GPBULLHOUND

INDEPENDENT TECHNOLOGY RESEARCH

Sector Update

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Electric Vehicles / Batteries

ELECTRIC VEHICLES AND BATTERIES – CHARGING AHEAD

Electric Vehicles are Starting to Look Like a Viable Option

Electric vehicles have been around before, at the turn of the last century and again during the 1990s. We are now beginning to witness a concerted effort on the part of governments, automotive and battery manufacturers to build a viable electric vehicle industry. Most of the major automotive manufactures have announced launches of electrically propelled vehicles recently including Renault-Nissan, GM, Toyota, Daimler, BMW and even Ferrari is launching a hybrid. Transportation accounts for 50% of oil demand today. It also accounts for 20% of global carbon emissions with the IEA anticipating this to double to 40% by 2050. As such, many governments are encouraging and incentivizing drivers to permanently park their internal combustion engine “ICE” propelled vehicle in favour of a low emission electrically propelled car. The road ahead is likely to be long with bumps along the way but it is our firm belief that the destination is well worth it.

Battery Technology Cost has Decreased for Mass Market Adoption

Battery technology has come a long way since the early versions of the lead acid battery. Concerns around safety have eased and battery lifetime and cost issues are likely to be addressed in the short term through subsidies and battery leasing. The key impediment to major electric vehicle uptake remains battery cost per unit of power and energy capacity. In the medium term, expensive batteries will limit the travelling range and broader uptake of electric vehicles. In the long term, we believe that as demand increases and technology improves, there will be significant scope for cost reductions. A significant proportion of these savings should trickle through to the consumers in the form of electric vehicles that are able to compete successfully with internal combustion engine vehicles based on a “total cost of ownership” basis.

Lithium-Ion Batteries Set to Dominate the Market

There are several competing battery chemistries vying for the top spot in the electric vehicle landscape. Nickel metal hydride technology is currently the dominant battery solution used in most hybrid electric vehicles owing to its technological maturity and long safety record. However, lithium-ion is fast emerging as the long term winner. Its lightweight nature, higher energy and power density translate into smaller and lighter battery packs ideally suited to cars. However the technology still has a long way to go in terms of its cost and assuaging people’s safety concerns. Significant funding is going into lithium-ion’s development, not least by the Chinese and the US Department of Energy “DoE”. A number of companies are working on solutions that have the potential to lead to transformational performance and price improvements.

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ELECTRIC VEHICLES – WHAT IS ALL THE FUSS ABOUT?

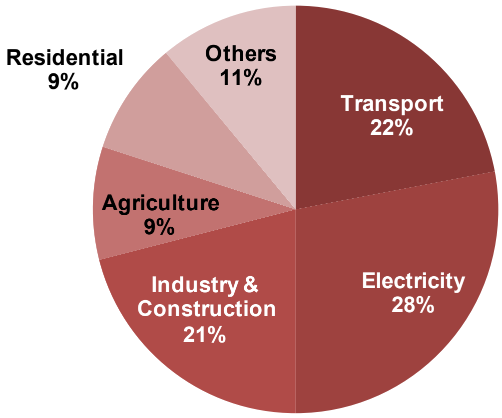
A few years ago electrically propelled vehicles (EVs) were anomalies seen only at the likes of the Detroit and Geneva auto shows. Nowadays, they are no longer the realm of science fiction but increasingly roaming our streets. The prospect of clean air, quiet streets and cars fuelled by an increasingly clean power grid is attractive as we look to a cleaner future. Hybrid Electrical Vehicles (HEVs) in particular are common in developed markets and more recently, several of the large automotive manufacturers have announced the launch of their own EVs as a key strategic objective. Carlos Ghosn of Renault Nissan has been one of the most vocal proponents of an EV future. According to Ghosn there are three trends pointing towards an electric future. One, a concerted effort on the part of governments with various incentives to stimulate consumer demand (check), two, an increasing hydrocarbon price amidst security of supply and climate change concerns (check), and three, a willingness of drivers to change their polluting ways and adopt a new paradigm to driving (not quite there yet, but increasingly moving in the right direction). According to Mr. Ghosn also believes as much as 10% of all vehicles on the roads could be purely battery driven by 2020. We think this is ambitious but subscribe to the general view that these developments are here to stay this time around. The future for EVs is likely to bring a mix of hybrids (HEV), plug-in hybrids (PHEV) and fully fledged electric vehicles (FEV).[1]

Although EVs would appear revolutionary they are by no means a new phenomenon. At the turn of the last century EVs were favoured as the preferred mode of transport for those looking to replace their horse drawn carriages. History may repeat itself. This time the horses remain in a different form, electric powered horsepower, note the Tesla Roadster, the high-performance electric sports car with 288 horsepower.

Transportation is responsible for a significant proportion of carbon and greenhouse gas emissions and as such the increased adoption of EVs is a credible way of structurally reducing emissions. The following exhibit provides a breakdown of EU greenhouse gas emissions.

[1] In this report we use the acronym EV to denote both the plug-in hybrid PHEVs and full electric vehicles FEVs.

Exhibit 1 – 2007 EU Greenhouse Gas Emissions



Source: European Environment Agency

There is considerable investment going into the broader EV sector with battery manufacturers, automotive and component manufacturers and charging infrastructure companies receiving significant support both from governments and private sector investment. According to the Cleantech Group the first quarter of 2010 saw the transportation sector as the largest recipient of cleantech venture capital investment with over $700 million being invested into the space during the quarter. The energy storage sector, which includes batteries, also experienced significant growth attracting $110m (up from $42m in Q4 2009) in investments. Among the themes driving the heightened interest are the increasingly stringent emissions regulations, concerns about energy security and global warming and growing appreciation for EVs in emerging markets such as China where local automotive manufacturers are in the front line of EV development.

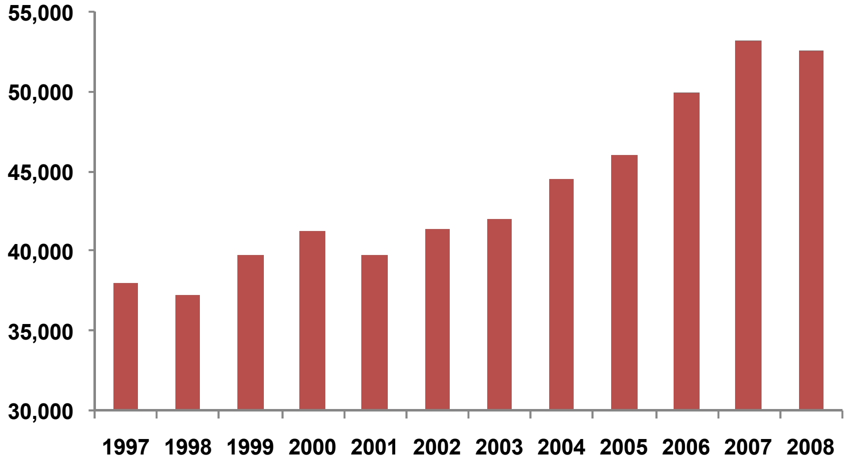
At the same time as investment has flowed into companies in the space, we have seen a number of exits and value crystallised, most notably through the IPO markets. A123 Systems, the battery manufacturer, raised $378m in its September 2009 IPO on NASDAQ and Tesla, the niche electric sports car manufacturer, filed for a $100m IPO in January this year. Even the Sage of Omaha, Warren Buffet, has joined the party. He acquired a 10% stake in Chinese EV and battery maker BYD Auto (BYD stands for Build Your Dreams) in the autumn of 2008 for $230m, an investment which has already increased considerably in value.

The sector is showing some encouraging early promise. According to SBI Energy, a research house, the Toyota Prius hybrid electric vehicle was the best selling car in Japan and 700,000 HEVs and EVs were sold globally in 2009 (99% of this number consisted of HEVs)[2]. This did, however, only represent 1.5% of total car sales globally in 2009. The fact that EVs are in the early adoption phase can be

[2] In spite of the fact that Prius with its relatively simple hybrid engine (and a small battery) we believe it is only marginally more environmentally friendly than the average high performance diesel car.

demonstrated by the example of Germany. According to the Associated Press, environmentally conscious Germany only had 1,452 EVs on its roads in August 2009, i.e. a negligible share of the total number of cars in the country. Exhibit 2 shows figures on global vehicle production. Even if 2009 is likely to see a small dip, all trends point towards growth of total volumes as emerging markets catch up with western production. As such, even a 10% market share for EVs (as forecasted by a number of industry participants) will translate into 5-10m electric based vehicles on the roads in 10 years time, equating to the total number of vehicles produced in Germany in 2008 according to the International Organization of Motor Vehicle Manufacturers.

Exhibit 2 – Global Passenger Vehicle Production (000's)



Source: International Organization of Motor Vehicle Manufacturers

Electric and Hybrid Vehicles – The Basics

There are many acronyms floating around in the world of vehicles which are powered by electricity in some form or fashion: HEV, PHEV and FEV (nothing compared to the amount of acronyms in the world of batteries). There are several fundamental technological as well as performance differences between these approaches towards electrical propulsion.

Hybrid Electric Vehicles (HEVs) are the most common of the electric related propulsion systems. In a nutshell, HEVs run on a combination of power from an internal combustion engine (ICE) and an electric motor powered by a battery. The combination of the two technologies offers fuel efficiency advantages compared to traditional ICE cars. The battery in an HEV stores energy that is produced by the ICE, and in some cases regenerative brakes and other technologies are used to generate energy. The stored energy is used to power the electric motor. When more power is required, for instance during high speeds, the combustion engine is used. HEVs do not plug into the grid to charge their batteries. Examples of HEVs include the Toyata Prius and the Lexus RX 400h.

Plug-in Hybrid Electric Vehicles (PHEVs) are one step closer to full electric cars and combine the capabilities of an ICE and an electric engine together to provide a meaningful electricity fuelled range that can be extended with the help of fuel when needed. The main difference between the HEV and the PHEV is that the latter comes with a much larger (and costlier) battery to power the larger electric motor and the functionality to use external charging sources to charge it. There are two types of PHEVs, one that uses the ICE to charge the batteries in the event of range extension demand, the other uses the ICE to drive the wheels directly in order to extend the range of the car. Examples of PEVs include the soon to be launched Chevy Volt and Fisker Karma.

Fully Electric Vehicles (FEVs) rely solely on an electric engine for their propulsion. They replace the ICE with larger batteries and an electric motor. As such, the requirements of the batteries are the strictest in FEVs as there is no back-up engine that can be used to extend range in the event of full battery discharge. FEVs have not been able to gain the same traction as HEVs and to date this is a segment limited to a minority of environmentally conscious commuters principally in larger cities. The main anxieties arise from the lack of charging infrastructure and the currently high cost of the batteries that power the cars, implying very high payback periods in the absence of tax breaks or subsidies. Examples of FEVs include the Reva G-Wiz and the Mitsubishi iMiEV.

The following Exhibit provides a simplified overview of the EV value chain. As the Exhibit shows, there are several key components, many of which are still in great flux. This should translate into several areas of potential innovation and investment.

Exhibit 3 – Electric Vehicle Value Chain

Source: GP Bullhound

The Market for Electric and Hybrid Vehicles

In the early 20th century, electric vehicles were the cars of choice before the proliferation of ICE cars. EVs also enjoyed somewhat of a renaissance in the 1990s, however the renaissance fizzled out fairly quickly. General Motors and Toyota launched models during the 1990s. EV-1, launched by General Motors in 1996, was sold through a leasing model and survived until 2003. General Motors decided to pull the model after having spent close to $1 billion on its development. Toyota's early EV was also pulled in 2003 after succumbing to the difficulties posed by high battery costs. The question that is now being asked is whether the EV will go the way of the Betamax video cassette or become a mainstay of automotive technology.

Exhibit 4 – Selected Automotive Manufacturers’ Current HEV and EV Commitments

	Current HEV	Current EV	EV Launch Date	EV Range	Comments
BYD AUTO	✓	X	2010	322 km	Jointly developing an EV with Daimler to be sold in China. Also co-operating with Volkswagen and launching its own model
DAIMLER	✓	X	2012	135 km	Hybrid versions of its models will be introduced. The EV to be launched is an EV version of the Smart
FIAT	X	X	n.a.	n.a.	Is planning to introduce HEVs, no EVs planned as yet
Ford	✓	X	2011	160 km	The Ford Focus EV will be launched in the US in 2011 and in Europe in 2012
GM	✓	X	n.a.	n.a.	Is not planning to launch any EVs. Will launch the Volt PHEV in 2010
HYUNDAI	✓	X	2010	160 km	Currently only selling one hybrid model in the home market Korea
NISSAN / RENAULT	✓	X	2010	160 km	The first EV will be the Nissan Leaf due in late 2010, followed by Renault's launch of several EV models in 2011
MITSUBISHI	X	✓	2010	160 km	Mitsubishi launched their iMiEV to consumers in Japan in the first quarter of 2010, the model will be launched in the UK in 2011
PEUGEOT	X	X	2010	160 km	Peugeot and Citroen will launch a re-branded Mitsubishi iMiEV in Europe

Source: Company Websites, Industry Research

With governments becoming increasingly aware of energy security and CO_2 concerns, many are turning their gaze towards alternative propulsion technologies. There is a clear demand side pull for EVs, which today is largely centred amongst a minority constituent of Californians and environmentally conscious Europeans. We believe that with a continued improvement in EV (battery) technology, an increase in the choice of models and the lowering of the total cost of owning an EV, there will be significant “pent-up” demand for EVs. This will make it the fastest growing segment of the automotive market and a “must have” category for the large automotive manufacturers as they battle it out in their core businesses.

Exhibit 3 – Selected Current FEV Models (Tesla Roadster, iMiEV, Reva G-Wiz)

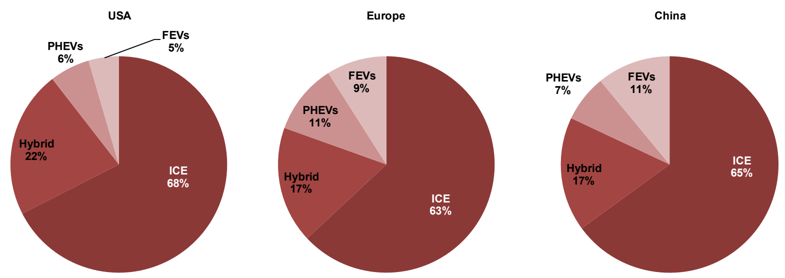
Source: GP Bullhound

With the EV market still in its nascence we believe that for this tipping point to be achieved, four key industry stakeholders need to work together. These four stakeholders include the (i) automotive manufacturers, (ii) the battery players, (iii) national governments and (iv) the electric utilities. The automotive manufacturers have to commit themselves to designing and producing EVs that the consumers will purchase, i.e. vehicles that can replace existing vehicles at an attractive price point rather than solely complementing existing cars with a small battery. The battery manufacturers need to work together with the automotive manufacturers to develop batteries that meet the stringent demands of the automotive industry (capacity, power, safety, life and longevity) as well as continue to progress performance characteristics to bring cost down. Governments will need to implement regulatory frameworks which offer incentives to stimulate EV demand in the interim period while battery technology works itself down the cost curve. An analogy here is the solar industry where a combination of grants, feed-in tariffs and large amounts of private venture and public market capital led to the solar industry making huge improvements in both cost and efficiency of solar cells and leading to the establishment of an entire new industry with players such as First Solar, REC and Q-Cells.

In the case of EVs, incentives are likely to take the form of grants for R&D, tax incentives for purchasers of EVs, or directly subsidizing the purchase of the cars. Finally, the power utilities will in time need to develop their grids in order to cope with the charging demands of EV drivers. Moreover, they will need to put a system in place that provides EV owners with a transparent pricing structure as well as construct, operate and maintain a charging network. Who ultimately owns the infrastructure and how the 'last mile' is regulated to third parties has not been addressed yet with most utilities taking a wait and see approach to ensure that the EV trend is sustained prior to committing investment.

The Exhibit below shows an estimate of the possible share of electric propelled engines versus the mainstay of the ICE vehicle. As one can see, EVs are expected to remain a minority for the foreseeable future.

Exhibit 5 – EV Penetration Comparison in 2020



Source: Industry Research

The Main Hurdles That Need to be Overcome

When talking about EVs the two primary concerns centre around the charging infrastructure and the battery technology.

Charging Infrastructure

With the EV industry still in its early stages, charging infrastructure has yet to be built out in any meaningful manner. EV drivers tend to charge their cars at home, usually when they get home at the end of the day, which works for a consumer who lives in a house and can charge in their driveway, it is not feasible for drivers that live in a flat on the 3rd floor in the centre of town. With the state of the current EV technology, there is a disconnect in that EVs' range limitation makes them most suited to commuting travel for city dwellers (e.g. London and New York), however these consumers tend to live in urban flats and apartments where charging their vehicles overnight is often not practicable (or will require very long power cords!). Some governments have begun to address the charging issue with investments in charging points as evidenced for instance by London's announcement in February of £17 million investment to build a network. It plans to build 1,600 charging points over the coming twelve months and 7,500 charging points by 2013. The 7,500 charging points are expected to break between 6,000 points at places of work, 500 on-street locations, 330 in public car parks, 50 at Tube stations, 140 in supermarket car parks and 120 for car clubs. An example of a privately funded charging infrastructure is the initiative funded by German utility RWE. RWE is investing in building a network of charging points in Germany and plans to have charging points available in all major German cities by the end of 2010. The power supplied from the RWE charging points is promoted as offering the added bonus of being 100% "green power" generated solely from renewable energy sources[3], which would make any EVs that charge with them truly zero emission.

In addition to the building of a meaningful charging point infrastructure within cities, the larger question remains what form battery ownership is likely to take and how charging infrastructure can be built to support long range travel. A number of start-ups have been founded to address this, one of the more well know examples is Better Place. Better Place is planning to build networks of charging stations where EV drivers can quickly and easily switch their depleted battery packs for fully charged battery packs. Their idea revolves around the premise that EV drivers will not own the batteries in their cars, they will lease them from the automotive manufacturers or other parties. The company is aggressively moving forward with the building of charging infrastructure in selected geographies, with Israel and Denmark in line as the first test markets owing to their welcoming regulatory regimes.

Better Place highlights a key point of interest to the EV industry, namely that of battery and charging *standardization*. If a system where entire battery packs are exchanged is ever to gain long term traction, the EV industry must introduce standards which automotive manufacturers and battery manufacturers adhere to. It remains to be seen if automotive manufacturers will be prepared to standardize their batteries to Better Place's standard set by its partner Renault-Nissan. The company does however have a dedicated following and has managed to raise close to $700m in venture financing, including the most recent $350m financing led by HSBC. It remains to be seen whether consumers will warm to having their batteries replaced as it raises a number of questions surrounding battery ownership and confidence in the new battery one receives. For the solution to be broadly marketable, car manufacturers must agree on battery standards to allow for multiple car models to use the network. Historically it has been difficult for the car industry as a whole to agree on many standards.

[3] This is largely marketing. Electricity is largely fungible and a large proportion of RWE's electricity output today still stems from coal fired power generation.

The other key issue that new businesses such as Better Place seek to address is *charging time*. Whereas it only requires a few minutes to fill up the tank with diesel or petrol, charging a car battery is time consuming. Depending on the technology used and battery size, charging a conventional car battery can take up to 10 hours using a conventional low voltage charging solution. There are alternatives to the Better Place solution. The main alternative is to have charging stations where batteries are merely charged rather than replaced. Charging points are popping up in some cities but significant investment will be required for an inter-urban charging network to facilitate longer trips. Think, the Norwegian EV manufacturer, recently announced a partnership with US company AeroVironment, Inc. to commercialize and test fast charging systems that will enable re-charging of a depleted battery up to 80% of full capacity in 15 minutes. Solutions such as this should allay fears of range limitation and charging times.

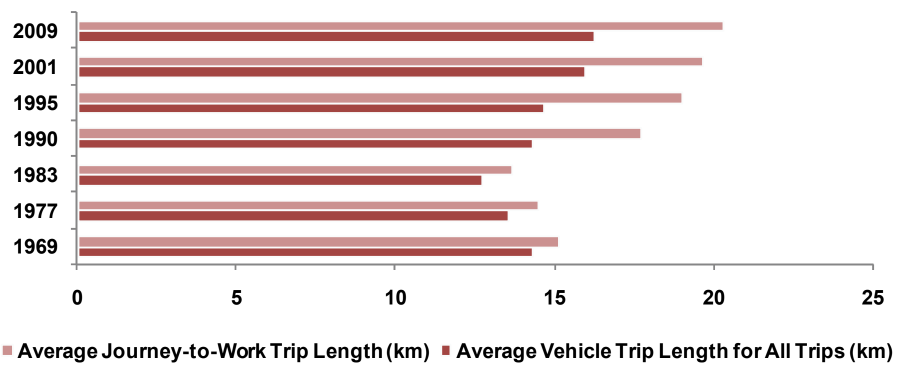
Exhibit 6 – Charging Time Example from an EV Manufacturer

Charging type	Charging time
Charging – Domestic 13A supply	Overnight charge: 12 hours – onboard charger
Charging – Domestic dedicated highpower socket	Standard charge: 4.5 hours – onboard charger
Charging – Three phase high power charger	Ultra-fast charge: 10 minutes

Source: The Lightning Car Company Limited

While people's anxiety with respect to range is an important consideration when thinking about the possible future size of the EV market, one should bear in mind the ranges currently available suffice for the majority of journeys that people make. General Motors estimates that a 65km range, the range that their Volt model can achieve before the petrol range extender is required, is sufficient to cater to 80% of America's daily usage. This will require a habitual change on the part of drivers in that while most people don't use the range in their ICE car today for the majority of car use, many do value the optionality of being able to do a long trip. The Exhibit below shows that the average journey to work trip length in the US was a mere 20km in 2009.

Exhibit 7 – Average Vehicle Trip Length in US

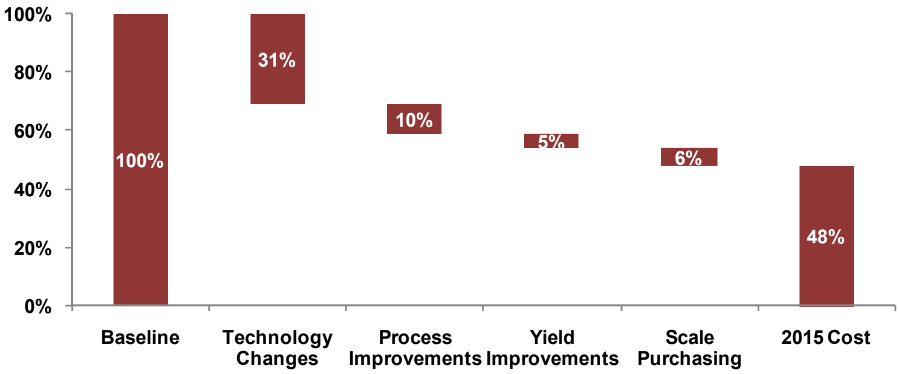


Source: US Department of Energy

Battery Pricing

Battery pricing was the big gating item to commercial uptake of EVs in the early 1990s and continues to be the biggest roadblock to broad uptake today. Most agree that lithium-ion batteries are poised to become the dominant battery technology. Lithium-ion is able to provide the energy density levels required to get adequate travelling ranges. Today, the lithium-ion batteries in cars account for as much as 40% of the total cost of the vehicle, more in some models. Significant work is required from automotive manufacturers and battery manufacturers to bring the costs of the batteries down, which will largely be a function of manufacturing at much larger volumes. While the automotive manufacturers keep their orders at today's modest levels there will be little scope for major price reductions with current technology. The Exhibit below provides an example of the variables likely to impact on battery costs. Most experts attribute much more to volume improvements.

Exhibit 8 – A123 Systems Cost Reduction Roadmap for Batteries



Source: Industry Research

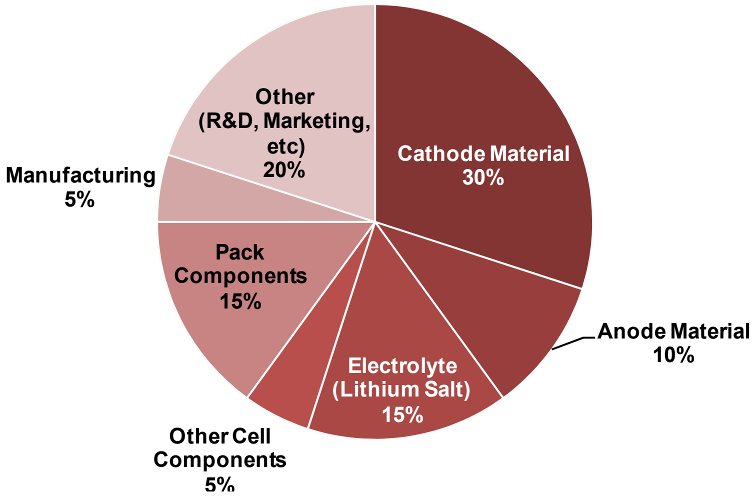
According to the experts we have spoken to, lithium-ion battery packs for automotive applications currently cost circa $1,000 - $1,200 per kWh. Assuming 20 kWh is required for a driving range of 100 km this implies a cost of the battery of over $20,000. Longer term, with production at larger volumes, it is forecasted that these costs may come down to as low as $250 - $500 per kWh (nearly comparable with today's consumer battery costs). Increased automation, volume purchasing and more efficient use of production lines holds the potential to bring down costs further. Materials account for over half of the total costs for batteries. If procurement and utilization of these input materials can be streamlined there is further scope for cost reductions. The US government has set a goal of $250/kw for lithium-ion battery technology and sees this as the level at which lithium-ion will make EVs broadly competitive with conventional ICE based drive trains (depends a little on the price of oil).

There will always be a trade-off in the pricing of an EV, a trade-off that results from the type of battery that is placed in the vehicles. Automotive manufacturers have to navigate between range capabilities, price and convenience. One thing that plays into both battery cost and charging infrastructure convenience are the potential cost savings that battery *standardization* could yield. With standardization larger orders could be placed and thus costs would come down meaningfully, good for the consumer, less good for the manufacturers who's profit margins will become much more visible.

With regard to raw materials and the potential impact that increased EV penetration is likely to have on the price of lithium carbonate in particular, there is little cause for concern just yet. According to a report by the Smith School of Enterprise and the Environment, there is enough economically recoverable lithium to support a projected global demand for 2.1bn vehicles over the next 50 years. On the other hand, if one were to replace all existing passenger ICE vehicles with lithium batteries, the current production levels of 100,000 metric tonnes per year would need to increase by a factor of 13. In the medium term, lithium supply could be a bottle neck if current production does not begin to ramp up. We believe, however, that production of lithium carbonate will be sufficient to meet the demand as current reserves in existing production sites are high and research is being conducted on various replacement materials that may lower the dependence on lithium. The main risks with lithium supply are more related to geopolitics as the bulk of supply sits in South America.

The Exhibit below provides a breakdown of the costs associated with the manufacturing of a battery, materials account for 75% of battery costs.

Exhibit 9 – Breakdown of the Lithium-ion Battery Manufacturing Costs



Source: Industry Research

The Role of Government

EVs are expensive. For the same size EVs one would have to pay more than for comparable ICE cars, principally due to the high cost of the battery. Studies have shown that the key variable to a consumer's decision to purchase a vehicle is the total cost of ownership (TCO), which factors in the upfront cash purchase of the car, life time fuel costs and costs of maintenance and spare parts. Consumers also demand charging infrastructure to be available in similar numbers to petrol stations and a good selection of car models (let's face it with the exception of the Tesla, the current hybrid and electric cars have generally lacked in their aesthetic appeal). Governments have a key role to play in the EV ecosystem. Several governments around the world have started to introduce incentives to EV and

HEV buyers, such as permitting owners to drive in special lanes on highways, exempting EVs from congestion charging, offering discounted or free parking, etc.

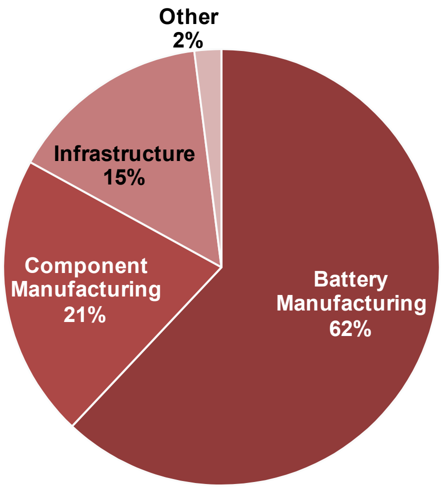
In addition to these "softer" incentives a few governments have introduced tax breaks and subsidies for EV purchasers. The UK recently announced that it intends to offer cash subsidies of up to £5,000 for anyone purchasing EVs from January 2011. Pursuant to the 2009 US fiscal stimulus legislation the US federal government offers up to $7,500 in tax credits to any household purchasing an electric vehicle. The strategy of offering a subsidy to EV buyers is offered by many countries including Japan, Canada and several European countries. Additionally, several countries including Sweden and Denmark have now implemented tax incentives that encourage consumers to buy cars that emit less CO_2, which clearly benefits EVs. Taxing large ICE gas guzzlers more than EVs in turn narrows the pricing gap between EVs and ICE cars.

We believe that consumer demand stimulus incentives need to be coupled with government support for research and development and manufacturing (the launch of the Volt was one of the key selling points of the plan put forward by GM when it applied for TARP funding). The US has been leading the way recently through the $25 billion Advanced Technology Vehicles Manufacturing Loan Program (ATVM), which is also known as the Green Retooling Fund. The aim of the fund is to support the upgrading of plants and research into technology that can enhance fuel efficiency, an area where US automotive manufacturers have generally been lagging. The Department of Energy (DoE) administers the fund and has received applications from various companies along the EV value chain, for example Tesla has applied for funding as have many battery manufacturers including A123 Systems.

Driven by security of supply concerns, the US is the country that is investing most into new technologies to increase vehicle efficiency. 2009 saw the US government, through the DoE, unveil a $2.4bn grant program to be directed towards research and development into advanced battery manufacturing and vehicle electrification. A significant difference between the $25bn ATVM and the $2.4bn grant program is that the latter does not have to be repaid, but for every dollar awarded the company in question must match that dollar. This funding program is part of a concerted effort by the US government to build the foundations that will make the US a leading battery supplier. According to a speech by Barack Obama in February 2010 the US now has the potential to increase production tenfold and potentially control 40% of the global lithium-ion market by 2015. The following Exhibit shows how the $2.4bn was distributed.

The government fund sources are attractive ways for venture investors to "lever" their investments by tapping into low cost non-recourse government capital and thereby lowering the 'at risk capital' in the companies they choose to back.

Exhibit 10 – Split of the Funds Awarded Through the DoE's $2.4bn Grants



Source: US Department of Energy

The UK government has also implemented measures to stimulate EV uptake. It was recently announced that the UK Department for Business, Innovation and Skills will commit £21m towards supporting Nissan's investment in a battery plant and car production in the North East of the country, in part to protect jobs. This UK support comes on top of other announced initiatives involving tax credits for EV buyers and investments in charging infrastructure.

Germany is also pushing hard for a more widespread adoption of EVs, in part as a defensive measure to protect its domestic automotive industry. It has set a target of 1 million EVs on the roads by 2020 and earmarked $705m to be used for technology development over the next three years.

Denmark is focussed on using the embedded energy storage that EVs would give to smoothen the peaks of its large base of intermittent wind based generation.

Are EVs More Environmentally Friendly Than ICE Vehicles?

Are EVs really better for the environment? The answer to this question is an unsatisfying "it depends". EVs are often touted as being zero emission vehicles. This is only true when not taking into account the electricity generation mix used to charge. An EV can be a zero emission vehicle but then 100% of the electricity used to charge them has to come from low carbon sources such as wind, hydro or nuclear. The energy generation mix of a country determines how much pollution can be reduced through the proliferation of electric vehicles. Countries that overwhelmingly use coal to generate electricity, such as India and China, will have less to gain from EVs as the incremental electricity that will be required to power the fleet is likely to be produced from carbon emitting sources of power generation (although it will address security of supply). Countries with a cleaner energy mix, such as France (high proportion of nuclear power) have relatively much more to gain, with every additional EV lowering the country's carbon emissions. The flip side is that most EV users will charge overnight when power demand and electricity prices are low (in some countries lower by a factor of 5) with the implication that even with a dirtier generation mix increased EV penetration should lower emissions in aggregate in that little incremental generation capacity would be required for overnight charging. For example it is estimated that the UK could convert 25% of all its cars to EVs without any incremental investments in the grid or power generation.

All in, however, EVs will always generate lower emissions than their ICE peers due to the higher efficiency of electric motors, i.e. electric motors are able to squeeze out more energy per unit of their fuel compared than ICE engines get out of theirs (by a factor of 3). As a result of the indirect emissions caused by EVs a move away from carbon based electricity generation should go hand in hand with an increased focus on EV transportation.

More pertinently than the environment, a structural shift to electric vehicles would help alleviate security of supply concerns allowing for a substitution of Middle Eastern oil for grid based power. In the case of the US, indigenous unconventional (shale) natural gas is growing with the advent of hydraulic fraccing and horizontal drilling technology having lowered the marginal cost of natural gas development. A lot of this indigenous gas will go towards domestic power generation. Similarly in Europe, the growth in the renewable mix and the fact that nuclear is back on the agenda in many countries should slowly reduce the reliance on crude as the only source of powering transportation. Shipping, aviation and bulk road transport (light vehicle transportation accounted for 65% of transportation petroleum demand in the US in 2007) will continue to rely on the diesel and gasoline ICE technology with current battery technology limiting range too much to have a role in these segments.

Total Cost of Ownership

So, is it cheaper to own an EV instead of an ICE vehicle seen over the total lifetime of the car? The answer depends on a number of variables including oil price, the cost of batteries, how much you drive and government incentives. With high government tax breaks for EV purchases the time it takes for full payback of the upfront cost can drop significantly to as little as a few years. The upfront cost of purchasing an EV is highly dependent on the cost of the battery pack.

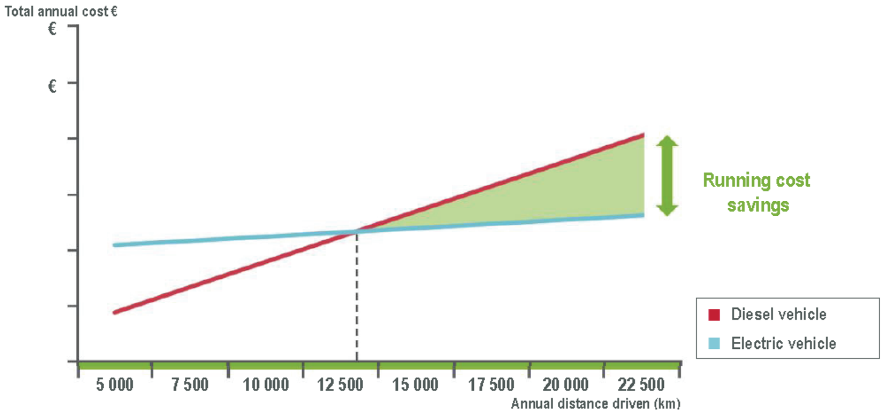
The cost per kilometre of driving an electric vehicle is lower than for petrol fuelled cars, in part due to the more efficient nature of EVs. The exact difference in price per kilometre depends a lot on the price of petrol and the fuel taxes which come on top. Fuel taxes differ substantially between countries, US fuel taxes are very low at around 19% of the total price whereas European taxes are much higher e.g. UK has 79% fuel taxes. According to a study conducted by Robert Bosch, one kilowatt of energy will allow an ICE vehicle to travel 1.5-2.5km.The same amount of energy will allow a diesel HEV to go a maximum of 3.2km and an EV 6.5km. The fact that most EVs are currently charged at home overnight means they are able to take advantage of low off peak electricity prices, further lowering the cost per km. Even charging during the day is cheaper than re-fuelling with petrol. In addition the price of oil is more volatile than the price of electricity. Also, EVs also have far fewer moving parts (no gaskets, filters or oil changes) that can break compared to ICE vehicles. As such EV owners are likely to save significantly on life time maintenance costs.

One way of bringing down the upfront cost of purchasing an EV and decoupling the price of the battery from the car is to separate the ownership of the car and the battery. By leasing batteries consumers will be able to view their batteries as running costs and alleviate the high upfront cost of the battery. Battery leasing also helps mitigate the risks associated with the uncertainties surrounding the way batteries will depreciate (in particular pertaining to technological obsolescence), Renault has adopted this approach with the launch of the *Leaf*. The issue we see with the leasing solution is that so much of the value of the car is tied up in the expensive battery. Moreover how the battery is maintained and charged can impact on longevity and capacity (range) which if outsourced naturally results in moral hazard of EV drivers potentially not properly maintaining the batteries.

Consumer purchase decisions are seldom 100 percent rational. In addition to the pure economic outlay people will take into account things like how others will perceive them driving an EV, the looks of the EV in question and the boost to their green credential egos. Certainly in developing nations it is increasingly cool to be seen to be environmentally conscious and there is no better item of green conspicuous consumption with which to show this than with one's car.

The following Exhibit outlines how even with a higher initial cost, an EV will provide substantial savings for those that travel more than a certain distance.

Exhibit 11 – EVs Can Offer Lower Annual Running Costs Than Diesel Vehicles

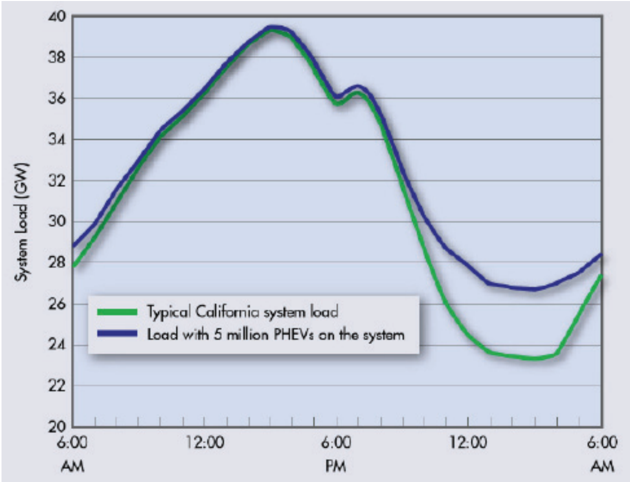


Source: Renault

Vehicle to Grid Technology

The Smith School of Enterprise and the Environment recently conducted a study on the potential effects of EV charging. They found that at least half of the additional electricity that will be required to meet the added electricity demand from EVs can be met by charging overnight when electricity demand is lower. This electricity demand can thus be met without having to increase production overnight and without a need to invest in expansion of current plant capacity. The report also noted that any increase in demand for charging will come gradually and as such extra capacity can be added over time to meet the increasing demand. The Japanese utility Tokyo Electric Power goes further by estimating that the current excess availability of night time electricity capacity will be enough to meet the demand of EV owners even in the event of full-scale EV substitution. The following Exhibit provides an example of the effect that EVs can have on off peak electricity demand.

Exhibit 12 – Effects of Charging Using Off-Peak Power



Source: Electric Power Research Institute

With an increasing number of EVs being adopted by consumers, there will be potential for EVs that have charged using off peak electricity to return some of this electricity to the grid at peak load times. EVs will thus have the ability to act as frequency regulators for the grid. Frequency regulation in electricity grids ensures that supply matches demand. When there is an imbalance between supply and demand, back-up generators (typically diesel fuelled), peakers (typically natural gas fuelled) or utility scale energy storage is mobilized to adjust the flow of electricity. With the possibility of having millions of EVs on the road, some with large enough batteries to power a house for many hours, they will at the margin be in a position to replace the need for the power generators to regulate frequency. Plugged in EVs can take a short break from charging to direct electricity the other way, towards the grid, thus acting to rebalance supply and demand. Using car batteries as broader energy storage devices would also allow grids to take better advantage of energy generated from lumpy renewable sources of energy. By way of example 50,000 EVs with 20 kWh battery packs contain an implied 1 GWh of power storage, the equivalent capacity of a large coal plant and larger than most, if not all, commercial utility battery storage solutions. With the likes of solar and wind based power intermittent in their energy generation (the wind does not always blow and the sun certainly does not always shine) EVs can potentially charge and store electricity from renewable generation when it is available and use the electricity when it is not.

At present there are a number of initiatives focused on creating a smarter electricity grid with the involvement of EVs. Ford and Microsoft recently announced that they plan to work together on a computerized link that will aid the efficient management of energy use. The system will allow EV owners to see when it is most cost efficient to charge their cars and thereby lower the burden on the power grid. Ford CEO Alan Mulally envisages that the system will eventually enable homeowners to use the energy stored in their EVs to power home appliances at times of peak load with energy that has been stored at off peak times, thus cutting costs at peak energy use times. Try to do that with your petrol based car!

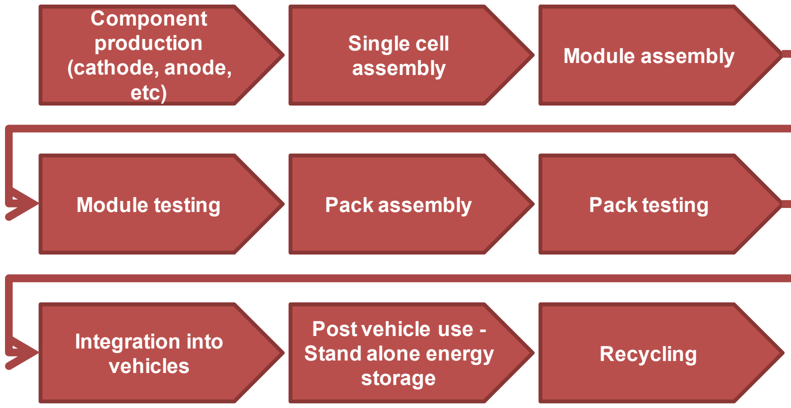
BATTERY TECHNOLOGY OVERVIEW

Batteries - The Basics

Batteries function by converting electrical energy into chemical energy while charging and reversing that process when discharging. Two solid electrodes in the battery are used to store the chemical energy, between which negatively and positively charged ions migrate in different directions depending on whether the battery is discharging or not.

The exhibit below provides an overview of the battery value chain. There is a lot of scope for companies of scale to be built.

Exhibit 13 – Overview Battery Value Chain



Source: GP Bullhound

The Challenges of Battery Development

Battery development is a tricky business. Development is constrained by the inherent tension among five main battery attributes: power, energy, longevity, safety and cost. Increasing power density (horsepower) requires higher voltage, which reduces longevity and safety and tends to come with a higher price tag; increasing energy density in turn reduces power density. Attempts to simultaneously optimize power, energy, longevity, and safety all increase battery cost. No single battery chemistry ticks all five boxes today but technology development is flourishing by start-ups and larger players alike and significant inroads have been made already. The stakes are high with many players vying for a slice of what is likely to be a very large addressable market.

As previously mentioned, lithium-ion batteries are beginning to emerge as the winners in the race to become the dominant battery type for EVs. However, significant hurdles remain for costs to come down and mass EV market adoption to gain traction in the absence of major subsidies. The main areas of focus for battery manufacturers focused on the automotive segment include: power density (i.e. the size and weight of the batteries), energy density (the range that one battery can provide at a given weight), charging time, cycle life and not least safety. The following sections provide an overview of each of these attributes.

Power Density determines the rate at which energy is transferred from a battery to the engine. The rate at which this energy can be transferred determines the acceleration capability of an EV and is measured in W/kg. The power of an ICE based vehicle is typically reported in horsepower, where 10 horsepower equates to 7.5 kW. For batteries, power is akin to the rate at which gasoline can be delivered to the engine - to accelerate faster one has to draw on more stored energy from the battery. With most of today's battery technologies, the absolute amount of power that they can contain is not an issue. To attain higher amounts of power one simply builds a larger and heavier battery (the Tesla for instance packs a 450 kg lithium-ion battery). However size is an issue in the development of vehicles in that batteries have to keep certain weight and size specifications for there to be sufficient passenger room in the vehicle and to meet safety specifications. The challenge therefore revolves around optimizing the amount of power for a given unit of size and weight (footprint). The power characteristics of today's batteries provides a torque that exceeds that which can be provided by conventional ICEs, which is why trains prefer using electric motors instead of ICEs and why the Tesla Roadster accelerates faster than the Lotus Elise on which it is modelled.

Energy Density or Capacity determines the range of an EV as it defines how much energy can be stored in a battery. The energy capacity of batteries is measured in kWh and as an example one can say that an average of 10 to 20 kWh is needed (depending on car size and weight) for an EV to travel a range of 100km under normal temperature conditions (cold weather significantly impacts capacity). There is typically a difference between the available and total energy of a battery. While a battery may have 20 kWh of total energy, a portion of this capacity may only be available for vehicle operations.

At the current cost of around $1000/kWh, the implied a cost of a 20 KW battery is $10,000 - $20,000, much too high for broad based market adoption. As with power density, energy density is a function of the size and weight, with higher battery weight providing longer range. As a comparison the following exhibit provides food for thought about batteries' tough competition in the field of energy density. There is some way to go for batteries to beat ICEs on energy density with diesel and petrol possessing six times as much energy density than a state of the art lithium-ion battery. These figures of course ignore the fact that typical ICE based technology is only 25-30% efficient as compared with an electrically powered engine which is up to 90% efficient i.e. a much higher proportion of the stored energy is transformed into useful (kinetic) energy.

Exhibit 14 – Energy Density of Common Fuels

Fuel	Energy Density (kWh/dm3)
Diesel	10.6
Petrol	9.5
Coal	7.6
Liquid Natural Gas	5.6
NH3BH3 (Ammonia Borane)	5.5
Methanol	4.4
Wood	3
Liquid Hydrogen	2.4
Natural Gas (200 bar)	2.3
Lithium-ion battery	1.7
Gaseous hydrogen (200 bar)	0.5

Source: Smith School of Enterprise and the Environment, Oxford University

Charging time is the time required to charge the battery. While this has improved quite a bit recently with high voltage charging technology, improvements still have to be made. Some EV drivers will say that charging time is not an issue for them as their EV batteries provide enough energy for them to be able to drive to work and then home with all of the charging done overnight. However, for mainstream adoption of EVs to become a reality, charging times must be brought from the current 4-10 hours down to levels where it doesn't necessitate a major change in the driver experience (for instance at 15-30 minutes one would be able to achieve a full charge while grocery shopping). Quick charging stations which recharge a depleted battery to 80% of maximum charge in short time periods do exist, however they are far and few between. Moreover quicker charging can result in battery degradation and impact on battery life.

Battery lifetime/Longevity can be viewed in two ways, (i) cycle life (the number of times a battery can be fully discharged and recharged until 80% of initial full charge capacity remains) and (ii) calendar life in years (i.e. how many years a battery is able to store sufficient energy). The lifetime of a battery depends on many variables. Among these are the speed of charging that the battery is subjected to and the temperature conditions (e.g. US Advanced Battery Consortium temperature range specifications are -46°C to +66°C) under which the battery must reside. Another issue with certain battery technologies that can shorten lifetime is the memory effect whereby batteries gradually lose their maximum energy capacity. As a reference point for desired battery life, automotive manufacturers target batteries that can function properly over the expected lifetime of the vehicles that they power. Today, most auto manufacturers look for batteries with a minimum ten year life span, after which they will have reached 80% capacity and would still be useful although not achieve the same range. It is expected that batteries that have exhausted their useful EV lifetime will be used in other ways after having been installed in EVs and prior to being recycled. The commonly mentioned use is as back up energy storage for homes.

Battery safety is critically important for the EV industry as a battery fire could have very negative effects for widespread consumer adoption as well as put people at risk in the event of a crash. While the batteries put into vehicles are significantly more advanced and have more safety features compared with the batteries used in consumer electronics applications, more work needs to be done on high temperature resistance. The main safety concern in batteries revolves around the risk of thermal runaway. Thermal runaway is, simply put, when a lithium-ion battery catches fire which cannot be stopped until the battery has consumed itself. Causes of thermal runaway can be short circuits, very high discharge rates and overcharging. In 2006, laptop batteries from Apple, HP, Toshiba, Lenovo, Dell and other notebook manufacturers were recalled because of fire and explosions due to thermal runaway. This issue is of particular concern in cars in the event of a crash where a battery would have the potential to act as a bomb. In 2007 Toyota announced that it would halt deployment of a lithium-ion battery for the next-generation Prius model (HEV) due to safety concerns, instead proceeding with an advanced nickel-metal hydride battery.

The risk of thermal runaway is being mitigated by several safety features in the batteries including mechanical and thermal cell design, cooling systems and battery monitoring that monitor discharge rates and internal temperature, etc. Battery safety has undoubtedly improved significantly over the past decade and one should put batteries in context to driving around with a tank full of highly flammable gasoline.

The Main Battery Technology Contenders

Lead acid batteries have been around for over 100 years. The batteries were used in EVs around the turn of the last century, and are still used in some FEVs such as Reva's G-Wiz model. They are also used as car batteries in conventional ICE vehicles. Lead acid batteries perform reliably as batteries to start vehicles as they provide a high surge of current. They are, however, less suitable for use in EVs as they have low energy density properties and therefore score low on range. Development continues on the next generation of lead acid batteries with the future of lead acid technology incorporating carbon into the battery to improve performance. The main issue with lead acid batteries is that the materials in them are hazardous and cannot be recycled, a similar issue to the cadmium based photovoltaic technology.

Nickel-metal hydride (NiMH) batteries have evolved into becoming the battery technology of choice for HEVs. They have gained traction owing to their longevity and reliability with a long established safety record in vehicle applications. In contrast to a lead acid battery, nickel-metal hydride technology has relatively high power density, making it much more suitable for accelerating a hybrid vehicle from a stop, or assisting the ICE at higher velocities. On the flip side they are heavy and have low energy conversion efficiency which means that they lose a high proportion of energy to the production of heat. Nickel-metal hydride batteries are thus only used in applications where limited energy storage is required, such as in HEVs. HEVs generally only require short discharges, usually in conjunction with acceleration. The technology has been around for a while and has a good track record which along with its relatively favourable price point will ensure that they will be around for a while. While we expect the nickel-metal hydride battery to be replaced by the next generation of lithium-ion batteries, we would not be surprised to see the technology used in HEVs for many years to come, in large part due to its cost and well trodden safety record.

Lithium-ion batteries are increasingly looking like they will capture the lion's share of the EV battery market, even if they are still in a rather early stage of development. Lithium-ion batteries offer superior range to the older technologies and the early success of the technology has inspired a range of competing chemistries within the lithium-ion space. The main contenders all exhibit varying performance with regard to the key technical parameters along which batteries are judged. As previously mentioned these technical parameters are; power density, energy density, charging time, cycle life and safety. A further benefit with lithium-ion is that the materials of which they are made of are not hazardous and they can be recycled.

Exhibit 15 – Overview of the Main Automotive Battery Technologies

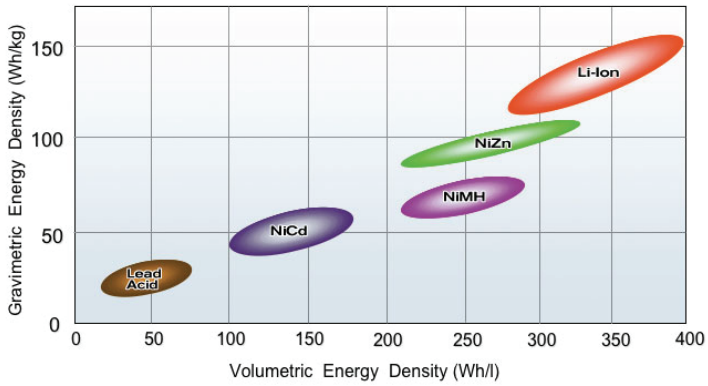
Battery Type	Energy Density	Voltage	Cycles Before Replacement	Pros	Cons
Sealed Lead Acid (SLA)	50 Wh/kg	2.1 V	500 - 1,000	• Suited for stationary or wheeled applications • Relatively low price, easy to maintain, low self discharge rate	• Have to be stored in charged state • Low energy density implies that they are heavy / bulky
Nickel Cadmium (NiCd)	50 Wh/kg	1.2 V	800 - 2,000	• Relatively inexpensive and robust • Used for applications that require long life, high power and extended temperature range	• Have memory effect • Cadmium is toxic and thus requires special recycling • Banned in the EU
Nickel Metal Hydride (NiMH)	70-80 Wh/kg	1.2 V	750 - 2,000	• Environmentally safe • Lighter, much higher capacities and less memory effect compared to NiCd	• Lower cycle life and requires more sophisticated charge control than NiCd
Lithium-ion (Li-Ion)	120-150 Wh/kg	3.6 V	1,000 - 3,200	• High energy density • No memory effect • Low self discharge rate	• More expensive • Require additional surrounding technology to ensure safety

Source: Industry Research, GP Bullhound

The Future Dominance of Lithium-Ion

We believe that lithium-ion is poised to become the dominant technology going forward as a result of a number of factors. One of the main reasons why it is well positioned is its high energy density, this implies that it can provide much longer ranges than the competing technologies. The higher energy density translates into smaller and lighter battery packs and consequently should in the long term imply lower costs. Another advantage with lithium-ion includes the fact that the technology has no memory effect, i.e. a full discharge is not needed in order to start recharging again without leading to battery degradation. Exhibit 16 provides an overview of the Energy density characteristics of various battery chemistries.

Exhibit 16 – Energy Density Comparison



Source: PowerGenix Corp.

Lithium-ion batteries still face significant competition in the EV world and we expect that to remain the case in the medium term. Nickel-metal hydride batteries are installed in virtually all commercial HEVs today. There is no substitute for commercial acceptance on a large scale, not least in an industry where technology adoption has been slow and safety concerns are paramount. Nickel-metal hydride batteries are currently significantly cheaper than lithium-ion batteries, which reflects their technological maturity, with lithium-ion for vehicle applications yet to be manufactured in large commercial quantities. Lithium's light weight means it scores very high on energy density and capacity. However in order for lithium-ion to achieve a leadership position, it needs to overcome issues of longevity and power. While lithium-ion batteries have high energy density levels, the chemistry associated with them makes it difficult to quickly release energy, i.e. there are limits to their power. Lithium-ion batteries would also benefit from improved durability, currently this is being solved by increasing the size and thus weight to add additional battery lifetime.

There is still a lot of uncertainty as to which chemistry of lithium will ultimately emerge as the winner. The most prominent chemistries being developed today include lithium-nickel-manganese-cobalt (NMC), lithium-nickel-cobalt-aluminum (NCA), lithium-manganese spinel (LMO), lithium titanate (LTO), and lithium-iron phosphate (LFP). The technology that is in commercial use in consumer applications (laptops, mobile phones, etc) is lithium-cobalt oxide (LCO), which is regarded as unsafe for EV use. More recently there has been a lot of hype around a seventh lithium based chemistry named "Lithium Air", a novel chemistry with the potential of ultra high energy capacity (some experts claim up to 10 times that of current lithium-ion based chemistries). As opposed to conventional lithium where cobalt or some other element is used as the cathode, lithium air draws on oxygen from the air as the active material for the cathode. Due to the lighter cathode and the fact that oxygen is freely available in the environment and does not need to be stored in the battery this theoretically allows for much higher storage with the only bottleneck being the lithium-ion battery's anode. Encouraging early results have been achieved in the lab, however this chemistry is a long way from being developed at scale and being commercially viable for vehicle applications.

Another area of research is looking at how the batteries' carbon based anodes can be replaced with other materials. This is of particular importance given that current energy capacity in lithium-ion batteries is capped as the carbon based anodes are operating at their physical limits. A company called Nexeon has developed a technology that replaces the carbon anode with a silicon one. Silicon is an able replacement to carbon as the material offers up to 200% higher capacity than carbon at a lower cost. Another example of innovation is Oxford based Oxis Energy. They are looking at a different lithium related route focusing on a new lithium-sulphide electrochemistry. They claim that their technology will be able to offer lower weight and higher performance rechargeable batteries. Developments like these hold the potential to revolutionize the industry and bring battery costs down significantly.

Exhibit 17 – Comparison of Lithium-ion Cathode Types

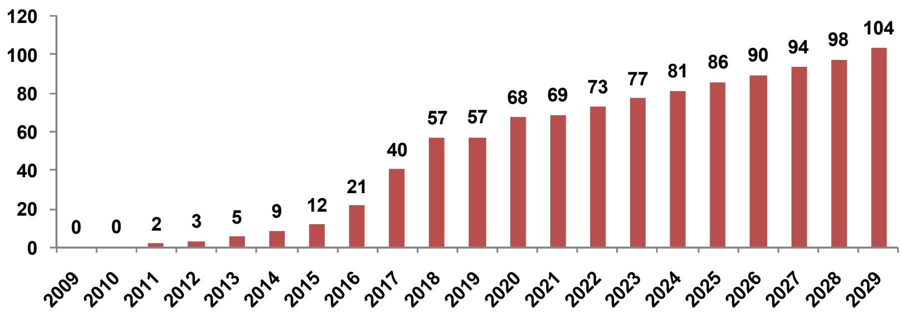
Chemistry Type	Energy Density	Pros	Cons
Lithium-nickel-cobalt-alumium (NCA)	160 Wh/kg	• High energy density • High power	• Safety concerns • High cost and commodity exposure • Low life expectancy and range of charge
Lithium-manganese spinal (LMO)	150 Wh/kg	• Low cost • Relatively safe • High power	• Low life expectancy • Low usable energy
Lithium-nickel-manganese-cobalt (NMC)	150 Wh/kg	• High energy density • High range of charge	• Safety concerns (although better than NCA) • High cost and commodity exposure
Lithium-iron-phosphate (LFP)	140 Wh/kg	• Relatively safe • High life expectancy and range of charge • Relatively low material cost	• High manufacturing costs • Low performance at low temperatures

Source: Industry Research, GP Bullhound

Potential Battery Market Size

If battery problems outlined above can be resolved, batteries are poised to grow into a large market. Predictions about the likely size of the future battery market vary widely, but all agree it will be large. Pike Research forecasts that the global market for lithium-ion batteries alone will be worth $8bn by 2015. A.T. Kearny predicts that the same market will be worth $74bn in 2020, and Credit Suisse is equally bullish on the lithium-ion market predicting a massive growth as per the Exhibit below.

Exhibit 18 – Estimated Market for Large Format Lithium-Ion Batteries ($bn)



Source: Credit Suisse

A FEW WORDS ON WHERE TO LOOK TO INVEST...

A good industry does not necessarily imply a great investment, however it is a good place to start looking for one. History has shown that the automotive industry has not been known for one with great long term economics. Moreover, as many a supplier to the industry will tell you, the automotive companies are challenging customers to supply into, owing to their thin margins and the fact that most components they source today are commoditised and multi-sourced from swathes of "approved suppliers". Nevertheless we believe the disruption brought about by electrically propelled vehicles (hybrids and plug-in hybrids followed by fully electric vehicles) should throw up some interesting new areas of potential private and public investing. If one buys into the fact that EVs are a long term secular trend that is attractive; we see a few avenues of potential investment:

1. *Battery technology*
2. *The vehicles and their parts: Established automotive manufacturers like Toyota, new independent companies a la Tesla or Reva, and component manufacturers*
3. *Charging infrastructure*
4. *The mining of the raw material lithium carbonate*
5. *Novel service based business models a la Better Place that address specific issues the industry will face such as battery charging and range*

At GP Bullhound we are sceptical of 5 and 2 and don't regard the investment in the raw material 4 as an obvious venture investment for most funds. Charging infrastructure is interesting but likely to be headed by the power utilities and the large component manufacturers such as ABB and Siemens. While lithium production is running close to full capacity, the material is abundant (20 million metric tonnes of reserves according to industry sources) and while not straightforward to mine, supply can be brought on stream in large quantities in a relatively short time frame, certainly shorter than the period required for adoption of EVs on large scale. With respect to 5, our experience from the internet revolution is that entirely new business models, such as Better Place that attempt to change the architecture of how cars operate today, are high risk, and require too many large entrenched constituents to adapt to be commercially feasible. Such business models have the ability to consume a lot of "tuition" capital in an effort to figure out what the right business model is to pursue. We hope we are wrong.

Novel battery technology we believe offers the most fruitful area for venture investment and for meaningful IP protection. Large scale battery technology is dominated by several large players (the half glass full interpretation being that there are plenty of strategic buyers) however we believe there is still room for innovation along various of the battery components not least novel electrolytes and electrodes (anodes and cathodes), and the nuts and bolts including separators, supply chain and technology to improve cell and cell pack design and architecture. A lot of this innovation is already ongoing in the labs of research organisations, universities and private start-ups, some of which are briefly described in our company profile section at the back.

CONCLUSIONS

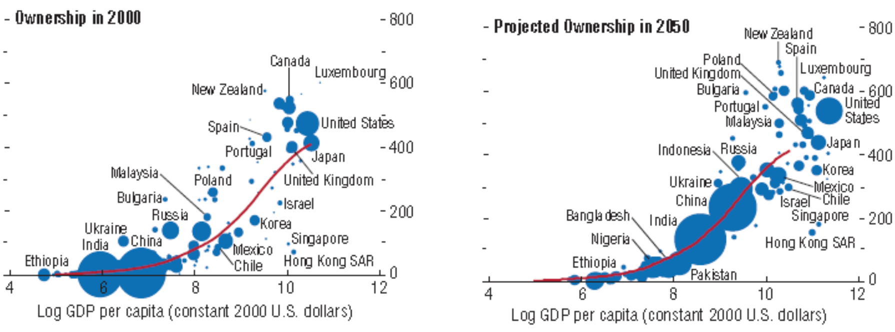
Developments in battery technology, government incentives and a concerted effort by automotive manufacturers have laid the foundations for a lasting presence and uptake of EVs. This time around there is broad support from the stakeholders to ensure that it will not be another false dawn.

While the EV industry remains in its early stages of development, many are beginning to see the benefits associated with EVs. In congested cities such as London it is clear there would be a massive improvement to everyone's quality of life if a large proportion of vehicles were electrically powered, far cleaner air and much less noise.

The average lifetime depreciation of a car is 15 years. As such, it will take a long time to replace even 10% of the global car fleet currently roaming the streets of the globe with most owners seeking to amortise their existing ICE car before moving on to an electrically powered vehicle. With this in mind, one should view 2020 as being the earliest date at which EVs will attain a meaningful share of the global automotive market.

With the fairly long take up period, the timing is currently beneficial for investors to get in the game. There are many areas across the EV value chain ripe for further private investment. Battery technology, car and engine components, EV manufacturers, charging solution providers and smart grid software developers all offer compelling products that will, in time, achieve mass market adoption (see previous section). Even if EVs only achieve a 10% share of all vehicles sold globally this will represent a significant number of EVs and potentially large addressable market for those playing in the value chain. In 2008, 52m passenger vehicles were produced, a number that is forecast to grow as Chinese and Indian consumers purchase their first cars (see Exhibit below).

Exhibit 19 – Projected Development of Car Ownership (Y-Axis: Cars / 1,000 People)



Source: International Monetary Fund

Why purchase an EV when one can already choose between a large number of proven HEVs? The answer is fairly simple, while HEVs reduce emissions through increased efficiency they don't eliminate the need for petrol. Thus, they do nothing to ease the concerns around energy security, CO_2 emissions and what are likely to be permanently higher oil prices. Hybrids are an inefficient solution to a broad set of problems. These arguments do not apply as clearly to PHEVs which are a solid interim solution.

The price of batteries remains the key gating item to EV adoption. We, believe that as technology develops and the various components within the battery value chain begin to manufacture at commercial scale, prices should come down to levels to make EVs competitive with fuel based technologies at north of $60/barrel oil prices. Experts we have spoken to estimate that 65-75% of the $1,000-1,200/KW lithium-ion battery cost today consists of variables that will come down with scale making a $250 KW target ambitious however not inconceivable over a 10 year time horizon.

In the short to medium term, however, costs could be impacted by rises in raw material costs. As lithium-ion becomes the generally accepted technology of choice for automotive applications, cost of the raw material could increase more than what would be justified by fundamentals similar to what happened to poly silicon in connection with the expansion of the photovoltaic industry.

With battery prices likely to continue their downward descent through technological progress, increased competition and a concerted government led push to build charging infrastructure, we expect EVs to be in a position to achieve a 10%+ share of the global automotive market by 2020, implying higher penetration in urban areas and developed economies. A continued high oil price environment and a global agreement on climate change to curb carbon emissions will put further wind in the sails of this industry, however we believe it will not be a condition to its ultimate success.

Continued progress will require several constituents to join forces not least the automotive manufacturers, battery suppliers, governments and power utilities. For consumers to take the plunge there needs to be a selection of attractive car models and designs to choose from, safe battery technology that can ‘go the distance’, and pervasive quick charging infrastructure that allows for a broadly similar driving experience to a conventional car. As with other disruptive technologies such as telecommunications, it is likely to result in the emergence of many innovative new business models, with a fair amount of ‘creative destruction’ along the way. All in all, we firmly believe electric vehicles are here to stay this time around and within our lifetime will be developed to a level where it becomes economically compelling to own one for all households even in the absence of the tax perks and subsidies.

SELECTED COMPANY PROFILES

better place

Business Description: Better Place is an electric vehicle services provider. The company is building infrastructure and an intelligent network to deliver a range of services to drivers. It develops battery exchange stations and charge spots to provide electric power for cars. The company was founded in 2007 and is based in the Palo Alto, California. It has operations in Israel, Denmark, and Australia.

Investors: HSBC, VantagePoint Ventures, etc.

Headquarters: USA

EV Segment: EV Charging

Website: betterplace.com

ELECTRO ENGINE

Business Description: Electroengine in Sweden AB has developed a system that makes it possible to convert standard cars with ICE to high performance EVs. The system that the company has developed can also be used in the production of new EVs. The company claims that its systems are more cost effective than other electric drive systems in the market. One of the reasons for this is a proprietary battery management system.

Investors: Almi Företagspartner

Headquarters: Sweden

EV Segment: Components

Website: electroengine.se

EVO ELECTRIC
the evolution of power

Business Description: EVO Electric Limited develops and manufactures advanced electric machines, drive systems and other integrated power products. The company's products are focused on a range of transportation and mobile power applications and are based on a proprietary axial flux technology. The company's technology offers an alternative to conventional radial flux machines. The company was founded in 2007 as a spin-out from Imperial College London, and is based in Woking, Surrey.

Investors: Imperial Innovations, etc

Headquarters: UK

EV Segment: Components

Website: evo-electric.com

Business Description: Liberty Electric Cars is engaged in the re-engineering of luxury cars and four wheel drives into emission-free, high performance electric vehicles. The company designs and manufactures a proprietary electric drive train platform with high performance and acceleration capable of powering a range of vehicles. Liberty Electric Cars first model, a converted Range Rover, can travel over 320 km before needing a charge.

Investors: -

Headquarters: UK

EV Segment: ICE / EV Conversion

Website: liberty-ecars.com

Business Description: The Lightning Car Company Limited designs and manufactures an electric sports car with a range of 300 km and a top speed of 209 km/h. The company is based in Peterborough, United Kingdom.

Investors: -

Headquarters: UK

EV Segment: Electric Vehicles

Website: lightningcarcompany.co.uk

Business Description: Nexeon Ltd. Is a battery materials company developing silicon anodes for lithium-ion batteries that provide the batteries with enhanced performance and more cost efficient characteristics. The company develops silicon anode technology for various applications, including consumer electronics and electronic vehicles. The company was founded in 2006 and is based in Abingdon, the United Kingdom.

Investors: Imperial innovations, PUK Ventures

Headquarters: UK

EV Segment: Battery Technology

Website: nexeon.co.uk

Business Description: Oxis Energy Limited is a battery materials company focusing on lithium-sulphide electrochemistry that is aimed at producing a high performance low-weight lithium rechargeable battery. The company is targeting applications in Electric Vehicles, e-Bikes and back-up power. The company was founded in 2000 and is based in Abingdon, the United Kingdom.

Investors: Oxford Technology Mgmt, etc | **Headquarters**: UK

EV Segment: Battery Technology | **Website**: oxisenergy.com

Business Description: Think Technology AS was founded in 2006 and is engaged in the production of EVs. The company also sells EV drive trains on a B2B basis. The company's current model, the THINK City, is being produced at Valmet Automotive's production facility and has gone on sale in a number of countries. Think has a US subsidiary and is currently applying for loans from the $25-billion Advanced Technology Vehicle Manufacturing loan program.

Investors: Ener1,Valmet Automotive, etc | **Headquarters**: Norway

EV Segment: Electric Vehicles | **Website**: think.no

Business Description: Oxford YASA Motors Limited is a spin out from Oxford University. The company was founded to commercialise the intellectual property developed on the YASA motor. The YASA motor offers a high specific torque, high efficiency and can be produced at a low cost. Oxford YASA Motors Limited is targeting the automotive, aerospace, marine and industrial markets. The company was founded in 2009 and is based in Abingdon, the United Kingdom.

Investors: Isis Innovation, Seven Spires | **Headquarters**: UK

EV Segment: Components | **Website**: oxfordyasamotors.com

SECTOR VALUATIONS

Selected Private Placements

Date	Target	Investors	Transaction Value ($m)	Business Description
18-Mar-10	Delaware Power Systems Corporation	Morningside Technologies	4.0	Development and commercialization of integrated battery platform technologies for the EV sector
24-Jan-10	Better Place	HSBC Holdings plc; Morgan Stanley Investment Management Inc.; Lazard Asset Management	350.0	Builds a transportation infrastructure that supports electric vehicles
Jan-15-2010	Fisker Automotive, Inc.	A123 Systems, Inc.; Ace Investments, Inc.; Kleiner, Perkins, Caufield & Byers	115.3	A sports car company, engages in the design, manufacture, and marketing of electric cars
21-Dec-09	Coulomb Technologies, Inc.	Rho Capital Partners, Inc.; Voyager Capital; Siemens Venture Capital; Hartford Ventures	14.0	Manufactures, sells, installs, and services networked charging stations for drivers
14-Sep-09	Tesla Motors, Inc.	Daimler AG; Aabar Investments PJSC; Fjord Capital Partners Limited	82.5	Design, manufacture, and sale of electric vehicles and advanced electric vehicle power train components
09-Sep-09	Oxford Yasa Motors Limited	Seven Spires Investments Ltd.	2.4	Manufactures lightweight electric vehicle components
24-Aug-09	Think Technology AS	Ener1, Inc; Investinor AS; Valmet Automotive Oy	50.0	Engages in the manufacture and sale of electric cars
16-Jun-09	Winstock Ecovia International	Wanderport Corporation	32.5	Intends to manufacture electric vehicles
24-Apr-09	ETV Motors Ltd.	21 Ventures, LLC; The Quercus Trust	12.0	Electric vehicle components to integrate into the turbine-powered range-extended electric vehicles
06-Apr-09	Fisker Automotive, Inc.	Eco-Drive (Capital) Partners LLC; Kleiner, Perkins, Caufield & Byers	85.0	A sports car company, engages in the design, manufacture, and marketing of electric cars
26-Jan-09	Coulomb Technologies, Inc.	estag | Capital AG	3.8	Manufactures, sells, installs, and services networked charging stations for drivers
12-Jan-09	Fallbrook Technologies, Inc.	Robeco Group N.V.; NGEN Partners, LLC	25.4	Develops patented transmission technology to improve the efficiency and performance of mechanical systems
03-Nov-08	Tesla Motors, Inc.	Draper Fisher Jurvetson; VantagePoint Venture Partners	40.0	Design, manufacture, and sale of electric vehicles and advanced electric vehicle power train components
23-Oct-08	Envia Systems Inc.	Bay Partners; Redpoint Ventures	3.2	Offers energy storage solutions using lithium ion batteries
17-Sep-08	PowerGenix, Inc.	Advent International Corporation; Bessemer Venture Partners; Technology Partners; etc	30.0	Develops and manufactures nickel-zinc rechargeable batteries
04-Sep-08	Fisker Automotive, Inc.	Kleiner, Perkins, Caufield & Byers; Palo Alto Investors, LLC; Qatar Investment Authority; etc	68.0	A sports car company, engages in the design, manufacture, and marketing of electric cars
01-Apr-08	Zhejiang Chaowei Power Co., Ltd.	Lehman Brothers, Private Equity Division	30.7	Produces sealed lead acid batteries and plates for battery and battery manufacturing equipment
15-Feb-08	Imara Corporation	Battery Ventures; Nth Power LLC	12.1	Research, design, and manufacture of lithium-ion batteries and packs
14-Jan-08	Fisker Automotive, Inc.	Kleiner, Perkins, Caufield & Byers	68.0	A sports car company, engages in the design, manufacture, and marketing of electric cars
05-Dec-07	International Battery, Inc.	Digital Power Capital LLC	25.0	Design, development, and manufacture of rechargeable cells and batteries
28-Nov-07	Axeon Holdings Plc	Ironshield Capital Management LLP	23.9	Engages in the design, manufacture, and marketing of lithium-ion batteries and charging systems
31-Oct-07	Atraverda Limited	EnerTech Capital; Scottish Equity Partners; WestBridge Fund Managers Limited; etc	21.6	An advanced material company, provides a conductive ceramic
29-Oct-07	Better Place	VantagePoint Venture Partners; Israel Corporation Ltd; Morgan Stanley; etc	200.0	Builds a transportation infrastructure that supports electric vehicles
27-Sep-07	EVO Electric Limited	Imperial Innovations; Consensus Business Group	3.0	Develops electrical motors and generators
29-Jun-07	Leyden Energy Inc.	Sigma Partners; Walden International; Lightspeed Venture Partners	4.5	Develops and manufactures rechargeable lithium-ion batteries
28-May-07	Oy Finnish Electric Vehicles Technologies Ltd.	Finnish Industry Investment Ltd; VNT Management Oy	2.8	Provides solutions for storing electrical energy
11-May-07	Tesla Motors, Inc.	Capricorn Holdings; Compass Technology Partners; Draper Fisher Jurvetson; etc	45.0	Design, manufacture, and sale of electric vehicles and advanced electric vehicle power train components
30-Apr-07	EEStor, Inc.	ZENN Motor Company Inc.	2.5	Designs, develops, and manufactures energy storage devices
05-Feb-07	GreenSaver Technology Corporation	SAIF Partners	20.0	Manufactures silicone power batteries
02-Dec-06	REVA Electric Car Company Private Ltd.	Draper Fisher Jurvetson; Global Environment Fund	20.0	Designs and manufactures electric vehicles

Source: GP Bullhound, Capital IQ

Selected M&A Activity

Date	Target	Buyers	Business Description	Transaction Value ($m)
30-Mar-10	Panasonic EV Energy Co., Ltd.	Toyota Motor Corp.	Manufactures and sells nickel metal-hydride and lithium ion rechargeable batteries and battery management systems	n.a.
19-Mar-10	50% stake in Toda America Inc. and Toda Advanced Materials Inc.	Itochu Corp.	Manufactures and markets cathode materials and their precursors	n.a.
10-Mar-10	SEV Group Limited	Smith Electric Vehicles U.S. Corporation	SEV Group Limited operates as a manufacturer of road-going commercial electric vehicles	55.4
07-Dec-09	Imara Corporation	Battery Ventures; Nth Power LLC	Research, design, and manufacture of lithium-ion batteries and packs	n.a.
28-Oct-09	Sumitomo Metal Industries Ltd., Secondary Battery Material	Chuo Denki Kogyo Co. Ltd.	Manufactures batteries such as lithium-ion and nickel-hydrogen batteries	30.3
27-Oct-09	Lifebatt Production Inc.	Pan-Jit International Inc.	Produces and supplies lithium ion rechargeable battery modules	n.a.
22-Sep-09	Societe de Vehicles Electriques	Dow Kokam LLC	Develops water-cooled lithium-ion batteries	n.a.
24-Aug-09	Plug-In Motors, Inc.	Electric Car Company, Inc.	engages in converting cars and trucks into electric vehicles	4.0
26-Jun-09	Cobasys LLC	SB LiMotive Co. Ltd.	Designs and manufactures energy systems for the transportation market	n.a.
05-May-09	Electric Motors Corporation, Prior To Merger With Optimax	Electric Motors Corporation	Develops and manufactures electric power drive systems for electric and hybrid vehicles	n.a.
07-Jan-09	ePower Synergies, Inc.	Ultimate Sports, Inc.	Engages in designing, developing, integrating, and marketing electric vehicles	n.a.
06-Jan-09	Enertech International, Inc.	Ener1, Inc.	designs, manufactures, sells, and exports lithium ion polymer batteries and rechargeable battery	2.7
15-Dec-08	Li-Tec Battery GmbH	Daimler AG	Develops, produces, and markets lithium ion battery cells for automotive applications	n.a.
06-Nov-08	Palladium Energy, Inc.	Marlin Equity Partners, LLC	Engages in the design, engineering, manufacture, and testing of custom battery pack solutions	14.0
05-Nov-08	Mountain Power, Inc.	Exide Technologies	Research, development, production, and commercialization of rechargeable lithium-ion batteries	n.a.
31-Oct-08	Hyundai Rotem Co., Ltd., Hybrid Electric Vehicle Components	Hyundai Mobis	Manufacture electric motors for the hybrid system	10.4
23-Oct-08	BluWav Systems, LLC	Magna Electronics	Engages in the design, development, production, and supply of electric propulsion and management systems	n.a.
15-Oct-08	Enertech International, Inc.	Ener1, Inc.	Designs, manufactures, sells, and exports lithium ion polymer batteries and rechargeable battery packs	52.2
23-Sep-08	V2Green, Inc.	GridPoint, Inc.	An integrated client-server solution, establishes two-way communication between plug-in hybrid electric vehicles and	n.a.
11-Jul-08	EnerDel, Inc.	Ener1, Inc.	Develops lithium-ion battery solutions for automotive manufacturers	26.7
02-Apr-08	Neosonic Li-polymer Energy Technology Corp.	Everskill International Holding Co., Ltd.	Provides lithium polymer, lithium ion, and nickel hydride batteries	14.6
22-Nov-07	Shanghai Yilaida Electric Vehicle Co., Ltd.	Zhejiang Pujiang Libahuang Bicycle Co., Ltd.	Manufactures and markets electric vehicles	n.a.
05-Nov-07	Engineered Assemblies Corporation	Electrochem Solutions Inc.	Engages in the design and manufacture of battery packs and charging systems	12.4
16-Oct-07	Li-Tec Battery GmbH	Evonik Degussa GmbH	Develops, produces, and markets lithium ion battery cells for automotive applications	n.a.
01-Aug-07	HC Starck GmbH & Co KG, Battery Materials Business	Toda Kogyo Corp.	Manufactures lithium ion and nickel hydride batteries and battery materials and products	n.a.
31-Jul-07	Johnson Controls Inc, European Diagnostics Division	SPX Corporation	Batteries for automobiles and hybrid-electric vehicles and systems engineering	43.8
13-Jul-07	Ristma AG	Axeon Holdings Plc	Manufactures battery packs with Li-ion battery technology	15.0
05-Mar-07	Avestor, Inc.	Bollore SA	Development of lithium polymer batteries for automotive and telecommunication applications	n.a.
30-Mar-06	NEC Lamilion Energy, Ltd.	NEC Corp.; NEC Tokin Corp.	Develops rechargeable lithium-ion batteries	n.a.

Source: GP Bullhound, Capital IQ

Analyst Profiles

GP Bullhound is a research centric investment bank with headquarters in London with offices in San Francisco.

Henry Makansi– Prior to joining GP Bullhound, Henry worked at Warburg Pincus for nine years and headed the European Energy team. He has investment experience spanning venture/growth/late stage private equity in Healthcare, TMT, Business services and Cleantech/Energy. Henry has an MSc Economics (cum laude) from LSE and Erasmus University Rotterdam.

Carl Bergholtz– Prior to joining GP Bullhound, Carl worked as an analyst at Jefferies International covering the TMT and clean technology sectors. While there he worked on a number of M&A and capital markets transactions. Carl graduated from the Stockholm School of Economics with a Masters Degree in International Economics and Business.

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