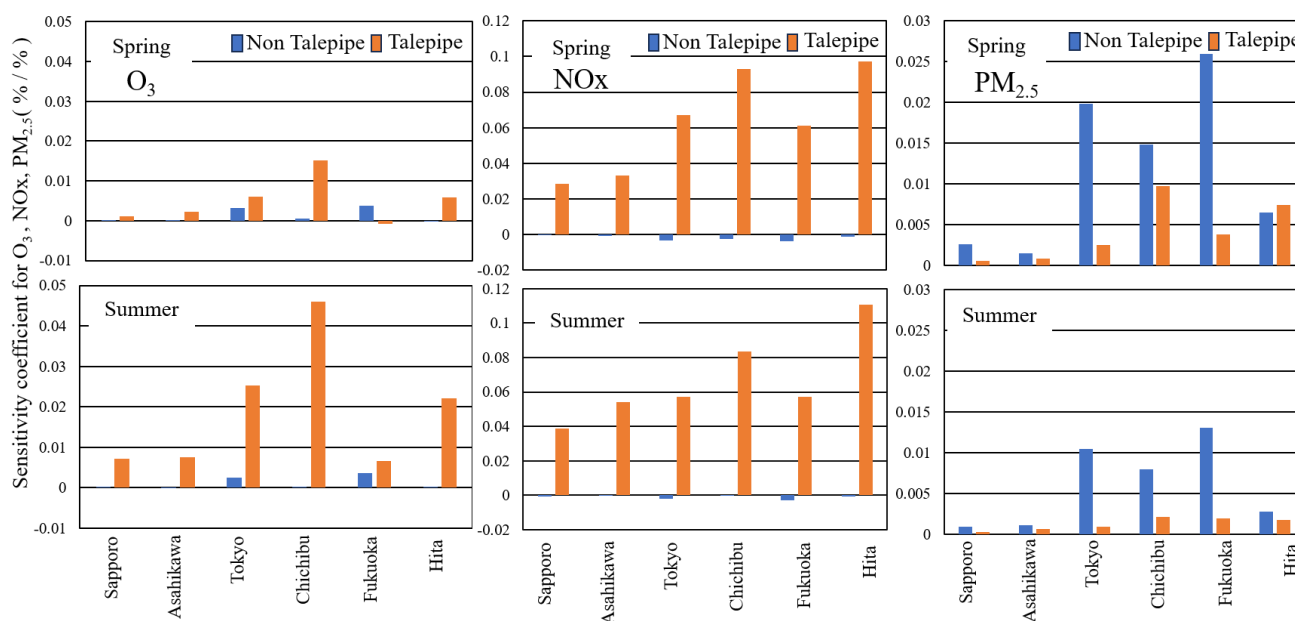


Fig1. Sensitivity of vehicle emissions for ambient O₃, NO_x, PM_{2.5} concentrations.