Vehicle Energy Efficiency

Vehicle energy efficiency (also known as vehicle fuel conversion efficiency) can be a difficult and confusing subject. First, a look at vehicle energy is helpful.

Moving Vehicles are Always Consuming or Dissipating Energy

As a vehicle is driven through a drive cycle, energy is always being dissipated. Friction and drag forces dissipate energy continuously as the vehicle moves. Also, a vehicle has minor energy use whenever it is turned on (controls, dash lights, etc.). The vehicle powertrains also dissipate energy. Even for the case of a battery electric vehicle (BEV) going downhill and charging the battery with regenerative braking, the potential energy loss is greater than the battery energy gains due to dissipative electrical losses and drag forces.

Vehicle Cycle Energy Conversion Efficiency

Vehicle energy efficiency is normally defined as the ratio of forward tractive energy required to move the vehicle over a drive cycle to the fuel energy consumed over that cycle. Forward energy refers to the effort needed to push the vehicle forward through the cycle. During portions of the cycle when brakes are applied, no forward push or effort (energy) is required and the tractive effort is zero during braking. Such efficiencies only apply to a specific drive cycle, and all differing drive cycles for a vehicle will have different efficiencies.

For a vehicle, the energy efficiency (or fuel energy conversion efficiency) for a given drive cycle is defined mathematically as,

$$\eta = E_{tr}/E_{fuel}$$

where η is the efficiency (normally expressed in %), E_{tr} is the forward tractive energy, and E_{fuel} is the energy of the fuel consumed for the cycle.

Regenerative Braking for Electrified Powertrain Vehicles

With the introduction of regenerative braking, some energy is recovered and reused instead of being dissipated as heat. The braking system literally produces electricity by using the kinetic energy of the vehicle to turn a generator (the electric motor can usually serve as the generator) which replenishes the battery.

High Cycle Efficiencies for Electric Vehicles

The electrical losses of the battery and electric motor drive train (battery-to-wheels) in electric vehicles is generally only 10%–20%. Because of the way cycle energy efficiency is defined, the efficiency can be quite high and can even exceed 100% for electric vehicles operating on certain drive cycles. An efficiency exceeding 100% means that over a drive cycle, the fuel energy used was less than the required forward tractive energy (work) to push the vehicle through the cycle. It takes a cycle with a large amount of regenerative braking to produce a value exceeding 100%.

Thomas, J. 2014. Drive Cycle Powertrain Efficiencies and Trends Derived from EPA Vehicle Dynamometer Results. SAE 2014-01-2562, https://doi.org/10.4271/2014-01-2562.

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