**Impact of the Improvement in Electricity Grid Mix on Life Cycle Efficiency and CO2 Emissions of Automotive Fuels in Indian Context**

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# Abstract

A comprehensive Well-to-Wheel (WTW) analysis was performed to evaluate WTW energy use, efficiency & CO2 emissions for 12 vehicle/fuel configurations for a passenger sedan in the Indian context. The WTW analysis covered gasoline, diesel, and compressed natural gas (CNG) powered conventional vehicles, series hybrids, and plug-in series hybrids. In addition, the hydrogen fuel cell-powered series hybrid and its plug-in version, along with a battery-electric vehicle, were also studied. The WTW analysis was repeated for a couple of electricity generation scenarios for the year 2030 to forecast future trends. The electricity pathway showed minimum Well-to-Tank (WTT) efficiency and maximum WTT CO2 emissions among the five fuels being considered for the study for all three electricity generation scenarios. The hybridization of vehicles showed improvement in the Tank-to-Wheel (TTW) efficiency and reduction in TTW CO2 emissions. Plug-in hybrid configurations of gasoline, diesel, CNG, and hydrogen showed higher TTW efficiency and lower TTW CO2 emissions than the conventional and series hybrid configurations. Battery electric configuration showed the maximum TTW efficiency of 68.2% and was associated with zero TTW CO2 emissions. For the current electricity generation scenario, the diesel hybrid showed maximum WTW efficiency, and CNG series hybrid showed the lowest WTW CO2 emissions. With the decrease in % share of coal, increased % share of renewables, and reduction in transmission and distribution losses, there was an increase in the WTW efficiency and a decrease in WTW CO2 emissions for plug-in hybrids and battery-electric vehicles. The results of the 2030 conservative scenario lay between the current 2020 and the 2030 aggressive scenario data for most vehicles. For the 2030 aggressive scenario, plug-in hybrids and battery electric vehicles showed substantial improvement in WTW efficiency, with diesel plug-in hybrids showing maximum WTW efficiency. For the 2030 aggressive scenario, emissions of CO2 were the lowest for CNG plug-in hybrid. CNG series hybrid, diesel plug-in hybrid, and battery-electric powertrains showed the second-lowest CO2 emissions for the 2030 aggressive scenario.

**Keywords**: Well-to-Tank energy efficiency, Tank-to-Wheel energy efficiency, Well-to-Wheel energy efficiency, CO2 emissions, Scenario Analysis