FINAL REPORT

THE IMPORTANCE OF NICKEL COMPOUNDS:

HYBRID CARS

Prepared for

European Nickel Institute

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1. INTRODUCTION

The market for hybrid cars is growing strongly in response to rising fuel prices, growing awareness of their environmental benefits amongst car buyers, regulatory pressures to reduce CO2 emissions, and tax incentives and exemptions given to hybrid cars within congestion charging schemes. Growing demand is also helping to reduce the incremental cost of production.

Hybrid cars offer customers a more environmentally attractive engine system, with similar performance to traditional vehicles. They achieve this using two propulsion systems, most commonly, a conventional internal combustion engine combined with an electric motor. There are a number of different types of hybrid cars, each offering different environmental benefits.

'Micro Hybrids' provide an electric motor that performs start/stop functions at traffic lights and a limited amount of regenerative braking, but the car cannot be driven in pure electric form, nor can the electric motor provide an additional boost to the engine during hard acceleration. In a 'Mild Hybrid', electric motor cannot drive the wheels independently, but assists the combustion engine during acceleration and hill climbing. A 'Full Hybrid' can be driven in pure electric mode, pure mechanical mode or in combination.

In all Hybrid Cars, the energy storage system is one of the most important components. In Micro Hybrids, ultra-capacitors and lead-acid batteries tend to be the preferred option. In both Mild Hybrids and Full Hybrids, where there is a need for much greater battery capacity, Nickel Metal Hydride (NiMH) batteries are the batteries of choice as they offer better recharging capacity and performance and operate at higher efficiencies.

Nickel compounds are critical in the production of NiMH batteries.

2. NICKEL AND HYBRID CARS

The nickel in Nickel Metal Hydride Batteries (NiMH) is used in the construction of the positive and negative electrodes of the individual battery cells. The negative electrode is constructed of specific metallic alloys of nickel such as lanthanum nickel ($laNi_5$) or zirconium nickel ($ZrNi_2$). The positive electrode consists of a plate containing nickel hydroxide ($Ni(OH)_2$. The electrolyte solution between the electrodes is usually a dilute solution of potassium hydroxide.

The importance of nickel, rather than competing materials, is linked to the basic nickel-metal hydride technology. Hydrogen ions can be stored in metal-hydride alloys at very high volumetric densities, leading to the superior energy density of metal-hydride batteries The nickel metal alloy contained in the negative electrode is a actually a complex construction. Such complexes are extremely efficient at

absorbing and releasing hydrogen ions in very high volumes which in turn provide the resulting energy to drive the vehicle.

Nickel Metal Hydride batteries are important for hybrid cars, because they deliver specific and valued benefits to vehicle producers and users. NiMH batteries have about 30-50% more charge per pound and weigh approximately 30 percent less than a lead-acid battery (LAB). This also makes them more 'power specific' than a lead acid battery - it weighs less for the same amount of power. An additional advantage is their operational longevity. A NiMH battery lasts for 8-10 years whereas an LAB is guaranteed to only last for 2-3 years. Finally, a hybrid car only uses 10% of the rated battery capacity, allowing thousands of charge/discharge cycles which allow Nickel Metal hydride batteries to assist in delivering fuel savings and lower engine emissions.

In the automotive sector, NiMH batteries are an enabling technology for hybrid electric vehicles (HEVs). Their key technological feature is the ability to store larger amounts of electricity when compared to existing batteries. The electrode construction based on the complex nickel alloy and nickel hydroxides are critical for the performance of the batteries within hybrid vehicles.

3. IMPORTANCE OF HYBRID CARS FOR THE EU

3.1. Economic Impacts

After many years of research and development, hybrid cars are now entering the European market. Over 50,000 were sold in the EU last year and most vehicle manufacturers in Europe now have, or are about to launch, a hybrid model as part of their range.

By 2015, the market for hybrid cars is forecast to reach 4-5% of all new car sales, and by 2020 this could rise to 15% of total sales. They will increasingly form part of the standard range of products offered by all major manufacturers including European manufacturers who are the global market leaders in the production of prestige cars.

The automotive industry in Europe is a substantial contributor to EU growth, employment and wealth. Sales of new cars in the EU reached 15.4 million in 2006 (or 33% of worldwide demand). The EU produces 16.2 million cars per annum, or 32% of worldwide car production. The industry employs 2.3 million people directly and supports a further 10.3 million people indirectly. The industry constitutes over 8% of value-added in the EU's manufacturing sector and spends over Euro 20 billion on research and development each year.

Hybrid cars represent a major economic opportunity for the EU. It is estimated that sales of hybrid cars could reach 920,000 per annum by 2015. Around 600,000 of these are likely to be 'Mild and 'Full' hybrids, using NiMH batteries as the energy storage system. Sales of 'Mild and Full hybrids could therefore rise to Euro 15 billion by 2015. At the moment, many hybrids are imported as Japanese manufacturers were

the first to penetrate the market (particularly Toyota), but this is forecast to change as European manufacturers launch their own models and build sales. Going forward this means that 'Mild' and 'Full' hybrid cars could generate Gross Value Added in the EU in excess of Euro 5 billion. This reflects the gross value added created in vehicle manufacturers, in car retailers, in component and service suppliers and through induced effects in the wider economy. Moreover, Mild and Full hybrid cars could support over 80,000 jobs in the EU through-out the value-chain.

3.2. Other Impacts

Hybrid cars in general and NiMH battery technology in particular, bring a number of other benefits to Europe in terms of innovation, safety, and sustainability.

Innovation - Hybrid cars represent a major opportunity for the automotive industry and its suppliers. Most European car manufacturers have invested heavily in research and development in this area, and see it as a major growth segment in the future. Hybrid cars also offer competitive opportunities for EU component manufacturers in the electric motor, power electronics, energy management systems, braking systems, and electrical auxillaries sectors. Many EU companies are leaders in these areas, including: Continental (Germany), Valeo (France), SAFT (France), Siemens (Germany), Robert Bosch (Germany), Hella (Germany), and Ricardo (UK).

Safety – NiMH batteries currently dominate the market for Mild and Full Hybrids, and are likely to continue to do so for the foreseeable future. Some research has been undertaken to explore the potential for Lithium Ion batteries in this area. Whilst Lithium Ion offers some potential improvements in specific energy and power, it also has significant disadvantages in terms of the safety of its constituent elements (as well as cost), especially in automotive applications. Recent negative experience with lithium ion battery technology in the laptop computer sector reinforces the safety benefits of nickel technology.

Sustainability – Hybrid Cars offer substantial environmental benefits. They contribute to the reduction of CO_2 emissions and to the reduction of other pollutants such as NO_x, HC and CO. For example, the Toyota Prius (the hybrid market leader) has substantially lower CO2 emissions than its non-hybrid equivalents in the Toyota range (104 g/km compared to 159 g/km). Hybrids also offer reduced urban pollution and lower harmful exhaust emissions (such as NOx) as they enable an emission-free start of the power-train and pure electric driving options.

Hybrids also have much lower fuel consumption. A midsize Full Hybrid delivers 40-50% more fuel economy compared to a conventional vehicle. In town fuel savings are much higher than for out-of-town driving, but for the Toyota Prius, even mixed driving conditions provide significant fuel savings compared to the petrol equivalent in the range (4.3 litres/100 km compared to 6.7 litres/100 km) and over 30% savings compared to the diesel equivalent in the range (4.3 litres/100 km compared to 5.7 litres/100 km).

Hybrids can also bring noise reduction benefits, particularly in built-up areas, where the car is operating primarily in electric mode. Above all, hybrid cars offer Europeans a technology platform towards meeting environmental goals, without reliance on untested technology or the need to invest in a new fuel distribution infrastructure.

4. CONCLUSIONS

Hybrid Cars, and the NiMH battery technology upon which they rely, offer significant socio-economic benefits to Europe. They represent a major innovation opportunity for car manufacturers and component suppliers in Europe. They also offer substantial environmental benefits in terms of reduced CO_2 emissions (e.g., they can today assist in meeting the proposed new vehicle emission target of 120 g CO_2/Km), lower fuel consumption, reduced noise pollution in urban areas, and the potential for engine down-sizing, without visible performance losses. In other words, they are a practical pathway to meeting social, economic and environmental goals.