[*CO-BENEFITS ANALYSIS OF ROAD TRANSPORT GREENHOUSE GAS REDUCTION IN SOUTH KOREA: CENTERED ON 2030 AND 2050*]

[Myeong Jin Jang, Sookmyung Women's University, Republic of Korea, +82-10-6267-2274, galejang@sm.ac.kr]
[Yeong Jun, Yeo, Sookmyung Women's University, Republic of Korea, +82-10-8614-7732, yeoyj1207@naver.com]
[Young-Hwan Ahn, Sookmyung Women's University, Republic of Korea, +82-10-2743-2660, yh.ahn@sm.ac.kr]

Overview

The integrated management of greenhouse gases and air pollutants requires comprehensive understanding of their interconnections, particularly in the transportation sector where emissions are influenced by multiple factors such as vehicle age, temperature, and engine deterioration. This study investigates the integrated management of greenhouse gases and air pollutants in South Korea's passenger vehicle sector from 2020-2050. It analyzes emission reduction pathways under baseline and carbon neutrality scenarios, focusing on three key measures: zero-emission vehicle deployment, biodiesel mixing, and traffic demand management. The research evaluates the effects of these measures on both greenhouse gas and air pollutant emissions, quantifying their co-benefits. By assessing the interactions between these dual reduction pathways, the study provides insights for developing effective integrated management strategies that simultaneously address climate change mitigation and air quality improvement in the transportation sector.

Methods

This study utilizes METER (Model for Energy Transition and Emission Reduction), a bottom-up optimization model that simulates fuel provision for passenger, commercial, and freight vehicles. The model minimizes total costs while meeting vehicle mileage requirements and incorporating consumer preferences for realistic technology adoption projections. Two scenarios are analyzed: a baseline (BAU) scenario and a carbon neutrality scenario incorporating measures from South Korea's national plans.

For air pollutant emission calculations, the study adopts the deterioration coefficient-adjusted approach, using age-specific emission factors derived from Korea's CAPSS data. To analyze co-benefits, the study calculates cross-elasticities between greenhouse gas and air pollutant reductions for each reduction measure. This approach quantifies the synergistic effects between carbon neutrality policies and air pollution reduction, examining how different measures affect various pollutants depending on vehicle age and type, with a focus on zero-emission vehicle deployment, biodiesel mixing, and traffic demand management.

Results

Under the carbon neutrality scenario, as a result of combining three reduction measures, zero-emission vehicles (hybrid, plug-in hybrid, electric, and hydrogen) increase to approximately one-third by 2030 and nearly all vehicles by 2050. Energy demand significantly decreases from 2020 levels, with electricity and hydrogen dominating consumption by 2050. Analysis of the accumulated effects by adding reduction measures sequentially reveals that zero-emission vehicle deployment shows the largest GHG reduction potential, followed by traffic demand management and biodiesel mixing.

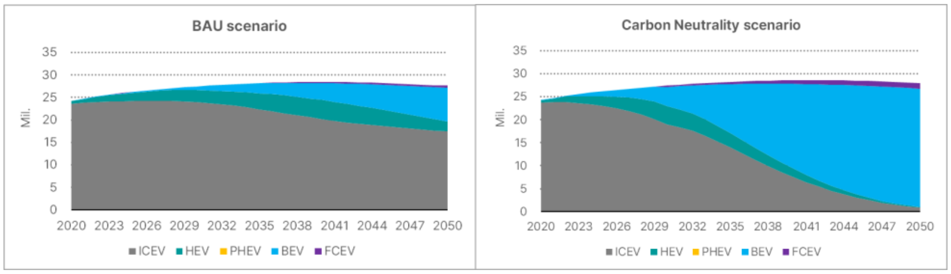

Figure 1 Vehicle Registration Composition by Scenario

Air pollutant emission patterns vary distinctly by pollutant type. CO emissions, mainly from gasoline vehicles, show stable emission factors after 2006, with significant decreases under the carbon neutrality scenario. NOx and $PM_{2.5}$ emissions, predominantly from diesel vehicles, show different patterns with emission factors gradually stabilizing at near-zero levels through strengthened emission standards, which can be attributed to the introduction of Ultra Low Emission Vehicles (ULEV) and the implementation of Euro emission regulations.

The effectiveness of reduction measures varies by pollutant type. Traffic demand management proves most effective for NOx reduction, particularly affecting older vehicles with higher emission factors, while zero-emission vehicle deployment shows highest effectiveness for CO and $PM_{2.5}$. This variation reflects the temporal impact of measures: zero-emission vehicle deployment affects future fleet composition, while traffic demand management impacts all existing vehicles, though its effect on NOx is limited due to NOx emissions' concentration in freight transport.

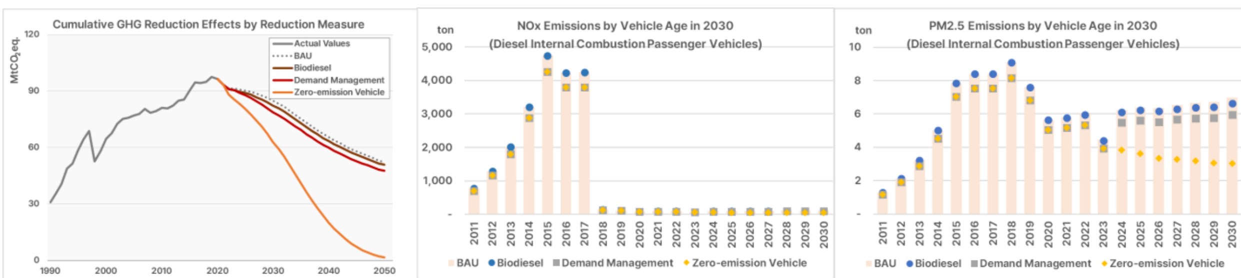

Figure 2 Figure 3 Cumulative GHG Reduction Effects by Reduction Measure (left) and Nox (center), PM2.5 (right) Emissions by Vehicle Age in 2030

Conclusions

The analysis demonstrates that co-benefits of greenhouse gas reduction policies vary across air pollutants due to differences in emission factor stabilization patterns and vehicle type distributions. The study finds that CO and $PM_{2.5}$ reductions benefit most from zero-emission vehicle deployment, as their emission factors stabilized earlier in 2010. In contrast, effective NOx mitigation requires policies targeting freight vehicles and early retirement of older vehicles, as NOx emission factors stabilized later in 2018.

By employing a bottom-up optimization model incorporating age-specific emission factors, this study identifies the most suitable management policies for each air pollutant. The findings underscore the importance of integrated management policies that account for the linkages between greenhouse gas and air pollutant emissions, considering factors such as vehicle age, temperature, and engine deterioration. These insights contribute to the development of efficient integrated policy designs that simultaneously address climate change mitigation and air quality improvement in the transportation sector.

References

Chen, W., Tang, H., He, L., Zhang, Y., & Ma, W. (2022). Co-effect assessment on regional air quality: A perspective of policies and measures with greenhouse gas reduction potential. *Science of The Total Environment*, *851*, 158119.
Jiao, J., Huang, Y., & Liao, C. (2020). Co-benefits of reducing CO2 and air pollutant emissions in the urban transport sector: A case of Guangzhou. *Energy for Sustainable Development*, *59*, 131-143.
Ou, Y., Shi, W., Smith, S. J., Ledna, C. M., West, J. J., Nolte, C. G., & Loughlin, D. H. (2018). Estimating environmental co-benefits of US low-carbon pathways using an integrated assessment model with state-level resolution. *Applied energy*, *216*, 482-493.