Impact of the Improvement in Electricity Grid Mix on Life Cycle Efficiency and CO_2 Emissions of Automotive Fuels in Indian Context

Yash Nandola[1], Uttam Krishna[1], Santanu Pramanik[1], Himabindu M[1], Ravikrishna R V[1]

1- Department of Mechanical Engineering, Indian Institute of Science, Bangalore, India.

Abstract

A comprehensive Well-to-Wheel (WTW) analysis was performed to evaluate WTW energy use, efficiency & CO_2 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 CO_2 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 CO_2 emissions. Plug-in hybrid configurations of gasoline, diesel, CNG, and hydrogen showed higher TTW efficiency and lower TTW CO_2 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 CO_2 emissions. For the current electricity generation scenario, the diesel hybrid showed maximum WTW efficiency, and CNG series hybrid showed the lowest WTW CO_2 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 CO_2 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 CO_2 were the lowest for CNG plug-in hybrid. CNG series hybrid, diesel plug-in hybrid, and battery-electric powertrains showed the second-lowest CO_2 emissions for the 2030 aggressive scenario.

Keywords: Well-to-Tank energy efficiency, Tank-to-Wheel energy efficiency, Well-to-Wheel energy efficiency, CO_2 emissions, Scenario Analysis