Vehicle-Cycle Energy and Emission Effects of Conventional and Advanced Vehicles

Paula Moon, Andrew Burnham, and Michael Wang

Center for Transportation Research, Argonne National Laboratory

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ABSTRACT

A vehicle-cycle module of the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model has been developed at Argonne National Laboratory. The fuel-cycle GREET model has been published extensively and contains data on fuel-cycles and vehicle operation. The vehicle-cycle module evaluates the energy and emission effects of vehicle material recovery and production, vehicle component fabrication, vehicle assembly, and vehicle disposal/recycling. The addition of the vehicle-cycle module to the GREET model provides a comprehensive lifecycle-based approach to compare energy use and emissions of conventional vehicle technologies and advanced vehicle technologies such as hybrid electric vehicles and fuel cell vehicles.

Using the newly developed vehicle-cycle module, this paper evaluates on a vehicle-cycle basis the energy use, greenhouse gas emissions, and selected air pollutant emissions of a mid-size passenger car with the following powertrain systems — internal combustion engine, internal combustion engine with hybrid configuration, and fuel cell with hybrid configuration. We found that the production of materials accounts for a majority of the vehicle-cycle energy use and emissions of all the vehicles examined. The energy use and greenhouse gas emissions increase for the advanced powertrain vehicles compared to the internal combustion engine vehicles, due to the use of energy-intensive materials in the fuel cell system of the fuel cell vehicle and the increased use of aluminum in both the hybrid electric vehicle and the fuel cell vehicle. In addition, the use of materials such as aluminum and carbon fiber composites increases the energy use and greenhouse gas emissions of lightweight vehicles.

Furthermore, in order to put vehicle-cycle results into a broad perspective, the fuel-cycle GREET model is used in conjunction with the vehicle-cycle module to estimate total energy-cycle results. Materials used to reduce the weight of a vehicle help improve fuel economy, and reduce the energy use and GHG emissions of the fuel-cycle and vehicle operation stages; however, production of lightweight materials is energy-intensive compared to production of conventional materials. However, when examining energy use and emissions on the total energy-cycle basis, our simulations show that in terms of reducing total energy use and emissions, there can be a significant net benefit from substituting lightweight materials.