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## FULL LIFE CYCLE ANALYSIS OF DIFFERENT VEHICLE TECHNOLOGIES

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### ABSTRACT

The main objective is to compare energy use and CO<sub>2</sub> emissions due to the full life cycle of different vehicle technologies:

- internal combustion engine vehicles;
- hybrid electric vehicles (parallel, series, full configurations);
- fuel cell vehicles (hydrogen from electrolysis or steam reformer);
- plug-in vehicles,
- pure electric vehicles.

The life cycle includes the material cycle (material extraction, parts manufacturing, assembling, and recycling), the fuel cycle (raw fuel extraction, refining, and pump transportation), and the use cycle (affected by the driving, route topography and powertrain technology). A comparison has also been made between standard (steel) and lightweights (aluminum) materials, between three degrees of recycling (standard, none, and high), and between two types of electricity production (United States and Europe).

It is seen that the material cycle represents only a small share (around 10% to 15%) of the energy required by the vehicle's full life cycle. The most penalizing item on the material cycle is the battery component for the electric based vehicles. Full hybrid configuration has the lower full life cycle energy consumption. Plug-in vehicles are 20% more energy efficient and emit 30% less CO<sub>2</sub> than conventional gasoline vehicles. In term of cost of utilization plug-ins are 3 times cheaper however have a production cost of more \$4000, due essentially to the battery, so, depending on political incentives, can have eventually smaller over cost at the acquisition stage. The less CO<sub>2</sub> life cycle belongs to the electric vehicle, due to the high efficiency of its powertrain. Fuel cell hydrogen based vehicles are only competitive with other technologies if hydrogen is produced by a fuel reformer instead of electrolysis (renewable or nuclear instead of coal based electric grid could invert this conclusion and even increase the interest in pure electric vehicles.

**KEYWORDS:** fuel life cycle, cradle-to-grave life cycle, driving cycle, plug-in vehicles, hybrids, electric vehicles, simulation.