

Analysis of CO2 Emissions and Cost-Effectiveness in Long-Term Scenarios for the Automotive Sector

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The Japanese government has announced its goal to achieve carbon neutrality by 2050 and a 46% reduction in greenhouse gas (GHG) emissions by 2030 compared to 2013 levels. As the automotive sector accounts for approximately 20% of Japan's total GHG emissions, actionable decarbonization strategies for this sector are indispensable. Using the long-term CO₂ emission estimation model CAMPATH, developed by the Japan Automobile Research Institute (JARI), this study evaluates emission pathways and their cost-effectiveness up to 2050 in alignment with the 7th Strategic Energy Plan. We analyze four scenarios: Business as Usual (BaU), Continued Technology (CTV), and two Strategic Energy Plan scenarios—Energy Policy Technology Advance (EPA) and Energy Policy Technology Revolution (EPR). The latter two scenarios assume the phase-out of new internal combustion engine passenger car sales after 2035, combined with varying adoption rates of carbon-neutral (CN) fuels (30% in EPA and 100% in EPR by 2050).

Methodologically, CAMPATH distinguishes itself by incorporating a multinomial logit model alongside macroeconomic metrics to forecast future vehicle fleet dynamics. Rather than assuming static adoption rates, the framework dynamically calculates the market penetration of next-generation new vehicles based on evolving purchase costs, fuel efficiency improvements, and user satisfaction parameters. Additionally, the model accounts for structural shifts in mobility demand, such as the growth of e-commerce, which simultaneously alters passenger travel patterns and freight transport volumes. By capturing these behavioral and operational transformations, CAMPATH enables an integrated simulation of energy demand across different vehicle categories. This structural approach ensures that both technological advancements and evolving usage patterns are rigorously reflected in long-term emissions.

In this study, results show that by 2050, next-generation vehicle (NGV) shares in new passenger car sales will reach 54% in CTV and 100% in EPA/EPR, corresponding to in-use car shares of 48% (CTV), 96% (EPA), and 98% (EPR) due to fleet replacement time lag. In contrast, trucks transition more slowly, reaching in-use NGV shares of only 21% in CTV, 70% in EPA, and 82% in EPR, highlighting a heavy reliance on CN fuels such as biofuels and e-fuels for commercial fleet decarbonization. Tank-to-Wheel (TtW) CO₂ emissions in 2050 decrease by 21% in BaU, 57% in CTV, 80% in EPA, and 100% in EPR. However, Well-to-Wheel (WtW) and Life Cycle Assessment (LCA) reductions in EPR are limited to 86% and 71%, respectively, constrained by grid electricity emissions, synthetic fuel manufacturing processes, and battery production impacts.

A key novelty of this research lies in the quantitative integration of costs for traffic flow management and vehicle utilization optimization (such as MaaS and logistics efficiency) alongside traditional standalone vehicle costs. While higher vehicle purchase costs in EPA and EPR are offset by improved fuel efficiency—keeping total annual fuel expenses at ¥6–7 trillion compared to ¥11 trillion in BaU—integrated measures add an estimated ¥12–13 trillion annually by 2050. Cumulative clean energy vehicle (CEV) subsidies from 2020 to 2050 require up to ¥19 trillion in EPA and ¥34 trillion in EPR. Evaluating TtW CO₂ reduction relative to annual costs yields an abatement cost of approximately ¥30,000 per ton of CO₂ for standalone measures (CTV), whereas EPA and EPR range between ¥110,000 and ¥160,000 per ton when attributing the full expense of traffic management and MaaS solely to carbon reduction. Because the primary objectives of integrated traffic measures are congestion mitigation, safety enhancement, and time-value creation, evaluating these non-climate co-benefits monetarily is essential to prevent the overestimation of carbon reduction costs and to optimize total automotive policy.

Table2 Assumption of Scenarios

Scenario	BaU	CTV	EPA	EPR
Vehicle Technology Improvement	2013 Level	Advanced Fuel Efficiency		
Vehicle Line-up Number	2013 Level	MOE Assumption	EPA Assumption	EPR Assumption
BEF(2050)	0%	5%	20%	
BDF(2050)	0%	3%	20%	
e-fuel(2050)	0%		10%	80%
Traffic flow Measurement	None		Partial	ALL
Optisum Car Utilization	None		Partial	ALL

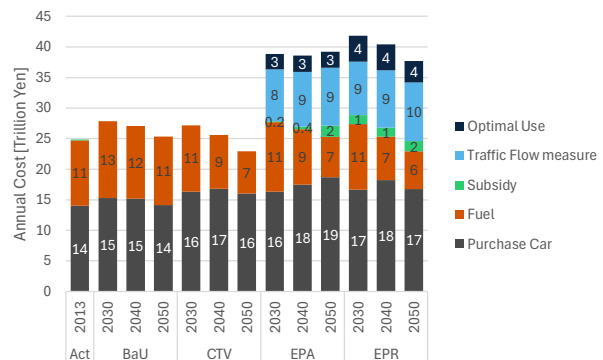


Fig.15 Annual Total Cost