

Hybrid Electric Vehicles

HIGHLIGHTS

■ **PROCESS AND TECHNOLOGY STATUS** – A hybrid electrical vehicle (HEV) is a vehicle equipped with either an internal combustion engine (ICE) and an electrical motor powered by electrical batteries. In 1997, Toyota sold in Japan the first modern hybrid electric car, the Toyota Prius. Today's HEVs are an emerging technology in the automotive market, with manufacturers designing and producing hybrid systems for passenger cars, light-duty vehicles, heavy duty vehicles, and even locomotives. The improved efficiency of HEVs over conventional (i.e. non-hybrid) vehicle is achieved by operating a smaller (more efficient) ICE within a narrower, more efficient operational speed/power band and using an electric engine and electrical storage (i.e. the battery) to balance the performance energy requirements. In general, in the current-generation HEVs, the combustion engine provides the main power during long-distance drive while the electrical motor can either complement the ICE or power the vehicle in electric-only mode (as long as energy is available from the battery) during the urban service, where the ICE is less efficient. The battery charge is provided by regenerative braking and excess energy from the ICE (stored when the vehicle has lower power requirements). There are however different grades of hybridization and many configurations of hybrid vehicles, including micro, mild, full hybrids, with different role for the electric motor. Currently, only hybrids combining a petrol or diesel combustion engine with an electric motor are commercially available. Improving battery capacity and technology may enable longer electric drive range and reduce the need for the ICE contribution. New-generation HEVs include batteries rechargeable from the grid (known as plug-in hybrid electrical vehicles, PHEVs, see also ETSAP TB05).

■ **PERFORMANCE AND COSTS** – The hybrid vehicles can benefit from the best features of both conventional ICE vehicles and electric vehicles. Hybrids offer drive range and rapid refuelling the same as conventional vehicles, and provide high efficiency at low loads, potentially better acceleration, environmental benefits and 25-40% CO₂ emissions saving as compared to conventional vehicles [1]. The HEVs cost however is higher. This is largely due to the high price of the battery. Currently most hybrids use NiMH battery packs, although Lithium-ion is the most promising battery technology for the future. Li-ion offers better performance and much greater power density (gravimetric 120+ Wh/kg, volumetric 300 Wh/litre), compared to NiMH (~70 Wh/kg and 150+ Wh/litre respectively). Smaller and lighter battery packs are therefore possible with Li-ion (around half the size/weight of NiMH). However, further developments are needed to improve capacity and lifetime, reduce volume and costs (currently around €250-€500/kWh for NiMH and €700-€1,400/kWh for Li-ion), and to be abuse-tolerant, safe and reliable.

■ **POTENTIAL AND BARRIERS** – Costs and technical bottlenecks still restrain the full deployment of both hybrid and full electrical vehicles. Various countries such as the US, Spain and Japan have set ambitious targets for the future deployment of hybrids. These targets form a major component of national and international policies for tackling climate change. In particular, Europe is subject to an array of regulations that restrict the emissions of the automotive sector and it is anticipated that HEVs will benefit. The future deployment of hybrid vehicles essentially depends upon substantial improvements in battery technology, electric motors and power electronics. Of particular importance is battery cost reduction as the single largest incremental cost component over conventional ICEs. World-wide sales of hybrid vehicles currently account for less than 1% of all vehicle sales. However, recent research has suggested that the annual uptake of hybrid vehicles could increase by 20% in the next few years, with as much as 13% of global vehicle sales being hybrids by 2020 (and almost 20% of sales in the US).

TECHNOLOGY STATUS AND PERFORMANCE -

The first hybrid electric vehicles (HEVs) were sold in Japan in 1997 and two years later in the United States. It has taken more than ten years for HEVs to achieve 1% of the global car market, and 2.5% of the US market [3]. Nowadays, several producers offer new generations HEVs. This is largely due to the advances made in battery technology. Hybrid electric vehicles (HEVs) are powered by the combination of a conventional petrol or diesel internal combustion engine (ICE) and an electric motor with battery storage charged by regenerative braking and excess energy from the ICE (available when the vehicle has lower power requirements). There are a wide range of possible configurations for an HEV,

depending on the role and capability of the battery and the electric motor. ■ **Micro Hybrids** - This technology has a starter-generator system coupled to a conventional engine. An electric motor provides stop-start operation of the engine, plus (usually) regenerative braking to charge the battery. The electric motor does not supply additional torque when the engine is running, and the cost of this type of hybrid is comparatively low due to the use of conventional batteries and drivelines. Compared to conventional vehicles, micro hybrids return fuel savings of up to 10% in city driving [1]. They are currently only found on light vehicles, and are most suited to urban applications where they can benefit from duty cycle [6]. ■ **Mild Hybrids** - An electric motor is