Developments in hybrid vehicles and their potential influence on minor metals

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Good morning Ladies and Gentlemen.

Hybrid gasoline-electric vehicles are a source of major new demand for minor metals, especially cobalt. The aim of this presentation is to throw light on why, when and by how much this new demand is likely to affect the market.

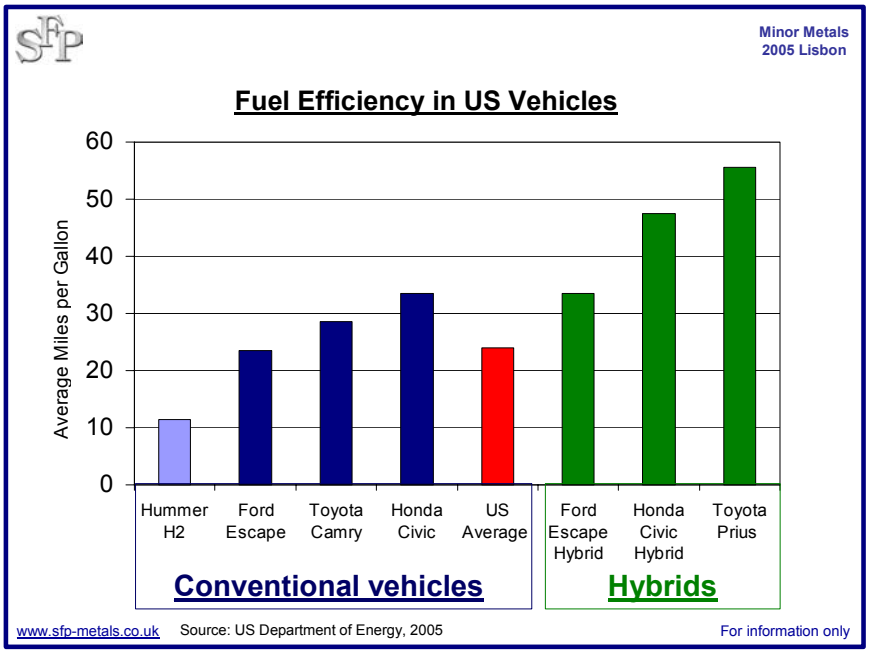
To that end I would like to

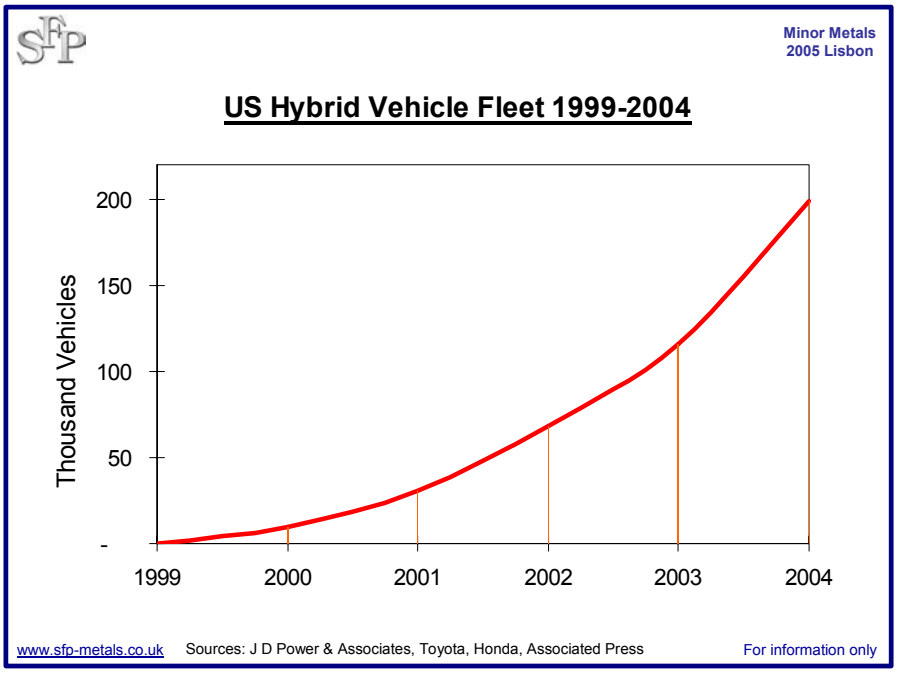
- Introduce hybrid vehicles in their modern context.
- Outline the dynamics behind the present hybrid vehicle market.
- Highlight the integral nature of cobalt to hybrid vehicles.
- Forecast the potential impact of hybrid vehicles on cobalt demand.

An Introduction to Hybrid Vehicles and Minor Metals

On the road, in the press and even at metals conferences it is becoming increasingly difficult to avoid hybrid vehicles - that is vehicles that draw their power from both an internal combustion engine and an electric motor.

By synchronising the engine and motor hybrids achieve levels of fuel efficiency far beyond that of conventional vehicles, and getting more miles to the gallon is very appealing to consumers faced with high fuel prices. They also produce less emissions, making them popular with politicians fighting air pollution[i].





The relevance of hybrid vehicles to minor metals is in the new materials-recipe that hybrids require. Those metals used in hybrid engineering will see demand increase proportionally to the production rate of hybrid automobiles, a rate that in the last few years has boomed.

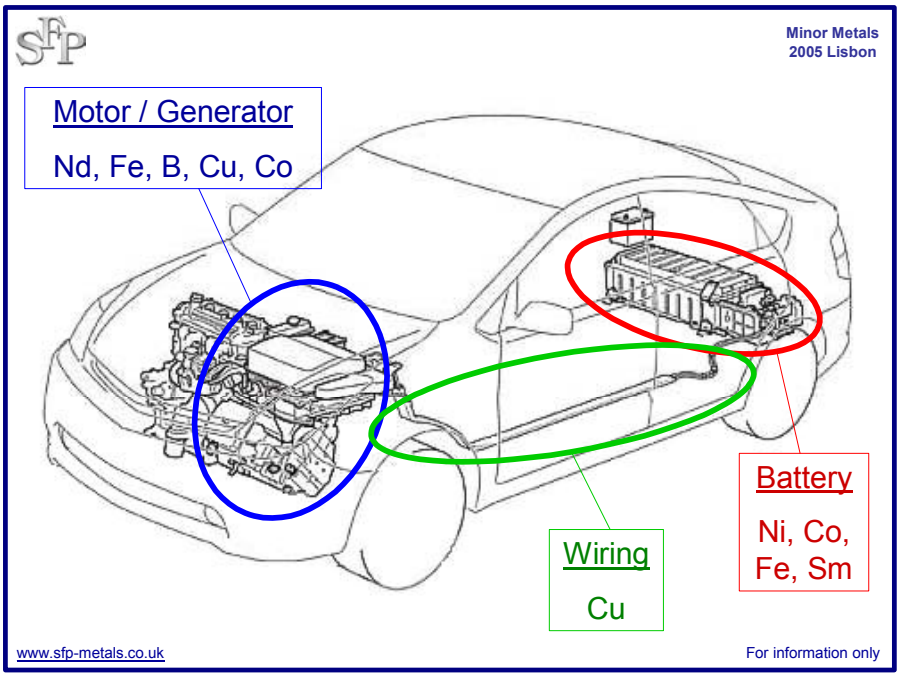
As illustrated on this stylised hybrid, the main metals used in the recipe for hybrid engineering are:

- In the rechargeable battery: up to 16kg of nickel[ii], also cobalt, iron, samarium & other rare earths.
- In the motor & generator: neodymium, iron, boron, cobalt, copper.
- In the wiring: up to 45kgs of copper[iii].

Leaving aside the big LME metals and the rare earth elements, cobalt emerges as the minor metal most affected by hybrid vehicle production.

As we shall see in a moment, hybrid-driven consumption is set to impact the cobalt market hard.

This review will concentrate on the US market where unique circumstances have so far translated into the highest sales of hybrid vehicles.

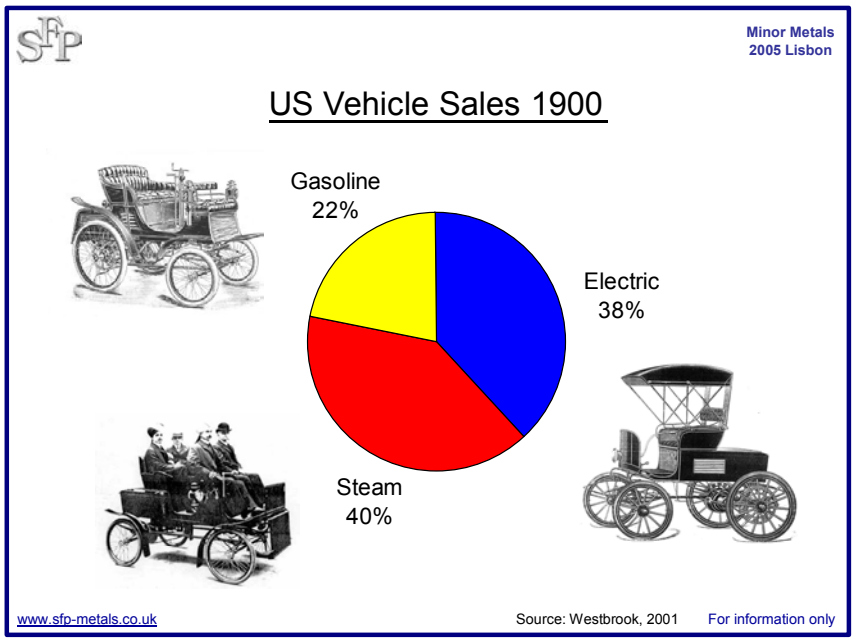


1. Developments in Hybrid Vehicles

Hybrids are among the most intriguing technological trends to appear in the past decade. However, while their mass-production is a recent phenomenon, hybrid technology is not itself new. Like a recessive gene hiding in automobile DNA, electric drive systems have been around ever since engineers first moved carts out of stables and into garages.

In the early days of automobiles, before the hegemony of gasoline (petrol) became unquestioned, steam, gasoline, electricity and even peanut oil[iv] all competed to be the power system of choice.

The shear diversity of automobiles in those early days is telling. In 1900, 4,200 cars were sold in the USA of which 38% were electric, 40% steam and only 22% gasoline[v].



Electric vehicles even held the world road speed record for three years between 1899 & 1902[vi] - a speedy 66 miles per hour (106 km/h) [vii].

Perhaps the worlds first hybrid was built by Dr Ferdinand Porsche who in 1899 built a vehicle that used a petrol engine to drive a generator that powered four electric motors[viii].

However, in 1909 the Model T Ford was launched and from then on gasoline was the unrivalled source of vehicle power.

The rare exceptions to this rule were specialised utility vehicles and concept cars, such as milk delivery vehicles and the Sinclair C5.

For decades little changed. Then in 1973[ix] the oil crisis started[x] causing gasoline prices to rise 50% in a year; suddenly fuel efficiency was an issue. Encouraged by government regulations[xi] by the late 1980s America's vehicle fleet was considerably more efficient and gradually the path was being prepared for hybrids.

One of the first modern hybrids was built by General Motors in 1986[xii], but with gasoline prices at under $1.00 per gallon[xiii] the project was scrapped in anticipation of low consumer demand[xiv].

General Motors' foray into hybrids was followed in 1993[xv] by the US Government's PNGV program, aimed at developing a "super efficient" car capable of 80 mpg. Despite a budget of over $1.4 billion it achieved very little[xvi] and the concept cars it produced were quickly forgotten.

However, across the Pacific Ocean, in Japan, things had taken a different turn.

As early as 1989 Toyota was funding research into hybrid technologies and in 1992[xvii] they published their first "Earth Charter", a manifesto for low emission vehicles. This ultimately led to the development of the Prius, which first emerged at the 1995 Tokyo Motor Show[xviii].

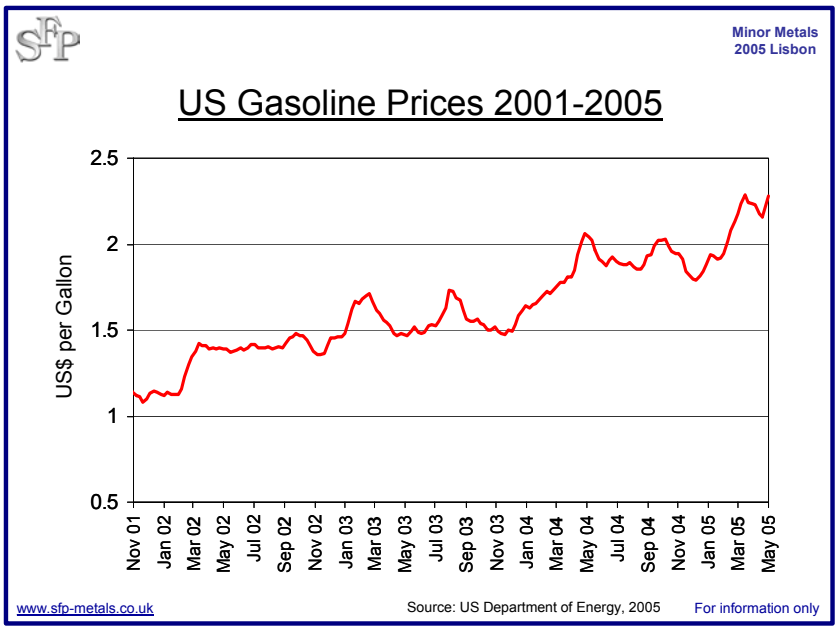
2. Circumstances of the US auto-market

The first hybrid to be offered in the USA was the Honda Insight in late 1999, followed in 2000 by the Toyota Prius. In just five and a half years hybrid vehicles have made manufacturers and consumers alike sit up and take notice.

But why now?

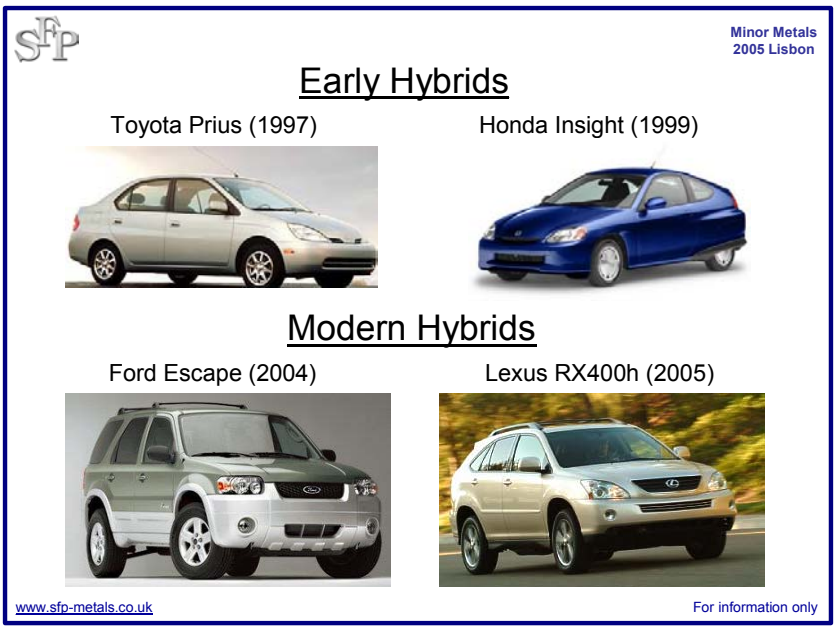
- **High gasoline prices**

An important factor, if not the most important factor, is the rising US gasoline price, reflecting higher crude oil prices. Since December 2001 average gasoline prices have more than doubled from $1.08 to $2.30 per gallon[xix].



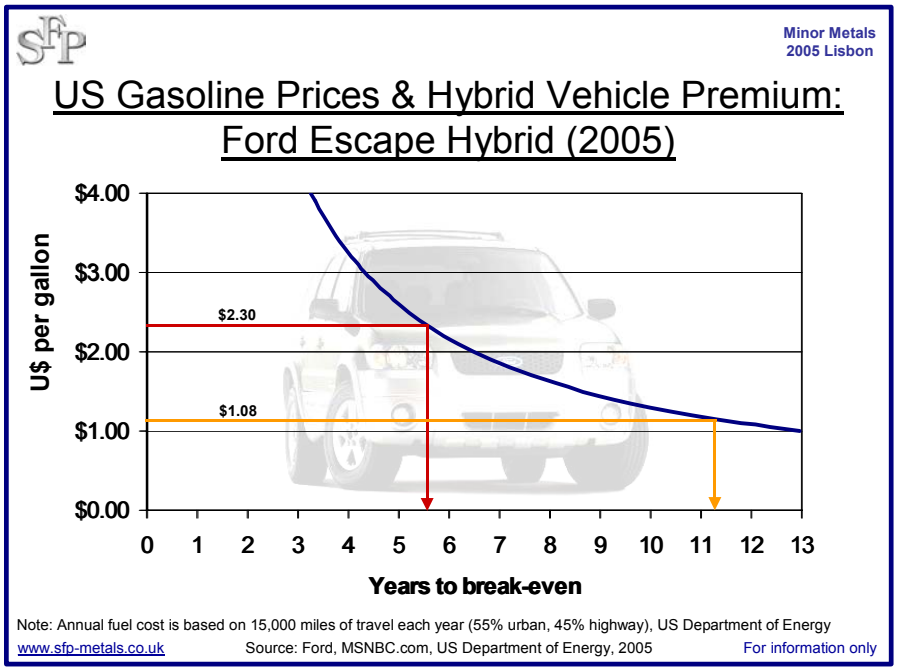
With gasoline at $1.08 per gallon and small, quirky designs, the early hybrids had a reputation of being cars for environmentalists.

Today, however, with gasoline at $2.30 per gallon and packaged in conventional designs, hybrid vehicles appeal on an economic level the mainstream public respond to strongly[xx].



High fuel costs make consumers acutely aware of a vehicle's fuel efficiency and in a recent survey 40% of consumers indicated that fuel efficiency would play a major part when deciding which new car to buy. The four most efficient vehicles on the market today are all hybrids.

Currently hybrids command a premium over equivalent conventional models of $500 to $4,000[xxi], but as you can see below, for the Ford Escape Hybrid measured against its non-hybrid sibling, the $2,600 premium is negated appreciably faster with higher fuel prices.



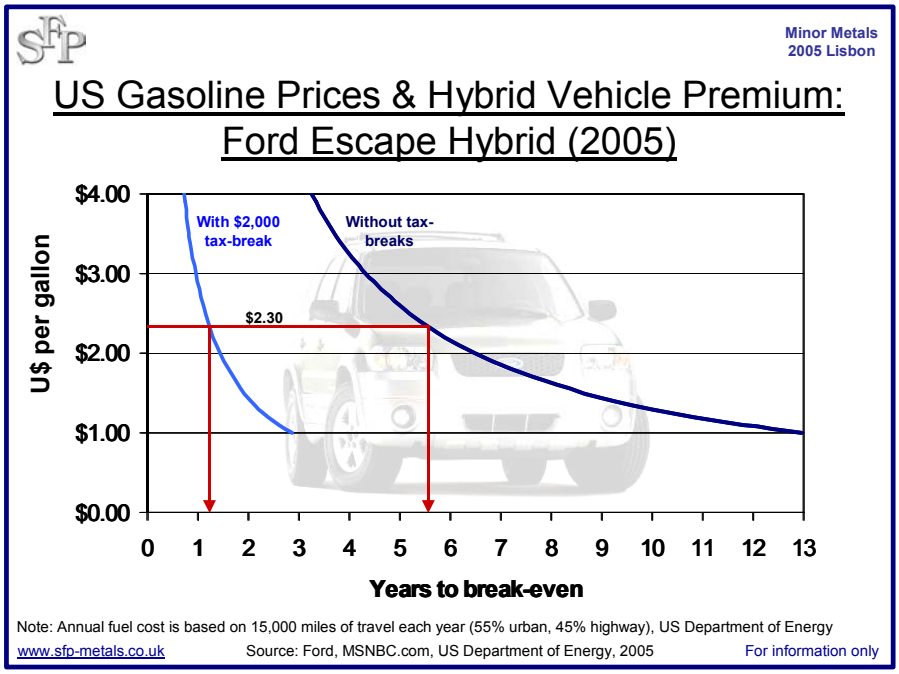
The time taken for the hybrid premium to break-even with the Ford Escape Hybrid is 11.3 years at $1.08 per gallon, but falls to 5.6 years at $2.30 per gallon.

The hybrid market is too young to accurately measure the elasticity of demand against rising fuel costs. This is because consumption of hybrids has so far been limited by tight supply.

But, with waiting lists for new hybrids of up to six months[xxii] the market fundamentals speak for themselves.

- **Tax incentives**

Hybrid vehicles are a hot political topic and are being actively promoted both in the fight against air pollution and as a strategy to reduce America's dependence on foreign oil. To this end, hybrid vehicle buyers in 2005 can claim a federal tax break of $2,000[xxiii].



If we look at the Ford Escape Hybrid again, we can see that with gasoline at $2.30 per gallon and a $2,000 tax break, the hybrid Escape breaks-even in just over a year.

Many US states also offer incentives to hybrid consumers[xxiv] and they even find approval with the White House.

In a speech last month in Virginia, President Bush[xxv] proposed that from next year "[to] conserve gas and protect the environment, … every American who purchases a hybrid vehicle [will] receive a tax credit of up to $4,000".

This will remove the premium on hybrid vehicles altogether.

- **Capable hybrid technology**

Both the computer programming and mechanical technology behind hybrid engines has come a long way in the last decade and continues to progress rapidly.

Parallel to the gains in hybrid engines, rechargeable batteries have also improved considerably since the early 1990s and are now up to the rigorous demands of hybrid vehicles.

Currently hybrids use nickel metal hydride batteries, and while there is an expectation that one day lithium-ion batteries will be used instead, industry insiders, including one US supplier close to Toyota and Honda, say that the switch is unlikely before 2012[xxvi].

- **An underdeveloped diesel market**

Another reason for the popularity of hybrids is that consumers in the US looking for low-cost vehicles do not have the option of diesels. Tight air quality regulations, which are set to get even tighter in 2007, have meant that today less than 1% of the US vehicle fleet is diesel powered[xxvii].

Diesel vehicles initially cost $1,000 to $3,000 more to buy, but like hybrids, they save money in the long run with their more efficient engines.

- **Fuel Cells Vehicles (FCVs) are not yet commercially viable**

FCVs are electric cars that generate their power from the chemical-electric reaction of hydrogen and oxygen. Their only emission is water, earning them the title “zero emission vehicles” (ZEVs). To many people, fuel cell vehicles are the Holy Grail of automotive design, removing transport pollution at a stroke.

However, FCVs currently lack supporting infrastructure, cost $800,000 each[xxviii] and are at least a decade away from commercialisation[xxix].

Hybrid technology is often billed as a stepping-stone to FCVs and indeed it is. The Economist has called hybrid technology the platform from which future clean vehicles will evolve[xxx] as all the motors and batteries from hybrid vehicles are two of the essential features of FCVs.

So, if and when FCVs reach mass production, cobalt will be there too.

- **Toyota**

It always helps to have a powerful backer when you are the new show in town, fortunately for hybrids, they have Toyota. Toyota’s President, Fujio Cho, has stated the goal that “Eventually each [Toyota] model range will have a hybrid version”.

Measured by vehicle sales Toyota is the second largest vehicle manufacturer in the world, having overtaken Ford in 2003. But sales figures alone miss the point. In the financial year to end March 2005 Toyota made $11 billion profit and has currently has a market capitalisation of just under $130 billion, making it by far the wealthiest vehicle manufacturer in the world.

Although one General Motors Vice Chairman has dismissively referred to Toyota’s financial commitment to hybrid vehicles, and the positive association it has gained as a result, as an “advertising expense”, Toyota has spent over $800 million so far on this project. If anyone has the power to make hybrids happen, Toyota has it.

Hybrids have arrived. Now lets look at where cobalt fits the picture.

2-2) Today's hybrid vehicles and their consumption of minor metals

As with all technologies, hybrids have numerous mechanical configurations. The three main varieties are:

- Soft- or Micro-hybrids

These are constructed like conventional vehicles but have an engine programmed to shut down when the car is in stationary traffic, thus saving fuel. Soft-hybrids have zero impact on cobalt consumption and are not included in the forecasts made later.

  - The Citroen C3 'Stop & Start' is a soft-hybrid[xxxi].

- Mild-hybrids

These vehicles, as well as having stop-start engines, have an electric motor that aids acceleration. The motor's rechargeable battery can be charged either by the engine or the wheels acting as generators during driving or breaking respectively.

  - Mild-hybrids include the Honda Accord, a car that uses up to 17%[xxxii] electric power.

- Full-hybrids

Full hybrids posses the abilities of mild-hybrids but can also be driven purely by the electric motor. Such a powerful system requires large motors and batteries to match.

  - The Toyota Prius is a full hybrid and uses up to 46%[xxxiii] electric power.

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Hybrid Technology

	Stop / Start Engine	Accelerator assistance	Regenerative breaking	Full-electric driving	
Soft- or Micro-hybrid e.g. Citroen C3 'Stop & Start'	✓				
Mild-hybrid e.g. Honda Accord Hybrid	✓	✓	✓		
Full-hybrid e.g. Toyota Prius	✓	✓	✓	✓	

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From this list variations occur, including plug-in hybrids that are charged off the national electricity grid, but this is not relevant here.

Hybrid vehicles consume cobalt in the electric motor and generator and in the rechargeable battery.

2-3. Motors and Generators

Hybrid vehicles employ approximately 1kg (2.2 lbs) of neodymium-iron-boron (NdFeB) magnets in their motors and generators, this is some 800g more than conventional vehicles.

These magnets are extremely strong, relatively light and are approximately 5-10% cobalt.

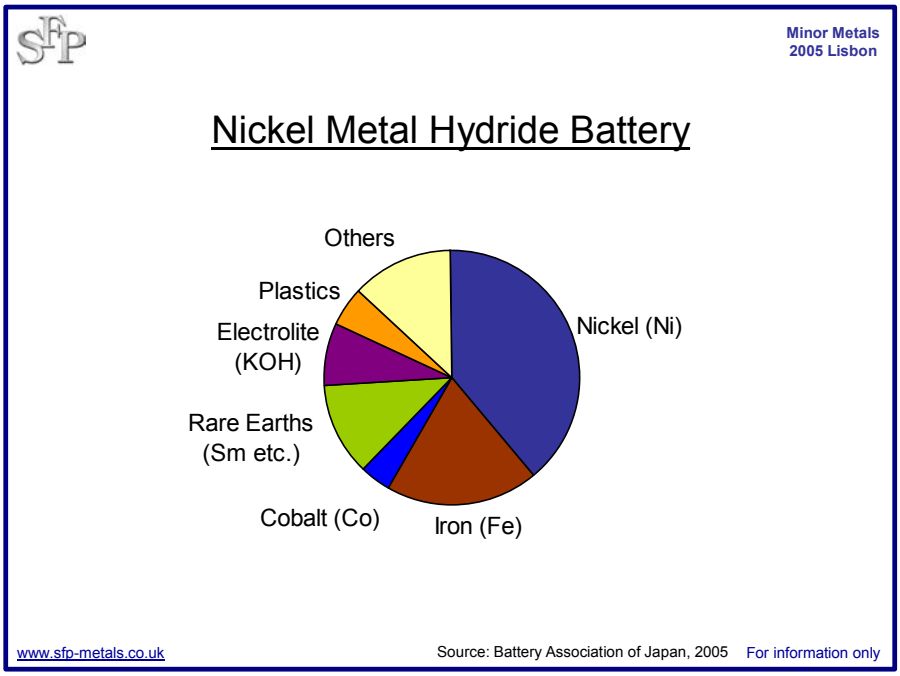
A hybrid vehicle will use approximately 75g of cobalt in its magnets.

2-4. Batteries

In 2004 98% of hybrid vehicle batteries were nickel metal hydride (NiMH) and made by just two companies:

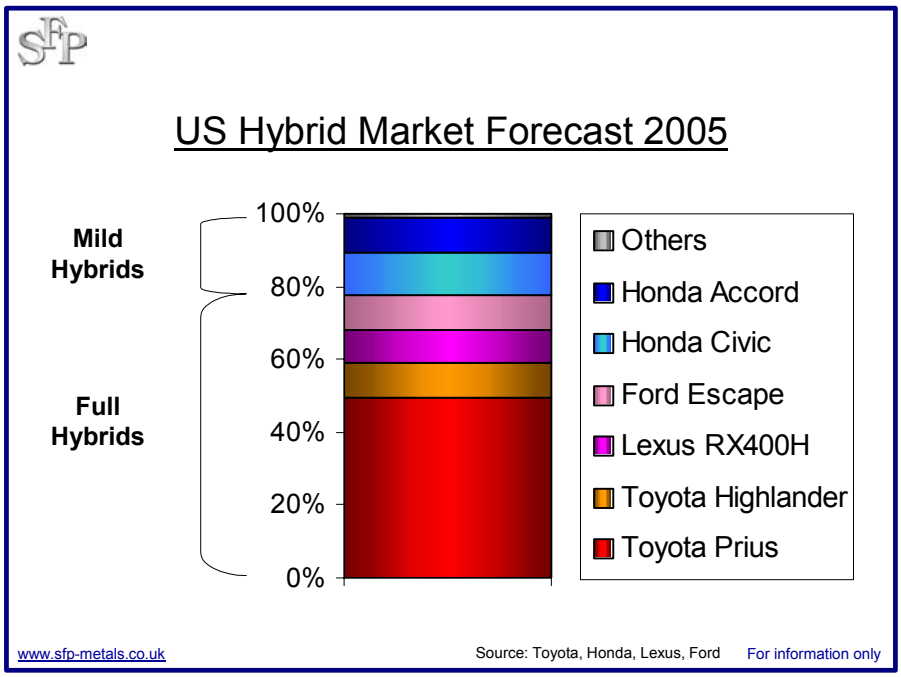
- Panasonic EV Energy[xxxiv]: part owned by Toyota and supplier of batteries for the Toyota Prius and Honda's Civic and Insight hybrids.
- Sanyo: supplier of batteries for the Ford Escape and Nissan Accord[xxxv].

Full- and mild-hybrids both use nickel metal hydride batteries as they provide the optimum trade-off between power density, weight, cost and safety.



In high quality nickel metal hydride batteries cobalt accounts for some 4-6% by weight and it is in batteries that the real surge in demand for cobalt is being generated.

The 800lb gorilla of the hybrid market is the Toyota Prius, forecast to capture 50% of the US market this year.



The Prius battery weighs 28kg and contains an estimated 1.4 kg (3 lbs) of cobalt.

This figure forms my 'average' hybrid battery size as Nissan's mild-hybrids, with their smaller batteries, are offset by four big new SUV full-hybrids with bigger batteries.

2-5. Summary

The average hybrid vehicle sold in 2005 will contain 1.47 kg (3.2 lbs) of cobalt.

3. Forecasts of Future Developments in Hybrid Vehicles

On a global level the drive for more efficient vehicles can be boiled down to a single bottom-line issue: the price of oil.

Unfortunately for car-drivers, but fortunately for hybrid vehicle sales, long-term oil prices are likely to remain relatively high[xxxvi].

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"High oil prices are here to stay… With the number of world motorists in the world set to double over the coming decade, the only one way for [gasoline] pump prices to go is up"

The Economist, *Intelligent Life* supplement Summer 2005

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In terms of hybrid vehicle sales, the non-US global market will be dominated by Japan. Here the near total absence of diesel vehicles[xxxvii], widespread use of urban small cars and popularity of technology, creates high demand for hybrids.

Toyota has made hybrids available in China too and although in the short term the premium may deter consumers, this is potentially a massive market.

Meanwhile in Europe, a fiercely competitive and deeply entrenched diesel sector accounts for 50% of new vehicle sales[xxxviii], meaning hybrids are likely to remain somewhat of a novelty at least in the short term.

In the foreseeable future the steady ascendancy of hybrid vehicles in the US looks assured as the market conditions outlined earlier, continue.

One indicator of just how fast a premium new technology is made economical and mainstream can be found in the uptake of automatic gearboxes[xxxix] and also anti-lock break systems (ABS)[xl].

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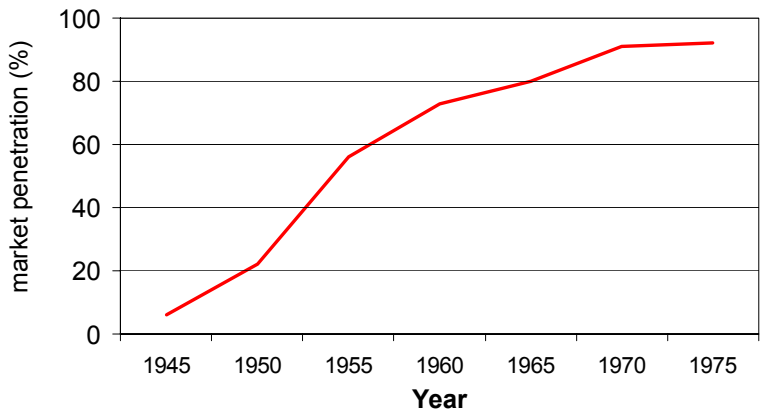
Growth in automatic gearboxes in US Vehicle sales



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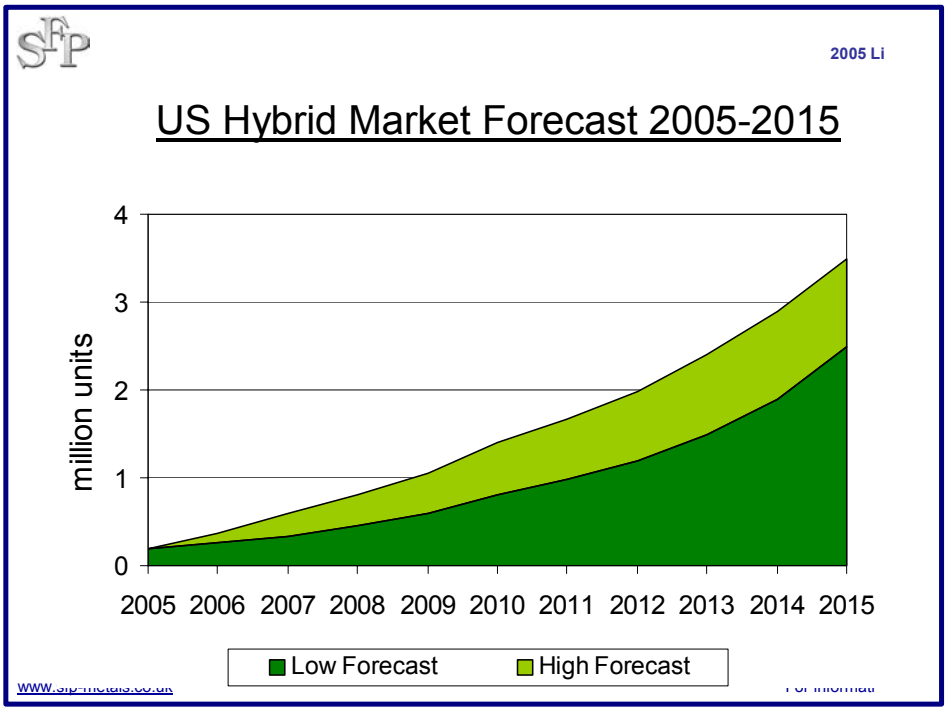
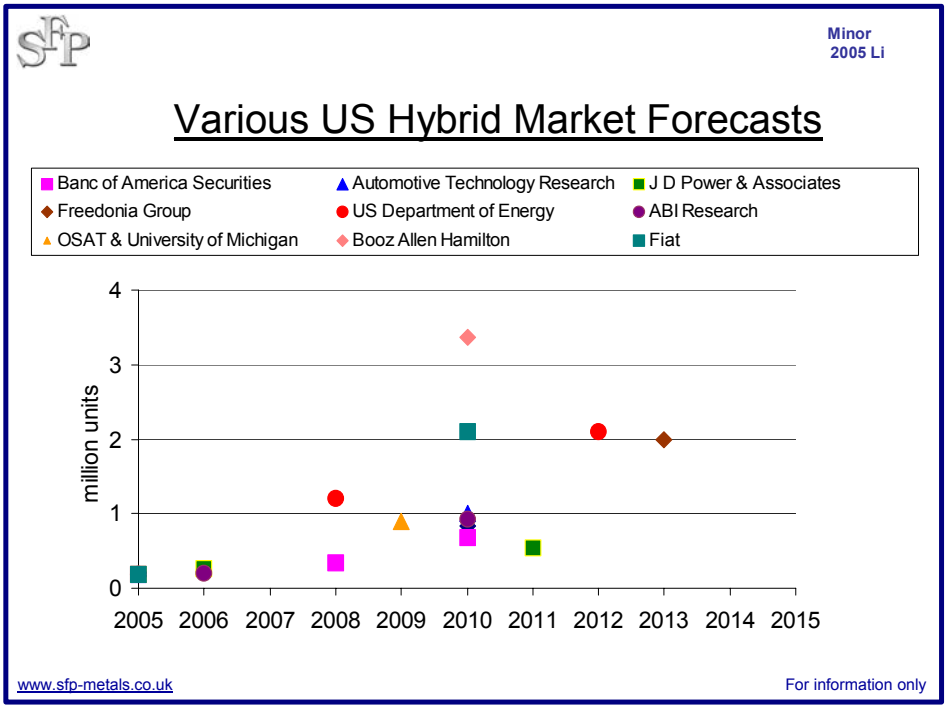
Hybrid vehicles are expected to continue their rapid growth to date. By 2010 the US market is expected to purchase 800,000 to 1.4 million hybrid vehicles per year, approximately a 5 to 8% market share, depending largely on how robust high gasoline prices are and how quickly new production lines are brought on stream.

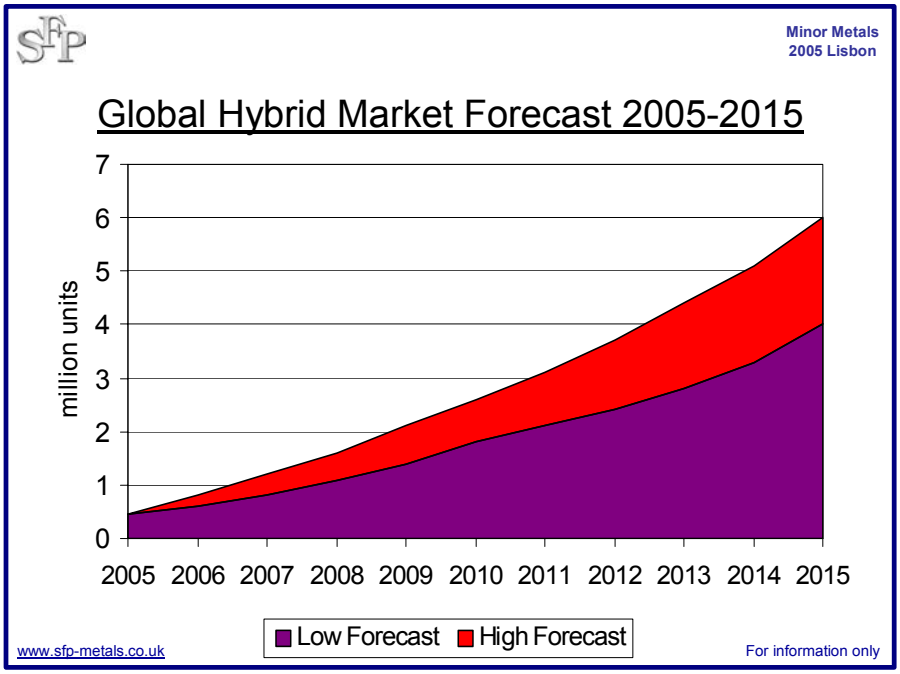


This is expected to increase to 2.5 to 3.5 million vehicles, a 15 to 20% market share, by 2015 as economies of scale and tighter emissions regulations make hybrids increasingly commonplace.

Other analyst's forecasts are available for comparison below.



Together, what these regional forecasts add up to, is global hybrid sales by 2010 reaching 1.8 to 2.6 million units, and rising to 4 to 6 million units by 2015 as increasing numbers of manufacturers and models come on line.

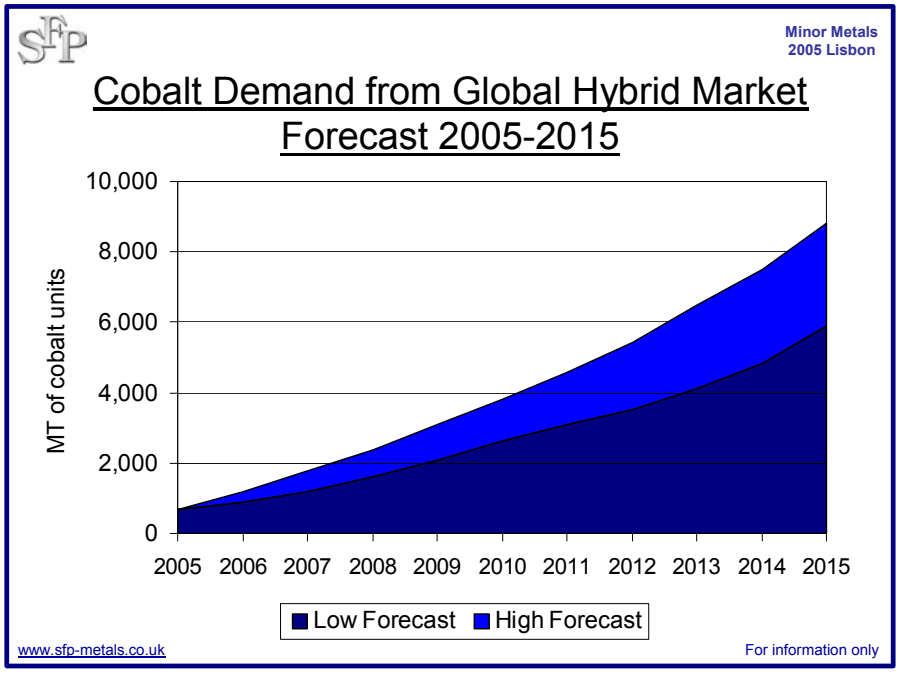


These figures do not include soft hybrids, military vehicles or industrial heavy vehicles, all sectors where hybrids are also generating interest.

Hybrids are here to stay and will play an increasing part of the world market, both in the number of units sold and number of models offered with hybrid features.

3-1. Hybrid vehicles and the cobalt market

Based on these estimates for the growth of hybrid vehicles, the new cobalt demand generated will be in the range 2,650 mt to 3,800 mt by 2010 and 5,500 to 8,500 by 2015.



Sourcing of the extra cobalt demand generated from hybrids will doubtless impact the market.

Today the cobalt market is tight. In March 2005 Mitsui Busan[xli] predicted the cobalt market would see a deficit of 1000 mt this year and at the recent CDI conference in Paris, Philip Tomlinson of the metals consultancy CRU Strategies said there was currently "strong demand for cobalt…In the short term, demand will be constrained by supply" leading to prices to be in the range $18 to $25 per lb through to 2008[xlii].

With cobalt producers all running at full steam, evaporating DLA stocks and no major new projects due to come online for at least 18 months, providing the additional cobalt units for hybrid vehicles may not be straightforward.

Conclusion

Hybrid gasoline-electric vehicles have come a long way from being a research concept and today they represent a bold statement about the future of vehicle engineering. Hybrids are the latest in a long line of pioneering automotive technologies to have reached economic maturity.

High fuel prices, one of the principal drivers behind demand for hybrid vehicles, are expected to remain in place at least in the short term, and, according to the US Department of Energy[xliii], probably in the long term too to some extent. This will benefit the hybrid market, not least by neutralizing the hybrid price premium which has been a stumbling block to hybrids' mass appeal in the past[xliv].

Toyota believe "hybrids are here to stay[xlv]" and have committed themselves to manufacturing hybrids on a cost parity with conventional vehicles[xlvi]. When this happens hybrid technology will become competitive and commonplace.

Twenty first century vehicles will incorporate increasing amounts of hybrid technology and this will cause a profound influence on the cobalt landscape.

Backed by the industry giants and caught by the popular imagination, hybrid vehicles are a taste of the future, today, and are on course to become a source of major new demand for cobalt.

Thank you.

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