

# OFFICE OF TRANSPORTATION TECHNOLOGIES

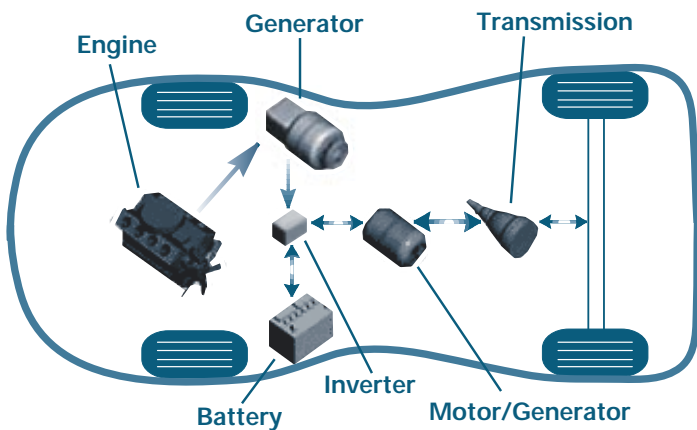
## *The Technical Background of Hybrid Electric Vehicles*

Hybrid Electric Vehicles (HEVs) combine two or more energy conversion technologies (e.g., heat engines, fuel cells, generators, or motors) with one or more energy storage technologies (e.g., fuel, batteries, ultracapacitors, or flywheels). The combination of conventional and electric propulsion systems offers the possibility of greatly reducing emissions and fuel consumption, while giving consumers both the extended range and convenient refueling they expect from a conventional vehicle. Advanced propulsion technologies are key to the success of HEVs and to the realization of these advantages.

### **How Do Conventional Heat Engines and Electric Propulsion Systems Combine?**

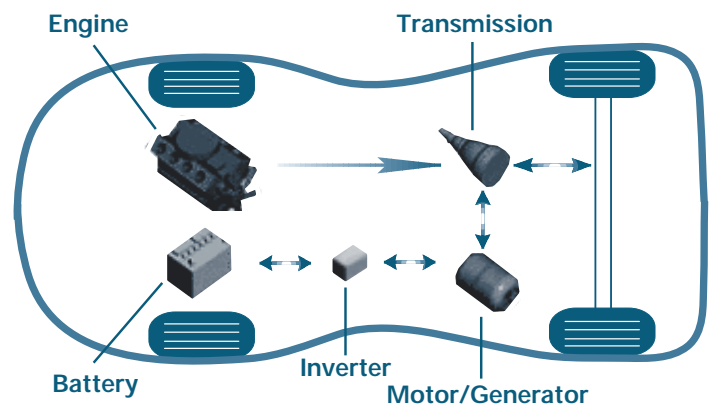
There are a number of competing and complementary technologies, which could potentially be utilized in a commercial HEV propulsion system. All HEVs require a hybrid power unit (HPU), usually a combustion engine. Candidate HPU technologies for use in an HEV include

the compression-ignition, direct-injection (CIDI); spark-ignition, direct-injection (SIDI); Stirling; or gas turbine engines. There are two basic HEV configurations: series and parallel.



### **Series Hybrid Configuration**

In a series HEV, a small fuel-burning engine directly drives an alternator to generate electricity. The electricity is then stored in the batteries or sent to the electric motor, which then powers the wheels. The vehicle can operate in zero-emissions mode, and when the batteries are drained to a certain level, the engine turns on and begins to recharge them. Since it is less dependent on the vehicle's changing power demands, the engine can operate within a narrower and more efficient range of speeds.



### **Parallel Hybrid Configuration**

A parallel HEV is configured with two power paths, so that either the HPU engine or the electric propulsion system – or both – can be used to produce the motive power to turn the wheels. In one approach, the electric-only mode can be used for short trips. For longer trips, the engine would provide primary power to the vehicle, with the electric motor assisting during hill climbs, fast acceleration, and other periods of high power demand. In such a vehicle, the engine can be downsized in relation to a similar-sized conventional vehicle, reducing weight and providing greater relative fuel economy.

## ***Various Size Configurations Trade Advantages***

Another way to classify HEVs is by the relative size of their conventional and electric propulsion systems. A power-assist HEV configuration is driven by an engine, with the electric drive system used primarily for starting or high load situations. Power-assist hybrids are generally in a parallel configuration. A dual-mode HEV configuration balances the two, with engine and battery sized to allow the vehicle to run comfortably on all electric or all engine power, or some combination of the two. A range extender HEV is essentially an electric vehicle with an on-board charging system. This capability provides additional driving range when the batteries are depleted.

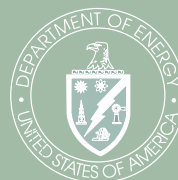
As suggested, HEVs generally have smaller engines and burn less fuel than comparable conventional vehicles. Electronic controllers manage the balance between the systems to select the most efficient mode of operation under all driving conditions. In addition, regenerative braking recaptures some of the energy lost in braking and stores it in the battery for later use, contributing to improved HEV fuel economy. The end result for the near-term is a vehicle capable of providing 100% better fuel economy than a comparable gasoline-only vehicle.

## ***Design and Operational Challenges***

The state-of-the-art is moving forward in HEV-enabling areas including high-power energy storage devices; cost-effective, high-efficiency power electronics; and fuel-efficient, low-emission engines. However, key challenges include:

- Energy storage devices (batteries) with high power-to-energy ratios to augment power for vehicle acceleration and hill climbing are not yet available. The devices must be thermally managed and have a high specific power, long life, and competitive cost.
- Frequent shut-down and start-up of the HEV heat engine complicates the management of electrical energy for propulsion systems and accessories, such as air conditioning and power steering. This requires advanced monitoring and control systems.
- Size, weight, and cost of power electronic devices must be reduced.
- Current engine-based HPU's need to convert fuel to useful power more efficiently while complying with stringent emission standards.
- More advanced mathematical models of propulsion system components (both steady state and dynamic) are needed. These will be used in computer-based simulation and analysis tools.

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