The Hybrid Vehicle market 2008-2015
Impact on the battery business

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Abstract: *The main goal of this survey [1] is to forecast the worldwide Hybrid Vehicle (HEV), Plug-in (PHEV) & Electric Vehicle (EV) market and its impact on the Battery Business. In 3 years, from 2004 to 2007, the Hybrid Vehicle market increased from 165 000 to more than 530 000 vehicles sold [2]. In 2008, the automobile industry as well as all the economy was decreasing. In this context, what will be the Car supplier's strategy? What will be the Market for HEV batteries in 2010 & 2015? Will the Li-ion battery with lower price cathode succeed? What is the price level to compete with NiMH technology? Will the HEV battery suppliers be the same as electronic device battery suppliers? Can European or US battery players have an opportunity in the HEV battery market? How will Ford, General Motors, Chrysler, Renault, Peugeot, Volkswagen or BMW manage there battery needs if there are no battery suppliers in the US & in Europe?*

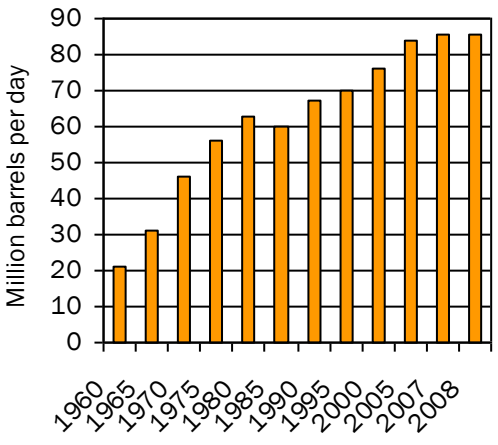
Keywords: HEV, EV, P-HEV, Battery, Market, Nickel metal hydride, Lithium-ion

1 Introduction

1.1 Hybrid vehicle… Why?

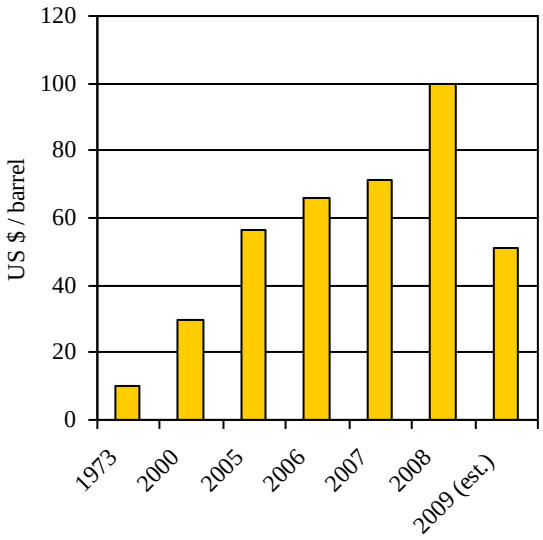
World petroleum consumption is growing drastically [3] and will continue to grow in the future, even if 2008 appears to be the first decrease in the last 25 years. (Figure. 1)

Figure 1: Petroleum consumption worldwide 1973-2008



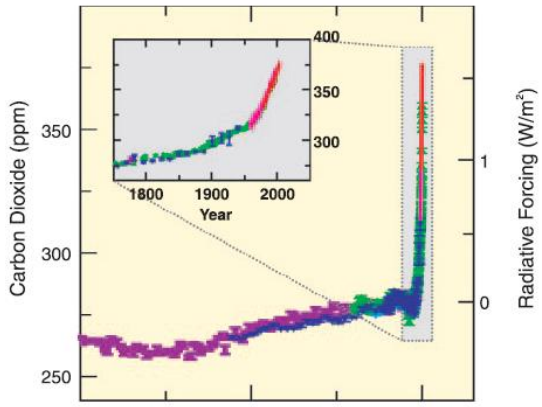
Reserves of oil are decreasing and in the last 20 years, the discovery of new oil dwells is growing less rapidly than demand. Also as shown in figure 2, the price of a barrel is extremely volatile [4] and independent of forecasting factors.

Figure 2: Yearly average price of the WTI barrel in US $



Then, as shown in figure 3, the CO_2 density in the atmosphere is increasing drastically [5].

Figure 3: CO_2 density in the atmosphere increase



For environmental, economical and political reasons, new energy sources have to be found for our cars. Fuel cells are one alternative which started 200 years ago in the 19th century. Total EV is another. The first Electric Vehicle was invented very long time ago but by then batteries were very heavy. Performances improved but the main problem remained: after 400 to 500 kilometers batteries had to be recharged for several hours. Finally, at the 1995 Tokyo Motor Show, Toyota unveiled a futuristic car powered by a gasoline-electric engine. This so-called hybrid engine packed in a car was called the PRIUS.

1.2 HEV Segmentation

We can split the market in five segments. The micro hybrid vehicle (Toyota Vit, Citroen C3), mild hybrid (Chevy Silverado, Toyota Crown), medium hybrid (Honda Civic) and full hybrid (Toyota Prius, Camry, Ford Escape). With the full hybrid, which combines full power assistance, regenerative breaking and start & go functionalities a car can save up to 25% of fuel with roughly 200 volts battery. With mild HEV or 42 volts batteries, savings achieve roughly 10% of fuel. Most of the hybrids today are full hybrid.

Table 1: Exemple of HEV models

Car Makers	TOYOTA	FORD	HONDA	GM
Model	PRIUS	ESCAPE	CIVIC	VUE
Engine (L)	1.5	2.3	1.3	2.4
Power (kW)	57	98	68	127
Electric engine (kW)	50	70	15	4.5
Electric power ratio (%)	47%	42%	18%	3%
Hybrid type	Full Hybrid		Medium	Mild
Battery size (kWh)	1.3	2	1	0.65

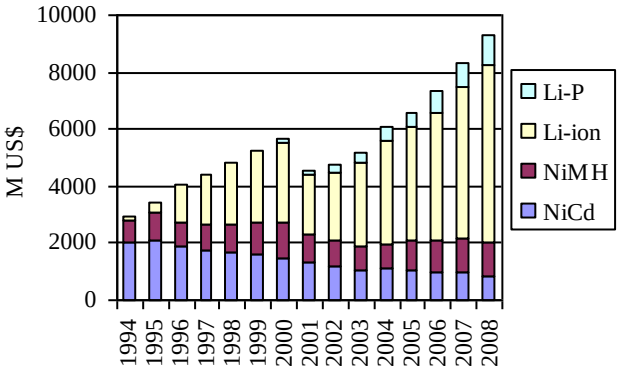
The latest hybrid version is the Plug In Hybrid which is in between total Electric Vehicles & HEV. The problem is that these batteries have to combine characteristics of HEV & EV, that is the power to accelerate & the energy for a wider range. It has to combine the charge sustaining mode, where the battery provides hundreds or more of cycles per day never approaching the fully-charged or fully-discharged stat, with the charge-depletion mode, where the battery is fully charged externally and is depleted at a steady rate during driving. Rapid calculations show that a 20-mile range plug-in battery will be 3 to 5 times costlier, bigger and heavier then an actual HEV battery. That is probably why a spokesman from Toyota declared several months ago that Toyota believes that with the state of the current technology, Plug-in HEV is not commercially or technically feasible. That is also why, in our opinion, Li-ion batteries are technologically advancing. Plug in Hybrid really needs Li-ion to penetrate the market.

2 Batteries for HEV in 2008

2.1 The rechargeable battery market in 2008

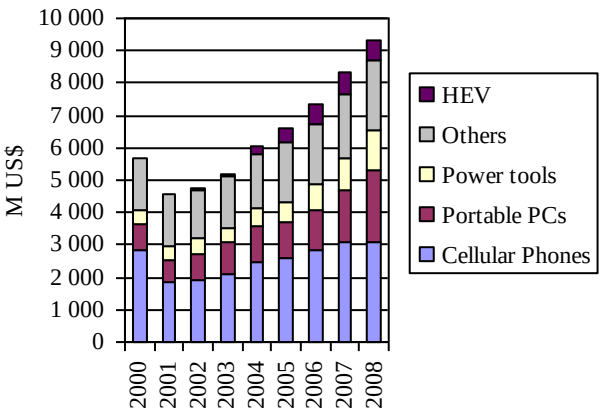
In 2008, the rechargeable battery market represent more than 9 Billion US$. In 10 years, Li-ion and Li-Polymer took almost 75% of this market, mostly driven by electronic portable devices like cellular phones & portable PCs (figure 4).

Fig 4: The rechargeable battery market worldwide



In 2008, the 1.2 billion mobile phones sold needed 1.5 billion Li-ion cells and portable PCs needed roughly 1 billion Li-ion cells [2]. NiMH batteries for the Hybrid vehicles market was roughly 620 million US$, 7% of the battery market (Figure 5).

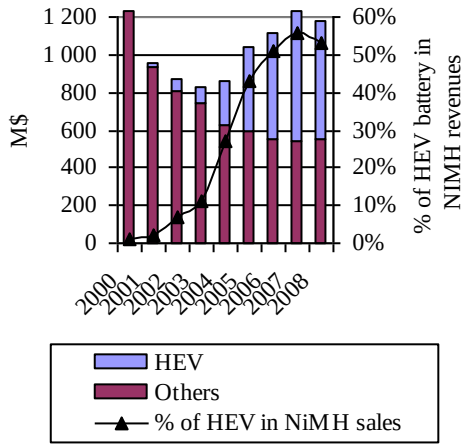
Figure 5: Rechargeable battery market by application



2.2 Impact of HEV on NiMH battery business

In 2000 with more than 60 % of the NiMH turnover Mobile Phones was the main battery driver for NiMH Batteries.
In 2008, NiMH batteries for cellular phones needs decreased tremendously. The NiMH battery market is now driven by retail batteries for cameras, toys and other electronic devices and hybrid vehicles, which represented 15% of the NiMH market in 2004 and more than 55% in 2007. As you can see in figure 6, Hybrid vehicles already brought back to life NiMH batteries.

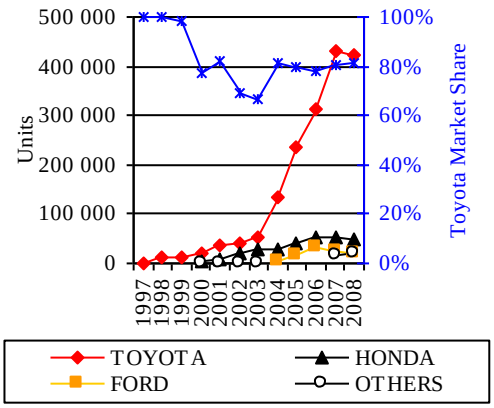
Figure 6: NiMH battery market. HEV Impact



3 HEV market in 2008 & main trends

In 2008, more than 515 000 hybrids were sold worldwide. More than 314 000 were sold in the US alone, 95 000 in Japan and only 78 000 in Europe. Because of the Automobile market decrease in 2008 (-5% worldwide), HEV sales decrease also but HEV proportion on the total sales still increase. In the US, HEV represents 2,4% of the total sales compare to 2,2% in 2007 & two times less in 2005.
Toyota is the leader of this market with more than 80% market shares. Toyota sold more than 420 000 hybrids. For the majority they sold the Prius and new Prius (280 000) but Toyota began to sell new models like Highlander or Camry in the US, a mini Van called Vitz in Japan. The Honda civic and Ford Escape were also, real successes in 2005 & 2006 but sales decrease in 2007 & 2008. GM launch 6 models in 2007 & 2008: Vue, Aura, Tahoe, Yukon, Malibu, Escalade for a total of more than 13 000 HEV in 2008.

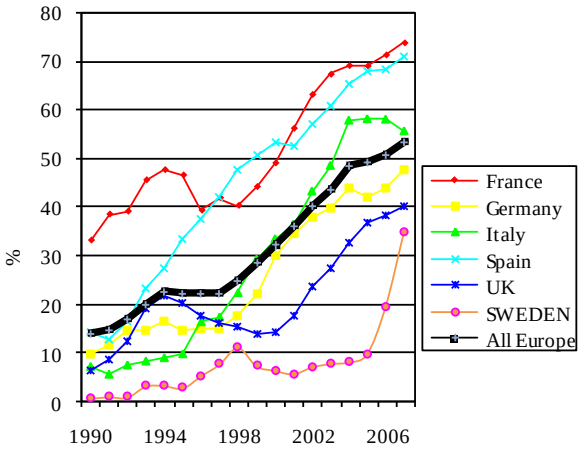
Figure 7: HEV sold worldwide by car makers



3.1 HEV market by geographic area

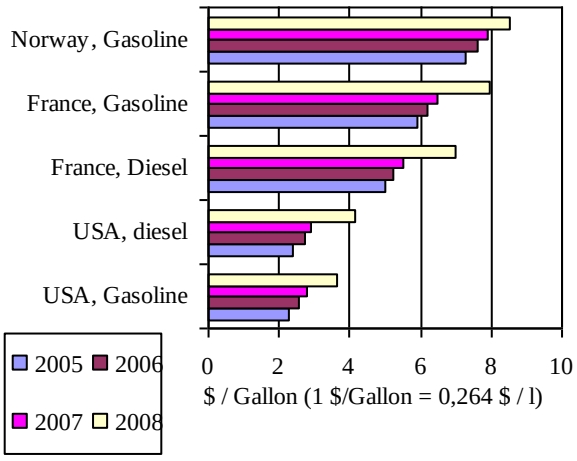
The market is quiet small in Europe with roughly 78 000 Hybrids sold in 2008. The main reason is the popularity of Diesel engines in Europe. Penetration of diesel engines in Europe grew from 12% in the 90's to 50 % in 2005 & even more in 2006 [6].

Fig 8: % of diesel engine registration, Non Professional vehicles, EUROPE, 1990-2006



Diesel engines consume between 20 and 30% less fuel and, as you see on figure 9, diesel prices are 20% less than gasoline in Europe. But gasoline is 3 times less expensive in the US than in Europe! Government taxes are very important in Europe: between 60 & 80% of the total costs depend on the country's taxation policy.

Fig. 9: Gasoline & diesel price in Europe & US



Therefore in the development of hybrids a very important parameter to take into account is the government strategy. Do they really want hybrid cars on the market or do they prefer earning money with high Gasoline taxes in Europe, or support the Oil Business in the US.

3.2 HEV market trends 2008-2015

3.2.1 Short & middle term HEV market

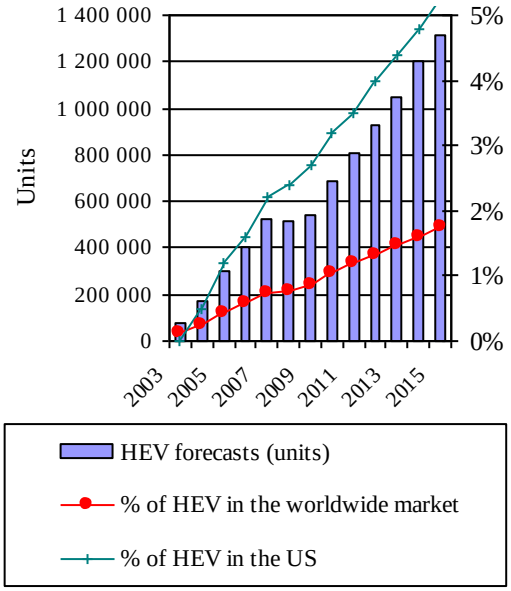
While the fates of future hybrid sales are tied to the uncertain prospects for the entire auto industry, there are signs that hybrids will resume

their growth trajectory in 2009. Honda will introduce the full hybrid Insight and a goal to achieve 100 000 units in North America. Toyota will roll out a new and improved Prius, and Ford will begin selling the Ford Fusion hybrid & the Mercury Milan Hybrid with the goal of doubling its hybrid sales to achieve 40 000 units. In the coming months, the most dramatic influences on future hybrid sales will continue to be gas prices, consumer confidence, and the availability of credit. Beyond that, President Barack Obama is expected to significantly expand industry and consumer incentives for hybrids & others fuel-efficient cars, as part a program to jumpstart development in the clean energy sector. All together, we forecast that the total hybrid vehicles market will increase by achieve 0,7 million units in 2010, that means 1% of the total car market.

3.2.2 Long term HEV market

On a long term basis, in January 2008 we forecast 2 million HEV sold worldwide in 2015. Those forecast were revised in January 2009 to 1,3 M HEV for 2015. This is less than the most pessimistic opinions of HEV people or makers like BMW or General Motors. More optimistic analysts forecasted 6 Million HEV.

Fig 10: HEV market worldwide 2003-2015

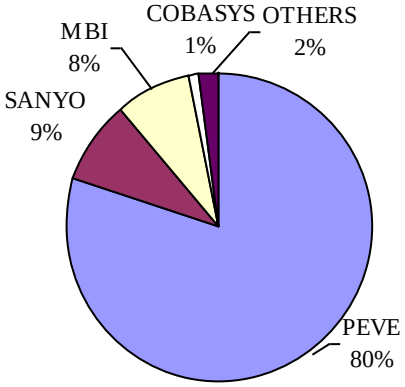


4 Batteries for HEV 2008-2015

4.1 Battery market in 2008

Today, batteries used for Hybrids are NiMH batteries. Matsushita-PanasonicEV (PEVE), owned by Toyota (60%) is leading the market supplying Toyota, Lexus & Nissan. Sanyo is the second Japanese maker supplying Ford but also Honda as second supplier.

Fig 11: HEV battery makers market share in value



4.2 2008-2015 NiMH Vs. Li-ion

4.2.1 NiMH batteries for HEV

NiMH is a reliable technology. Developments & improvements of energy, power, temperature range, and cyclability continue even if most of the money is going today for Li-ion developments.
NiMH success in HEV is greatly due to its recharge flexibility, its wide temperature range, long cycle life capability, long life time & last but not the least its proven safety, which is not the case for Li-ion.

Table 2: Prius I & Prius II battery pack caracteristics

	PRIUS I	PRIUS II
Capacity	6.5 Ah	6.5 Ah
Cells	228 (38 * 6)	168 (28 * 6)
Voltage	273.6 v	201.6 v
Specific power	1000 W/kg	1300 W/kg
Specific energy	46 Wh/kg	46 Wh/kg
Total power/HEV	36 kW	37.8 kW
Total energy/HEV	1778 Wh	1310 Wh

Further Li-ion batteries are in everybody's opinion the future of HEV because Li-ion batteries are much more powerful.
NiMH batteries are generally viewed as an interim battery technology, soon to be eclipsed by the Lithium ion battery. The question is when, and which company will be the first to take the lead?

4.2.2 Li-ion developments

The main Li-ion batteries developers today are Toyota and Nissan In house but also NEC Lamilion working with Nissan, and Sanyo working with Honda, Ford, Chrysler, and VW. There are also Korean makers like Samsung or LG working with Hyundai. LG was also chosen to supply the Li-ion battery for the future PHEV GM-VOLT to be launch in late 2010. The European auto part makers Bosch.is also active on this market: JV with Samsung. However, several US makers entered the HEV battery market, such as the joint venture between Johnson Controls & SAFT, working with Chrysler, Cobasys who supply the GM Vue Saturn or A123.

Today, Li-ion is already in our cell phones, PDA or portable PCs. The lithium ion could provide a significant advance in the hybrids and will be a necessity for the plug-in hybrids anyway. Li-ion batteries got the same power as NiMH units but cut the weight of hybrid power trains.
However we are not in the portable device industry where it takes between 10 to 20 months to launch a new product. In the car industry, it takes between 4 to 7 years to launch a new model. It is thus quite easy to assess whether Li-ion will be in our cars in the next 2 to 3 years. The answer is no. Nevertheless on a long-term basis, from 2010 to 2015, it is much more difficult to make forecasts.

As the cobalt Li-ion batteries get bigger, in addition of the Cobalt cost problems, Li-ion has also a problem of thermal runaway. Incidents or recalls observed with cellular phones or Portable PCs will be unacceptable in the car industry.

Battery suppliers & car makers developed alternative solutions for Cobalt Li-ion batteries. Alternative solutions at lower costs, but solutions that have to fulfill the technical requirements in terms of temperature range, cyclability, thermal management and life duration.

Today, $LiNiCoAlO_2$ cathode is developed by Toyota but also Johnson Controls Saft.

Toyota is also working hard on Li-ion technology. Several hundreds of researchers are researching on Li-ion for Toyota in Japan.
However, Toyota has a battery that is quite capable and unless they are changing just to be at the forefront of the market, there is really no reason for them to do so. A more likely candidate would be Nissan with NEC or GM.

Nissan & NEC developed the spinel technology with $LiMn_2O_4$ for the Li-ion cathode. But Mn pack suffers from lack of durability. Lithium iron Phosphate ($LiFePO_4$) developed by A123 in the US, Sud chimie in Europe, or Nippon Chemical in Japan is on the way to be the Li-ion technology for HEV as well as Power tools however for the automobile industry more developments have to be made to achieve the industry standards.

4.2.3 New battery suppliers?

More and more Car makers are looking for other solutions than PEVE. Some of Toyota's competitors complain because arguing that Toyota's shares in this market are to important. The general view is that most competitors entered that market a decade too late. The world's auto giant's now find that they have to leave or buy technology from Toyota. Because Toyota has not only invested untold millions of US $ into developing hybrid engines and systems, but has also moved quietly and aggressively to cultivate a network of suppliers for critical hybrid parts.

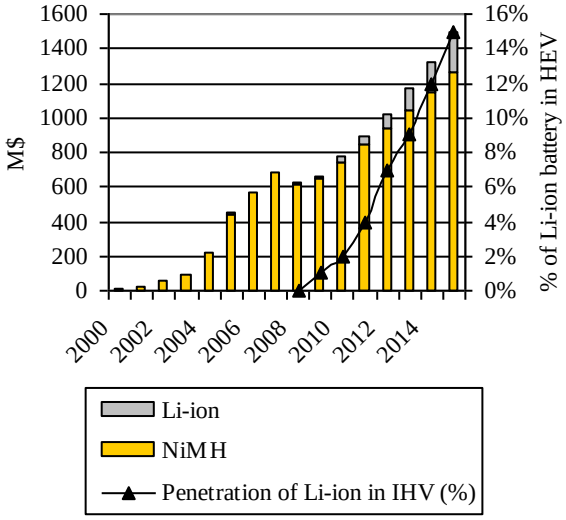
Ford top Product executive declared in 2005 :"to get the volume of battery we want, we need to produce them here in the United States, and we need to actually be able to be much more in control of the situation."[7] In other words, "Given the increasing volumes of hybrids in North America, there clearly is a need for a North American supply base". [8]

The other big development in those markets is the combination of hybrid technology & diesel engine. As cleaner diesel is now on the market, mostly in Europe, the proposal of combining fuel-shipping diesel & electric motors to improve fuel economy is getting loud.
"A diesel hybrid is, we think, one of the engines of the future" said Mark Fields, Ford's executive Vice President for the Americas.
In Europe, Peugeot is also working on diesel hybrid version & Volvo just announced a new diesel hybrid model for the near future. Finally, we can forecast that the Li-ion will appear after 2010 on the high end HEVs. In 2015, we forecast that 15% of the HEV sold will be equipped by Li-ion technology.

5 Conclusions

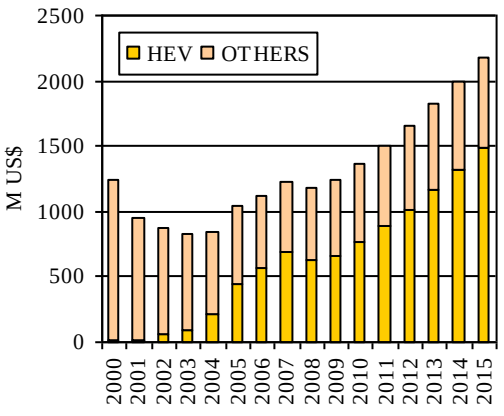
With the assumption of 0,7 Million hybrid cars sold in 2010, and 1.3 M in 2015, the number of NiMH cells for HEV will achieve 125 Million cells in 2010 & 275 Million in 2015.
In terms of value, the NiMH battery pack market for HEV will increase from roughly 625 Million US$ in 2007 to 750 Million US $ in 2010 & 1,8 Billion US$ in 2015.
In 2010-2011, we expect to see several Li-ion based models and the market for Li-ion in HEV will start slowly. In 2015, we forecast the Li-ion market for HEV at less than 250 Million US$ (15% of the HEV equipped)

Fig 12: HEV battery market worldwide in US$



As shown on figure 13, the impact of hybrid vehicles on the NiMH market is huge. After 2000, the NiMH market was decreasing. Hybrid vehicles brought back to life this market.

Fig 13: NiMH battery market worldwide in US$



As the demand changed from electronic devices to cars and trucks, customers changed as well. The three US leaders in the automobile industry would like to get their batteries and hybrid systems from US partners as well as in Europe. This second birth of NiMH market may give a second chance to US or European battery makers to compete with Japanese, Korean and Chinese makers. The growth is so high that there is some opportunity for the US or European Battery industry.

To conclude, I think that this decade marks a transition in vehicle technology, characterized by a significant increase in vehicle electrical power requirements. The industry is requiring higher performances.

It is not that hybrids are going to sweep the automotive world immediately. But, it is now clear that hybrid systems have muscled their way into acceptance. The extra cost and bulk of powerful electric motors and battery packs, initially viewed as impossible hurdles for the industry, has begun to seem less of an obstacle as production increases and automakers gain more production experience.

Multiple power source technologies are contending to capture their section of this fast growing market for higher performance energy storage systems.

All hybrids currently produced employ an internal combustion engine, a generator and a NiMH battery. All the specialists agree that Li-ion is about 3 to 5 years away for hybrids and another 5 to 8 years away to get a rational price point. In our opinion it will serve the Plug in hybrids.
Even if Toyota suggests that it may start with Li-ion at an irrational price point it is clear that Li-ion for hybrids will not be representative on the mass market before 2012-2013.

Then, on very long term basis, the total Elecctric Vehicle (EV), can also change drastically the automobile industry. Some ambitious projects like Better Place are on the go in US, Europe & Asia. But, as Bill Reinert, Toyota National Alternative-fuel vehicle manager says, “I am conservative about the number (2000 to 3000 EV for Toyota worldwide in 2012), because the charging infrastructure has to be ready & the customers have to be ready [9].

Battery makers, power managers, designers, developers, processor makers and integrators are searching for new innovations to build new products and concepts at reasonable costs. I really think that innovation for new concepts, new products, new developments is the key to success. Think new and create new dream.

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