9 June 2008

Electric Cars: Plugged In

Batteries must be included

Deutsche Bank

FITT Research

Fundamental, Industry, Thematic, Thought Leading
Deutsche Bank Company Research's Research Product Committee has deemed this work F.I.T.T. for investors seeking differentiated ideas. Rising oil prices, regulations, and advances in battery technology set the stage for increased electrification of the world's automobiles. We see implications not only for automakers and traditional auto parts suppliers – but also for battery companies, raw material producers, electric utilities, alternative power, oil demand, and the global economy.

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Companies featured	
General Motors (GM.N),USD17.05	Hold
BorgWarner (BWA.N),USD50.61	Hold
Ford Motor (F.N),USD6.40	Hold
Johnson Controls (JCI.N),USD33.44	Hold
Magna International (MGA.N),USD69.51	Hold
TRW Automotive (TRW.N),USD24.47	Buy
Samsung SDI (006400.KS),KRW82,700.00	Hold
Sanyo Electric (6764.T),¥282	Sell
Rockwood (ROC.N),USD40.00	Buy
Continental (CONG.DE),EUR71.12	Hold

Fundamental, Industry, Thematic, Thought Leading
Deutsche Bank Company Research's Research Product Committee has deemed this work F.I.T.T. for investors seeking differentiated ideas. Rising oil prices, regulations, and advances in battery technology set the stage for increased electrification of the world's automobiles. We see implications not only for automakers and traditional auto parts suppliers – but also for battery companies, raw material producers, electric utilities, alternative power, oil demand, and the global economy.

Fundamental: monumental challenges for the global auto industry
Rising gasoline prices have caused unprecedented shifts in industry mix, along with sharp declines in the residual value of less fuel efficient vehicles. Already we have seen the sales of hybrid vehicles rise markedly last year and in 2008 to date. There is also growing recognition that it may not be possible to meet onerous fuel efficiency targets through upgrades to conventional powertrains and drivetrains.

Industry: from change comes opportunity
Even if oil was not as large a driver as it is today, regulatory initiatives aimed at improving fuel efficiency/CO_2 emissions present a huge obstacle for the global auto industry. Taken together, we believe that peak oil and a barrage of stiffer regulations are likely to spur the electrification of the automobile – sharply.

Thematic: the battery is key – and we see lithium ion technology winning
High energy, cost-effective, long lasting, and abuse tolerant batteries will be the key technical enablers for this shift. There have been recent breakthroughs in this area. Based on discussions with automakers and suppliers, we have almost no doubt that lithium ion battery chemistries will take over from nickel metal hydride – ultimately dominating this market.

Thought Leading: the repercussions are far-reaching
We find electric vehicles destined for much more growth than is widely perceived. But beyond that, ultimately we see even bigger beneficiaries. We see tremendous growth potential in large-format lithium ion batteries – in other markets as well as autos. Along with the battery makers, producers of inputs consumed in battery manufacturing are also nicely positioned. Connection to the electric grid holds unexplored potential too, and this technology could transform alternative power.

Opportunities for many traditional auto parts companies – and elsewhere
We see many companies we cover now benefiting from this trend, including BorgWarner, Johnson Controls, TRW and Continental. In this report, we also describe the competitive landscape in the emerging lithium ion battery market and in the vital commodity, lithium. Another intriguing theme is the emergence of service-oriented companies that can take upfront costs away from the consumer.

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Executive summary

Outlook: dramatic change fosters the rise of electric vehicles

Rising oil prices, increased societal concern about climate change, and a barrage of regulations focusing on fuel/energy efficiency/CO_2 emissions have the potential to cause profound changes in the global auto industry over the next five to 10 years. Industry market share, mix, competitive advantages, vehicle content levels, used vehicle values, the frequency of consumer purchases, and powertrain technology – all could change more dramatically over the next five years than they have in the past 50.

We are already bearing witness to profound changes… Rising gasoline prices have had several repercussions:

- *Unprecedented shifts in industry mix:* U.S. segment market share for light trucks fell 720 basis points in May 2008.
- *Dramatic residual value declines for less fuel efficient vehicles:* A new Chevy Tahoe large SUV costs $13,000 more than a Toyota RAV4 small CUV, but a four-year-old used Tahoe now sells for $3,000 less.
- *The emergence of new technology:* Sales of hybrids in the U.S. rose 39% in 2007 and are up 17% YTD 2008).

These changes raise many questions about the intermediate-term prospects for the auto/auto parts companies in our universe. Yet we continue to see opportunities for companies focused on technologies that enhance energy efficiency – notably BorgWarner.

…and lately, we have become more convinced of further dramatic changes to come. Automotive engineers are recognizing that it may not be possible to meet the onerous fuel efficiency targets required of them through upgrades to conventional powertrains and drivetrains. A growing number of industry executives predict that increased levels of electrification will be required.

We believe that rising fuel prices and regulatory challenges are likely to increase the electrification of the automobile – sharply. There's another major influence here – advances in battery technology. High energy, cost effective, long lasting, and abuse tolerant batteries will be the key technical enablers for this shift, and there have been recent breakthroughs in meeting these requirements.

We find electric vehicles destined for much more growth than is widely perceived. This includes hybrid electric vehicles, plug-in hybrid electric vehicles, and even fully electric vehicles.

- In the U.S. alone, 13 hybrid electric vehicle models were available in 2007, 17 are expected by the end of 2008, and at least 75 will be available within by 2011. NHTSA's April 2008 report on proposed Corporate Average Fuel Economy Standards projected that hybrid vehicles could rise to 20% of the U.S. market by 2015, from just 2% of the market in 2007. Global Insight projects 47% hybridization of the U.S. market by 2020.
- In Europe, where fuel economy requirements are on an even steeper trajectory, Roland Berger and J.D. Power estimated that the market for hybrids/electric vehicles could rise to 50% by 2015 (mostly micro hybrids), from approximately 2% in 2007.

Batteries – and their inputs, especially lithium – should benefit in particular. Several of the largest traditional Tier One Auto Parts suppliers (including Continental, Denso, Magna, and Delphi) are involved in developing control systems that integrate hybrid powertrains. But we believe that ultimately the biggest beneficiaries may be:

- Automotive battery manufacturers
- Producers of resources and components consumed in battery manufacturing

Based on discussions with automakers and suppliers, we see almost no doubt that lithium ion battery chemistries will ultimately dominate this market. We see tremendous growth potential in the market for large-format lithium ion batteries – to $10-$15 bn in the automotive market alone by 2015, versus $7 bn for the overall lithium ion battery market today. The automotive market for lithium ion batteries could reach $30-$40 bn by 2020.

In addition to the impact on automakers, traditional auto parts suppliers, and battery companies, we see significant opportunities arising for electric utilities and alternative power. Perhaps the most interesting near-term opportunity resides amongst raw material producers, given the rapid growth in demand we see for key commodities including lithium. Based on current plans for lithium production capacity, and our projection of material that will be consumed in automotive battery production, we believe that lithium production could bump up against supply constraints by 2020.

Risks

We are bullish on the long-term prospects for electrification of automobiles and long-term demand for products such as large format lithium ion batteries. Still, we would caution that near-term demand (i.e. 2009, 2010, 2011) for lithium batteries from this market will be relatively low, as automakers and suppliers are still validating products and gearing up for large scale production (we also believe that nickel metal hydride batteries may still dominate mild and full hybrid applications even in 2015).

Consequently, expectations for near-term spikes in demand for commodities and battery production values may turn out to be overly optimistic (growth in lithium supply may exceed growth in lithium demand near term). In addition, we note that many of the companies leading the field for automotive lithium ion battery production have limited experience in producing these products on an automotive scale. Consequently, the ramp up to commercial production involves risks.

Note on valuation: By its nature, this report is not oriented toward our Buy, Hold, and Sell recommendations on Deutsche Bank's standard 12-month time horizon. Our typical valuation methods include an EV/EBITDA valuation methodology for our companies with extensive liabilities and P/E valuation methodology for companies that generate considerable free cash flow and exhibit an ability to consistently grow earnings.

For disclosures pertaining to recommendations or estimates made on a security mentioned in this report, please see the most recently published company report or visit our global disclosure look-up page on our website at http://gm.db.com.

Key themes for the global auto industry

Peak oil is driving change…

In a recent report on peak oil, Deutsche Bank's Oil Research team laid out the world's acute oil problems very succinctly: They estimated that the world is currently consuming 87 million barrels of oil per day. Trend demand growth is roughly one million barrels per day per year. They noted that a growing chorus of oil industry executives, including the CEOs of ConocoPhilips and TOTAL, believe world is converging on peak oil production of up to 100 MM barrels per day.

These production concerns are partly responsible for the 115% rise in oil prices since January 2007. Those price increases are already having a profound impact on the auto industry, which is experiencing unprecedented shifts in segment mix away from less fuel efficient vehicles.

In April 2006, when asked about the implications of $100/bbl oil, GM Vice Chairman Bob Lutz was quoted saying "that would basically bring the industry to a halt." Yet prognostications such as this have ended. Now automakers, auto parts suppliers, and investors are developing strategies to deal with oil's recent rise, and the very real potential for oil to move even higher.

The EIA and IEA both expect oil demand to exceed 100 mb/d demand by mid-next decade. If the views of the oil "peakists" are proven correct, Deutsche Bank's oil analysts believe oil could rise to $150/bbl oil in the intermediate term. Under such a scenario, we believe there would be significant upside to the $3.99/gallon U.S. average retail price for regular gasoline ($5.95 per gallon in Brazil, the $8.38 in the UK, $8.73 in Norway, and $9.28 in Germany).

…along with a barrage of regulations

Even if oil was not as large a driver as it is today, regulatory initiatives aimed at improving fuel efficiency/CO_2 emissions present a monumental challenge for the global auto industry. This barrage of regulations, and the momentum behind it, should drive dramatic changes.

The cost of compliance with U.S. CAFÉ standards is increasing… On April 22, 2008, the U.S. NHTSA released final draft regulations outlining new U.S. Corporate Average Fuel Economy (CAFE) standards for 2010 through 2015. The rules are part of the Energy Independence and Security Act of 2007, which requires that U.S. light vehicles will have to achieve a CAFÉ standard of 35 MPG by 2020, vs. 25 MPG in 2010. More than half of this (31.6 MPG) improvement is to be achieved by 2015. NHTSA estimated the cost of compliance with the 2015 standards at $47 bn.

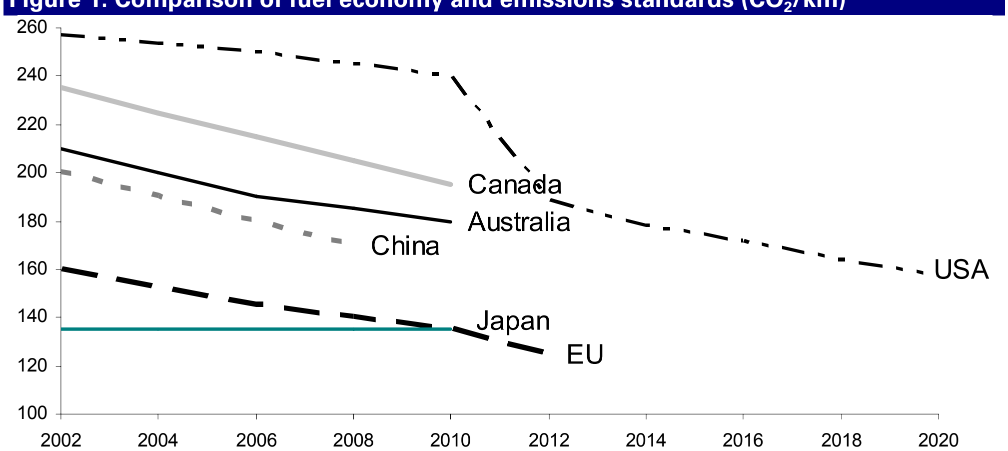
GM estimates that achieving the U.S. CAFÉ standard of 35 MPG by 2020 will cost the industry $100 billion per year ($5,000 per vehicle). And given the 5-7 year product cycles that prevail in the industry, automakers have begun to consider the technologies that will be required to meet these standards, and standards beyond this timeframe. Margo Oge, director of the EPA's Office of Transportation and Air Quality, indicated in an April speech that passenger cars and light trucks may have to average 75 miles per gallon by the 2030's in order to meet a widely backed scientific-community proposal to cut greenhouse gas emissions by 50-80% by 2050 from 2000 levels.

…and the EU wants to make European standards even stiffer. Average fuel economy levels in Europe are already at the equivalent of 35 MPG (European standards limit CO2 per kilometer, which is essentially the same as mandating CAFÉ, since each gallon of gasoline/diesel burned will always produce 19.4/22.2 pounds of CO_2). But the EU is pushing for 130 grams/km by 2012 (vs. 160 g/km today), which is roughly equivalent to 45 MPG. Based on an analysis by Roland Berger published in July 2007, the cost of compliance with these regulations could be in the $23 bn range ($2.2 bn for Ford and Volvo, $1.9 bn for General Motors. And many European automakers expect significant tightening beyond this level (to 100 g/km, or 60 MPG) as they look out to 2020.

Various jurisdictions are using carrot and/or stick. Many countries, cities and states are placing taxes, fees, and other restrictions on less fuel efficient/higher CO2 emitting vehicles, and providing benefits to stimulate purchase of more efficient vehicles.

- Several cities in Europe have begun assessing charges for less fuel efficient vehicles to enter the city; hybrids and electric vehicles are free.
- France has begun implementing a "feebate" system, charging fees ranging from Euro 750 to Euro 1,600 to purchasers of large vehicles, and passing along rebates (Euro 200 to Euro 700 in most cases) for smaller vehicles and hybrids.
- Denmark and Israel are promoting the purchase of electric vehicles by offering these vehicles tax free, whereas purchasers of internal combustion vehicles pay taxes ranging from 60-150%.
- California has enacted a Zero Emissions Vehicle program mandating automakers to achieve ZEV credits for a small percentage of total vehicle sales, and the state is looking into other ways to regulate CO2 emissions.
- Several cities in China, including Shanghai and Beijing, have already placed significant restrictions on gasoline powered 2-wheelers, which has resulted in the world's largest (30 MM units) market for plug-in electric motorcycles. And these cities are taking similar steps against less fuel efficient cars, by applying license plate fees ranging from 2% to 20%, depending on engine size.

Figure 1: Comparison of fuel economy and emissions standards (CO_2/km)



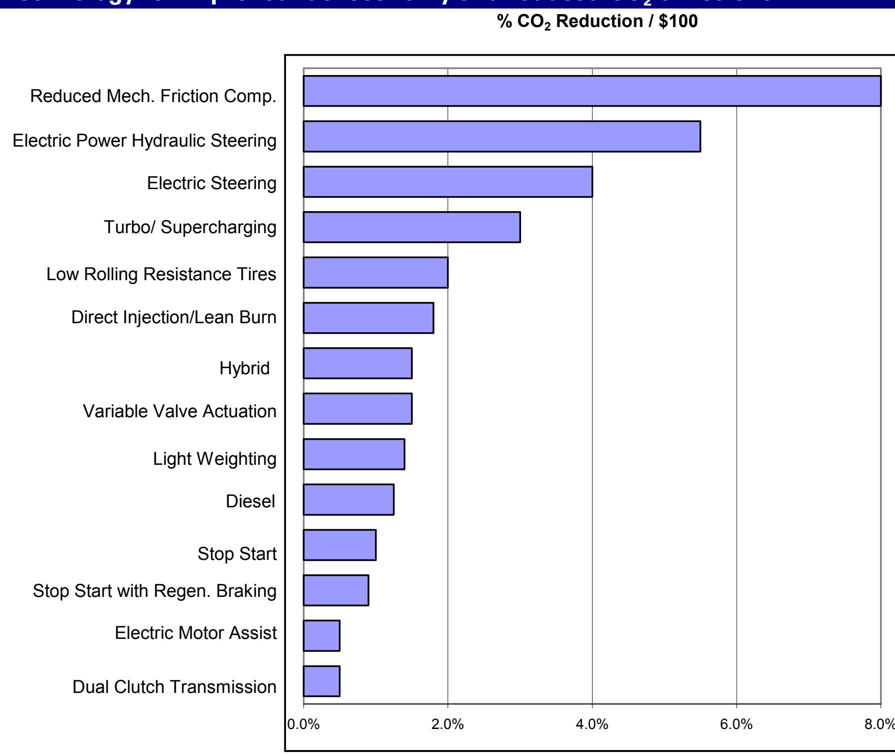
Source: Roland Berger, NHTSA

From change comes opportunity

As a result of these secular trends, we believe that vehicle technology could change more over the next five years than in the past 50.

Within our coverage universe, BorgWarner has become synonymous with fuel efficiency. We expect it to continue to benefit from booming demand for efficiency-enhancing technologies such as turbochargers, advanced timing systems, diesel engines, and dual clutch transmissions. Other companies we cover, including Johnson Controls, Continental, TRW, and Magna, also have growing technology businesses related to fuel efficiency.

Figure 2: Technology for improved fuel economy and reduced CO_2 emissions



	% CO_2 Red.	Cost
Reduced Mech. Friction Comp.	4%	$50
Electric Power Hydraulic Steering	4%	$70
Electric Steering	5%	$120
Turbo/ Supercharging	13%	$450
Low Rolling Resistance Tires	3%	$150
Direct Injection/Lean Burn	12%	$600
Hybrid	33%	$2,200
Variable Valve Actuation	6%	$425
Light Weighting	10%	$750
Diesel	25%	$2,000
Stop Start	4%	$300
Stop Start with Regen. Braking	7%	$800
Electric Motor Assist	5%	$1,000
Dual Clutch Transmission	7%	$2,000

Source: King Review, Deutsche Bank, NHTSA

However, more dramatic changes are likely

More recently, we have become increasingly convinced of the need for more dramatic changes to powertrain technology. Consumers are demanding – and regulators are requiring – considerable increases in fuel economy. These will be difficult to reach using conventional internal combustion engines alone.

The efficiency of internal combustion engines can be enhanced… Gains are achievable via turbocharging, direct injecting fuel, cylinder deactivation, advancements in engine timing, etc. Regardless, though, various mechanical processes occur within these engines:

- Intake of air and fuel into the cylinder,
- Compression of air and fuel,
- Combustion and expansion,
- Driving of the crankshaft,
- Conversion of the engine's mechanical power via the transmission,
- Transmission driving the axles which drive the wheels.

HEVs, PHEVs, and even fully electric vehicles appear destined for much more growth than is widely perceived

…but will always be inherently less than that of electric motors. Electric motors simply convert electrons to mechanical energy. According to the DOE's web site dedicated to fuel economy, only 15-20% of the energy contained in gasoline is used to propel the vehicle; the rest is lost primarily as waste heat. In contrast, electric motors are able to convert roughly 86% of available electric energy into motive power. They are relatively more efficient at low speed, when internal combustion motors are relatively less efficient.

This oversimplifies the gasoline versus electric comparison, and we point out that we need to take into account the efficiency of electricity generation. In addition, there are significant constraints related to the cost and practicality (i.e. range, refueling) of purely electric vehicles.

We nonetheless anticipate a significant increase in the electrification of the automobile. We and other observers expect hybrid electric/internal combustion vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and electric vehicles (EREVs and EVs) all to show dramatic growth over the next 10 years. In the U.S. alone, 13 hybrid electric vehicle models were available in 2007, 17 are expected by the end of 2008, and at least 75 will be available within three years (by 2011). As we noted earlier, NHTSA projects a 20% hybridization rate for the U.S. market by 2015, and Global Insight projects 47% for the U.S. by 2020. (Note that U.S. market share for hybrids was just 3% in 2007.) In Europe, hybridization is projected to reach 50% by 2015.

Figure 3: Planned automotive HEV product offerings

Compacts & Sedans	SUVs and Minivans	Class 1 Trucks
Available:	Available:	Available:
Honda Civic	Ford Escape	GM Silverado
Lexus GS 450h	Lexus RX 400H	GM Sierra
Satrun Aura Green Line	Toyota Highlander	
Nissan Altima	Mercury Mariner	
Toyota Camry	Saturn Vue Green Line	
Toyota Prius	Chevy Tahoe	
Chevy Malibu		
Lexus LS 600H		
Expected or planned:	Expected or planned:	Expected or planned:
Honda Subcompact	Toyota Sienna Minivan	Dodge Ram
Hyundai accent	Dodge Durango	
	GMC Yukon	
	Porsche Cayenne	
	Chrylser Aspen	
	Mercedes ML 450	
In the works:	In the works:	In the works:
Ford Five-Hundred	Audi Q7	
Ford Fusion	Cadillac Escalade	
Hyundai Sonata	Ford Edge	
Kia Rio	Lincoln MKX	
Mercury Milan	Mazda Tribute	
	Volkswagen Touareg	

Source: Hybridcars.com,

Improvements in battery technology will allow for increased power, increased electrical propulsion, and bigger gains in fuel economy. Batteries can account for up to 75% of the incremental cost of HEVs and PHEVs. The market for advanced rechargeable batteries for hybrids is relatively small today – roughly $900 MM, dominated by Toyota Subsidiary PEVE, and other makers of nickel metal hydride batteries. But based on discussions with automakers and suppliers, there is almost no doubt that lithium ion technology should supplant NiMH. For a given weight or size, lithium ion batteries provide 1.4x-2.0x the power and energy, and have potential to significantly reduce cost compared with NiMH technology, which significantly increases their attractiveness (i.e. vehicle OEM's can replace more of the vehicle's power with electric power).

Rise of the electric vehicle

Fuel savings potential

A function of electric power capability – which in turn stems from battery capacity

The fuel savings potential of electric vehicles is largely dependent on the extent to which it can operate on electric power. This, in turn, is typically limited by the capacity (energy and power) of the battery.

Today's EVs, and those on the drawing board, are typically grouped into five categories. Each can progressively use electric power to a greater extent:

- **Micro hybrid:** Micro hybrid systems only stop the engine during idle (while still running heat, A/C, etc.), and instantly start it when the vehicle is required to move, providing efficiency gains in the 5%-10% range.
- **Mild hybrid:** Mild hybrids stop the engine during idle and provide additional power during vehicle acceleration, providing fuel efficiency gains in the 10%-20% range.
- **Full hybrid:** Full hybrids provide enough power for limited levels of autonomous driving at slow speeds, and they offer efficiency gains ranging from 25%-40%.
- **Plug-In hybrid:** Plug-in hybrids, which will begin rolling out in 2010, will allow for vehicles to store enough electricity (from an overnight charge) for the first tens of miles to be driven solely on electrical power. Beyond this range, they function like full hybrids.
- **Electric vehicle:** Electric vehicles do not have dual mechanical and electrical powertrains. 100% of their propulsion comes from electric motors, energized by electricity stored in batteries.

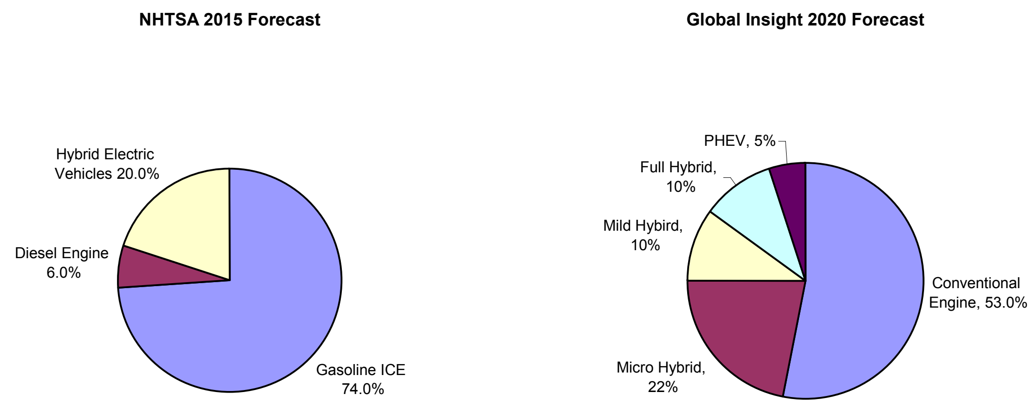
Figure 4: Hybrid fuel efficiency gains and costs

	Battery Cost	Non Battery Incremental Cost		Total Cost	Fuel Efficiency Gain
Micro Hybrid	$100	$500		$600	5% - 10%
Mild Hybrid	$600	$1,000		$1,600	10% - 20%
Full Hybrid	$1,200	$1,000		$2,200	25% - 40%
PHEV	$6,000	$2,000		$8,000	40% - 65%
Electric Vehicle	$11,000	$0	*	$11,000	100%

* = Incremental costs offset by elimination of ICE and other components

Source: Deutsche Bank

Figure 5: NHTSA and global insight hybrid penetration rate estimates for the U.S.



Source: NHTSA, Global Insight

Cost/benefit proposition is straightforward and compelling

We see costs and payback periods declining

Based on our cost benefit analysis of HEVs, PHEVs and EVs, we see growth being propelled by the compelling consumer payback offered by these technologies. Over time, we expect the incremental cost of upgrading a vehicle to a basic 1 kWh HEV will decline to approximately $1600 ($600 for the battery, and $1000 for the associated system controls, motors, power split devices and wiring). We estimate annual fuel savings at $4 per gallon and 12,000 of driving miles per year at $533, implying a 3 year payback. The payback is roughly half as long in markets such as the UK, Germany and Norway where gasoline costs more than twice as much per gallon. The payback for a 40 mile plug-in hybrid electric vehicle would be roughly 7.4 years in the US, assuming $1100 of annual fuel savings and $8000 of incremental cost. In Europe, fuel savings from this technology could approach $2100 per year, and the payback would be approximately 3.9 years.

Government sponsorship is a key variable

Government sponsorship could accelerate the payback, and growth trajectory of this market

Given higher up front cost, we believe that penetration levels for fully electric vehicles may depend on the extent to which governments provide incentives for zero-emission and zero-petroleum-consuming vehicles (through tax incentives, and sponsorship of recharging infrastructure), or the extent to which new business models emerge which eliminate the upfront cost of the battery, and spread this cost into the per mile cost of fuel. Government incentives to promote increased electrification of the vehicle parc appear to be justifiable. Aside from the environmental benefit, each 10% reduction in oil imports, and a commensurate increase in domestic (coal, nuclear, renewable) energy consumption would add at least $60 bn to the U.S. economy.

We note that even small volumes could represent fairly large pieces of business for suppliers to electric vehicles. The governments of Israel and Denmark have recently decided to initiate such incentives, by exempting EV's from motor vehicle VAT taxes, which range from 60% to 150% in those countries.

New business models will emerge…

New business models significantly increase the appeal of electric vehicles

With gasoline at $5.95 per gallon in Brazil, $8.38 in the UK, $8.73 in Norway and $9.28 in Germany, the cost per mile of a relatively fuel efficient car (35MPG) would still be in the $0.17-$0.26 range. For 12,000-18,000 miles per year of driving, this would equate to $2040-$4680 per year for fuel. Looking at the electricity equivalent cost, we assume roughly $0.10 per kWh and a range of roughly 5 miles per kWh, implying an equivalent cost per mile of $0.02.

A key problem, however is that a vehicle with reasonable electric range (100 miles) would require a $12,000 battery pack ($500 per kWh and 22 kWh). Although the incremental cost may be justified ($12,000 amortized over 150,000 miles equates to just $0.08 per mile), there are questions about whether consumers will be willing to bear the incremental up front cost.

Interestingly, we see new service-oriented companies emerging that will be able to take the upfront cost away from the consumer. One of the emerging leaders in this area, Project Better Place, is establishing a business model in which it will own the battery and sell the consumer "miles" at a lower cost than the equivalent cost of gasoline in each country (this is the only model that we know of in which the consumer can immediately benefit from lower fuel costs, without incremental upfront cost in the vehicle). A direct relationship between Project Better Place and electric utilities means that the cost of electricity will be absorbed by Better Place. Preferential tax treatment for electric vehicles will also provide an additional cost advantage for consumers purchasing electric vehicles. We see these factors as having a significant impact on the future growth of electric vehicles.

…led by breakthroughs in energy storage technologies

Batteries and ultracapacitors make this possible…and we expect lithium ion batteries to dominate

The key technical enabler for all HEVs, PHEVs, and EVs is high-energy, cost-effective, long-lasting, and abuse-tolerant batteries. The battery also accounts for up to 75% of the incremental cost of achieving full HEV, PHEV, or EV capability. The world market for rechargeable batteries is approximately $22 bn, and is still dominated by lead acid batteries, at $15 bn. The market for lithium ion batteries is approximately $7 bn per year, dominated by consumer electronics (Sanyo, Toshiba).

The market for lithium ion automotive batteries is insignificant at this point in time, since nearly all hybrid and electric vehicles are currently powered by nickel metal hydride batteries ($900 MM market for NiMH, dominated by Toyota Subsidiary PEVE). But based on discussions with automakers and suppliers, there is almost no doubt that lithium ion battery technology will ultimately dominate this market. For a given weight or size, lithium ion batteries provide 1.4x-2.0x the power and energy, and have potential to significantly reduce cost compared with NiMH technology, which significantly increases their attractiveness (i.e. vehicle OEM's can replace more of the vehicle's power with electric power).

Our analysis suggests that the market for "large format" automotive lithium ion batteries will reach $10-$15 bn by 2015 (versus $7 bn for the overall lithium ion battery market today), and it could reach $30-$40 bn by 2020. We would note that even small contracts for automotive batteries will be significant. The relatively low volume (50,000 units per year) GM Volt platform is expected to generate $400 MM per year in revenue for one of the two battery producers bidding for this contract.

Figure 6: Battery energy density and cost comparison

Energy Density	Cost	Charge Cycles
Lead Acid 30-40 wh/kg*	Eur/wh 0.15	500-1000
NiCd 40+*	Eur/wh 0.20	1000-2000
NiMH 71 WH/kg*	Eur/wh 0.60	1000-2000
Li Ion 105-170 wh/kg**	Eur/wh 0.3-0.4	7000+

Source: M. Keller and P. Birke, Continental Powertrain

…which could find many other large and important markets

Large format lithium ion batteries could benefit commercial truck, stationary power, and aviation markets

We believe that many markets will emerge for large format lithium ion batteries, including commercial truck, stationary power, and aviation. In addition, as vehicles become increasingly electrified, we see an emerging opportunity for vehicles to provide/sell electricity back to the grid to balance fluctuations in load and adapt to equipment failures. Today's electric grid has essentially no storage, and it has to maintain excess capacity in order to meet regulation control (fine-tuning the frequency and voltage of the grid), peak demand, and spinning reserves (reserves available to come on line quickly in the event of an outage).

Connection to the electric grid also holds great potential

A 2004 study of these costs by Willett Kempton and Jasna Tomic of the University of Delaware estimated that economic the cost of meeting these needs equates to roughly $12 bn per year for U.S. utilities. Typically, light vehicles are only used 4% of the time for transport. Assuming that future plug-in hybrid and electric vehicles will be similarly utilized, there is potential for them to be connected to the grid (in the garage or in an office parking lot) for some portion of the remaining 96% of the time. Using real world pricing from the California Independent System Operator (CAISO), and the capacity and throughput of a Toyota RAV4 electric vehicle using older NiMH battery technology, Kempton and Tomic estimated that regulation services could theoretically provide $3285-$4928 of annual revenue to the RAV4 owner.

Utilities have begun purchasing large format lithium ion batteries themselves

We'd note that regulation of the grid would be expected to only use a very small (i.e. 4%) part of a typical vehicle's battery capacity, which may not even be noticeable for the vehicle owner). Given the compelling financial benefits of having storage available, utilities have recently begun purchasing large format lithium ion batteries themselves. For example, we are already aware of a 2 MW battery sale by A123 in October, 2007, and 20 MW bookings more recently.

Alternative power could be transformed by this technology

The storage capacity of lithium ion batteries would also have significant implications for certain types of alternative power, as energy can now be economically stored during peak PV (solar) power generation during the day, or at night during peak wind power generation. Dong Energy, a primarily wind powered utility based in Denmark, recently signed an agreement with Project Better Place that will enable the utility to store energy generated at night within Project Better Place electric vehicles, and utilize some of that stored energy during the day, when it is less windy.

Electric vehicles: under the hood

Why go hybrid?

In considering the challenges facing the industry, including dramatically increased desire for fuel efficiency, regulatory requirements for fuel efficiency/lower CO2 emissions, and the desire to maintain many of the physical and performance attributes of today's vehicles, automotive engineers are recognizing that increased levels of electrification will be required. As noted earlier, hybrids describe vehicles that combine two or more sources of propulsion energy—fuel and electricity—and use internal systems to balance the use of an internal combustion engine and electric motors to achieve greater overall operating efficiency.

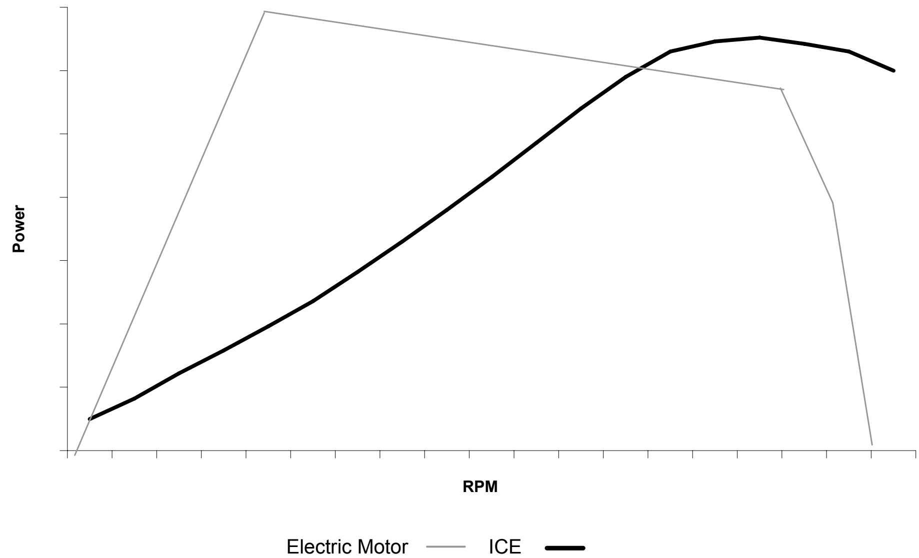
A typical HEV is able to increase the efficiency of a vehicle through three mechanisms:

- Shutting down the engine at idle when stationary, or traveling at low speeds, eliminating unnecessary fuel consumption;
- Recovering energy for future use through regenerative braking, and;
- Downsizing the internal combustion engine, and switching between the engine, the electric powertrain, or running both in order to operate each source near its optimal efficiency.

Of these factors, the third is by far the most significant. The biggest fuel efficiency gain for a hybrid vehicle comes from the differential efficiency curve of an internal combustion engine versus an electric motor. In simple terms, this means that conventional internal combustion engines are relatively inefficient at slow speeds (as low as 5-10% efficient). But at full throttle, the efficiency for gas engine could be closer to 28%. On average a gasoline engine is estimated to be 15-20% efficient. A diesel engine at full throttle can reach 33% efficiency, versus the 23% average quoted by DOE. The problem is that engines rarely function at maximum power – especially in urban environments.

In contrast to gas and diesel, electric motors have a very different efficiency curve. They are capable of producing maximum torque at launch, and they maintain a relatively flat efficiency curve until they reach a relatively higher speed. The advantage of the hybrid electric powertrain is its ability to use a combination of the two, maximizing the use of the electric powertrain at slow speed, and shifting to the internal combustion engine at speeds that give the internal combustion engine an advantage.

Figure 7: Electric motor vs. gas engine efficiency curve



Source: Deutsche Bank, A123, Toyota

Hybrid categories

The fuel savings potential of HEVs is largely dependent on the extent to which it can operate on electric power. This, in turn, is typically limited by the capacity (energy and power) of the battery. Today's hybrids, and those on the drawing board, are typically grouped into four categories, each of which can progressively use electric power to a greater extent.

Micro hybrids include systems that allow the engine to stop during idle, and instantly start when the vehicle is required to move. These types of vehicles offer minimal if any electric power to propel the vehicle, and the lowest level of regenerative braking. The cost of these systems is lowest, and they can be integrated into virtually any platform by replacing the starter/alternator with a high power starter alternator. Fuel consumption improvement from a micro hybrid is typically in the 5-10% range (per Johnson Controls). NAS and EEA reports estimate the incremental cost of this technology at $563-$600 per vehicle, including the addition of electric steering (replaces hydraulic steering because hydraulic power is not available during engine stop), and upgrades to 42 volt electric power.

Mild hybrids have engine start-stop capability, plus small electric motors and slightly upgraded batteries. These are sufficient to provide some electric boost to the propulsion system. Although autonomous driving is not possible on the small electric motors built into mild hybrids, the boost potential does allow for some engine downsizing. There are several versions of this technology, which affects the cost and benefit. Generally, fuel economy savings from mild hybrids are estimated in the 15% range. The Northeast States Center for Clean Air Future (NESCAF) study estimated incremental cost for mild hybrids at $2310-$2940.

Full hybrids provide all of the benefits of the prior systems. Their electric motors and batteries are large enough to provide some level of autonomous driving on electric power. Full hybrids offer fuel efficiency gains ranging from 25% to 40%. EPA estimates the cost of full hybrids at $3700-$3850.

Figure 8: Payback of current hybrid offerings

	NiMH Hybrid Cost Premium	Fuel Economy Avg	Gas Savings @ 3.61/gal	Yrs. To Break Even @15k mi/yr NiMH Battery
2008 Nissan Altima 2.5S 4dr		27		
2008 Nissan Altima Hybrid 4 dr	$ 1,561	34	490	3.2
2008 Toyota Camry LE 4dr		26		
2008 Toyota Prius 4dr	$ 3,489	47	989	3.5
2008 Honda Civic EX 4dr		31		
2008 Honda Civic Hybrid	$ 2,803	43	578	4.8
2008 Saturn Vue XE		23		
2008 Saturn Vue Greenline hybrid	$ 4,770	29	684	7.0
2008 Escape XLT		23		
2008 Escape Hybrid	$ 4,161	32	568	7.3

Source: Edmunds.com

Plug-in hybrids have even greater electric capability than full hybrids. They are characterized by providing the ability to charge the vehicle with electricity off of the electric power grid, which would enable the first tens of miles to be driven entirely on electric power. Since 50% of consumers drive less than 25 miles per day (80% drive a maximum of 50 miles per day), a significant portion of the energy consumed could come from electric power. Beyond an initial 10+ mile electric range, the plug-in hybrid would effectively operate like a full hybrid, with primary propulsion provided by the internal combustion engine, augmented by the low speed efficiency of an electric powertrain. Plug-in hybrid vehicles are expected to be designed such that they can operate 50% of the time on electricity. The other 50% of their operation would be at a Toyota Prius-like 46 mpg (5.1 liters per 100 km).

Overall, PHEV's are expected to have the ability to deliver a 40%-65% improvement in fuel economy (versus non-hybrid vehicles), at a cost of $4500-$10,200. Ultimately, the cost and fuel savings will be somewhat dependent on the size and cost of the battery.

Plug-in electric vehicles and extended range electric vehicles

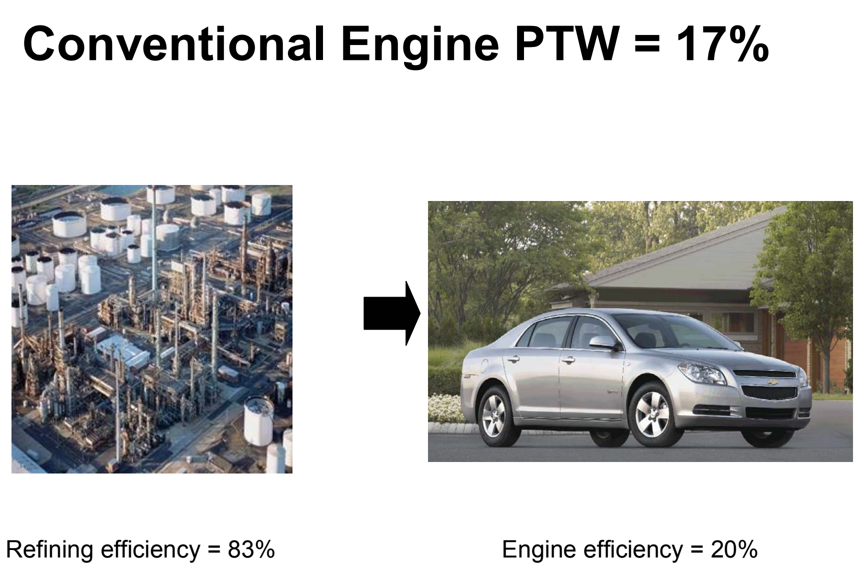
Moving beyond HEVs, we have observed an unprecedented amount of development work on electric vehicles being conducted by global automakers including General Motors, Nissan, Renault, Volkswagen, Mitsubishi, Chrysler, Subaru, Chery, BYD, and others. Electric vehicles are differentiated from plug-in hybrids in that they do not have dual mechanical and electrical powertrains. 100% of their propulsion comes from zero emission electric motors, energized by electricity stored inside large on-board batteries. Positives include additional reliance on the electric grid for energy, which is inherently more efficient, more reliable (electric motors contain one moving part, versus 400 in a typical internal combustion engine), and potentially more fun to drive (electric vehicles can offer higher torque at low speeds). Drawbacks associated with this technology include range, cost, time to refuel/recharge, and size/weight.

In comparing electricity generated by a utility with energy generated in a mobile internal combustion engine, it is difficult to escape the conclusion that large scale production of energy running at a high level load is better than millions of small mobile engines running at variable load. A simple comparison could be made to illustrate this conclusion, based on one of the few remaining large scale diesel powered electric utilities. Using data from a utility in Anguilla, 1 gallon of diesel is sufficient to generate 18.21 kWh of electricity. This electricity would be sufficient to propel an electric vehicle for 89 miles (using 4.9 miles per kWh). This compares with 38 miles per gallon for the same gallon being consumed in the diesel engine of a comparable car.

In order to take a holistic view of the energy consumed in propelling a vehicle, comparisons between powertrain technologies typically use “Well to Wheel” or “Tank to Wheel” analysis. In the case of an internal combustion engine that is powered by gasoline or diesel, the analysis combines the energy efficiency of fuel extraction, refining, and transportation of fuel in the “well to tank” segment, and the conversion of gasoline to mechanical energy in the tank to wheel segment. For electric vehicles , the well to tank segment also includes the extraction and distribution of fuel (coal, oil), as well as the generation and distribution of electricity in the well to tank segment, and the storage and conversion of electricity into motive energy in the tank to wheel segment. Since the resource extraction function (i.e. mining coal or drilling for oil) is similar, irrespective of whether the resource is used to produce electricity or gasoline, comparison between electric and gasoline internal combustion vehicles often focuses on the plant to wheel portion of the energy conversion life cycle.

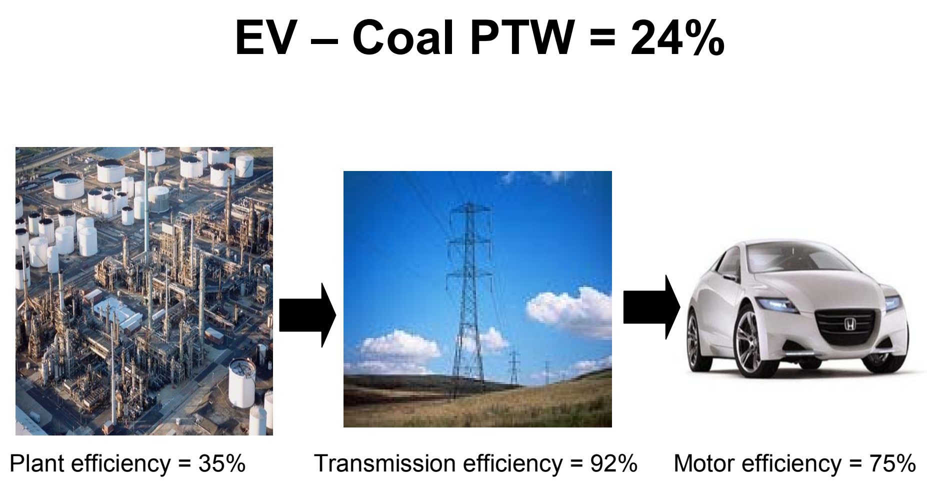
Looking at the plant to tank efficiency path, oil and gas refineries are actually very efficient. Heat is consumed in the distillation and in the catalytic cracking of oil. Nonetheless, full petroleum refining and distribution (i.e. delivery to gas stations) efficiency is estimated at 83%. As stated earlier, the energy efficiency of a typical internal combustion gas engine is in the 18-23% range. Combining these two efficiency statistics, the total PTW efficiency for a gasoline engine is estimated at 15-19%.

Figure 9: PTW of a conventional engine



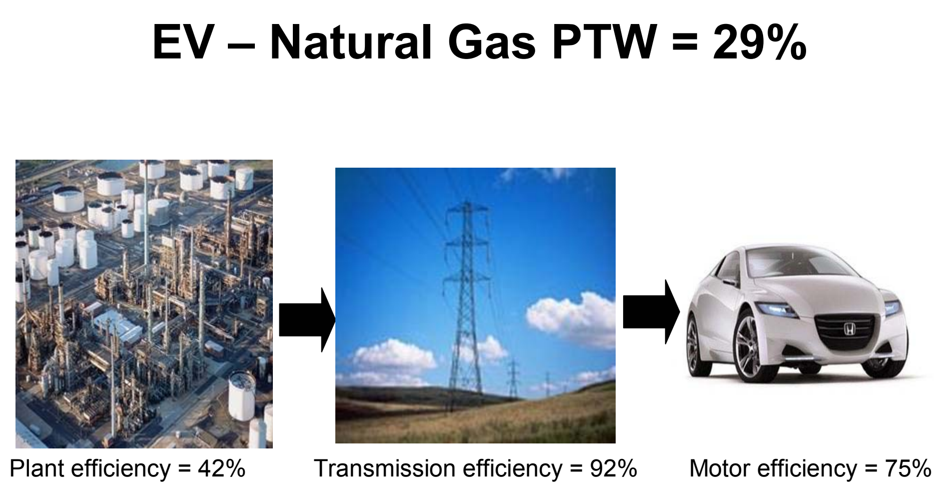
Source: World Wide Fund for Nature

Figure 10: PTW of coal powered electric vehicle



Source: World Wide Fund for Nature

Figure 11: PTW of natural gas powered electric vehicle



Source: World Wide Fund for Nature

The comparative efficiency of an electric vehicle depends somewhat on the source of electricity. Solid coal has a relatively low energy content per unit of carbon, and hence, a relatively low efficiency rate of roughly 35% (per the IEA). Natural gas powered plants operate at efficiency levels of 42%. Grid transmission and distribution losses are 8%. Taken together, the plant to tank efficiency for electricity is therefore 32%-38% using coal and natural gas as the sources of power. As mentioned earlier, the efficiency of an electric vehicle's electric drivetrain is approximately 86%. However, taking into account charging losses and losses of efficiency in the battery, we use estimates in the 75% range. (A 2001 study by Sweden's Lund University found battery electric vehicles operated at 57% efficiency, but estimated that efficiency would rise to 76%; a recent IEA report estimated BEV efficiency at roughly 74%).

Taken together, we estimate the PTW efficiency for electric vehicles at 24-29% for coal and natural gas. And we would note that with electric vehicles, electricity could be generated from many more sources, including even more efficient nuclear energy (more efficient than coal or natural gas), or efficient renewable sources such as wind, solar, geothermal, hydro, etc. We expect many countries to promote the use of electric vehicles as a path to reducing CO2 emissions, increasing the use of renewable energy sources and reducing dependence on foreign oil (which could have massive implications for reducing trade deficits and stimulating domestic economies).

Irrespective of regulatory or environmental drivers that will likely drive some growth for electric vehicles, we see demand growing in many markets based on economics. With gasoline at $5.95 per gallon in Brazil, $8.38 in the UK, $8.73 in Norway, and $9.28 in Germany, the cost per mile for a relatively fuel efficient car (35 MPG) would still be in the $0.17-$0.26 range. For 12,000-18,000 miles of driving, this equates to $2,040-$4,680 per year for fuel. Looking at the electricity equivalent, we assume roughly $0.10 per kWh and a range of roughly 5 miles per kWh, implying an equivalent cost per mile of roughly $0.02. To account for depreciation of the battery, we assume a long range electric vehicle requires a $12,000 battery pack ($500 per kWh and 22 kWh), and we assume a 150,000 mile life expectancy to derive an $0.08 per mile depreciation cost.

Adding together the cost of electricity to the cost of depreciation, we arrive at a $0.10 per mile cost per mile for electricity to propel an electric vehicle. Assuming 12,000-18,000 miles per year this would equate to $1,200-$1,800, which we believe to be 40-60% less than the cost of fueling a comparable internal combustion vehicle (including the cost of the battery). The cost of the rest of the vehicle, without the battery, should actually be somewhat lower than the cost of an equivalent internal combustion fueled vehicle, considering that the electric vehicle would not require an engine ($1500 cost), or complex transmission (electric vehicles can use simpler, 2-3 speed transmissions that cost $300, versus $600-$800 for a comparable 5-6 speed transmission).

Figure 12: Cost of fueling – electric vs. gasoline ($)

		Gasoline			
	Electricity	US	Brazil	UK	Germany
Cost per Gallon / kWh	0.10	4.00	5.95	8.38	9.28
Miles per Gallon / kWh	5	35	35	35	35
Fuel Cost per Mile	0.02	0.11	0.17	0.24	0.27
Battery Depr per Mile	0.08	-	-	-	-
Miles per Year	15,000	15,000	15,000	15,000	15,000
Fuel Cost per Year	1,500	1,714	2,550	3,591	3,977

Source: Deutsche Bank

The drawbacks of electric vehicles include battery cost, range, time to refuel/recharge, and size. But as described earlier, the cost of the battery is actually less of a concern than it might appear, since the cost of depreciation on the battery plus electricity is actually less than the equivalent cost of gasoline or diesel in most markets – we see the higher up front capital cost of the battery as primarily a financing issue. We would also note, for example, that companies including Project Better Place and Think are intent on changing the fueling business model, and they themselves want to own the battery. In the case of Project Better Place, the company wants to provide the battery, and sell miles to consumers who subscribe to their services (much like a mobile phone service provider provides the phone, and charges minutes). This is the only model that we know of in which the consumer will immediately benefit from lower fuel costs, without incremental upfront cost in the vehicle. We see this factor, along with government incentives promoting zero-emission vehicles, as having a significant impact on the future growth of electric vehicles.

Although companies such as Better Place also plan to establish battery exchange centers that will facilitate range extension, the issue of range is still significant. A battery powered vehicle will always have a lower range than a gasoline or diesel fueled vehicle for a given size and weight, given its lower energy density. Gasoline has approximately 13 kWh/kg of energy, whereas the best performing lithium ion batteries have 0.17 kWh/kg. Even if we consider that the gasoline powered vehicle only uses 15-20% of its available energy, gasoline would still provide 2-2.6 kWh/kg of useable energy. Even at 89% conversion efficiency, the electric motor would utilize 0.15 kWh/kg of useable energy. The bottom line is that a battery would have to be approximately 10x the size of a gasoline fuel tank in order to provide an equivalent driving range. Using 0.14 kWh/kg energy density for the NEC battery that will be used in Renault's Electric Megane model, we estimate that a 22 kWh battery will weigh nearly 160 kg (345 lbs). And this battery will only provide about 100 miles of range when new (assuming that 90% of the battery is useable, and assuming roughly 4.9 miles per kWh for this vehicle). Higher vehicle loading, the use of air conditioning, or driving in hilly areas could significantly reduce this range (BorgWarner's engineers have noted that it take 9kw to move a reasonably sized vehicle up a 30% grade).

To be fair, a 100 mile range should be sufficient for most driving needs. A U.S. DOT survey in 1990 found that half of all motorists in the U.S. traveled 25 miles (40 km) per day or less and 80% drove a maximum of 50 miles (80km) or less. The 2007 Transportation Energy Data book indicated the average trip in the U.S. was 9.9 miles, and the average daily vehicle drive was 32.7 miles. EV's may be even more popular in Europe, and in other countries with lower geographic dispersion and higher gas prices. In the EU-25, the average daily drive is approximately 17 miles (27 km). In the UK, more than 75% of car journeys are less than 10 miles (16 km); 93% are less than 25 miles (40km).

Despite the ability to practically use EVs for over 95% of typical daily driving needs, consumers may still have difficulty accepting a vehicle that is range limited to 100 miles or less. GM expects to overcome this range issue by installing an onboard 50 HP generator in its first EVs. This generator will replenish the battery or provide electricity for driving once the vehicle's 16 kWh battery is depleted to a specific charge level (around 30%). In combination with the on-board range extender (generator), GM's electric vehicle is expected to have a 400 mile range.

The battery is key

The key technical enabler for all HEVs, PHEVs, and EVs is high energy, cost effective, long lasting, and abuse tolerant batteries. And as we indicated earlier, the battery also accounts for roughly 75% of the incremental cost of achieving full HEV, PHEV, or EV capability.

The function of the battery in a vehicle is to store electricity. The amount of electricity that the battery can store is measured in kWh. In general, an increase in the kWh capacity of a battery translates into the ability to drive further on electric power, or providing more electric boost, increasing fuel efficiency.

Today: nickel metal hydride (NiMH)

NiMH is reliable and long-lived…but heavy and expensive, among other things

Today's HEVs are generally powered by nickel netal hydride (NiMH) battery chemistry. These batteries are reliable and have long life expectancies. But they are expensive (due to high nickel content) relatively heavy, have less than ideal energy conversion efficiency (i.e. they get hot), and they experience significant degradation if discharged completely, such as would be the case in an electric vehicle.

To overcome some of these problems, NiMH batteries are typically discharged only briefly, in order to provide spurts of energy boost to support an internal combustion powertrain. But they are not relied on heavily. Indeed, typically only 10% of a NiMH battery's capacity is charged and discharged. Most of the extra capacity available in a NiMH battery is there as a buffer to ensure that the battery will meet a specified performance levels after degrading somewhat by the end of its 10-year design life.

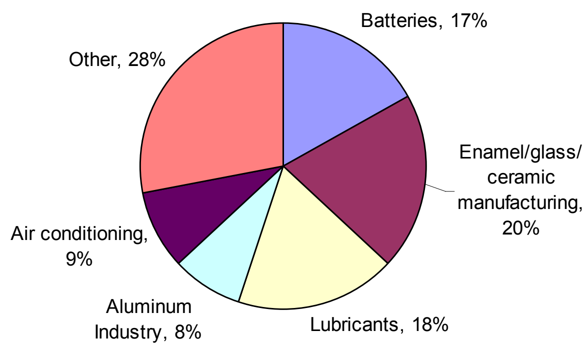
The future: lithium ion chemistries

Lithium is non-toxic, light, high energy, has other desirable properties…plus, it's still cheap and available

Of all metals available for battery chemistry, the battery industry has long considered chemistries based on lithium ions to be the most promising. It is not toxic (lithium is used in drugs, and was an original component of the 7-Up soft drink), it is light (the lightest metal on the periodic table), it has a high specific energy content, and it possesses other desirable electrochemical properties (organic electrodes are protected from corrosion by "filming" on those electrodes; this film, called the SEI layer, protects electrode, but still allows lithium ions to pass through). In addition, lithium is currently inexpensive and readily available. 15 million tons of lithium occur in brine resources and more than 2 million is in ore deposits. Large producers of lithium include SQM (Chile), Chemetall (Part of Rockwood Holdings), FMC, and Admiralty Resources (Argentina).

Based on discussions with battery industry experts, it is believed that nearly all of the new HEV and EV development programs amongst the global automakers will use lithium ion batteries (GM has said that all of their hybrid vehicles after 2010 will incorporate lithium ion batteries). Industry players have identified 55 specific lithium ion HEV and EV development programs.

Figure 13: Lithium market breakdown



Source: Professor Martin Winter University of Muenster

Lithium ion batteries have several advantages…

When compared with NiMH batteries, Li-Ion battery modules have several advantages:

- **Higher power:** They have 1.4x to 1.7x the power density of NiMH. Available energy per unit of volume at comparable power levels is 20%-80% higher, overall modules are 20%-30% smaller and 30%-40% lighter. This implies smaller and lighter batteries, and lower cost.
- **Utilization/cost:** For certain chemistries, more of this power could be utilized, which also means lower cost, because lithium ion batteries can use smaller cells.
- **Efficiency:** Certain chemistries have better charge/discharge efficiency, which means they don't get as hot, which should lead to longer life and increased safety.
- **Input costs:** Li-Ion batteries typically have lower metal cost per kWh (though we note that they have higher cost for all other components).

These attributes have resulted in Li-Ion batteries gaining a substantial share of the market for rechargeable consumer electronics batteries. But we note that consumer electronics batteries typically have life expectancies in the 2-3 year range, they do not typically operate in temperature extremes, and they are easier to protect from the catastrophic abuse that can occur in a vehicle (such as in an accident).

…as well as challenges

- **Safety:** Overcharges, charging in extremely cold weather, short circuits, and other abuse conditions could destroy the battery and potentially cause safety problems including "thermal runaway", and fire (batteries contain combustible materials such as lithium, electrolyte solvents, and other gases).
- **Performance:** Most lithium ion cells have difficulty operating at very low/very high temperatures, and many deteriorate at very low or very high charge levels.

- **Durability:** All batteries degrade over time. But given their cost, lithium ion batteries will be required to last thousands of charge/discharge cycles (300,000 for HEV's and 7.000 for EV's), and achieve a 15+ year calendar life, while maintaining 80% of their initial power and energy capacity levels at the end of their lives. Most automakers design extra margin into the batteries, in order to ensure that their batteries still meet minimum performance levels after degradation (GM's 16 kWh battery for the Volt only requires 8 kWh of capacity). But this adds considerably to battery size, weight, and cost.
- **Cost:** The U.S. Advanced Battery Consortium (USABC), a partially DOE funded consortium of U.S. Automakers involved in funding battery research, has established a price target of $500/system for HEV batteries, and $1,700-$3,400 for 10-mile and 40-mile PHEV batteries. As we discuss below, today's battery offerings do not yet meet all of these cost criteria.

Even though not all of these objectives have been met, approximately $1 bn per year of R&D is going into lithium ion battery chemistry, with an increasing proportion of this money being allocated toward automotive applications. The R&D initiatives have had noteworthy success. Original lithium ion 18650 cells, which are commonly used on laptops, had power density levels of roughly 90 wh/kg in 1990. The latest Matsushita batteries have 232 wh/kg.

Safety issues have been addressed through three mechanisms:

- **Chemical formulations:** Changes to the chemical formulations of electrodes have made them more stable, longer lived, more powerful;
- **Cell level engineering:** This includes the incorporation of extremely thin but robust electroactive separators (which prevent short circuits), special cell housings, specially engineered electrolyte chemistries with additives that can break down and shut down the battery under certain conditions;
- **System level controls:** These include cooling systems, electronic voltage controls (to prevent potential for overcharges), cell balancing mechanisms, and other means.

Figure 14: Battery energy density and cost comparison

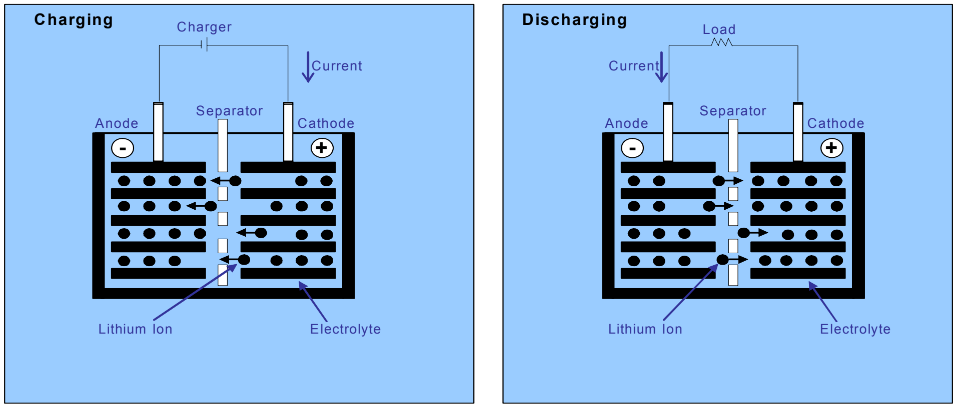
Energy Density	Cost	Charge Cycles
Lead Acid 30-40 wh/kg*	Eur/wh 0.15	500-1000
NiCd 40+*	Eur/wh 0.20	1000-2000
NiMH 71 WH/kg*	Eur/wh 0.60	1000-2000
Li Ion 105-170 wh/kg**	Eur/wh 0.3-0.4	7000+

Source: M. Keller and P. Birke, Continental Powertrain

There are four main types of automotive lithium ion batteries

A lithium ion battery is, in principle, a simple device. Within the battery there are two host electrodes – one a cathode (+) and one an anode (-) – that can accommodate lithium ions. During discharge, the lithium ions travel from the anode to the cathode through electrolyte and a separator. During charge, the opposite occurs. The composition of the cathode is the single biggest determinant of cell energy, safety, life expectancy, and cost. Anodes have typically been made of graphite, but companies have been experimenting with changes to the anode material (changing from graphite to lithium titanate, modified surface graphite, or hard carbon) in order to mitigate some of the shortfalls of graphite.

Figure 15: Function of a battery



Source: Deutsche Bank, Advanced Automotive Batteries

Based on data from battery companies, and automakers, we believe lithium battery technologies for automotive applications typically fall into four major categories, as seen in Figure 16. Each has specific advantages and disadvantages – but there is no clear winner based on chemistry alone.

Figure 16: Battery technology comparison

Chemistry	Wh/Kg	Positives	Negatives	Makers	Applications
Lithium Nickel Cobalt Aluminum (NCA)	170 Wh	Most proven High energy density High power	Safety Cost (cobalt / nickel) Life expectancy Range of charge	JCI/Saft PEVE	HEV
Lithium Manganese Spinel (LMO)	150 Wh	Cost	life expectancy Safety Low temp performance	LG Chemical Electrovaya	HEV
Lithium Titanate (LMO/LTO)	150 Wh	Safety Life expectancy Discharge time Range of charge	Cost vs. LMO Energy density	EnerDel Toshiba AltairNano	HEV
Lithium Iron Phosphate (LFP)	140 Wh	Safety Life expectancy Range of charge Cost	Low temp performance	A123	EV / PHEV

Source: Advanced Automotive Batteries, Company reports, Deutsche Bank

Lithium Nickel Cobalt Aluminum (NCA) cathodes

Nickel Cobalt Aluminum (NCA) cathodes are the most proven. Johnson Controls/Saft and Toyota have demonstrated extremely long life (15 years, 350,000 charge cycles). NCA also appears to have the highest potential energy density and power. These batteries appear to have advantages in HEV applications, but they may be less suitable for PHEV, EV, and stationary power applications.

Disadvantages include safety concerns and cost. NCA cathodes are the most thermally unstable of the automotive lithium ion chemistries, and they begin to degrade at high charge levels (high charge increases the chances of thermal runaway, which may mean that these batteries cannot use all of their capacity). They are also the most expensive due to heavy use of cobalt and nickel. Safety and life expectancy concerns have been resolved through engineering—separators, cooling systems, and controls to prevent too low or too high a charge. But it will be difficult to make them cost competitive with other chemistries, due to heavy use of cobalt. Safety and cost concerns have resulted in the development of other materials, including $LiNixCoxMnzO_2$. This chemistry helps reduce costs, and is believed to be somewhat safer, but cycle life at high charging (oxidation and gassing occur, impedence rises at high charge), safety, and cost remain issues.

Lithium Manganese Spinel (LMO) and Lithium Manganese Polymer cathodes

Manganese Spinel (LMO) cathodes are considered safer, and more environmentally friendly than NCA cathodes. They have a lower cost per kg, but since their energy density is lower, they may not necessarily be cheaper on a per watt hour. Safety and durability questions also remain. LG Chem and Electrovaya are among battery companies pursuing this technology.

Certain variants of this technology experience significant capacity fade during cycling and at more than 40°C, have more difficulty charging at low temperature (lithium metal plating occurs), and they can experience decay over time as manganese goes into solution and migrates to the anode. LG Chem and Electrovaya are among the battery companies pursuing Lithium Polymer based cathode technology.

Lithium Titanate (LMO/LTO) cathode/anode materials

LMO/LTO materials are being promoted by several companies (including Ener1, Toshiba, and Altair Nano) as a solution to some of the safety drawbacks of LMO. These batteries also use manganese cathodes, but are differentiated from LMO batteries in that they use titanate anodes. The resultant batteries become more stable, charge quickly even at low temperatures, they are long lived, and a wider range of their capacity can be used (i.e. 0-100% charge). The disadvantages are that lithium titanate batteries contain less energy (they operate at 2.5 volts instead of 3.5-4.0 volts for competing chemistries) which may require automakers to use more of them to overcome electrical resistance in auto components. And they are expected to be somewhat more expensive than LMO batteries. Despite these drawbacks, industry players believe this technology holds promise. Appropriate applications for this technology include those that require ultra long life, low energy, but high power applications such as in HEV's.

Lithium Iron Phosphate (LFP) cathodes

Lithium Iron Phosphate (LFE) cathodes appear to solve many of the safety problems associated with cobalt oxide and manganese spinel batteries. Many believe that they are the safest, because it is very difficult to release oxygen from their electrodes, which reduces risk of fire, they are much more resistant to overcharge, and they may be the lowest cost. Like LTO, a much wider range of battery capacity can be used. Most batteries are run between 30% and 70% charge in order to avoid undesirable side effects. Lithium Iron Phosphate batteries are able to run safely between 10% and 100% charge.

The low cost and ability to use a wide range of charge appears to make these types of batteries most suitable for PHEV and EV applications, which benefit from wide charge windows and low cost (because the batteries in these types of applications are the largest). On the negative side, LFE batteries appear to have weaker cold weather performance, and they may be more challenging to monitor electronically. A123 Systems in the U.S. is a leader in commercializing Lithium Iron Phosphate batteries for automotive, stationary power, aerospace, and consumer electronics applications (other developers of Lithium Phosphate technology include GS Yuasa in Japan and BYD in China).

Analysis of cost

Automotive batteries are typically described in terms of their power, which can be measured in kilowatts (kw), or energy content, which is often quantified in kilowatt hours (kWh). Hybrid electric vehicles, which only require brief, 5-10 second spurts of power from their electric motors use batteries specifically designed for power, and the ability to discharge quickly (referred to as C-Rate). Prices for "power batteries" are often quoted in terms of dollars per kilowatt. Batteries for plug-in hybrid electric and electric vehicles, which rely on electric power for long distance propulsion, are often referred to as "energy batteries". Prices for such batteries are often quoted on a per kilowatt hour basis.

For HEV Power Batteries, the USABC (Automotive Battery Consortium) has set an objective of developing cells that can generate pulse discharge power of 25 kw for 18 seconds at a cost of $20 per kw – i.e. a $500 battery. For reference, today's Toyota Prius has a 25 KW/1.2 kWh NiMH battery that we estimate at $1,200 (cost estimates for NiMH are $900-$1500/kw).

For PHEV's, USABC's cost target is approximately $500 per kWh, which translates to $1,700 and $3,400 battery cost targets for 10-mile and 40-mile PHEV batteries. For reference, the GM Volt is expected to utilize a 16 kWh battery, implying that the battery pack will cost approximately $8,000 per vehicle (EV's may require batteries in excess of 20 kWh, costing $10,000-plus). Importantly, GM estimates that achieving a 40 mile electric range with their Volt will only require 8 kWh (1 kWh is sufficient for 5 miles of range).

In other words, GM is over-sizing the battery, and will operate the battery in a 30% to 80% "State of Charge" window in order to accomplish two objectives:

- GM is allowing for a significant amount of degradation over 10 years, and wants to ensure that the vehicle will still achieve this level of performance rating at the end of its life, and;
- Operating the battery within a narrower charge window is expected to increase the battery's life expectancy.

Key drivers of battery costs include cell materials (i.e. lithium, manganese, cobalt, nickel, graphite, electrolyte chemicals, copper foil), packaging, manufacturing, and electronics. The raw materials themselves typically only account for 15%-20% of the overall battery cost. In terms of packaging, soft pouches are typically cheaper, but potentially less robust versus metal enclosures. Manufacturing of cylindrical (roll) type cells is typically cheaper than manufacturing of prismatic square cells (although prismatic squares often have advantages in terms of space utilization, and thermal management).

Aside from tuning the physical materials in the cells to contain more energy and power and increase safety and life expectancy, an important focus of battery R&D efforts is to develop batteries that degrade less (state of the art Lithium Iron Phosphate battery performance is predicted to degrade by 20% over 10 years), and which can safely use a larger state of charge charge window. Higher energy battery cells allow users to use less of them, which creates size and weight advantages, and this also reduces costs associated with connectors and electronics. This appears to be a key benefit of NCA and cobalt manganese mixed chemistries.

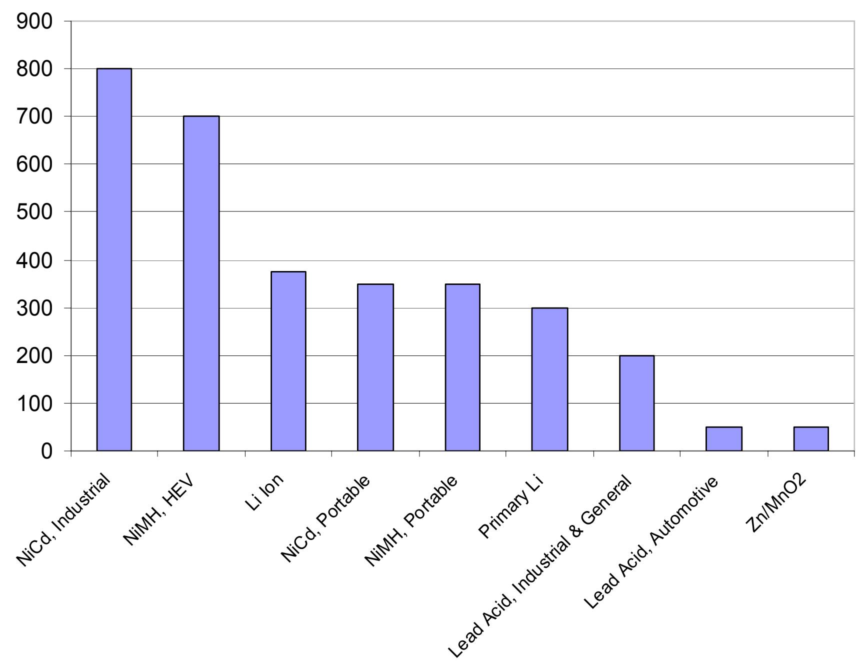
Interestingly, the ability to operate over a larger charge window is also important. This appears to highlight a key advantage of LMO/LTO and Iron Phosphate battery technologies over their competitors – these chemistries are able to use 90% of their capacity (i.e. the batteries can be charged to 100%, and depleted to 10%). Certain competing chemistries are limited to operations within 30%-70% charge windows in order to maximize life expectancy. As battery companies make more progress on reducing battery fade, and expanding charge windows, the cost of lithium ion batteries in automotive applications will decline even further.

Figure 17: Lithium ion power battery cost/kw estimates are as follows

NCA	$40/kw	JCI, Toyota, Samsung
LMO/LTO	$40/kw	Ener1
LMO/C	$40/kw	Hitachi, NEC
LiFE	$30/kw	A123
USABC Target	$20/kw	For 25 kw hybrid vehicle battery

Source: Deutsche Bank estimates

Figure 18: Average battery cost at cell manufacturing level in $/kWh (before electronics and connections are added to form the battery)



Source: Advanced Automotive Batteries

Analysis of market

We see an inflection point around 2012

Given the number of variables, including the outlook for oil prices, regulatory drivers, the potential for government or even electric utility intervention/stimulus, and the immature state of this technology in automotive applications, any forecast of the outlook for automotive lithium ion battery makers individually, or for the market in aggregate beyond the 2012 timeframe is highly speculative. Nonetheless, we are currently aware of 55 lithium ion specific HEV, PHEV and EV development contracts currently awarded, or nearing award. We would note that we see very small numbers of lithium ion equipped vehicles through 2011. But we expect to see an inflection point for the rollout of lithium ion automotive batteries in the 2012 timeframe.

Based on our estimates as well as discussions with numerous companies and industry experts, we believe the automotive lithium ion battery market could reach $10-$15bn by 2015 and it could grow to $30-$40bn by 2020.

Looking out to 2015, we project hybridized/electric vehicles will represent 20% of new vehicle sales in the U.S. (slightly above NHTSA's 20% estimate) and 50% of Western European sales (in line with Roland Berger and JD Power estimates). By 2020, we estimate penetration rates could increase to 49% in the U.S. and 65% in Europe. Micro hybrids (start-stop) will represent a significant portion of hybridized vehicles in the U.S. and Western Europe. We believe that through 2020, the majority of these hybrids will utilize valve regulated lead acid batteries due to their lower cost.

We see lithium ion capturing 30% of battery systems by 2015 – and 70% by 2020

By 2015, we estimate NiMH batteries will still account for 70% of the battery systems in mild and full hybrids. However, we believe lithium ion batteries should have close to 70% market share of this segment by 2020. We assume the majority PHEV and full EV vehicles will utilize lithium ion batteries due to their superior power density. Our revenue estimates are based on the following cost per lithium ion battery: mild hybrid $500 (1kWh), full hybrid $1000 (2 kWh), PHEV $6,000 (12kWh) and EV $11,000 (22 kWh).

While we cannot forecast hybrid and electric vehicle penetration rates in other markets with a high degree of confidence, we assume penetration rates will be significantly below those of U.S. and Western Europe. For the purpose of our analysis, we assume ROW lithium batteries will be 25% of those in Western Europe and the U.S.

We believe our estimates could prove conservative

We believe our estimates could prove conservative and highlight they are particularly sensitive to our penetration rate assumptions. For example, every additional percentage point of penetration of EVs in Europe could add $2bn to the lithium battery market.

Estimates of the segmentation of the market are beyond the scope of this report. However, our base case view of the market anticipates that HEVs will account for a much larger segment of the market than PHEVs and EVs. This conclusion is based on a simple cost/benefit analysis that suggests HEVs provide the biggest benefit for consumers.

For the purpose of this analysis, we compare the payback of HEVs, PHEVs and EVs based on the fuel consumption of a small/midsize car which we estimate has an average fuel economy in the 30mpg range. Current HEVs achieve approximately 45mpg utilizing a 1 kWh battery. We estimate the current battery cost is approximately $1200 per kWh and other components (primarily system controls, motors, power split devices, and wiring) cost another $1500 per vehicle. Based on the approximate fuel savings of $533 per year we estimate a payback of approximately 5 years (with NiMH) at $4 per gallon gasoline.

We expect the switch to lithium technology to reduce payback periods

Over time, we believe the switch to lithium technology will reduce the cost of the battery to approximately $500 per kWh and additional volume should reduce other costs to approximately $1000 per unit. This would reduce the payback to approximately 3 years. However, the lighter weight and smaller size of lithium ion batteries could allow automakers to install a more powerful battery, thereby increasing fuel economy. We believe a 2 kWh battery could improve fuel economy to 65mpg for $700 of additional cost which would further improve the payback to 2.8 years.

We believe the current payback of PHEVs and EVs of 7.4 years and 8.1 years remains too high for these technologies to dominate the U.S. market at current gasoline prices, without other incentives, or new business models such as Project Better Place's "pay by the mile" concept. (Note that our assumptions could change materially if business models such as Project Better Place take off -- since that business model effectively provides the consumer with an immediate payback / no incremental cost). Nonetheless, we believe there will still be a significant market for these products. In particular, in markets such as Europe, where fuel prices are running 2x those prevailing in the U.S. (which will cut the payback time in half), we expect the payback to improve with lower battery costs.

Figure 19: Our forecast for the automotive lithium ion battery market

	2015	2016	2017	2018	2019	2020
US Penetration						
Micro Hybrid	7.0%	10.3%	12.4%	16.7%	17.5%	22.0%
Mild Hybrid	6.0%	7.0%	8.0%	9.0%	10.5%	10.0%
Full Hybrid	6.0%	7.0%	8.0%	9.0%	10.5%	10.0%
PHEV	2.0%	2.5%	3.0%	3.5%	4.5%	5.0%
EV	1.0%	1.2%	1.6%	1.8%	2.0%	2.0%
Total US HEV/PHEV/EV Market Share	22.0%	28.0%	33.0%	40.0%	45.0%	49.0%
US HEV/PHEV/EV Volumes ('000)						
Micro Hybrid	1,314	1,972	2,421	3,326	3,555	4,559
Mild Hybrid	1,126	1,340	1,562	1,793	2,133	2,072
Full Hybrid	1,126	1,340	1,562	1,793	2,133	2,072
PHEV	375	479	586	697	914	1,036
EV	188	230	312	359	406	414
Total US HEV/PHEV/EV Volumes ('000 un	4,129	5,361	6,444	7,967	9,142	10,154
Europe Penetration						
Micro Hybrid	32.0%	32.1%	31.2%	30.3%	30.4%	30.0%
Mild Hybrid	8.0%	9.5%	11.0%	12.5%	14.0%	15.0%
Full Hybrid	7.0%	9.0%	11.0%	13.0%	14.0%	15.0%
PHEV	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
EV	1.0%	1.4%	1.8%	2.2%	2.6%	3.0%
Total Europe HEV/PHEV/EV Market Share	50.0%	54.0%	57.0%	60.0%	63.0%	65.0%
Europe HEV/PHEV/EV Volumes ('000)						
Micro Hybrid	6037	6117	6005	5890	5968	5949
Mild Hybrid	1509	1810	2117	2430	2748	2974
Full Hybrid	1321	1715	2117	2527	2748	2974
PHEV	377	381	385	389	393	397
EV	189	267	346	428	510	595
Total Europe HEV/PHEV/EV Volumes ('00	9433	10290	10970	11663	12368	12888
Market Share of HEV Batteries						
Nickel Metal Hydrid	70%	65%	60%	50%	40%	30%
Lithium Ion	30%	35%	40%	50%	60%	70%
Developed World Lithium Batteries ('000)						
Mild Hybrid	791	1,103	1,472	2,111	2,929	3,533
Full Hybrid	734	1,069	1,472	2,160	2,929	3,533
PHEV	753	860	971	1,086	1,307	1,433
EV	376	497	659	786	917	1,009
Lithium Batteries ('000 Units)	2,654	3,528	4,573	6,143	8,082	9,507
ROW World Lithium Batteries ('000)						
Mild Hybrid	198	276	368	528	732	883
Full Hybrid	184	267	368	540	732	883
PHEV	188	215	243	271	327	358
EV	94	124	165	197	229	252
Lithium Batteries ('000 Units)	663	882	1,143	1,536	2,020	2,377
Lithium Battery Revenue Per Unit						
Mild Hybrid	600	600	600	600	600	600
Full Hybrid	1,200	1,200	1,200	1,200	1,200	1,200
PHEV	6,000	6,000	6,000	6,000	6,000	6,000
EV	11,000	11,000	11,000	11,000	11,000	11,000
Lithium Battery Revenue ($MM)						
Mild Hybrid	593	827	1,104	1,583	2,197	2,649
Full Hybrid	1,101	1,604	2,208	3,240	4,394	5,299
PHEV	5,645	6,448	7,281	8,144	9,802	10,745
EV	5,175	6,827	9,059	10,810	12,606	13,878
Lithium Battery Revenue ($MM)	**12,514**	**15,706**	**19,651**	**23,777**	**28,998**	**32,572**

Source: Deutsche Bank estimates based on discussions with Global Insight, Roland Berger, battery companies and automakers

Figure 20: Hybrid/PHEV/EV cost/benefit analysis at US fuel costs

HEV/PHEV/EV Payback Analysis

	HEV vs. ICE	High Power HEV vs. ICE	PHEV-40 vs. ICE	PHEV-40 vs. HEV	PHEV-40 vs. HP HEV	EV vs. ICE	EV vs. HP HEV	EV vs. PHEV - 40
NIMH Costs								
kWh	1.0	2.0	12.0	12.0	12.0	22.0	22.0	22.0
Battery $/kWh	1200	1200	1200	1200	1200	1200	1200	1200
Battery total cost	1200	2400	14400	13200	12000	26400	24000	12000
Other incremental costs	1500	1700	2000	500	300	2000	300	0
Total incremental costs	2700	4100	16400	13700	12300	28400	24300	12000
Annual fuel savings	533	862	1084	551	223	1360	498	276
Payback (years)	5.1	4.8	15.1	24.9	55.2	20.9	48.8	43.5
Li Ion Incremental Costs								
Battery $/kWh	600	600	500	500	500	500	500	500
kWh	1.0	2.0	12.0	12.0	12.0	22.0	22.0	22.0
Battery total cost	600	1200	6000	5400	4200	11000	9200	5000
Other incremental costs	1000	1200	2000	1000	800	0 *	-1200	-2000
Total incremental costs	1600	2400	8000	6400	4000	11000	8000	3000
Annual fuel savings	533	862	1084	551	223	1360	498	276
Payback (years)	3.0	2.8	7.4	11.6	17.9	8.1	16.0	10.9

Cost of fuel	4.00
Cost per of electicity/kWh	0.1
Total miles driven	12000
PHEV-40 Assumptions	
Miles driven HEV	4000
Miles driven EV	8000
Fuel economy ICE	30
Fuel economy HEV	45
Fuel economy High Power HEV	65
Fuel economy EV (miles per kWh)	5

* = Incremental costs offsets by elimination of ICE and other components

Source: Deutsche Bank estimates, ACEEE Study

Figure 21: Hybrid/PHEV/EV cost/benefit analysis at European fuel costs

HEV/PHEV/EV Payback Analysis

	HEV vs. ICE	High Power HEV vs. ICE	PHEV-40 vs. ICE	PHEV-40 vs. HEV	PHEV-40 vs. HP HEV	EV vs. ICE	EV vs. HP HEV	EV vs. PHEV - 40
NIMH Costs								
kWh	1.0	2.0	12.0	12.0	12.0	22.0	22.0	22.0
Battery $/kWh	1200	1200	1200	1200	1200	1200	1200	1200
Battery total cost	1200	2400	14400	13200	12000	26400	24000	12000
Other incremental costs	1500	1700	2000	500	300	2000	300	0
Total incremental costs	2700	4100	16400	13700	12300	28400	24300	12000
Annual fuel savings	944	1526	2070	1126	545	2633	1108	563
Payback (years)	2.9	2.7	7.9	12.2	22.6	10.8	21.9	21.3
Li Ion Incremental Costs								
Battery $/kWh	600	600	500	500	500	500	500	500
kWh	1.0	2.0	12.0	12.0	12.0	22.0	22.0	22.0
Battery total cost	600	1200	6000	5400	4200	11000	9200	5000
Other incremental costs	1000	1200	2000	1000	800	0 *	-1200	-2000
Total incremental costs	1600	2400	8000	6400	4000	11000	8000	3000
Annual fuel savings	944	1526	2070	1126	545	2633	1108	563
Payback (years)	1.7	1.6	3.9	5.7	7.3	4.2	7.2	5.3

Cost of fuel	8.50
Cost per of electicity/kWh	0.1
Total miles driven	10000
PHEV-40 Assumptions	
Miles driven HEV	3333
Miles driven EV	6667
Fuel economy ICE	30
Fuel economy HEV	45
Fuel economy High Power HEV	65
Fuel economy EV (miles per kWh)	5

* = Incremental costs offsets by elimination of ICE and other components

Source: Deutsche Bank estimates, ACEEE Study

Lithium ion battery competitors

We see 10 developers at the leading edge

There are many derivatives of lithium ion chemistry

Based on discussions with automakers and suppliers, we believe that 10 developers of lithium ion battery technology are at the leading edge of consideration by the major global automakers:

- The Johnson Controls/Saft joint venture (NYSE-JCI and P-SAFT)
- A123 Systems
- LG Chem (KS-051910)
- Ener1 (ASE-HEV)
- AESC (joint venture of Nissan and NEC)
- PEVE (owned by Toyota and Matsushita)
- GS Yuasa
- Hitachi
- Sanyo
- Samsung

Numerous smaller companies are developing lithium ion cells for automotive applications – e.g., Altairnano (OTC-ALTI), Valence (OTC-VLNC), Electrovaya (T-EFL). These developers may have some success in niche markets, such as retrofitting commercial trucks. But based on discussions with automakers and suppliers, we believe that companies with automotive system and mass manufacturing experience have a clear advantage in vying for automotive contracts.

Figure 22: Li-Ion HEV key developers cell matrix

Li-Ion HEV Key Developers Cell Design Matrix

Company	Cathode	Anode	Electrolyte	Packaging	Structure	Shape
Toyota	NCA	Graphite	liquid	Metal	Spiral	Elliptic
Panasonic	NMC	Blend	liquid	Metal	Spiral	Elliptic
JCS	NCA	Graphite	liquid	Metal	Spiral	Cylindrical
Hitachi	LMO/NMC	Hard Carbon	liquid	Metal	Spiral	Cylindrical / Elliptic
AESC	LMO/NMC	Hard Carbon	liquid	Pouch	Stacked	Prismatic
Sanyo	LMO/NMC	Blend	liquid	Metal	Spiral	Cylindrical
GS Yuasa	LMO/NCA	Hard Carbon	liquid	Metal	Spiral	Elliptic
A123 Systems	LFP	Graphite	liquid	Metal	Spiral	Cylindrical / Elliptic
LG Chem	LMO	Brend Carbon	Gel	Pouch	Stacked	Prismatic
Samsung	LMO/NMC	Graphite	liquid	Metal	Spiral	Cylindrical
SK Corp	LMO	Graphite	liquid	Pouch	Spiral	Prismatic
Toshiba & EnerDel	LMO	LTO	liquid	Pouch/metal	Spiral	Prismatic
AltairNano	LMO	LTO	liquid	Pouch	Stacked	Prismatic
BYD	LFP	NA	liquid	Metal	Spiral	Cylindrical / Elliptic
Electrovaya	LMP	NA	NA	NA	NA	NA
Valence	LFP	NA	polymer	Pouch	Stacked	Prismatic

Source: Deutsche Bank, Advanced Automotive Batteries

Johnson Controls, A123, and Ener1

Johnson Controls (JCI)

JCI's Power Solutions business, which accounted for 12.5% of 2007 revenue and 27% of EBIT, is primarily engaged in providing lead acid batteries to the auto industry, where it maintains approximately 35% global market share (over 60% share in the U.S.). JCI's joint venture with SAFT has been involved in the development of lithium ion batteries, and it has already been awarded lithium ion battery production contracts for upcoming Mercedes, BMW, Chery and SAIC hybrids. And the company has been awarded development contracts for 16 additional vehicles. Longer term, it is not clear whether JCI's Nickel Cobalt Aluminum (NCA) technology will become the preferred chemistry for plug-in hybrid and electric vehicles, but it appears to be well positioned for HEV applications. We believe JCI may developing (or it may acquire) other chemistries. And its automotive systems capability and experience in large scale manufacturing significantly increases the probability that JCI will become a major player in the automotive lithium ion battery market (note that SAFT's interest in the JV will decline as JCI commits more capital to automotive applications, and we expect JCI to ultimately buy out its partner).

Separately, we believe that JCI's existing lead acid battery business also has potential to grow. While lithium ion batteries will most likely dominate mild, full hybrid and electric vehicle applications, we believe that more advanced valve regulated lead acid batteries, which can cost twice as much as typical car batteries, will be used to power micro hybrids through the middle of next decade. We expect micro hybrids to become a significant portion (50%+) of the European hybrid fleet.

A123

A123 is a U.S.-based private company founded in 2001 with the objective of commercializing a proprietary nanotechnology based manufacturing process for manufacturing battery electrodes with 8x the conductive material of competing technologies. It is currently involved in commercializing Lithium Iron Phosphate (LFP) batteries for automotive, stationary power, aerospace, and consumer electronics. High profile investors in the company include GE, Proctor & Gamble, AllianceBernstein, Northbridge Partners and Motorola. We believe that A123 is currently working on eight development contracts for 11 vehicles with many of the world's major OEM's (it is a contender for the Chevy Volt and Saturn Vue battery packs), and it has also obtained five production contracts, including contracts for the Think electric vehicle, hybrid Volvo trucks and Mercedes buses. Non-automotive contracts include starter batteries for Cessna aircraft, stationary power contracts with electric utilities, and contracts to provide lithium ion batteries for power tools (DeWalt).

Based on advantages including safety, cost and durability, we believe LFP technology has the potential to become a major winner in this industry, and A123 currently appears to be the leader. Although A123 currently operates commercial scale production of batteries for the power tool industry, a major challenge for A123 will be transitioning from development to commercial production of automotive scale batteries and avoiding the common pitfalls of fast-growing startup companies.

Ener1 (AMEX: HEV)

Ener1's automotive battery subsidiary, EnerDel, was formed as a partnership between Ener1 and Delphi in 2004. The company also has a fuel cell group and a nano-manufacturing group, but it is generally viewed as a pure-play lithium ion battery manufacturer.

The company's core chemistry is LMO/LTO (Lithium Manganese Spinel cathode and a Lithium Titanate anode). The key selling point for this technology is safety. LTO batteries pack less energy than competing LFP and NCA batteries. Nonetheless, in independent tests, this chemistry still outperforms NiMH batteries (when installed into a Prius, the Ener1 equipped vehicle was capable of delivering 77 mpg versus 62 mpg for the stock Prius, with a battery pack half the size). While the company currently has no material revenue, EnerDel recently shipped prototype electric vehicle batteries to Think Global for testing. If testing is successful, EnerDel will supply lithium ion batteries for the Think City electric vehicle, with production beginning in late 2008 and minimum revenue to EnerDel of $70 MM through 2010. Think's planned production run through 2010 is 10,000 units, with A123 having a portion of the volume above a minimum guarantee to Ener1. Ener1 is one of four battery companies in the USABC program (DOE funded consortium of US Automakers involved in advanced battery development and the ramp up to commercial scale production) and its battery prototypes have been successful within that program.

Although Ener1 currently has one production contract (for THINK electric vehicles), it is essentially a start up company today, with only prototype scale production. At this point, major automakers appear reluctant to issue large scale contracts until the company proves its manufacturing capability.

Another major challenge for Ener1, as with others, will be the ramp-up to commercial scale production. Ener1's facility has maximum capacity to produce 300,000 HEV batteries annually (or 30,000 EV batteries).

LG Chem, Sanyo, Samsung, Hitachi, Valence, GS Yuasa, Polypore, Asahi Kasai, Enova, Quantum

Compact Power Inc./LG Chem (Ticker: 051910.KS, LGCLY, Korean Stock Exchange)
LG Chem is a $14 bn revenue Korean-based chemical / materials business. It is a leading producer of lithium ion batteries for cellphones, laptops, and other portable equipment. Total monthly rechargeable battery production capacity is 23.5 MM cells, and we estimate that lithium ion battery production accounts for 18.5-20% of the company's sales and EBIT. Its subsidiary Compact Power Inc. (CPI) is a member of USABC, and is developing lithium ion batteries for automotive applications. CPI is using an LMO chemistry. It is currently believed to be the supplier for the prospective Hyundai Elantra hybrid due in Summer of 2009, and it is competing (against A123) for a contract to supply GM electric vehicles (Chevy Volt)

Technical challenges for LMO chemistry include calendar life, particularly at elevated temps. This chemistry has experienced poor cold cranking and low temp charging characteristics.

Sanyo (JP-6764) (DB Rating: Sell)
Sanyo is the world's leading producer of rechargeable batteries (including NiMH and Li-Ion). Sanyo currently produces NiMH batteries for Honda and Ford hybrids. The company's rechargeable battery business (for all applications) comprised 18% of total corporate revenue ($19.2 bn) in FY2007. Its overall battery business had FY2007 sales of $4.7 bn and operating profit of $530 MM, comprising 24% of corporate revenue and an impressive 52% of operating profit. Operating margin of 11.3% is significantly higher than any other Sanyo business unit.

Sanyo recently announced an aggressive ¥80 bn investment through 2015 in lithium ion battery production for HEV's and PHEV's. The company believes this investment will allow them to produce 10 MM cells per month by 2015 (enough cells for approximately 2 MM HEV's per year). This is inline with Sanyo's recent assertion that their goal is to have 40% market share of what they expect to be a 4-4.5 MM unit market by 2015. Sanyo recently announced a partnership with Volkswagen to develop Li-Ion batteries for VW hybrids, expected to begin sales in 2011.

Samsung SDI (KS-006400) (DB Rating: Hold)
Samsung is the third-leading producer of Li-Ion batteries, behind Sanyo and Sony. This division comprised 17.7% of total corporate revenue and was the only business unit to avoid losses in 2H07. The company expects 18% growth in the overall Li-Ion market (including 12% for mobile phones, 23% for notebook PC's, and 30% for power tools). Currently, we are not aware of development work for automotive applications; however, we believe that Samsung is a potential large player in this market, based on its experience with lithium ion.

Hitachi Vehicle Energy Ltd.
HVE is a JV between Hitachi Ltd (NYSE: HIT; TSE: 6501) (65%), Shin-Kobe Machinery Co, Ltd (TSE: 6934) (25%), and Hitachi Maxell Ltd (TSE: 6810) (10%). Hitachi produces a variety of products including consumer electronics, electric machinery, and semiconductors. Hitachi Maxell is a large-scale producer of Li-Ion batteries for various applications (batteries account for 26% of sales and 42% of operating income and lithium ion is the leading battery product within the segment). Shin-Kobe is a manufacturer of lead acid batteries.

HVE uses a NMC chemistry in its automotive batteries. It also produces motors and inverters for use in electrical drive systems and is the supplier of motors for GM's current mild hybrid system. Building on that relationship, Hitachi was named the Li-Ion battery supplier for GM's next-generation of mild hybrid vehicles and expects to supply 100k units per year for that program (Saturn VUE, Saturn Aura, Chevy Malibu) beginning in 2010. The prototype for those vehicles delivers 33% more power than the current NiMH battery with 40% less mass.

Valence (NASDAQ: VLNC)
Valence Technologies utilizes a Lithium Iron Phosphate technology in its batteries, similar to A123. Although we believe this chemistry is promising, A123 appears to be much farther along in achieving commercial orders. The company is not a participant in the US Automotive Battery Consortium. The company lost $5.7 MM in the most recent quarter on revenue of $3.4 MM and has an accumulated deficit on its balance sheet of $531 MM. There was little news over the last few years until the company announced a contract with Tanfield Group PLC (LSE: TAN), a producer of electric delivery trucks and vans. Tanfield primarily sells to the European market but is building a plant in California to potentially produce 10,000 trucks annually for the US market. VLNC announced that the contract called for "up to $70 MM" in batteries (an announcement that boosted VLNC shares by over 100%). Valence currently derives the bulk of its revenues from sales of batteries for the Segway motorized vehicles.

GS Yuasa (JP-6674)
GS Yuasa, formed in 2004 from the merger of Yuasa Corporation and Japan Storage Battery, is primarily a lead acid battery supplier for automotive and industrial applications. Total corporate revenue in FY2007 was $2.2 bn and automotive batteries were approximately 45% of that total. GS Yuasa formed Lithium Energy Japan, a JV with Mitsubishi Corp (GS Yuasa 51%, Mitsubishi Corp 34%, and Mitsubishi Motors 15%) in late 2007 for the development of lithium ion automotive batteries, using GS Yuasa's lithium iron phosphate chemistry (LFP). The JV appears to be focusing on a 50 amp-hour battery that would be applicable to a full electric vehicle. It has been tested on a Mitsubishi vehicle. We are not aware of any other contracts for GS Yuasa in lithium ion technology.

Polypore (NYSE: PPO)
Polypore is a specialty chemical company that produces membrane separators for lead acid and lithium ion batteries. The company's energy storage segment represented 71% of sales in 2007 (within that, lithium ion separators were 16% and lead acid battery separators were 55%). Total PPO revenues were $537.1MM. Polypore forecasts a 21% CAGR for Li-Ion battery separator demand between 2007 and 2011 (11% of that CAGR is from HEV opportunities alone), implying that segment sales could grow to $156 MM from $88 MM in 2007. Company filings state they are have a top three position for Li-Ion and are the top

producer for lead acid. PPO produces battery separators in facilities in Charlotte, NC, Tianjin, China, Shanghai, China, and Prachinburi, Thailand.

Asahi Kasai (JP-3407)
Asahi Kasai is another significant player in the lithium ion battery separator market, with an estimated 40-50% of the current market. Separators are part of the company's chemicals group, which comprised 52% of total corporate revenue of $1.7bn and 51% of operating profit of $128MM. Separators are part of specialty products, within chemicals, a group that alone comprised 12% of total corporate revenue and 22% of operating profit. In order to satisfy forecasts of significant demand increases the company is building a new plant (Hyuga) and expanding another (Moriyama).

Enova (AMX: ENA)
Enova is a developer/producer of hybrid/electric motors and control units. The company currently has production contracts with Th!nk, Tanfield/Smith Electric Vehicles (delivery trucks/vans), IC School Bus (owned by Navistar), and First Automotive Works (for buses produced in China). Also in 2007, it delivered prototypes to Hyundai and its systems were used in 15 service vans delivered to Verizon. The company delivered 384 electric drive systems in 2007, a 10-fold increase from 2006, generating revenue of $9.1 MM. In terms of growth, Enova is expected to deliver 1,000 units each to Th!nk and Tanfield in 2008. And its contract with IC for hybrid school buses (70% fuel economy increase) is valued at $120 MM through 2010.

Quantum Technologies (NASDAQ: QTWW)
Quantum has traditionally been focused on hydrogen system development, but recently acquired a small lithium ion battery maker (Advanced Lithium Power Inc.) and is increasingly focused on PHEV's. It recently converted 20 Ford Escapes and 30 Toyota Priuses into PHEV prototypes under contract from a California governmental agency. The company has produced prototypes for GM, Toyota, U.S. Army, Suzuki, Lockheed Martin, Yamaha, US Department of Energy, among others. Quantum also is a supplier of solar energy modules for residential, commercial, and automotive applications.

Revenue for the 9 months ended 1/31/08 was $16 MM. Gross profit was $10.7 MM but R&D of $11.7 MM and SG&A of $11.8 MM led to significant losses. Nevertheless, we believe Quantum's expertise in powertrain engineering, systems integration, and manufacture and assembly of fuel and battery control systems makes the company a legitimate competitor for HEV integration contracts.

Ultracapacitors: a complementary market

Ultracapacitors are devices that are capable of storing electrical charges on their surface (like a static charge). While ultracapacitors are not used in automotive applications today, the automotive market (including micro-hybrids) is believed to be the industry's biggest growth opportunity. The amount of stored energy is limited, but the advantage is that capacitors are able to charge and discharge much faster than a battery. This feature makes them complementary to batteries in applications such as hybrid electric vehicles – particularly micro-hybrids, where quick bursts of energy storage and discharge are necessary.

Maxwell Technologies (OTC-MXWL)
Maxwell is a $260 MM market cap public company that produces ultracapacitors for applications in multiple industries, including transportation, automotive, telecom, energy, and consumer electronics. Revenue in FY2007 was $57.3 MM, up 6% from the prior year. Their major competitors are Panasonic and Nesscap.

During 1Q08, Maxwell announced a contract with Continental to supply ultracapacitors as part of an electrical stabilization system for a major OEM. Also announced was a contract with JCI Saft to supply electrodes for lithium ion batteries (Maxwell's deposition technology has potential to significantly improve the efficiency of lithium ion battery electrode manufacturing, which currently relies on a relatively slow and capital intensive coating process). Another significant customer is Siemens.

Nesscap Co., Ltd.

Nesscap is a privately held company spun off from Korea-based Ness Corp in 2000. Along with Maxwell, it is considered a market leader in ultracapacitors. Indeed, the two companies nearly merged at one point, then engaged in patent infringement litigation, and recently (early May 2008) signed an MOU settling the litigation (terms undisclosed pending final agreement). Nesscap received a $4.5 MM USABC grant in 2005. Although the company is privately-held and customer data is difficult to find, we believe Nesscap ultracapacitors are currently being applied in areas such as solar/wind power generation (for load balancing), cordless tools (for rapid recharging), and into hybrid vehicles (particularly for storage of regenerative braking power).

Commodities: lithium

Overview: industrial metals

Industrial materials: a key theme in battery development

Although industrial raw materials are a relatively small component in battery manufacture, their use will likely be a key theme in the sector's development. As a sector, commodities are amid a bull cycle that is unprecedented in length in modern history. More specifically, most metals prices have surged to record levels in nominal terms with many heading all-time inflation adjusted highs.

The unexpected potency of the structural shift in global demand trends resulting from the social and economic transformation in the emerging markets has sustained the commodities bull cycle well beyond consensus expectations. These conditions have generated a situation in which industrial metals producers simply have been unable to meet demand, leaving all metals with historically low stock-to-consumption ratios. In our view, commodity prices are undergoing a global-wide "re-rating," meaning that consumers and producers across the entire sector are increasingly recognizing most prices are unlikely to return to long-term historical averages any time soon (i.e. the mean reverting theory).

Demand for several commodities will likely rise significantly with the strength of vehicle electrification

While many metals already have a strong correlation to the global auto industry, there are a number of commodities in which demand will likely rise significantly with the strength of vehicle electrification. Lithium will be the primary beneficiary, but there are other metals required as inputs for battery (cobalt, nickel, copper) and vehicle construction (aluminum, alloyed steel products).

Most industrial metals have been in structural deficit (demand volume outweighs production) throughout the current commodities cycle. Historically, commodity prices tended to fluctuate in cycles, with periods of market deficit switching to periods of market surplus as producers ramped up production to capture attractive prices. However, this cycle is different because despite significant production increases, demand has continually outweighed supply. Thus we believe this period will be remembered as a demand shock as opposed to the supply shock suffered in the 1970s. Over the last decade, the world has persistently underestimated the impact of emerging market growth (led of course by China) and in fact most forecasts still point to a general global slowdown from here. While we acknowledge there may be temporary dips in annual growth, we think the overarching theme of supply struggling to keep up with demand will continue over at least the next decade, sustaining an elevated price environment.

Energy costs and energy supply security will be the most important issues facing commodity producers. Recent energy crises in South Africa and China highlight the precarious nature of power supply across the globe. Ironically, the industrial raw materials needed to construct the batteries may be constrained for the very reason the electric vehicle sector is set to grow.

In many regions of major mining, producers have often enjoyed preferential power treatment or subsidies to encourage the industrial sector. The recent rapid energy price inflation has forced many governments to reconsider these policies – with a number of ramifications across the sector. High costs compel companies to re-evaluate the economics of certain projects. This year alone has seen several large-scale mine and smelter new-builds and expansions become delayed or all-together abandoned. Furthermore, once financial penalties for carbon emissions become more widespread, pressure on the industrial sector will only intensify.

As a result, miners are increasingly forced to look to non-traditional regions for new production. Such areas tend to be more remote and more politically sensitive, caveats that also increase costs and supply risks.

Figure 23: Commodity requirements for automotive lithium ion battery market (tons)

	2012	2015	2018	2020
Lithium	10,703	33,301	62,544	85,870
Nickel	5,946	18,501	34,747	47,261
Cobalt	2,378	7,400	13,899	18,904
Aluminum	2,378	7,400	13,899	18,904
Manganese	3,568	11,100	20,848	28,357
Iron	3,568	11,100	20,848	28,357
Phosphate	3,568	11,100	20,848	28,357
Copper	21,406	66,603	125,088	170,140
Graphite	6,279	19,537	36,693	49,908
Hard Carbon	3,140	9,768	18,346	24,954

Source: Deutsche Bank

Aluminium: While this metal had previously lagged in performance relative it other base metals, that is certainly no longer the case. Aluminium has been the best performer on the London Metal Exchange so far in 2008 and we expect prices to remain at elevated levels over the next several years. The lightweight metal is the most exposed to the power markets because of its high intensity of energy use. This central theme has led to several markets dynamics that present bullish fundamentals. For example, China, which is both the largest aluminium consumer and producer recently decided it wanted to limit exports of energy intensive products and aluminium was at the top of that list. Through a series of trade tariff changes and industrial production stipulations to encourage efficiency, China's National Reform and Development Commission's (NDRC) hoped to decelerate primary aluminium production growth. So far in 2008, this is exactly what has occurred, meaning less of the metal for the rest of the world. We are forecasting market deficits this year and next and are expecting prices to rise throughout this period.

Figure 24: Deutsche Bank aluminium supply/demand model (2005-2010E, million tonnes)

	2005	2006	2007	2008E	2009E	2010E
Total primary production	32.0	33.9	38.1	41.4	45.0	49.0
World primary consumption	31.9	34.4	38.0	42.0	45.0	48.1
Market balance	**0.05**	**-0.44**	**0.15**	**-0.57**	**-0.06**	**0.87**
Stock-to-Consumption ratio (weeks)	4.9	3.9	3.7	2.7	2.4	3.2
Average cash price (USD/t)	**1899**	**2570**	**2641**	**2883**	**3031**	**2800**

Source: IPAI, WBMS, Brook Hunt, Deutsche Bank estimates

Cobalt: The primary use for cobalt is in superalloys, the manufacture of specialized, hard metals for use in the auto, aerospace, audio and chemical sectors. It is produced primarily in Central Africa and China, but there is also a healthy amount of secondary or recycled material in the market. Like most other metals, prices have remained near all-time highs for several years and given supply constraints, market dynamics will likely remain similar in the coming years. The Democratic Republic of Congo and Zambia are homes to some of the world's richest cobalt (as well as copper) reserves. However, the region is plagued with energy supply difficulties, infrastructure problems, controversy over foreign investors' ownership and operations as well as persistent political instability. Although we are bearish on this frontier region of the world, if the region is ever able to mine to its potential, cobalt prices would certainly retract from their current record highs. Ultimately, because cobalt is mostly mined in association with copper, the fortunes of that market provide insight to where cobalt prices are headed in the long term.

Figure 25: Deutsche Bank cobalt supply/demand model (2005-2010E, tonnes)

	2005	2006	2007	2008E	2009E	2010E
World supply	54,910	57,710	58,384	64,719	68,914	73,985
World consumption	54,044	57,023	60,838	64,977	69,114	73,585
Market balance	**866**	**687**	**-2454**	**-258**	**-199**	**400**
Average price (USD/lb)	**14.5**	**15.3**	**27.9**	**45.1**	**30.0**	**25.0**

Source: Cobalt Development Institute, World Bureau of Metal Statistics, Brook Hunt, Deutsche Bank estimates

Copper: Copper has been one of the best performing metals in this cycle, primarily as a consequence of its high correlation to industrial production growth. Predominantly used in power and telecommunications infrastructure as well as in residential and commercial construction, demand for the metal has surged over the last decade amid housing and emerging markets demand. We remain positive for the outlook based on a continuation of the developing world's appetite and the inability of producers to offer enough supply. For example, Chile, supplier of over one-third of the world's copper is facing severe power shortages as a result of drought in hydro-electric dependent regions and insecurity of natural gas supply from neighboring Argentina. Moreover, similar to cobalt, much of the expansion in new supply comes from areas of the world lacking in infrastructure and political stability, namely central Africa and central Asia.

Figure 26: Deutsche Bank copper supply/demand model (2005-2010E, million tonnes)

	2005	2006	2007	2008	2009	2010
World refined production	16.54	17.32	18.13	19.02	20.22	21.11
World refined consumption	16.98	17.53	18.23	19.09	20.01	20.77
Market balance	**-0.45**	**-0.21**	**-0.09**	**-0.07**	**0.21**	**0.35**
Stock-to –Consumption ratio (weeks)	2.6	2.8	2.5	2.2	2.6	3.4
Average copper cash price (USD/t)	**3682**	**6725**	**7091**	**7519**	**6917**	**5512**

Source: ICSG, WBMS, Brook Hunt, Deutsche Bank estimates

Nickel: Most primary nickel goes into the stainless steel sector which has enjoyed exceptional consumption growth this decade. The sector is chiefly exposed to the construction sector, but high quality stainless steel is also an important input into the auto and aerospace manufacturing. Nickel prices have had a much more volatile run throughout this cycle compared to its compatriots, but on average has also delivered extraordinary performance against insatiable demand – again led by China and the other emerging markets. Although we are expecting the market to return to surplus condition in the coming two years, we also remain cognizant of supply risks as future metal availability relies on a small number of large-scale operations scheduled to come to market during this period. Any delay in delivery could quickly swing the market balance in the opposite direction.

Figure 27: Deutsche Bank nickel supply/demand model (2005-2010E, thousand tonnes)

	2005	2006	2007	2008E	2009E	2010E
Total primary production	1288	1361	1463	1542	1674	1809
World refined consumption	1264	1376	1429	1570	1659	1787
Market balance	**23.4**	**-15.4**	**33.5**	**-28.0**	**14.2**	**21.4**
Stock-to –Consumption ratio (weeks)	5.7	4.0	5.0	3.7	3.9	4.3
Average nickel cash price (USD/t)	**14,751**	**24,237**	**37,060**	**29,652**	**27,889**	**24,471**

Source: ICSG, WBMS, Brook Hunt, Deutsche Bank estimates

Lithium supply and demand

A key input to the lithium ion battery production process is obviously lithium – specifically lithium carbonate (Li_2CO_3). Although there is enough lithium to supply current demand, the level of economically recoverable material to supply future demand is less clear as many operations' recovery costs have not been determined. The vast majority of this material is currently produced from salt lakes in Chile (55%), Argentina (16%), and Nevada (12%). The remainder of current production (17%) comes from China, from another type of lithium deposit called spudomene.

There is also currently ongoing development of salt lake sites in China; these are projected to add significantly to current global production by 2010. Primary uses of lithium are Li-Ion batteries for consumer electronics and power tools, lubricating greases, and ceramics. World lithium demand is growing at approximately 7% per year, driven almost exclusively by demand for batteries (20% of lithium production and growing at 20% per year). Based on announced capacity increases, we believe production could increase by approximately 100% from 2006-2010E.

Figure 28: Lithium production (metric tons) and locations

		Production (metric tons)	
Location	**Companies**	**2006**	**2010E**
Argentina	FMC / Admiralty Resources (10% in '10)	12,000	30,000
Bolivia		-	-
Chile	SQM (65%) / Chemetell (ROC) (35%)	41,000	55,000
China	CITIC Guoan (MGL) / Sterling Group (8% in '10)	13,000	60,000
USA	Chemetell (ROC)	9,000	8,000
Total		**75,000**	**153,000**

Source: Meridian Research

Industry consultants estimate that the ultimate maximum production of lithium from current sources (not including Bolivia) is approximately 200 k tons per year, and that reserves in these locations total approximately 15-20 MM tons. Much of the remaining 15-20 MM tons of global known reserves is contained in salt lakes in Bolivia where there is currently no production. Although it is feasible to produce in Bolivia, there are some challenges, including remoteness of location, high altitude (affecting evaporation rates), high magnesium content (affecting lithium recovery rates), and political issues (sites are owned by the Bolivian government). The Bolivian government recently announced plans to develop the lithium resources. They are attempting to go it alone (without any private company assistance) and are targeting approximately 60,000 tons per year of production beginning in 2013, with potential for increases thereafter.

While we believe that rapid demand growth for lithium will lead to increases in the cost of the material (as well as the need for production from less economically advantageous sites), we also believe it will lead to allocation of resources to discover and exploit additional lithium reserves. The price of lithium increased 48% to $6.30 per kg during 2007. We believe that a 2 kWh HEV battery would contain approximately 2.75kg of lithium.

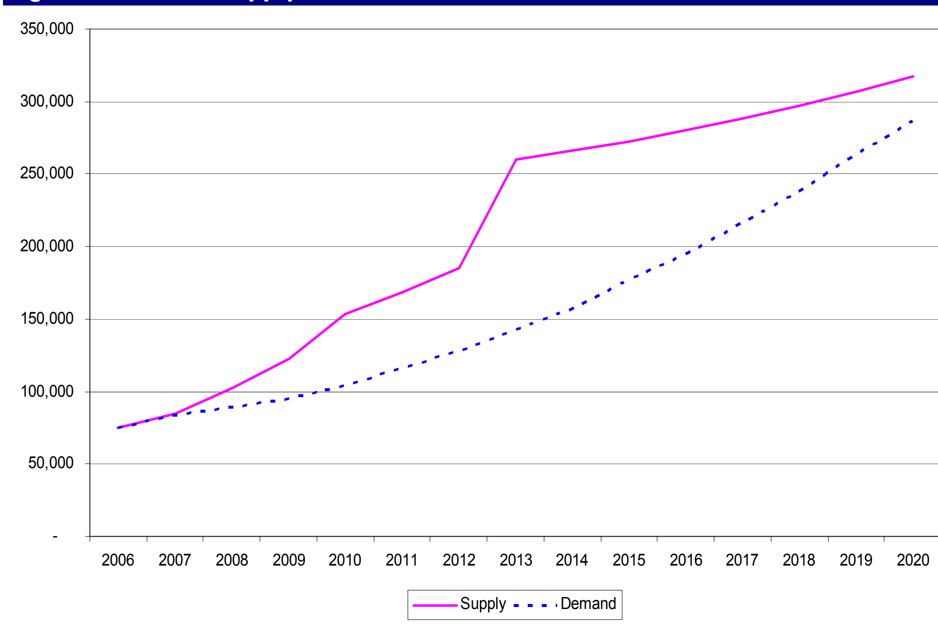
Figure 29: Lithium demand in 2020E from automotive batteries

	Total Electrified Units (000's)	Lithium-Ion Batteries (000's)	kWh per unit (Li-Ion)	Lithium Content per battery (@ 1.38kg / kWh)	Lithium Required (000 Tons)
MicroHybrids	10,508	-	-	-	-
Mild Hybrids	5,930	4,416	1	1.38	6.1
Full Hybrids	5,930	4,416	2	2.75	12.1
PHEV's	1,791	1,791	12	16.50	29.5
Full EV's	1,262	1,262	22	30.25	38.2
Total	25,419	11,884			85.9

Source: Deutsche Bank

Based on our projections for automotive lithium ion cell production, and growth assumptions for other markets, we believe that lithium ion demand could bump up against the 200,000 ton maximum production capacity, excluding Bolivia, by 2017. If Bolivian production comes on-line, we believe supplies will become an issue in 2030. Our demand forecast assumes a continuation of 7% annual growth for consumer electronics and other current uses. We expect the economic disadvantages of the Bolivian site, as well as rapidly increasing demand in general, will likely lead to further increases in the price of lithium in the medium term. By approximately 2017, we would expect that additional mining sites may be discovered, new technologies may be developed to enable lithium mining from other types of sources, and a large-scale battery recycling will have been developed. We believe these factors will enable lithium to remain a viable, relatively abundant source of power for automobiles over the long-term.

Figure 30: Lithium supply/demand outlook



Source: Meridian Research

Leading producers

SQM (NYSE: SQM)

SQM mined approximately 65% of the Lithium Carbonate production in Chile during 2007 and approximately 34% of the world's production. The company's Lithium and Derivatives division generated $180MM of revenue in FY2007 (15% of total corporate revenue of $1,187MM), up 39.5% yoy driven by a 48% increase in price per unit. Gross profit for the Lithium group was $112MM (62% gross margin) which was 34% of the total company's gross profit.

SQM mines 65% of the lithium that comes out of the Salar de Atacama region of Chile. It competes with Chemetall (division of Rockwood Holdings) in that area. This lake has very favorable characteristics, including a very high lithium content and relatively lower altitude and dryer climate than other sites which enhances evaporation and thus speed of production. The lake has an estimated 8 MM tons of recoverable reserves, over 20% of the world's known reserves. Another positive aspect of SQM's operations is that lithium is a secondary product to the company's main products: Potassium Chloride and Potassium Sulfate. Multi-commodity operations are important to make lithium extraction economically feasible.

The company has three other primary business units, including Specialty Plant Nutrition (49% of revenue and 29% of gross profit), Iodine and derivatives (18% of revenue and 24% of gross profit), and Industrial Chemicals (7% of revenue and 5% of gross profit).

Overall corporate earnings in FY2007 was $6.84 per share, up 27% over $5.37 in FY2006.

FMC Corporation (NYSE: FMC)

FMC is the sole producer of lithium in the Salar de Hombre Muerto region of Argentina. 2006 production was 12,000 metric tons, approximately 16% of global production. This region is a less favorable source than SQM's site, due to lower lithium content and higher elevation. The Salar de Hombre Muerto holds 4 MM tons of reserves (approximately 11% of global known reserves).

FMC Corporation generated $2.6 bn of revenues in FY2007, up 12% from FY2006. FY2007 EPS increased 13% yoy to $3.09. Lithium mining operations are included in the company's Specialty Chemicals group, along with Biopolymer. The overall unit generated revenue of $660 MM (25% of total corporate revenues), an 11% yoy increase, and earned $142.7 MM (32% of total corp), a 20% yoy increase.

FMC's other two business units, similar to SQM, are Agricultural Products (35% of revenue and 47% of segment earnings) and Industrial Chemicals (41% of revenue and 21% of segment earnings).

Rockwood Holdings / Chemetall (NYSE-ROC) (DB Rating: Buy)

Rockwood Holdings' Chemetall group mines lithium in the Salar de Atacama region of Chile (along with SQM) as well as in Nevada. In 2006, the company produced 14,000 tons in Chile and 9,000 tons in Nevada. Production in Chile is expected to grow 34% by 2010 but production at the Nevada site is in decline and production is expected to decrease somewhat.

Rockwood's FY2007 revenue was $3.3 bn, up 1% yoy. Chemetall is part of the Specialty Chemicals business unit which had sales of $1.1 bn, up 18% yoy. EBITDA was $262 MM (24% margin), which was 40% of total company EBITDA. We believe that lithium accounts for 20% of the company's EBITDA and that lithium will be a prime driver of organic growth.

With a 30-35% share in the 140-150 MM lb lithium carbonate market and the ability to double its low cost Chilean lithium capacity for a modest $60 MM, Rockwood is well positioned to benefit from growth in lithium ion battery powered cars. We estimate that at 5-10 lbs of lithium carbonate/car, current lithium carbonate prices of $3.50/lb (or $20-$30 of lithium carbonate/car), a 40% EBITDA margin and a 35% market share, every 1 million lithium ion battery powered cars adds $0.08-$0.09, or 4%, to Rockwood's EPS.

Admiralty Resources (ASX (Sydney, AU): ADY) (Pink Sheets: ARYRY)

ADY is a start-up company that is developing 10 iron ore mines in Chile, a lithium and potash mining site at Salar de Rincon, Argentina, and a nickel/cobalt site in Australia. The company had no material revenue in FY2007 (through 6/30/07) and had $2.77 MM revenue in 1H08 (through 12/31/07). Initial mining of iron ore began in 2007 and first shipments to a customer occurred in June 2007. The company announced that it will pursue a demerger, listing the unlisted public company Rincon Lithium Limited (RLL) sometime in 2008. RLL holds all of the company's lithium/potash assets.

The lithium/potash site is expected to be in full production by mid-2009 and produce 8,000 tons of lithium per annum (approximately 5% of global production in 2010) and 80,000 tons of Potash per annum (full production by mid-2010). At current prices, those levels of production would generate approximately $100 MM of revenues. The company also claims to be in negotiations to become the technical advisor to the Bolivian government in its project to develop significant lithium reserves (as mentioned above).

CITIC Pacific (HK: 0267)

CITIC's subsidiary CITIC Guoan controls the largest potential salt-lake lithium mining site in China. It also has a controlling interest in Guoan Mengguli Corporation (MGL), the leading producer of lithium ion cathode material in China. Although these operations currently represent only approximately 1% of CITIC's overall results, the subsidiaries could become material given expected growth. The company inaugurated a 35,000 ton per year lithium production facility in January 2007. Although production will take time to ramp to this level, 35,000 tons would represent over 20% of expected 2010 global production (at current prices, approximately $200 MM of revenue). In addition to supplying cathode material for other companies' battery production, MGL itself recently produced a small number of lithium ion batteries for use in Beijing's experimental fleet of hybrid buses. Also, CITIC Pacific has significant experience with automotive, as its main business unit, produces specialty steel for the industry. Its customers include Toyota, General Motors, Honda, Volkswagen, and Volvo.

Appendix A

Overview of CO_2 based vehicle taxes in the EU

Austria
A fuel consumption tax (Normverbrauchsabsage or NoVA) is levied upon the first registration of a passenger car. It is calculated as follows:

- Petrol cars: 2% of the purchase price x (fuel consumption in litres – 3 litres)
- Diesel cars: 2% of the purchase price x (fuel consumption in litres – 2 litres)

Under a bonus-malus system starting on 1 July 2008, cars emitting less than 120 g/km receive a maximum bonus of €300. Cars emitting more than 180 g/km pay a penalty of €25 for each gram emitted in excess of 180g/km. (160 g/km as from 1 January 2010). Alternative fuel vehicles attract a bonus of maximum €500.

Belgium
Tax incentives are granted to private persons purchasing a car that emits less than 115g CO2 /km. The incentives consist of a reduction of the invoice price with the following amount:

- Cars emitting less than 105g/km: 15% of the purchase price, with a maximum of €4,350
- Cars emitting between 105 and 115 g/km: 3% of the purchase price, with a maximum of €810

The company car tax is based on CO2 emissions.

The deductibility of expenses related to the use of the car (60 to 90%) is linked to CO 2 emissions.

The Walloon Region operates a bonus-malus system whereby new cars emitting 145 g/km or less obtain a bonus (maximum €1,000 for cars below 105g/km) and cars emitting more than 195 g/km pay a penalty (maximum €1,000 for cars emitting more than 255 g/km).

Cyprus
The rates of the registration tax (based on engine capacity) are adjusted in accordance with the vehicle's CO2 emissions. This adjustment ranges from a 30% reduction for cars emitting less than 120 g/km to a 20% increase for cars emitting more than 250 g/km.

The rates of the annual circulation tax (based on engine capacity) are reduced by 15% for cars emitting less than 150 g/km.

A premium of €683 is granted for the purchase of a new car when its CO2 emissions are below120 g/km. For the purchase of hybrid and flexible fuel vehicles, the premium amounts to €1,196.

Denmark
The annual circulation tax is based on fuel consumption:

- Petrol cars: rates vary from 520 Danish Kroner (DKK) for cars driving at least 20 km per litre of fuel to DKK 18,460 for cars driving less than 4.5 km per litre of fuel.
- Diesel cars: rates vary from DKK 160 for cars driving at least 32.1 km per litre of fuel to DKK 25,060 for cars driving less than 5.1 km per litre of fuel.

Registration tax (based on price): An allowance of DKK 4,000 is granted for cars for every kilometre in excess of 16 km (petrol) respectively 18 km (diesel) they can run on one litre of fuel. A supplement of DKK 1,000 is payable for cars for every kilometre less than 16 km (petrol) respectively 18 km (diesel) they can run on one litre of fuel.

Finland

The registration tax is based on CO2 emissions. Rates vary from 10% for cars emitting 60 g/km or less to 40% for cars emitting 360 g/km or more. The system is fully linear and technologically neutral.

The annual circulation tax (currently based on weight) will be based on CO2 emissions from 2010 onwards. Rates will vary from €20 to €605 per year.

France

Under a bonus-malus system, a premium is granted for the purchase of a new car when its CO2 emissions are below 130 g/km. The maximum premium is €5,000 (below 60 g/km). A "super-bonus" of €300 is granted when a car of at least 15 years old is scrapped simultaneously. A tax is payable for the purchase of a car when its CO2 emissions exceed 160 g/km. The maximum tax amounts to €2,600 (above 250 g/km). The different thresholds are strengthened by 5 g/km every two years.

The regional tax on registration certificates ("carte grise") is based on fiscal horsepower, which includes a CO2 emissions factor. Tax rates vary between €25 and €46 per horsepower according to the region.

The company car tax is based on CO2 emissions. Tax rates vary from €2 to €19 for each gram for cars emitting 100 g/km or less to €19 for each gram emitted for cars emitting more than 250 g/km.

Germany

The Federal Government has announced its intention to change the basis of the annual circulation tax from cylinder to CO2 emission as from 1 January 2009. The system should be linear. Cars with CO2 emissions below 100 g/km should be exempt.

Ireland

As from 1 July 2008, the registration tax will be based on CO2 emissions. Rates will vary from 14% for cars with CO 2 emissions up to 120 g/km to 36% for cars with CO 2 emissions above 225 g/km. Hybrid and flexible fuel vehicles will benefit from an additional tax relief of €2,500.

The annual circulation tax will also be based on CO2 emissions. Rates will vary from €100 (up to 120 g/km) to €2,000 (above 225 g/km).

Italy

A tax incentive of €800 and a two-year exemption from annual circulation tax is granted for the purchase of a new passenger car complying with the Euro 4 or Euro 5 exhaust emissions standards and emitting not more than 140 g of CO2 /km, provided a Euro 0 or Euro 1 car is scrapped simultaneously. The exemption from annual circulation tax is extended to three years for cars with a cylinder capacity below 1,300.

Luxembourg

The annual circulation tax is based on CO2 emissions. Tax rates are calculated by multiplying the CO2 emissions in g/km with 0.9 for diesel cars and 0.6 for cars using other fuels respectively and with an exponential factor (0.5 below 90 g/km and increased by 0.1 for each additional 10 g of CO2 /km).

The Netherlands
The rate of the registration tax (based on price) is reduced or increased in accordance with the car's fuel efficiency relative to that of other cars of the same size (length x width). The maximum bonus is €1,400 for cars emitting more than 20% less than the average car of their size, the maximum penalty is €1,600 for cars emitting more than 30% more than the average car of their size. Hybrid cars benefit from a maximum bonus of €6,400. Cars emitting more than 232 g/km (petrol) respectively 192 g/km (diesel) pay an additional tax supplement of €110 per gram emitted in excess of these thresholds.

The annual circulation is reduced by 50% for cars with CO2 emissions up to 110 g/km (petrol) respectively 95 g/km (diesel).

Portugal
The registration tax is based on engine capacity and CO2 emissions. The CO2 component is calculated as follows:

- Petrol cars emitting less than 120 g pay [(€5 x g/km) - 475]. Diesel cars emitting less than 100g pay [(€15 x g/km) – 1,100]
- The highest rates are for petrol cars emitting more than 210g [(€115 x g/km) – 19,285] and for diesel cars emitting more than 180g [(€160 x g/km) – 21,190].

Spain
The registration tax is based on CO 2 emissions. Rates vary from 0% (below 120 g/km) to 14.75% (above 200 g/km).

Sweden
The annual circulation tax for cars meeting the Euro 4 exhaust emission standards is based on CO2 emissions. The tax consists of a basic rate (360 Swedish Kroner) plus SEK 15 for each gram of CO2 emitted above 100 g/km. This sum is multiplied by 3.15 for diesel cars registered for the first time in 2008 and by 3.3 for other diesel cars. For alternative fuel vehicles, the tax is SEK 10 for every gram above 100 g/km.

A premium of SEK 10,000 is granted for the purchase of "environmentally-friendly cars":

- Petrol/diesel/hybrid cars with CO2 emissions up to 120 g/km
- Alternative fuel/flexible fuel cars with a maximum consumption of 9.2 l (petrol)/8.4 l (diesel)/9.7cm/100 km (CNG, biogas)
- Electric cars with a maximum consumption of 37 kwh/100 km

United Kingdom
The annual circulation tax is based on CO2 emissions. Rates range from £0 (up to 100 g/km) to £300 (petrol, diesel)/£285 (alternative fuels) for cars emitting more than 225 g/km.

Company car tax rates range from 15% of the car price for cars emitting less than 140 g/km to 35% for cars emitting more than 240 g/km. Diesel cars pay a 3% surcharge.

Source: *ACEA: OVERVIEW OF CO2 BASED MOTOR VEHICLE TAXES IN THE EU*

Appendix B

European city congestion tax overview

United Kingdom

London: From 27 October 2008 London introduces its new CO2 charges, which include:

- A 100 per cent low CO2 discount for cars that:
  - Produce less than 120 g/km CO2 and meet the Euro 4 standard for air pollution emissions or
  - Produce no more than 120 g/km of CO2, and appear on the PowerShift register
- The introduction of a higher charge (£25) for cars and certain pickups with two rows of seats that produce high levels of CO2. Vehicles liable for this charge are:
  - Cars first registered with the Driver and Vehicle Licensing Agency (DVLA) on or after 1 March 2001 that produce above 225 g/km of CO2
  - Cars first registered with the DVLA before 1 March 2001 with engines greater than 3,000cc
  - Pickups with two rows of seats (extended-cab dual-purpose pickups) with CO2 emissions of greater than 225 g/km or with engines greater than 3,000cc in size
- The removal of the 90% Residents' Discount from the Congestion Charge for residents who continue to drive cars liable for the CO2 charge
- The closure of the 100% Alternative Fuel Discount (AFD) to new registrations, and the phasing out of the AFD by January 2010
- A change to the NHS reimbursement scheme. We will only reimburse patients travelling in those cars that are liable for the higher charge a maximum of £8, not the full £25
- The introduction of the Euro V incentive - a time-limited reduced Congestion Charge of £6 for lorries and heavier vans that meet the Euro V standard for air pollution emissions.

Durham: Durham was the first city in UK which implemented a congestion charge in 2002. Drivers have to pay £2 10:00am to 4:00pm for entering the city.

Manchester: The proposed scheme for Manchester is similar to the London scheme, however it covers a wider area but a much smaller daily charging window covering the morning and evening rush hours.

Edinburgh: The implementation of a congestion charge was rejected after a referendum in February 2005.

Norway

Bergen: As the first city in Europe, Bergen implemented a congestion charge for traffic entering the town during the week from 6am to 10pm.

Bergen has now a fully automated toll plaza system that is based on passing without stopping for all traffic.

Oslo: A similar system was introduced for the Oslo Toll Ring from February 2, 2008.

To ensure interoperability of electronic fee collection in Norway a system called AutoPass is used throughout the country for toll roads and congestion charging schemes.

Sweden

Stockholm: Stockholm has a congestion pricing system, Stockholm congestion tax, in use on a permanent basis since August 1, 2007, after having had a seven month trial period from January 3 to July 31, 2006. The City Centre is within the congestion tax zone. All the entrances and exits of this area have unmanned control points operating with automatic number plate recognition. All vehicles entering or exiting the congestion tax affected area, with a few exceptions, have to pay 10–20SEK (1.09–2.18EUR, 1.49–2.98USD) depending on the time of day 6:30am to 6:29pm. The maximum tax amount per vehicle per day is 60SEK (6.53EUR, 8.94USD). Payment is done by various means within 14 days after one has passed one of the control points, one cannot pay at the control points.

Italy

Bologna: Since May 2006, Bologna has a congestion charge.

Rome: There is a complete driving permission for the historical centre of Rome for private passenger cars. Only owners of entry permission (costs EUR360 for one year) and taxies, buses and suppliers are allowed to drive in the historical centre.

Milan: On the 2nd of January 2008, Milan introduced a congestion charge on a trial basis for the next two years. Between 7am to 6pm, drivers have to pay a charge between zero and then Euro, depending on the exhaust air emission.

France

Paris: There are no congestion charges planned because of fears of riot and civil commotions within the outskirts.

Germany

In most German major cities, local governments rather implemented pollution free "green" zones than real congestion charges like other European cities. Environmental badge obligatory are available in three colours (red, yellow and green), which describe the pollutant category the car is allocated to. Depending on the zone within the city (also red, yellow and green), usually most cars get at least a yellow obligatory and are allowed to drive into the zones, if they have a catalyser or are not considerably older than ten years. Berlin, Hanover, Dortmund, Cologne, Mannheim and Stuttgart have already implemented a pollution free zone and Augsburg, Frankfurt, Hamburg and Munich are currently planning the implementation for the upcoming year 2008. However, the new Hamburg government consisting of the CDU party and the GAL (regional Alliance '90/The Greens) are already negotiating the idea of the implementation of a congestion charge for downtown Hamburg in the upcoming years.

Source: *ACEA, Transport for London, Wikipedia*

Appendix 1

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Sell: Based on a current 12-month view of total share-holder return, we recommend that investors sell the stock

Hold: We take a neutral view on the stock 12-months out and, based on this time horizon, do not recommend either a Buy or Sell.

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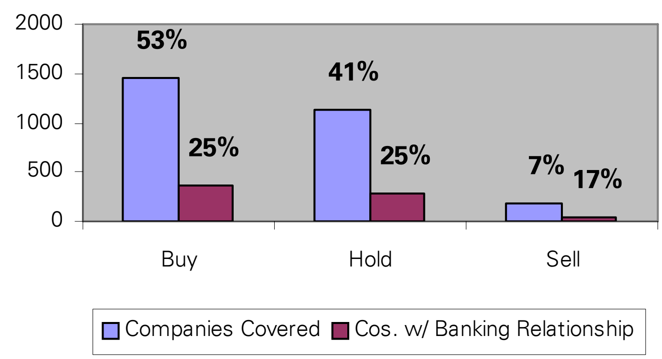

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