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A White Paper on a Facet of the Energy Sector

THE RACE FOR THE ELECTRIC CAR:

A Comprehensive Guide To Battery Technologies And Market Development

Alternative Energy

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Executive Summary

Amidst a global economic meltdown, the continued downswing in the fortunes of the auto industry, further anticipated bailout money for the U.S. auto industry contingent on their producing "greener" vehicles, global warming and tighter regulation on emissions, we see a great opportunity arising in the form of next-generation clean transportation enabled by advanced battery technologies hitherto unavailable to the automotive industry. Although the concept of electric vehicles is not new, what is different this time is the availability of reliable batteries that possess excellent energy and power capabilities in a practical form factor. That technology is available, here and now, through companies like A123, Altair Nano, Electrovaya, Ener1, Exide, Johnson Controls and Valence. Ultimately, we see a larger portion of automobiles incorporating increasing degrees of electrification of the drivetrain, as automakers begin to import hybrid drivetrain technologies from their core hybrid vehicle offerings to a broader range of vehicle models.

We believe that advanced energy storage companies offer the best way for investors to participate in the greening upgrade cycle of vehicles; this market could reach $10-15 billion annually in the 2015-2020 time frame. We also see alternative fuel systems and specialized integrators of hybrid/electric drivetrains as an attractive avenue for investors.

Although advanced battery technologies have been around for several years (such as in cell phones and laptops), reliable large-format, mass-produced batteries for electrified vehicle drivetrains have presented challenges in the past. Because these technologies are new, costly and have yet to meet the high standards of the European and North American automotive industry, we would characterize this as a high risk sector; however, we believe the reward can be very high for selective investors who are willing to take this risk and carry a long-term investment horizon.

We expect to see high levels of capital raising activity over the next few years among advanced energy storage companies, particularly in the United States, given the historical absence of a domestic advanced battery supply infrastructure and automakers' aggressive plans to make cars with increasing levels of electrification. We see independent factories as well as battery assembly factories owned by the automakers themselves evolving over time. Given the long-term trends in the sector, we expect continued venture capital interest in the market place.

We are widening our research coverage of the Alternative Energy industry to include clean transportation and energy storage technologies and are initiating coverage of Ener1, Inc. (HEV), Exide Technologies (XIDE) and Maxwell Technologies (MXWL).

A Shift To Cleaner Modes Of Transportation Is Inevitable; The Time Is Now

Amidst a global economic meltdown, the continued downswing in the fortunes of the auto industry, further anticipated bailout money for the U.S. auto industry contingent on their producing "greener" vehicles, global warming and tighter regulation on emissions, we see a great opportunity arising in the form of next-generation clean transportation enabled by advanced battery technologies hitherto unavailable to the automotive industry. **Although the concept of electric vehicles is not new, what is different this time is the availability of reliable batteries that possess excellent energy and power capabilities in a practical form factor.** That technology is available, here and now, through companies like **A123, Altair Nano, Electrovaya, Ener1, Exide, Johnson Controls** and **Valence**. Ultimately, we see a larger portion of automobiles incorporating increasing degrees of electrification of the drivetrain, as automakers begin to import hybrid drivetrain technologies from their core hybrid vehicle offerings to a broader range of vehicle models. We also highlight that switching from gas to electricity as a fuel makes sound strategic sense because electricity can be generated through a variety of sources—coal, oil, gas, solar, nuclear, wind and biomass—versus an overdependence on oil.

This report is broken down into the following sections:

- Industry drivers (page 11)
- Barriers (page 18)
- Market opportunity (page 21)
- Lithium supply and demand situation as it relates to automotive lithium ion batteries (page 25)
- Next generation transportation technologies (page 27)
- Enabling energy storage technologies (page 49)
- An in-depth look at battery manufacturing costs, a subject most manufacturers are reticent to discuss (page 74)
- Analysis of the cost to own and operate a hybrid/electric vehicle versus a conventional vehicle (page 76)
- Examination of shortage concerns of a grid capacity to accommodate the charging needs of millions of plug-in electric vehicles (page 80).

No Silver Bullet Solution; Energy Storage Sector The Best Way To Participate In The Greening Of The Vehicle Fleet

We do not see a silver bullet solution to the greening needs of the global vehicle fleet, rather we see a multi-pronged approach in the form of smaller and lighter vehicles, fuel-efficient engines, natural gas and other lower carbon fuel powered vehicles, as well as the electrification of vehicle drivetrains through hybrid, plug-in hybrid and battery electric vehicles. It is the last prong that we think offers the best way for investors to participate in the greening upgrade cycle of the vehicle fleet, through advanced energy storage technology players that enable the electrification of the vehicle fleet.

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Within energy storage technologies, we believe that today's nickel metal hydride technology will continue to be relevant for hybrid electric vehicles, while lithium ion has a bright future in hybrid, plug-in hybrid and battery electric vehicles. However, we note that some automakers are beginning to shift to lithium ion batteries in vehicle models for which nickel metal hydride batteries would normally suffice, such as the Mercedes S Class 400 Hybrid and BMW 7 Series ActiveHybrid. We see the predominant lead acid battery continuing to power the vast majority of the vehicle fleet, conventional vehicles as well as micro and mild hybrid vehicles. We also envision a bright future for ultracapacitors as a key component in electric drivetrains, whether in conjunction with batteries, or as a stand-alone storage device, as some would hope. **We see the market for advanced automotive energy storage technologies growing to $10-15 billion in annual revenues in the 2015-2020 time frame.**

Automakers Making Their Moves With Regard To Energy Storage Technologies; U.S. Battery Companies Quick To Line Up For Federal Funding To Establish Battery Infrastructure

Major global automakers like **Daimler, Honda, Mitsubishi, Nissan** and **Toyota** are already laying their stakes with respect to advanced battery technology by either investing in battery suppliers or establishing joint ventures to secure captive battery supply for their next generation of electrified vehicles that they plan to roll out in 2010 and beyond. Domestically, **GM** also put to rest speculation about the battery supplier for its Chevy Volt plug-in hybrid, choosing **LG Chem** over **A123**. However, **GM** has chosen a different path from its competitors, viewing battery pack assembly as a core competency to have in-house and sourcing cells from **LG Chem**. Given the nascence of the advanced battery industry, it remains to be seen which business model makes more sense. That said, while we are not questioning GM's business logic in building a fully-owned battery pack assembly plant, political posturing about creating local jobs and developing a local battery infrastructure may have factored into **GM's** decision.

Despite being the largest end market for automobiles, the United States does not have an established advanced battery (nickel metal hydride/lithium ion) infrastructure. Most battery manufacturers are located in Asia, where their governments backed and nurtured a policy decision to invest in battery infrastructure. Shipping costs, tariffs and duties add hundreds of dollars to imported battery pack costs. Given that hybrid, plug-in hybrid and battery electric vehicles feature prominently in the turnaround plans of the Big 3, a domestic battery infrastructure in their backyard makes a lot of sense to them.

In the United States, there is a rush to tap low cost federal funding under the $25 billion Advanced Technology Vehicle Manufacturing Program aimed at retooling car factories to make more fuel-efficient vehicles. Of the 75 applicants to the program, which include the Detroit Big 3, are two prominent lithium ion battery manufacturers, **A123** and **Ener1**, that are seeking a combined $2.3 billion in funding to set up massive domestic facilities for battery packs for electric vehicles.

We expect intense lobbying efforts to create a battery supply infrastructure in the United States. We note the recent formation of a U.S. consortium of 14 companies called the National Alliance for Advanced Transportation Battery Cell Manufacture, which includes battery producers, such as **ActaCell, Johnson Controls, Ener1** and **EnerSys**, and specialty materials providers like **3M** and **FMC**. The consortium intends to solicit as much as $1 billion in federal funds to construct a plant to produce battery cells of various chemistries and sizes for the member companies, which would turn the output into finished batteries adding their own proprietary electronics. The consortium is modeled after Sematech, the group formed by U.S. computer-chip companies in 1987 and funded by the federal government to compete with the Japanese and credited with helping U.S. companies regain their footing by focusing on manufacturing and design advancements.

The Four Legs Of The Electric Vehicle Chair

Although the economic, regulatory and environmental background is favorable for a shift to cleaner modes of transportation, it will still take considerable work and coordination between participating stakeholders to make that possible future a reality.

1. **Automakers** need to create relevant hybrid, plug-in hybrid and battery electric vehicles that consumers will buy.
2. **Battery suppliers** need to partner with automakers to customize an integrated energy storage solution that can meet the highest automotive standards.
3. **Utilities** need to smarten the grid in order to handle an anticipated increase in demand from battery recharging, create Time of Use rates to encourage off-peak/overnight charging, and partner with automakers with whom they will share a common customer. Utilities and their regulators will also need to work with automakers and battery suppliers to develop industry standards as a battery charging infrastructure is built out. In addition, automakers and battery suppliers will need to develop standards for battery charging as well as control protocols and hardware.
4. **Government** plays an important role in funding advanced R&D in partnership with the private sector as well as creating the regulatory framework and parameters to encourage competition, allowing the market to separate winners from losers rather than mandating a certain technology.

Smart Government Intervention And Early Fleet Adopters Key To Overcoming "Chicken Or Egg" Conundrum

We cannot overstate the role the government plays in shaping the future of the vehicle fleet. It will take a combination of a "carrot and stick" approach (i.e., government incentives and tougher regulation on emissions) and the willingness of far-sighted fleet owners to create initial demand visibility and provide incentives for automakers to introduce cleaner vehicles and for advanced battery producers to invest in large scale commercial production.

For example, some studies conclude that automakers can easily meet a 35mpg fleet average fuel economy by 2015 and 40mpg by 2020, whereas current legislation calls for 35mpg by 2020. Acceleration in the mandated fuel economy would spur more production and sales of hybrid and electric vehicles.

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Below is a partial list of government tools available to foster the industry:

1. Federal bridge loans to automakers to help them survive, reorganize and retool;
2. Clean vehicle purchase incentives such as tax credits;
3. Federal and state manufacturing grants for supply chain development;
4. Aggressive regulations on emissions and fuel economy that give long-term visibility;
5. Public and private partnerships to better utilize talent in federal labs to work with the best minds in the industry as well as facilitate stronger partnerships between institutes of learning and industry; and
6. Government fleet programs that can catalyze the market because the U.S. government owns one of the nation's largest vehicle fleets.

As mentioned previously, given the relative newness of electric vehicles and uncertainties about advanced battery life, it would take early adopters in the form of far-sighted vehicle fleet owners to kick start commercial activity. In order to provide incentives to early adopters and insure them against battery risk, some suggest the creation of an **"advanced battery trust fund"** by vehicle makers and their battery suppliers. These early fleet adopters play a very important role as vehicle makers and battery suppliers collect several thousands of miles of usage data from these vehicles that are then used to make improvements in a "Gen 2" offering.

Along these lines, the American Recovery and Reinvestment Plan, or the stimulus bill signed into law by President Obama, contains the following provisions related to clean transportation:

- $2 billion in grants to support U.S. manufacturers of advanced vehicle batteries, hybrid electrical systems, components and software designers;
- $10 million from the $6 billion provided to the Innovative Technology Loan Program directed toward the Advanced Technology Vehicle Manufacturing Program;
- An enhancement to the existing plug-in electric drive tax credit by changing the phase-out trigger for the tax credit from cumulative vehicle sales of 250,000 to 200,000 vehicles per manufacturer;
- A new 30% credit for advanced energy investment, including manufacturing of new qualified plug-in electric drive motor vehicles or components that are designed specifically for use with such vehicles, including electric motors, generators and power control units;
- A temporary increase in the alternative fuel recharging credit;
- $300 million to replace federally-owned older vehicles with higher fuel economy vehicles, including hybrid, plug-in hybrid and electric vehicles;
- $100 million in discretionary grants to public transit agencies for capital investment that will assist in reducing the energy consumption or greenhouse gas emissions of their public transportation systems;
- $400 million to promote near-term deployment of electric drive vehicles and recharging infrastructure; and
- $300 million for the Clean Cities-based Alternative Fueled Vehicles Pilot Program.

We Favor Vertically Integrated Battery Solutions Providers Over Cell Producers

Despite a lot of advancements in the field of electrode materials for advanced batteries over the past few years, competition at the cell level remains intense with a plethora of lithium ion cell producers in Asia, mainly China, Japan and Korea. At the battery pack level (batteries are made from a series of interconnected individual cells), however, there is very little competition in the automotive market with **Toyota's Panasonic EV Energy** dominating the nickel metal hydride market. **Sanyo**, soon to be acquired by **Panasonic**, is a key lithium ion battery producer. In terms of capital, technology and expertise, shifting from being a cell producer to a fully integrated battery solutions provider with a "plug and play" offering is admittedly a big step, but one that potentially separates a company from its competition. Therefore, we would favor integrated battery pack suppliers over cell producers, particularly those with tier 1 supplier and auto OEM relationships whose products have borne out rigorous testing and certification procedures.

Our Take On Lithium Supply – No Shortage Of Lithium Reserves, But Production Will Need To Ramp To Meet Lithium Ion Battery Maker Demand

Lithium ion appears to be the technology of choice for most automakers looking to roll out plug-in hybrid and all electric vehicles; and recently, a lot of concerns have been raised about a potential shortage of lithium. We have looked at global production capacity of lithium carbonate (a raw material used in lithium ion batteries) and the production process as well as performed a detailed analysis of the lithium content in automotive lithium ion batteries. Our analysis (see page 25) suggests that there is no impending shortage of lithium reserves in the world; however, it is apparent that with the lithium carbonate industry running at capacity utilization in excess of 90% in 2008, capacity expansion will be needed to meet demand from automotive lithium ion battery makers. So, in the long term we do not see supply issues, however, we believe capacity expansion projects will need to be undertaken sooner rather than later to avoid any potential hiccups. We also point out that lithium carbonate accounts for only 4-6% of the bill of materials in a lithium ion battery; thus, we do not see pricing of lithium carbonate inordinately impacting battery maker economics.

Payback On Hybrid/Electric Vehicles Versus Conventional Vehicles Driven More By Government Incentives And Battery Prices Than Gasoline Prices

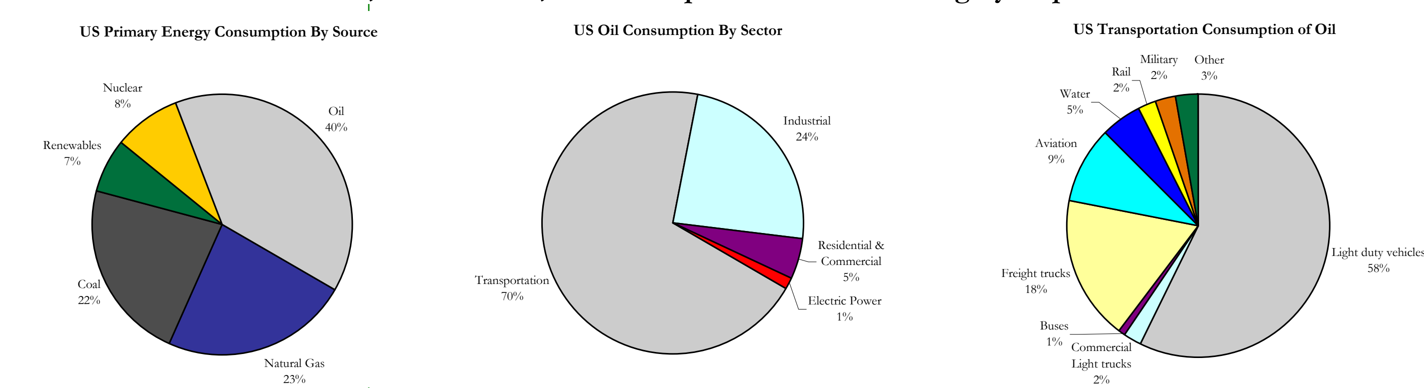
Our payback, cost of fuel and total cost of ownership analysis on page 76 suggest that government incentives and battery pricing are the two largest variables that drive payback periods of hybrid/electric vehicles versus conventional vehicles. One-time incentives such as the federal tax credit can reduce the payback period in years from double digits to single digits, while advanced batteries will need volume production-based pricing for next generation hybrid/electric vehicles to make economic sense. We also note that these vehicles could make more economic sense than conventional vehicles even with gasoline pricing as low as $2 per gallon, based on our simplifying assumptions.

INDUSTRY DRIVERS

1. Oil Dependence And Price Volatility

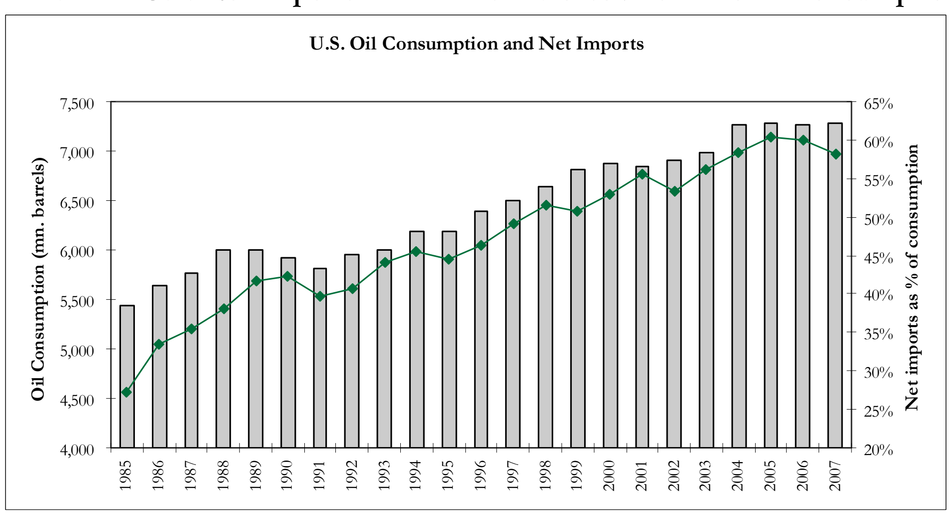
The transportation sector accounted for about 70% of U.S. oil needs in 2007. Over the past two decades, net imports of oil have seen an unhealthy upward trend from 27% of total consumption in 1985 to almost 60% currently. With personal automobiles, light trucks and buses accounting for 60% of the transportation sector's demand for oil, there is an increasing focus on increasing fuel economy through more efficient vehicle design and electrification of vehicle drivetrains as well as alternative fuels such as natural gas of which there is plenty of domestic availability and lower carbon fuels. In addition, oil price volatility, long-term trends in pricing and geopolitical tensions call for alternatives to wean the nation of its thirst for oil. Hybrid electric vehicles can improve fuel economy anywhere from 5% to 50%.

Exhibit 1 – The United States, In Particular, The Transportation Sector Is Highly Dependent On Oil



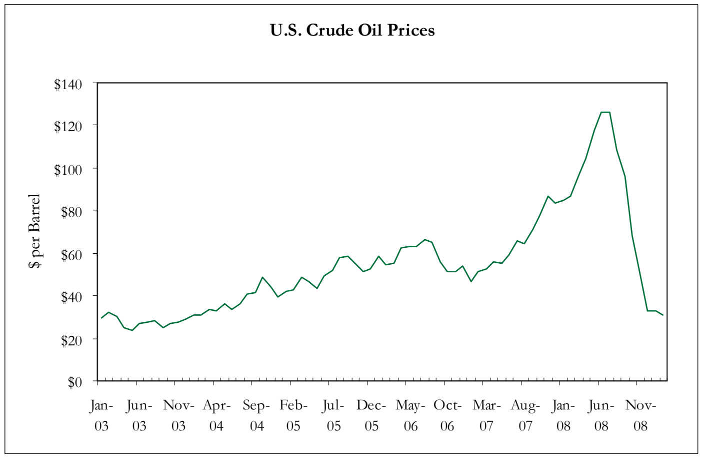
Source: EIA Annual Energy Review 2007

Exhibit 2 – U.S. Net Imports Of Oil Has Increased As Share Of Consumption



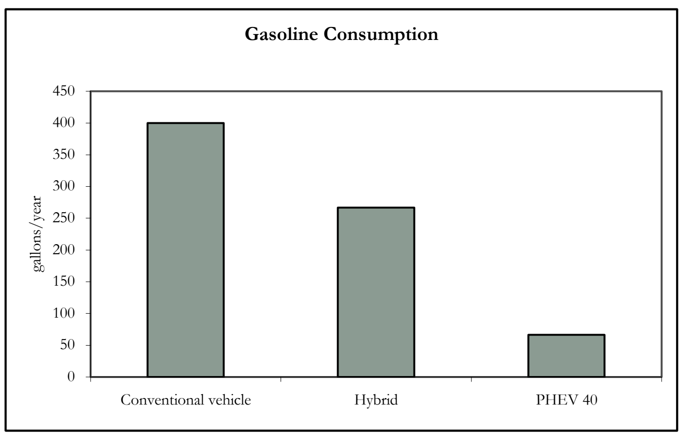
Source: EIA Annual Energy Review 2007

Exhibit 3 – Though Oil Pricing Has Taken A Hit Driven By A Global Recession, Long-Term Trends For Prices Remain Upward Biased



Source: Illinois Oil and Gas Association

Exhibit 4 – Gasoline Consumption Of Hybrid Vehicles Compared With Conventional Vehicles



Assumptions
12,000 miles traveled per year
Fuel economy of conventional vehicle 30mpg
Fuel economy of hybrid vehicle 45mpg
Plug-in hybrid with 40 mile electric range, 9,000 miles per year in electric mode

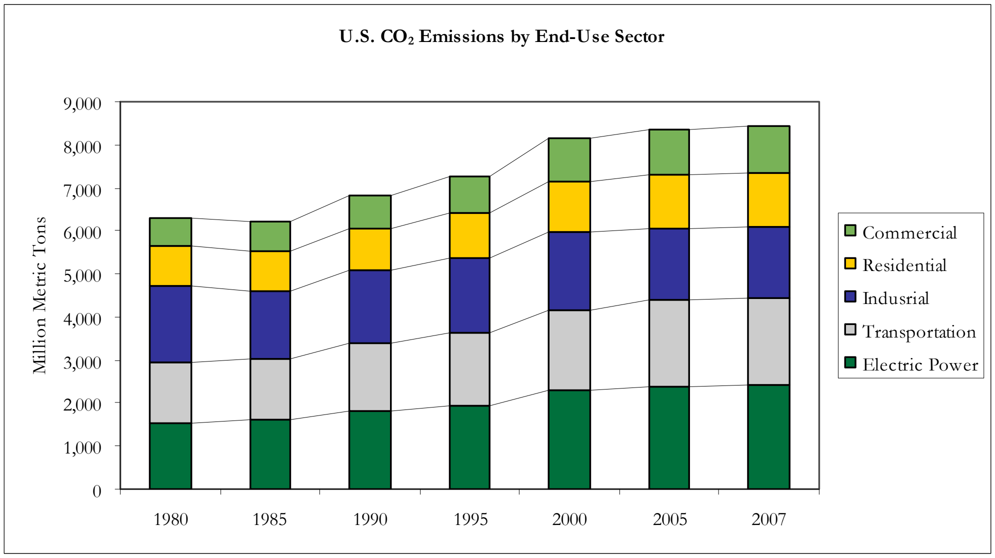
Source: Thomas Weisel Partners LLC

2. Environmental And Health Concerns

The correlation between climate change and greenhouse gas emissions is no longer doubted, and the transportation sector alone accounted for 28% of U.S. greenhouse gas (GHG) emissions in 2007 and 24% of U.S. carbon dioxide emissions. In addition, between 2000 and 2007, transportation has grown the fastest of all end-use sectors in terms of carbon dioxide emissions (7.6% versus.3.3% overall).

As society has become more dependent on carbon-based fuels, there has been a rapid increase in the atmospheric concentration of CO_2 from around 280 parts per million (ppm) prior to the Industrial Revolution to 370 ppm today. If current trends of fossil fuel continue, we could see up to 700 ppm of $C0_2$ levels by the end of this century, which could lead to global warming of 1.4°C-5.8°C, according to the Intergovernmental Panel on Climate Change (IPCC). Also, emissions can lead to acid rain, ozone layer depletion, as well as diseases such as skin cancer and respiratory ailments.

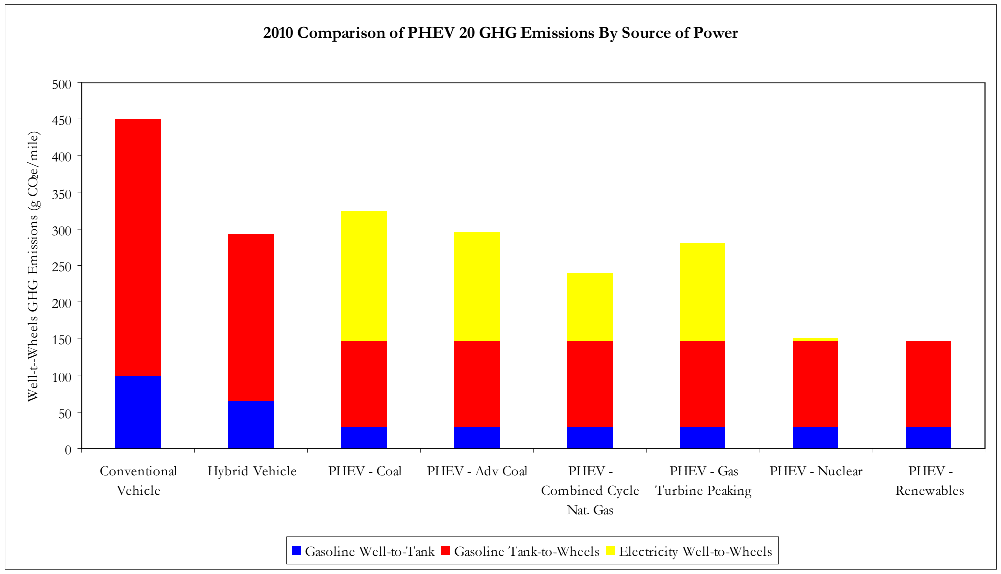
Exhibit 5 – Transportation Accounts For 24% Of U.S. Carbon Dioxide Emissions And Has Grown Fastest Of All End-Use Sectors



Source: EIA

Some argue that hybrid electric vehicles that use grid power as fuel rather than gasoline simply shift the source of emissions from the tailpipe to smoke-belching coal plants and natural gas plants. However, this argument does not consider the full picture. To compare tailpipe emissions from a conventional vehicle with emissions associated with power plants that generate power to recharge a hybrid electric vehicle's batteries, a full "well-to-wheels" emissions analysis must be conducted. For the conventional vehicle, this analysis takes into account the fuel extraction process, refining and transportation as well as the conversion of the energy content in gasoline by a highly inefficient internal combustion engine to deliver power to the wheels. For electric vehicles, this analysis would need to include extraction of the fuel (e.g., coal, natural gas, etc.), conversion into electricity, transmission line losses, storage efficiency of the battery in the vehicle, and conversion efficiency of power delivered to the wheels. As is evident in Exhibit 6 from an analysis conducted by the Electric Power Research Institute (EPRI), hybrid vehicles have significant potential to reduce well-to-wheel greenhouse gas emissions.

Exhibit 6 – GHG Emissions, Hybrid And Plug-In Hybrid Vehicles Compared To Conventional Vehicles



Source: EPRI

3. Regulations That Clamp Down On Emissions And Traffic Congestion

Government regulation plays a very important role in the mass adoption of next generation vehicles.

United States

In the United States, the Corporate Average Fuel Economy (CAFÉ) standards that were first introduced in 1975 were revised as part of a new bill in December 2007 after languishing since 1985. The new CAFÉ standards call for an average of 35mpg for passenger cars and light pickup trucks combined by 2020, a 40% increase to be achieved in annual increases of about 4%. OEMs are assessed a fine of $5.50 per 0.1mpg their fleet is under the target, multiplied by the number of vehicles produced in the model year. In addition, California is leading an alliance of 18 other states in an attempt to set higher fuel economy standards that the state has enjoyed under the federal Clean Air Act. While the Environmental Protection Agency (EPA) has refused to grant California the necessary waiver to set new fuel economy standards since 2002, we believe that under the new administration things could change quickly. Note that some of the strictest emissions standards in the world today are set by the California Air Resources Board (CARB).

Europe

In December 2007, the European Commission adopted a proposal that the average CO_2 emission limits for new cars become mandatory at 130g of CO_2 per km (equivalent to about 45.5mpg for gasoline) by 2012. For light vans the proposed target will be 175g/km by 2012 and 160g/km by 2015. The current average for gasoline light passenger vehicles in Europe is around 160g/km or 34.1mpg.

Japan

Japanese OEMs have exceeded the fuel economy targets set for them to date, but the Japanese government introduced new regulations in 2007 that require them to improve the average fuel efficiency of their vehicles to 40mpg from around 32mpg in 2004.

Several other countries including Australia, Canada, China, Taiwan and South Korea have set fuel economy or CO_2 emission targets. Several countries also charge annual registration fees based on CO_2 emissions. European cities such as London and Stockholm also charge congestion fees based on CO_2 emissions aimed at reducing traffic and pollution.

4. Incentives

In the United States, incentives from federal, state and city governments have played an important role in accelerating sales of hybrid vehicles, making it the largest market in the world with a 60% share. For example, purchasers of hybrid electric vehicles have been eligible for federal tax rebates as high as $5,000 per vehicle, although the rebates phase out once the OEM has sold 60,000 hybrids in the United States. Several states also offer incentives, and many cities offer the use of high-occupancy lanes with only the driver on board as well as free or discounted parking and toll. As part of the financial bailout bill that was passed into law in 2008, plug-in hybrid and electric vehicles won a federal tax credit. For vehicles less than 10,000lbs and with batteries storing at least 4kWh of energy, the tax credit is a base of $2,500 and $417 per kWh in excess of 4kWh, capped at $7,500. The stimulus bill passed in 2009 builds on the existing plug-in electric drive tax credit, by changing the phase-out trigger for the tax credit from cumulative vehicle sales of 250,000 to 200,000 vehicles per manufacturer.

Incoming President Obama's campaign promise of putting one million plug-in electric vehicles with a fuel economy better than 150mpg by 2015, a $7,000 tax credit for the purchase of advanced technology vehicles and 50% of all cars purchased by the federal government to be plug-in hybrids or all-electric by 2012 has also received a lot of attention.

Elsewhere in Europe, France has announced an incentive of 5,000 francs to purchasers of vehicles that emit less than 60g/km of CO_2. Portugal wants 20% of its public vehicle fleets to consist of zero emission cars starting in 2011 and plans to offer income tax credit, write-offs and parking credits to consumers and businesses to encourage electric transportation. Germany also is said to be pushing for one million electric and hybrid cars by 2020. The Chinese government too has stepped into the game, announcing maximum subsidies of RMB 50,000 for hybrid passenger vehicles, RMB 60,000 for all electric vehicles and RMB 250,000 for fuel cell electric vehicles, with subsidies for alternative fuel buses ranging from RMB 420,000 to RMB 600,000 for a fuel cell bus. We note, however, timing and size of the program are yet to be announced.

5. Natural Gas A Cleaner And Cheaper Alternative

Natural gas is a much cleaner burning fuel than gasoline or diesel. For example, the U.S. EPA calculated that using compressed natural gas (CNG) versus gasoline in light duty vehicles can reduce CO emissions by 90-97%, CO_2 emissions by 25% and NOx emissions by 35-60%, while emitting little or no particulate matter and fewer toxic and carcinogenic materials. Also, even allowing for the lower energy content of CNG versus gasoline and diesel, CNG is a cheaper fuel.

Exhibit 7 – October 2008 Overall Average Fuel Prices On Energy-Equivalent Basis

	Nationwide Avg. Price in Gasoline Gallon Eqvt.	Nationwide Avg. Price in Diesel Gallon Eqvt.	Nationwide Avg. Price in Dollars per Million Btu
Gasoline	$3.04	$3.39	$26.33
Diesel	$3.27	$3.65	$28.38
CNG	***$2.01***	***$2.24***	***$17.37***
Ethanol (E85)	$3.99	$4.44	$34.53
Propane	$4.67	$5.21	$40.46
Biodiesel (B20)	$3.69	$4.11	$31.94
Biodiesel (B2-B5)	$3.45	$3.85	$29.89
Biodiesel (B99-B100)	$4.58	$5.10	$39.66

Source: U.S. Department of Energy Clean Cities Alternative Fuel Price Report October 2008 issue

Although natural gas accounts for only 2% of the transportation sector's fuel consumption versus gasoline, which accounts for 96%, it is beginning to feature more prominently as an alternative fuel while being the nation's second largest energy source and domestically abundant, with reserves twice that of petroleum.

6. Technology Advances In Batteries

In the early 1900s, electric propulsion and engine propulsion competed for dominance in automobiles. At that time, however, the energy constraints of batteries restricted vehicle range, allowing gasoline powered engine technology to take over. The problem for batteries was the size and weight required to provide vehicles with a decent range and acceleration. For example, in order to completely replace a gasoline tank and engine, it would have taken a lead acid battery pack weighing as much as 1,800-2,000 lbs.

Advancements in battery technology have now made electric propulsion of vehicles feasible. The ubiquitous lead acid battery technology is still undergoing various tweaks. As a result, it is not only used in conventional vehicles to provide starting, lighting and ignition, but also in today's mild and micro hybrid cars, thanks to much improved energy and power density. Technologies such as nickel metal hydride, which is being used in today's full hybrid electric cars, can store as much as twice the energy of a standard lead acid battery, meaning the battery needs to weigh only half as much for a given amount of energy. Lithium ion, commonly used for consumer electronics, is the technology of tomorrow. It has 1.5-2x the energy density of nickel metal hydride and can feasibly provide vehicles with driving ranges in excess of 100 miles. Most automakers are partnering with battery manufacturers to include this technology in their next-generation of plug-in hybrid and battery electric vehicles.

7. Success Of Hybrid Versions Of Ford, Honda And Toyota Vehicles Prove The Viability Of Cleaner Cars And Boosted Consumer Interest

The success of the Toyota Prius (over 1 million sold worldwide), and to a lesser extent the hybrid versions of the popular Toyota Camry and Highlander, Honda Civic and Ford Escape, proves that there is a market for well made hybrid electric vehicles that provide fuel economy and/or performance advantages for a modest premium to conventional models. These cars have helped to clear doubts in consumers' minds about "unconventional" electric drives. While we acknowledge that interest in hybrid vehicles has waned over the past few months as gasoline prices dropped sharply, we would argue that high gasoline prices are but one of several reasons to buy a hybrid vehicle, and more importantly, we expect gasoline prices to climb rapidly as the world emerges from a recession.

8. Federal Bailout Of Big 3 Calls For Hybridization Of Power Train As Key Requirement

It appears that any government bailout of the Big 3 Detroit automakers will likely require some sort of commitment and road map that details their plans for a turnaround involving fuel-saving and electric vehicle technologies. Because the Big 3 account for about a quarter of global automobile production, we see a bright future for next generation vehicles and their enabling energy storage technologies. For example, **Ford Motor Company** unveiled an aggressive plan to electrify its fleet of vehicles, including plans to offer an all-electric van-type vehicle in 2010 for use in commercial fleets, complemented by a battery-powered sedan in 2011. By 2012, the company will bring a family of hybrids, plug-in hybrids and battery electric vehicles to market. In 2010, **GM** plans to launch its extended range plug-in hybrid electric vehicle, the Chevy Volt. By 2012, it also plans to introduce 15 hybrid models that will employ the Volt power train. **Chrysler** plans to introduce the Dodge Ram Hybrid as well as the company's first electric drive vehicle in 2010, followed by three additional electric drive models by 2013. Other large automakers such as **BMW, Honda, Hyundai, Mitsubishi, Nissan, Toyota** and **Volvo** also have aggressive plans to roll out new plug-in hybrids as well as electric vehicles.

9. $25 Billion "Green Retooling" Fund Over And Above Auto Bailout Provides Further Stimulus

Over and above any federal bailout, the U.S. Department of Energy is charged with administering the Advanced Technology Vehicles Manufacturing Loan Program (ATVM), also known as the "green retooling" fund. The loans under this program are intended to help pay up to 80% of project costs for modernizing factories to build more fuel-efficient vehicles and give priority to plants that are 20 years or older. $2.5 billion is also set aside for companies with 500 employees or less. Automakers, as well as makers of components such as batteries and electric drivetrains, may apply for the loans. While financing terms and conditions are based on final approval and negotiations, interest rates on the loans could be as low as 4%. Vehicles built must be at least 25% more fuel efficient than required by law. The DOE reported 75 applications were received. Other than the usual suspects like Ford and GM, lithium ion battery producers Ener1 and A123 have also applied for substantial funding under the program, as have electric sports car maker Tesla and drivetrain developer AFS Trinity, both driven by the opportunity for low-cost, non-dilutive financing in very challenging capital market conditions.

SEVERAL HURDLES TO BROAD ACCEPTANCE OF NEXT GENERATION VEHICLES

1. Electric Charging Infrastructure And Standardization

As discussed previously, the absence of a comprehensive grid-aware charging infrastructure could likely be an obstacle to mass market acceptance of next generation electric transportation. While there is sufficient generation, transmission and distribution capacity to charge electric vehicles during off-peak periods, it will take significant investment and public-private partnerships between governments, utilities and private enterprises to build a broad and smart charging infrastructure, which would be needed to electrify a significant portion of the vehicle fleet. We are seeing significant global efforts to tackle these issues being undertaken by governments, utilities, automakers such as **Nissan-Renault, Toyota, Daimler, Subaru** and **Hero Electric**, as well as charging infrastructure companies such as **Project Better Place** and **Coulomb Technologies**. We also highlight that the auto industry will need to collaborate with the utility industry in developing standards, regulations and rates that govern the flow of electricity to and from electric vehicles. A broad infrastructure will also require some sort of standardized recharging hardware, software and connectors to handle the plethora of vehicle models and battery vendors.

2. Prices Of Advanced Batteries

Until now, the dominant battery technology powering today's hybrid electric vehicles has been the nickel metal hydride battery, which meets the high power requirements. Significantly more energy is needed to extend range, however, which increases costs appreciably. For example, a 1.2kWh nickel metal hydride battery for the Toyota Prius can be replaced at a cost of about $2,500. However, advanced lithium ion batteries that have the energy density to handle 100 mile-plus driving ranges are priced as high as $20,000-25,000, accounting for more than 50% of total cost for the next generation of electric vehicles. Battery pricing remains high, primarily because of low production volumes, which exist because consumers, deterred by high battery costs, remain reluctant to adopt new transportation technologies. This "chicken or egg" situation will continue to hinder the industry until automakers place volume orders with battery producers to bring costs down.

3. Battery Life Concerns

While advanced lithium ion batteries for plug-in hybrid and battery electric vehicles have undergone plenty of tests to verify cycle life, calendar life and miles, there is still very little on-the-road experience to provide reasonable certainty about the performance and durability of batteries. This uncertainty combined with the high initial cost of batteries could dampen initial enthusiasm.

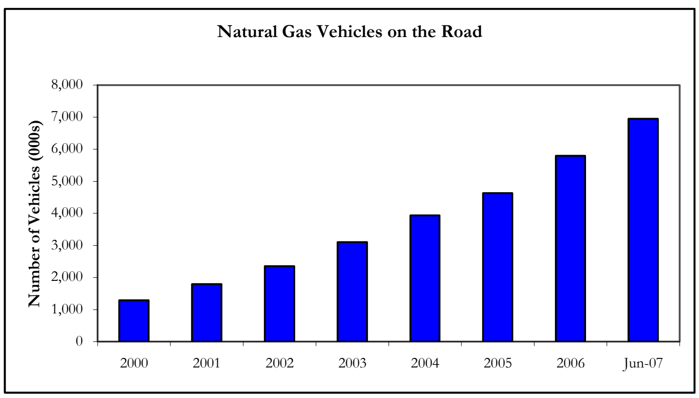
4. Vehicle Range Concerns

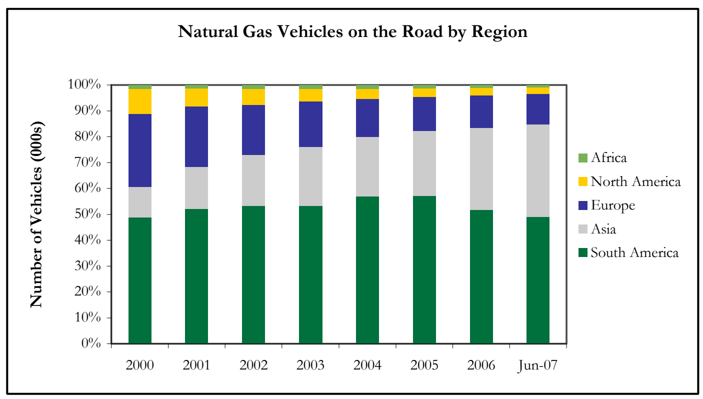
The limited electric-only range of plug-in hybrid and battery electric vehicles remains an issue for some consumers, particularly in the case of battery electric vehicles that do not have a range-extending internal combustion engine and can take a long time to recharge. However, we also note that the vast majority of Americans and Europeans have short daily commuting distances (e.g., most Europeans travel only about 30 miles per day, while 78% of Americans travel less than 40 miles per day), which should be adequately addressed by lithium ion battery powered vehicles with at least 40 miles of electric range.

5. Natural Gas Refueling Infrastructure

The lack of a natural gas refueling infrastructure has been the main hindrance to the adoption of natural gas vehicles (NGVs) in the United States. We believe that the United States accounts for only about 160,000 of the global fleet of 7 million NGVs on the road, compared with over 200 million gasoline powered vehicles on U.S. roads. The United States also has only 1,340 natural gas refueling stations, versus over 200,000 gasoline fueling stations. Additionally, low production volumes mean higher price tags on NGVs. As a result, natural gas has primarily made inroads into fleet vehicles that refuel at a central location, such as transit buses, short-haul delivery vehicles, taxis, government cars and light trucks.

Exhibit 8 – Natural Gas Vehicle Markets Driven Primarily By South America And Asia





Source: International Association for Natural Gas Vehicles

6. Unfamiliarity And Need For Specially Trained Mechanics

As plug-in hybrid and battery electric vehicles begin to be featured more prominently in the vehicle fleet, we believe car mechanics will need to upgrade their skills in order to meet the servicing and maintenance needs of hybrid and electric drives. Also, even though brake maintenance upkeep should reduce with regenerative braking, spare parts could be more expensive initially.

WE THINK INITIAL VOLUMES OF PHEVS AND BEVS WILL BE DRIVEN BY FLEET PURCHASES

Today's nickel metal hydride batteries, which are used in the Toyota Prius, come with either an eight year/100,000 mile warranty or a 10 year/150,000 mile warranty in California compliant states. As the first generation Toyota Prius batteries approach the end of their warranty period, preliminary data suggests they are running well even after completing 100,000 miles. Moreover, these batteries can be replaced at a cost of $2,000-2,500, which though not cheap, is not unaffordable either.

In the case of next generation lithium ion batteries that will power plug-in hybrid and battery electric vehicles, however, the technology is new. Also, even though prototype batteries have undergone lots of testing, there is a relative dearth of real world data. The high cost and relative uncertainty about lithium ion batteries raise questions about battery warranty terms: what is an appropriate level of warranty reserves and who will foot what portion of the bill for warranty expenses? As a result, battery suppliers may experience initial hesitation from automakers, dealers and buyers on their "Gen 1" offering. We believe that battery warranty issues, which could have automakers pushing for more favorable warranty terms and longer coverage periods from the battery suppliers, will need to be sorted out between the two parties.

Therefore, we believe that as plug-in hybrid and battery electric vehicles gradually become available in the mass market, fleet owners such as federal and state governments, utilities, logistics service providers, airports and transit vehicle operators will drive initial sales volumes. As confidence in the durability and performance of the new vehicle technologies and batteries rises, we expect to see increased sales to fleet operators as well as broader market acceptance among consumers. **We believe the federal government could be one of the early adopters of plug-in hybrids, considering President Obama's campaign promises to: (1) convert the entire White House fleet to plug-ins in his first year as President; and (2) have half of all cars purchased by the federal government be plug-in hybrids or all-electric by 2012.**

A Potential Alternative To Owning Battery – Lease Battery; Buy Just The Car

One way to avoid the cost (as high as $15,000-25,000) and risk of a relatively new technology could be to lease the battery and own just the car. This strategy was adopted by Norwegian electric car maker, Think Global: a Think City car sells for $15,000-17,000, we believe, while the battery is leased for $100-200 per month. Under the terms of the lease, all battery maintenance and replacement are covered. It remains to be seen if this strategy will become prominent as plug-in hybrid and battery electric vehicles hit the market in 2010 and beyond.

$10-15 BILLION MARKET FOR ADVANCED AUTOMOTIVE BATTERIES BY 2015-2020

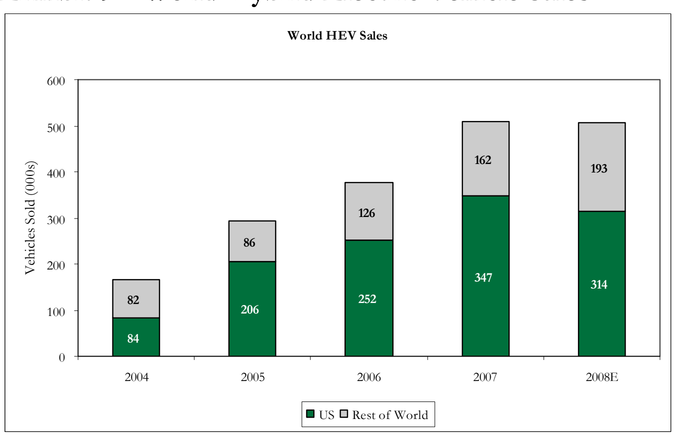
To date, the United States has been by far the largest end market for hybrid vehicles, accounting for about 60% of the 520,000 vehicles sold worldwide in 2008. We believe that Asia-Pacific comes next, generally accounting for about 30% of global hybrid sales, while Europe accounts for most of the remaining 10%.

The main reason that Europe lags in terms of hybrid vehicle sales is the popularity of high fuel economy clean diesel vehicles. We believe that this could change rapidly with the European Commission's decision to adopt a proposal mandating the average CO_2 emission limits for new cars at 130g of CO_2 per km by 2012 (equivalent to about 45.5mpg for gasoline, versus today's equivalent average of about 34mpg). This presents a meaningful opportunity for micro and mild hybrids powered by lead acid batteries with engine start/stop capability and regenerative braking, as well as for plug-in hybrid and battery electric vehicles.

Though global hybrid vehicle sales as a percentage of total light duty vehicle sales still flounders at about 1%, we believe this could change with the introduction of plug-in hybrid and battery electric vehicles with significant battery-powered range.

Several auto industry analysts predict that hybrid/electric vehicle sales could reach as much as 10-20% of total vehicle sales in the 2015-2020 time frame. Assuming hybrid/electric vehicle sales reach 10% of total vehicle sales, we estimate the market for advanced battery technologies for automotive applications will grow to $10-15 billion in the 2015-2020 time frame. By comparison, we believe the automotive lead acid battery market is currently about $7-10 billion.

Exhibit 9 – World Hybrid Electric Vehicle Sales



Source: Green Car Congress and Thomas Weisel Partners LLC estimates

We have not included the market potential for batteries in electric two-wheelers, which could be a substantial opportunity, especially in China and India, as it is outside the scope of this report. However, we believe that the market for electric two-wheelers (about 15 million sold in 2007) is ultra-competitive, with several hundreds of lead acid, nickel metal hydride and lithium ion battery producers offering smaller, more commoditized products with less stringent requirements than those of automobiles and larger vehicles.

COMMERCIAL VEHICLE MARKETS – ANOTHER UNTAPPED MARKET, ALTHOUGH FLEET OWNERS INCREASINGLY LOOKING AT WAYS TO REDUCE CARBON FOOTPRINT AND COMPLY WITH EMISSIONS REGULATIONS

Although not as big as the consumer vehicle market, the commercial vehicle market is an important end market for hybrid electric, hybrid hydraulic and natural gas vehicles. Commercial vehicles in an urban environment account for only 12% of total miles driven, but contribute 25% of total GHG emissions. Purchasing decisions are made by vehicle OEMs or fleet owners. Sales cycles involving fleet owners can be extremely long, often at 12 months or more. The process usually involves a fleet owner developing vehicle specifications and suppliers delivering prototype vehicles for testing, all before the fleet owner finally puts out an RFP to evaluate a multitude of offers. The fleet owner then selects the winning bidder and negotiates a contract with the OEM, who in turn then enters into a contract with the hybrid system developer.

More often than consumers, fleet owners also tend to base their purchase decisions more on economic rationale, meaning fuel and maintenance upkeep savings need to provide a reasonably quick payback on the premium. As a result, the commercial world of hybrid drives, with costs and benefits varying by technology used, is more complex than the consumer market.

The short driving distances and frequent stop-and-go duty cycles of commercial vehicles make them excellent candidates for incorporating cleaner modes of propulsion, which can increase fuel economy by 30-40%, reduce harmful emission by up to 30% and reduce maintenance costs by up to 30%. With heavy-duty diesel vehicles offering extremely poor fuel economies of 3-5mpg, a 30-40% improvement can result in significant fuel consumption savings.

The revenue opportunity per vehicle to hybrid drive system integrators in this market can range from $30,000 to $200,000, depending on the vehicle size, technology, degree of hybridization and configuration. Some of the most attractive segments in this market are:

- **Transit buses:** There are approximately 2,000 municipal and local transit agencies in the United States and Canada. These agencies have over 80,000 registered buses in service and take delivery of over 6,000 new vehicles a year. According to the Federal Transit Authority (FTA), at least 50 U.S. transit agencies have begun buying hybrid buses. **ISE**, a developer and integrator of hybrid electric drive systems for heavy-duty vehicles, estimates that at least 25% of the buses purchased in North America over the next four years are likely to include hybrid systems. **BAE Systems** and **Allison Transmission** are poised to participate in this marketplace.
- **Short haul medium-duty and heavy-duty commercial vehicles:** This category includes package delivery vehicles, airport vehicles, and shuttle vans and buses, among others. According to **ISE**, the annual opportunity within heavy-duty is 50,000 new vehicles and includes some of the heaviest and most polluting diesel trucks. Therefore, this segment stands to benefit significantly from hybrid technology. **Azure Dynamics**, which specializes in hybrid and electric drivetrains for medium-duty and heavy-duty vehicle, estimates its market opportunity at 50,000 units per year. Delivery companies such as **FedEx, UPS** and **Purolator** have already begun to convert some of their smaller package delivery vans to run on hybrid systems.
- **School buses:** With about 65,000 school buses sold each year, the U.S. school bus market is substantially larger than the U.S. transit bus market.

In addition to lower emissions, lower maintenance costs and better fuel economy, hybrid and alternative fuel deployments are being driven by some factors that are unique to the commercial vehicles market, including:

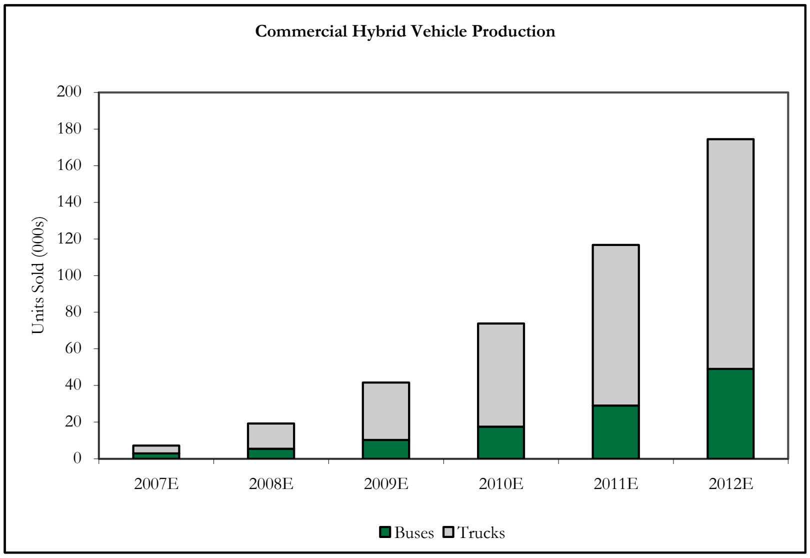
Federal and state subsidy programs: About half of the transit bus purchases in the United States are made by municipal and local transit agencies with federal matching funds administered by the FTA under the Transportation Equity Act (TEA). Under the August 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act – A Legacy for Users (SAFETEA-LU), $52.6 billion in funding was approved. Transit agencies can use the federal funds to cover up to 80% of the sales price of standard diesel buses, plus up to 90% of the incremental cost of alternative fuel buses. As a result, federal funds can cover approximately 83% of the total sales price of a hybrid transit bus, which can reduce the payback time on the premium from 8-9 years to 2-3 years. Additionally, states such as California, New York and Texas have programs to help heavy-duty vehicle fleet operators finance the purchase of alternative fuel vehicles. For example, the California Air Resources Board (CARB) administers the Carl Moyer Program, which offers grants up to $35,000 per vehicle in proportion to NOx emission reduction.

Tax incentives: A federal income tax credit is available to purchasers of qualifying medium-duty and heavy-duty hybrid vehicles over 8,500lbs that have an at least 30% improvement in city fuel economy. The tax credit is a percentage of the incremental cost of the hybrid vehicle, and ranges between 20% and 40%, depending on the improvement in fuel economy. The credit, which is set to expire in December 2009, is capped at $7,500 for vehicles under 14,000lbs; $15,000 for vehicles between 14,000lbs and 26,000lbs; and $30,000 for vehicles over 26,000lbs. For NGVs, the caps on tax credits range from $4,000 to $32,000.

Emissions regulation: In addition to tougher EPA and CARB emissions regulations that make it increasingly expensive to purchase and operate heavy-duty diesel vehicles, the Clean Air Action Plan, prepared by the heavily polluted ports of Los Angeles and Long Beach, is driving a lot of action in the heavy-duty diesel space. The program, implemented in the spring of 2007, aims to replace or retrofit 16,800 container movement trucks operating at the ports within a five year period. The ports will ban older, more polluting trucks from carrying cargo containers and may provide grants to assist truck operators in adopting cleaner technologies such as hybrid propulsion and natural gas. Under the program, at least 50% of the trucks are expected to run on alternative fuels such as liquefied natural gas (LNG) and compressed natural gas (CNG).

Canada-based **Westport Innovations**, a provider of natural gas engine systems to medium-duty and heavy-duty vehicle markets, is benefiting significantly from the ports' decision to go with CNG/LNG for at least 50% of the eligible fleet because its 15 liter Westport ISX G and 8.9 liter CWI ISL G engines are the only ones approved under the program. The company has a worldwide installed base of over 17,000 natural gas fueled engines in 19 countries and offers the only heavy-duty natural gas system with diesel equivalent performance. We believe several other ports, such as New York, New Jersey, Oakland and Seattle, are planning on embarking on similar projects, which should provide plenty of visibility to the company. **Westport Innovations** also has a 50/50 joint venture with diesel engine manufacturer **Cummins**. Called **Cummins Westport**, the joint venture targets the medium-duty vehicle market. The company also has non-port customers such as Wal-Mart and the San Diego Metropolitan Transit System.

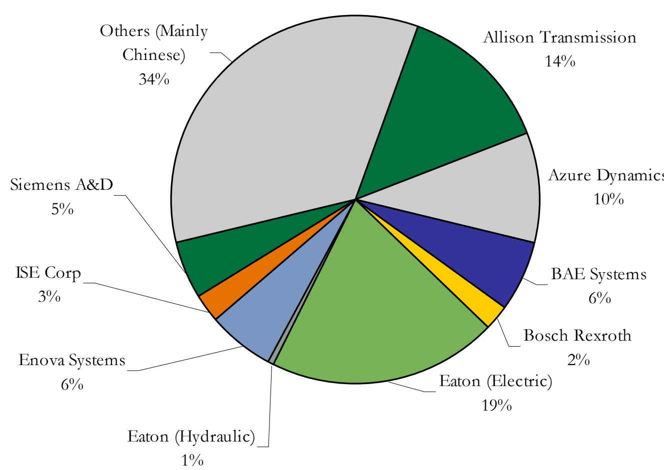
Exhibit 10 – Commercial Hybrid Vehicle Production



By region	2007E	2008E	2009E	2010E	2011E	2012E
North America	40%	25%	20%	19%	20%	22%
Europe	9%	9%	10%	11%	14%	16%
Asia-Pacific	47%	61%	65%	64%	61%	57%
ROW	4%	5%	5%	5%	5%	5%

Source: ABI Research

Exhibit 11 – 2007 North America Hybrid Power Train Business Share By Supplier



Source: ABI Research

Lithium Supply For Automotive Batteries Of Tomorrow – No Shortage Of Lithium Reserves, However, Lithium Carbonate Production Needs To Ramp In Order To Satisfy Demand From Vehicle Manufacturers

With lithium ion widely regarded by consensus as the technology for the next generation of electrified drivetrains, a lot of press in recent months has been devoted to a potential shortfall in lithium supply spurred by a spike in automobile demand for lithium ion batteries. Following is a brief overview of this issue.

First, some basics: Lithium does not need to be produced in metallic form for use in lithium ion batteries. Rather, the required raw material for batteries is lithium carbonate. The primary mineral sources of lithium containing compounds are:

- Brine lakes and salt pans, which produce lithium chloride
- A hard mineral called spodumene, which is a silicate of aluminum and lithium

Today, most of the lithium minerals procured from mining spodumene are used directly as ore concentrates in ceramics and glass applications, rather than as feedstock for lithium carbonate and other lithium compounds. The main producers of lithium minerals are Chile, Australia, Argentina, China, Russia and the United States.

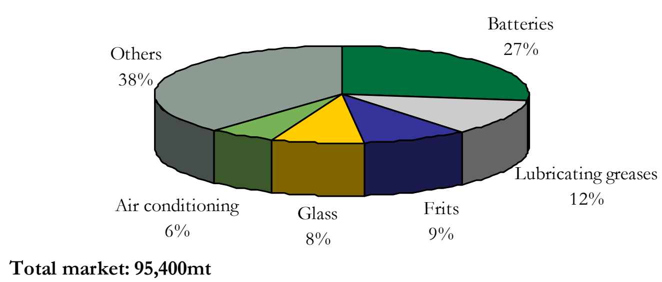
Exhibit 12 – World's Largest Lithium Carbonate Producers

	Location	Annual Capacity (mt)
SQM	Chile	40,000
Rockwood	Chile, Nevada	24,500
FMC	Argentina	15,000
Others		25,000
Total		104,500
Total (Lithium eqvt.)		***19,751***

Source: Company reports and Thomas Weisel Partners LLC

As seen above, current lithium carbonate production capacity stands at about 105,000mt, while actual demand in 2008 is estimated at 95,400mt, of which 27% is expected to come from lithium ion batteries (primarily used for consumer electronics).

Exhibit 13 – 2008 Expected Lithium Carbonate Demand



Source: SQM

Lithium is the thirty-third most abundant element in the world, and the U.S. Geological Survey estimates that globally identified lithium resources amount to about 14 million mt. This is equivalent to about 73 million mt of lithium carbonate, enough for 1.7 billion EVs or 16.7 billion PHEVs with a 10 mile electric range (as seen in Exhibit 14).

In Exhibit 14, we have also attempted to quantify the production of lithium carbonate that would be required to support sales of lithium ion battery powered vehicles. To provide a frame of reference, 500,000-600,000 hybrid electric vehicles using nickel metal hydride batteries were sold globally in 2008.

With the lithium carbonate industry currently running at over 90% capacity utilization, it is evident that demand from automotive lithium ion battery makers will impact the market for lithium carbonate. However, the long-term supply for the raw material should not be a concern because of healthy reserves. As such, we believe lithium carbonate production would need to ramp significantly in 2012-2015 as market adoption of PHEVs and EVs rises.

We believe expanding lithium carbonate production capacity could be relatively time consuming and expensive, as the brine lakes from which lithium carbonate is extracted occur in some of the world's most unforgiving deserts (in conditions of high solar and wind evaporation as well as low humidity and precipitation). It is these conditions that have allowed the soluble lithium from volcanic origins to naturally concentrate. Also, lithium carbonate production is a very time consuming process that can take almost two years. To understand why, a brief explanation of the production process follows: The salty water from the brine lakes is pumped into a series of shallow ponds and left to evaporate for 12-18 months. Different salts crystallize at different times as the solution becomes more concentrated. At one point, the solution is treated with lime to remove magnesium. Finally, the initial volume of water is reduced to produce concentrated lithium chloride brine, which is then treated with soda ash to precipitate out lithium carbonate. This must then be further purified to reach purity levels appropriate for use in batteries.

Based on public announcements from various lithium carbonate players, we believe 2010 production capacity could rise to as much as 150,000mt, should companies like Admiralty Resources, CITIC Guoang and Qinghai Salt River Industry Group ramp production successfully in 2009 and 2010. **In addition, we believe that U.S. Geological Survey's estimate of 14 million mt of lithium reserves could be potentially conservative, as noted by geologist R. Keith Evans, who estimates 28.4 million tons of lithium reserves (equivalent to 150 million tons of lithium carbonate) in his March 2008 report entitled, "*An Abundance of Lithium*".**

Either way, we believe that lithium carbonate accounts for only about 4-6% of the bill of materials in a battery pack and, therefore, is unlikely to inordinately impact battery maker economics.

Exhibit 14 – Plenty Of Lithium Reserves To Support Li Ion Battery Production, But Lithium Carbonate Production Must Increase

	Required Energy (kWh)	Required Li content (kg)	Eqvt Li2CO3 Content (kg)	No. of autos supported by current 2009 prodn capacity of Li2CO3 (millions)	No. of autos supported by global identified Li reserves (millions)
*PHEV 10	3	0.8	4.3	24.0	16,739.7
*PHEV 40	12	3.3	17.4	6.0	4,184.9
BEV	30	8.2	43.5	2.4	1,674.0

Note:
** assumes mid-sized sedan requiring 300Wh of battery energy per mile*
assumes 274 grams of lithium per kWh of energy capacity
assumes 18.9% lithium equivalent in lithium carbonate or 1.45kg of lithium carbonate per kWh

Annual Li_2CO_3 Production Required As Li ion Powered Vehicle Sales Ramp (metric tonnes)
(2009E annual production capacity of 146,500mt)

	1mn	2mn	3mn	4mn	5mn	6mn
% of 2009 expected auto production	*2%*	*3%*	*5%*	*7%*	*8%*	*10%*
PHEV 10	4,349	8,698	13,048	17,397	21,746	26,095
PHEV 40	17,397	34,794	52,190	69,587	86,984	104,381
BEV	43,492	86,984	130,476	173,968	217,460	260,952

Source: Thomas Weisel Partners LLC estimates

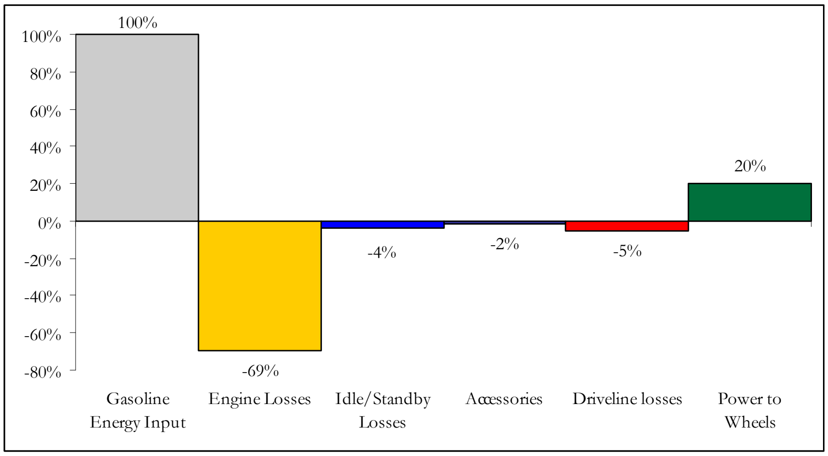
We would like to highlight that the data in Exhibit 14 is but a very rough exercise in estimating the supply/demand situation for lithium. For example, the above analysis does not account for potential demand from lithium ion powered commercial and transit vehicles. We have also assumed that all electric vehicles will be either plug-ins or battery-only and will be powered solely by lithium ion batteries (none by advanced lead acid, nickel metal hydride or other chemistries). Moreover, none of the battery producers have made public either their cost structures or their lithium content per cell. As a result, our very simplified assumptions are based on an Argonne National Laboratories report from 2000 entitled, "*Costs of Lithium Ion Batteries*".

THE RATIONALE FOR HYBRID AND ELECTRIC VEHICLES

A hybrid vehicle is, by definition, one that uses two or more distinct power sources for propulsion. The term most commonly refers to hybrid electric vehicles (HEVs), which combine an internal combustion engine (ICE) burning a fossil fuel and one or more electric motors.

A regular vehicle, in contrast, exclusively uses an ICE to power the drivetrain. The conventional automotive drive system uses the ICE coupled to the transmission and the wheels through a gearbox, which is used as a matching device between the engine and its load. To provide sufficient power at the wheels for adequate acceleration and hill climbing at a reasonable speed, it is necessary to use an engine with a maximum power output of about 10 times greater than would be required to propel the vehicle at the same speed along a level road. This makes the engine highly inefficient at the relatively low power required under most normal operating conditions. Additionally, the vast number of moving parts within the system requires a large amount of energy to be expended against the forces of friction. Also, a large portion of energy released from the burning of the fuel is wasted in the form of heat, resulting in significant fuel consumption and emissions.

Exhibit 15 – The Internal Combustion Engine Is Extremely Inefficient, Delivering Only Up To 20% Of Input Power To The Wheels

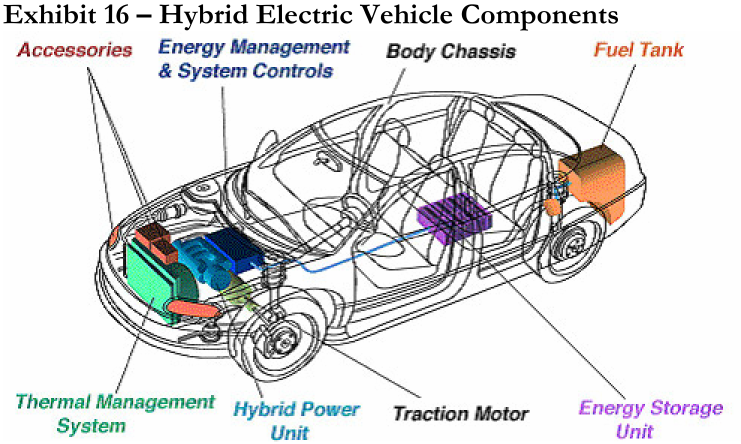


Source: Argonne National Laboratories and Thomas Weisel Partners LLC

Using an electric motor rather than an ICE, particularly during inherently inefficient times like idle and acceleration, could allow the engine to operate more efficiently. Electric motors also differ from most ICEs in that they can generate near maximum torque (a measure of ability to cause rotation around a central point such as an axle) at a very low speed. This forms the rationale for today's hybrid vehicles, which use a smaller ICE along with a high voltage, large battery pack that powers an electric motor to provide additional power for acceleration and overcoming loads.

HOW HYBRIDS WORK

Exhibit 16 – Hybrid Electric Vehicle Components



Source: U.S. Department of Energy

A HEV uses one or more electric motors and an ICE to propel the vehicle. Depending on the design, the ICE may exclusively propel the vehicle, act together with the electric motor to propel the vehicle or drive a generator to recharge the vehicle's batteries. Some hybrids rely exclusively on the electric motor during low speeds, the ICE exclusively at high speeds and both during some driving conditions such as acceleration.

The HEV's motor is powered by batteries, which are recharged by a generator driven by the ICE. The battery may also be recharged through regenerative braking. When the driver hits the brakes in this mode, power electronics and control software in the electric drive cause the motor to stop providing power to the wheels. Instead, the motor behaves like a generator, providing a charge voltage and current to the batteries. A tremendous amount of energy is wasted when a multiple ton vehicle comes to a stop from a high speed, and it makes a lot of sense to harness this energy through regenerative braking. In stop-start driving such as in crowded cities and urban areas, regenerative braking is also a very efficient method of battery recharging for commercial delivery vehicles.

Key Elements Of The Electric Drive – Advanced Batteries Represent Approximately 50% Of The Electric Drive Cost And Remain Chief Bottleneck

The major elements of the electric drive that provide propulsion in a hybrid architecture are as follows:

Battery Pack

Hybrid electric systems, as explained previously, function by combining a conventional ICE with a large, high voltage power storage device, typically batteries, capable of powering the electrical systems most of the time, while assisting the engine at inherently inefficient times. In conventional vehicles, a battery's main function is to provide a quick power burst to start the engine and then run the electrical system (e.g., HVAC, lights, controls, power steering and brakes, etc.). In a typical full hybrid, however, the battery is also required to propel the vehicle from a full stop and at low speeds as well as assist the vehicle during acceleration. As a result, the requirements of a battery for a HEV are significantly higher.

Several types of batteries are used in hybrids, but the most important characteristics by which their feasibility is judged are:

- **Energy density** in kWh/kg is a measure of the storage ability of the battery. It is crucial for determining the range of the vehicle on electrical power alone before requiring a recharge.
- **Power density** in kW/kg is a measure of ability to provide large energy bursts over very short durations of time. High power density means a rapid rate of discharge, enabling quick acceleration.
- **Durability**, which is measured in calendar life and cycle life, is the number of round-trip charge and discharge cycles the battery can withstand before performance falls below a certain threshold.

Today, the dominant battery technology for automobiles remains the lead acid battery, a technology that is more than 150 years old. While several tweaks have been made along the years to improve performance, battery players have looked at alternative chemistries, including nickel metal hydride, lithium ion, and nickel-sodium chloride, to provide better combinations of energy density, power density, voltage and battery life to power the next generation of hybrid vehicles.

Thomas Weisel Partners LLC
Dilip Warrier 415.364.2983

A battery is a collection of interconnected individual cells. Advanced battery suppliers typically do not just sell a battery. They also facilitate easy integration into the automobile by including: a battery casing; electrical connectors for interfacing to the automobile's electrical system; as well as a battery management system that monitors the battery's state of charge and controls the recharging process. These suppliers provide a fully integrated solution to the automotive OEM.

As seen in Exhibit 18, advanced batteries that meet the energy density, power density, durability and reliability requirements of today's hybrid vehicles represent almost half the cost of an electric drive. Part of the reason for the high cost is advanced chemistries, but low production volumes to date combined with a lack of purchase commitments from automakers are also a factor. As a result, a typical **NiMH (nickel metal hydride) battery pack can cost as much as $5,000, while a typical Li ion (lithium ion) battery pack can cost as much as $15,000-20,000**, which further increases the cost of the automobile, potentially putting it out of the reach of most middle income families.

Ultracapacitors – Often Used As Backup Or In Conjunction With Regenerative Braking

An ultracapacitor is like a capacitor on steroids; it has the ability to hold a charge several times greater than a regular capacitor. It can charge and discharge instantaneously and therefore deliver large amounts of power, although not for long periods of time.

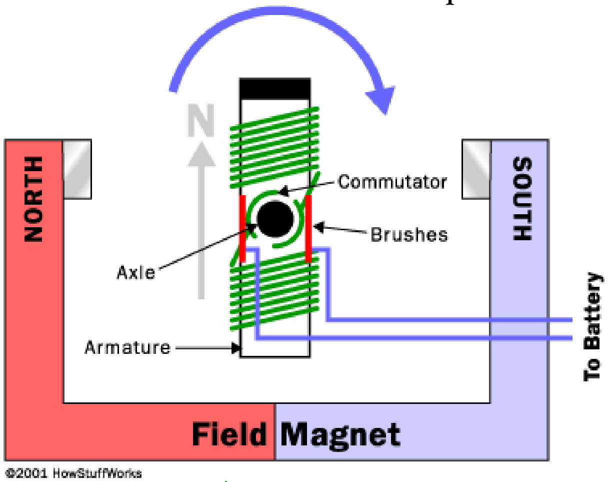
Ultracapacitors are currently used in hybrid systems to provide emergency back up power for electric brakes. They are maintenance-free devices that can withstand an infinite number of charge/discharge cycles without degrading and have a long service life. They are also very good at capturing the large amounts of energy from regenerative braking and can deliver power for acceleration and heavy loads.

While providing a cost-effective storage reservoir for quick bursts of energy, such as during acceleration, most ultracapacitors today do not compete with batteries in terms of energy density and, therefore, are not a candidate to replace them. As a result, ultracapacitors are used for peak power demands, allowing for smaller and less expensive batteries for main energy storage. Ultracapacitors also have the advantage of very quick charging, which makes them ideally suited for regenerative braking.

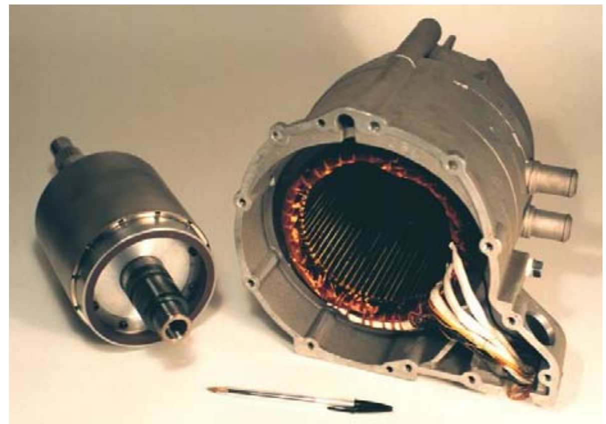
Electric Motors

The size and number of electric motors in a HEV can vary depending on the type, size and degree of hybridization. Working on the principle of magnetism, the electric motor converts electrical energy into mechanical energy.

Exhibit 17 – Basic Electric Motor Operation



Source: HowStuffWorks



Source: Courtesy of UQM Technologies, Inc.

In an electric motor's simplest form, current flows through a solenoid wrapped around a rotor or armature. The armature is surrounded by a permanent magnet called the field magnet or stator. The current flowing through the solenoid induces an electric field, causing the armature to spin due to attraction between unlike poles and repulsion between like poles of the rotor and stator. An axle is connected to the rotor to harness the energy of the motion. Under normal circumstances, the rotor would only go through one half turn as it reaches a state of equilibrium, where its poles align with the opposite poles of the stator. Using a commutator, however, the charge of the DC motor is flipped, causing the rotor to go through one more half-turn before the commutator kicks in again to ensure continuous rotation of the rotor.

Higher voltage levels lead to higher electric field strengths. As a result, vehicle electric drives operate at much higher voltages (as much as 500V) than typical electrical systems in convention vehicles, which operate at 12V.

While motors acting as electromagnetic devices are highly efficient (as much as 90% efficiency), they generate waste heat, including from the friction in the mechanical systems connected to the axle. Heat dramatically reduces motor efficiency, so cooling is required. Motors also require insulation, both from the magnetic fields they generate, which can cause interference with other electric components and sensors, and the heat given off. Motors generally are sealed and maintenance free.

A Note On Regenerative Braking – Increases Range And Reduces Brake Wear And Tear

During regenerative braking, power flows in reverse from the motor, which now acts like a generator, to charge the battery or ultracapacitor. Some of the vehicle's kinetic energy, which is normally absorbed by the brakes and turned into heat, is instead converted into electricity by the armature's rotation within the magnetic field of the field magnet, which induces a flow of current. Regenerative braking increases the electric range of the vehicle, especially in stop-and-go traffic when brakes are used frequently. The driving range of a battery electric vehicle (BEV) can be increased as much as 25% by using regenerative braking. Additionally, regenerative braking decreases brake wear and tear and reduces maintenance costs.

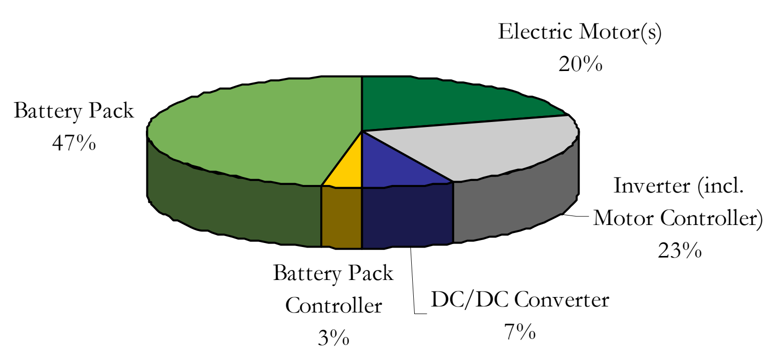
Controllers And Conditioning Circuitry – The "Magic Glue" That Binds It All Together

The controller is responsible for determining how and when to apply electric motor power. It also determines the correct amount and type of electricity that is supplied to the electric motor. The controller not only needs to determine when the motor should be active, whether it should be providing power or recharging the batteries and at what magnitude in each direction, but it also has to condition the power by converting DC power provided by the batteries to AC or DC power of a desired voltage. This is an extremely complicated task as the controller must take into account the speed and gear of the ICE, the driver's input on the accelerator pedal, road conditions and, in cases where each axle or wheel is driven separately, the speed of the wheels and axle. Thus, while the parts that make up the controller are inexpensive, its programming and control system are extremely complex. After advanced batteries, the controller is where most R&D dollars go in development of electric drives.

DC-AC converters (inverters) are used to provide both AC power to internal parts (e.g., an AC motor) and auxiliary 110V standard outlets. Because a motor is a variable voltage device whose output changes based on the level of voltage input, it uses a variable converter, which is more expensive than a fixed controller.

DC-DC converters are used to charge auxiliary 12V batteries and to provide 12V power from the higher voltage battery to legacy subsystems.

Exhibit 18 – Component Costs In A Full Hybrid Architecture



Source: Delphi Electronics and Safety

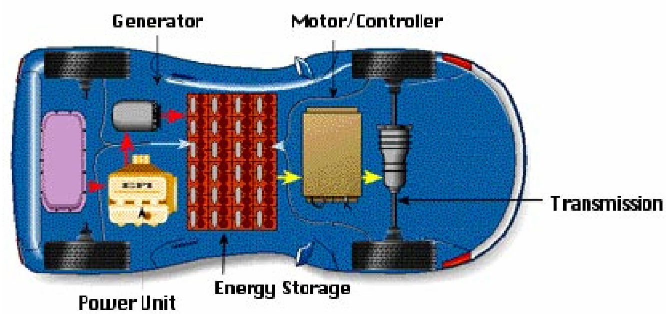
TYPES OF ELECTRIC DRIVES

Hybrid electric drives are characterized by whether the electric motor alone or a combination of an ICE and electric motor provide the propulsion

Series Hybrid Electric Drive

In a series hybrid design, sole propulsion is by a battery-powered electric motor, while electric energy for the batteries comes from the ICE. In this design, the engine turns a generator, which in turn either charges the batteries or powers the electric motor that drives the transmission. The ICE never powers the vehicle directly. A series hybrid schematic is shown in Exhibit 19.

Exhibit 19 – Series Hybrid Electric Drive



Source: U.S. Department of Energy

Advantages: As the engine is only operated to keep the batteries charged, it can continuously operate at its most efficient speed and load. It also never idles, reducing vehicle emissions. Another advantage is a simpler design, as series hybrids typically do not need a transmission, clutch or torque converter.

Disadvantages: The main disadvantage of the series hybrid drive is cost, size and weight, as a large electric motor is required to drive the wheels using only its own shaft power, and a reasonably large ICE is required to generate enough power to keep a large battery pack charged. There is also the inefficiency of converting chemical energy in the fuel to mechanical power by the ICE and electrical power by the generator, the latter which is then stored by the battery chemically and converted back to mechanical power by the motor.

Series Drive Best Suited To Commercial Vehicles; However, New Developments Promise A Future For Series Drives In Consumer Vehicles

At low speeds in high traffic and stop-and-go applications, it is possible to have the ICE operating (providing power to the electric motor or charging the batteries) at both a constant speed and optimum efficiency. As a result, the series drive is best suited to commercial vehicle applications, such as mass transit buses, shuttle buses, school buses and delivery vehicles. At higher speeds, it is much too inefficient to convert mechanical energy from the ICE to electrical energy, and then back to mechanical power at the motor. Due to this reason, as well as the higher cost and size of electrical drive components, the series hybrid drive has not caught on in consumer vehicles.

The Chevy Volt – GM's Great Hope In A Series Hybrid Extended Range Vehicle

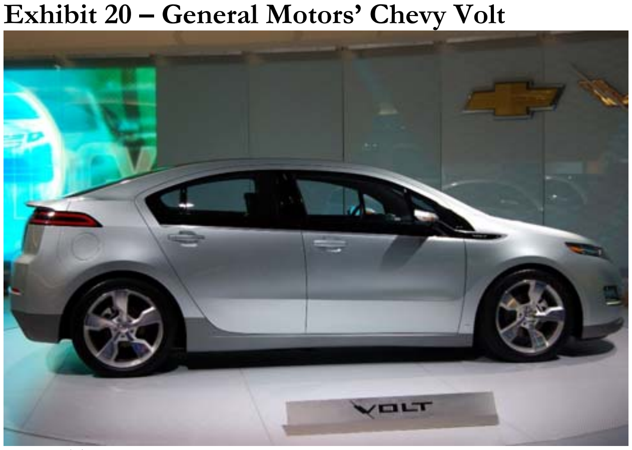
In the wake of the automotive industry's difficulties and an anticipated government bailout of Detroit's Big 3, **General Motors'** expected 2010 rollout of the Chevy Volt has received a lot of attention. Though **GM** does not refer to the car as a hybrid (the company calls it an electric vehicle with a "range extending" gasoline powered ICE, or an Extended Range Electric Vehicle), it uses a combination of batteries and an ICE to power an electric motor that delivers power to the wheels. As such, this makes it a series hybrid configuration.

The Volt features a 16kWh lithium ion battery pack that is rechargeable through a common 120V/240V electrical outlet and provides the vehicle with a 40 mile all electric range, which is sufficient for satisfying the daily commuting needs of 75% of Americans. A full charge would take eight hours on a standard 120V outlet and less than three hours on a 240V outlet. **GM** recently chose Korea-based **LG Chem** to supply the battery cells, which will then be taken in-house and integrated into a complete battery pack. GM plans to have an assembly plant for this process running in time for commercial production of the Volt.

After 40 miles, the range of the Volt is extended by 300 miles through the use of a small four-cylinder ICE, which drives a 53kW generator. The electrical power from the generator is sent to either the electric motor or the batteries, depending on the state of charge of the battery pack and the power demanded at the wheels.

The car is expected to be priced around $40,000 in the United States, with tax credits of $7,500 bringing the effective purchase price down to $32,500. The vehicle is expected to hit show room floors by the end of 2010.

Exhibit 20 – General Motors' Chevy Volt

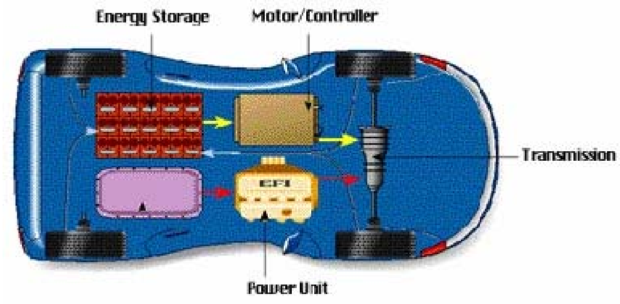


Source: Thomas Weisel Partners LLC

Parallel Hybrid Electric Drive

In a parallel hybrid drive, both the electric motor and the ICE work together to power the vehicle. In most cases, the electric motor is used to assist the ICE.

Exhibit 21 – Parallel Hybrid Electric Drive



Source: U.S. Department of Energy

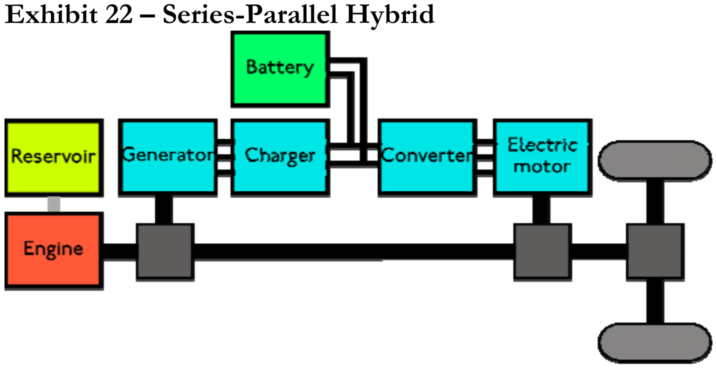
Advantages: One of the advantages of the parallel hybrid drive is that the vehicle can be powered by a combination of a smaller ICE and motor than in a series drive, as total power available for propulsion is a combination of engine power and motor power. Most parallel drive vehicles do not need a separate generator because the motor regenerates the batteries through regenerative braking. Also, power does not need to be redirected through the batteries and can therefore be more efficient, particularly at highway speeds.

Disadvantages: The main disadvantage of the parallel drive is the complexity of software needed to seamlessly blend ICE and motor power. Another concern about the parallel configuration is that it needs to be engineered to provide proper heating and air conditioning system operation when the ICE stops at idle.

Series-Parallel Hybrid Electric Drives

Most current hybrids use a combination of the series and parallel configurations due to the flexibility that this offers (despite the added complexity). In this design, the vehicle can be driven by either the ICE or the motor. The hybrid control system shuts off the engine when there is ample power from the motor to propel the vehicle. The engine is turned on when extra power is needed or when the batteries need to be recharged. The vehicle can be powered by the ICE alone (such as at highway speeds), the electric motor alone (during idle and at very slow speeds) or a combination of the two (such as during acceleration). **The Toyota Prius and the Ford Escape Hybrid are the best examples of series-parallel configurations.**

Exhibit 22 – Series-Parallel Hybrid



Source: Wikipedia (Structure of a combined hybrid vehicle. Designed by Peter Van den Bossche)

Advantages: As a result of the dual drivetrain, the engine more often operates at near optimum efficiency. At lower speeds, it operates more as a series vehicle. At high speeds, when the series drivetrain is less efficient, the ICE takes over and energy loss is minimized. Thus, the series-parallel seeks to leverage the strengths of both the series and parallel configurations, and has the potential to perform better than either of the configurations alone.

Disadvantages: The chief disadvantage is the higher cost of the system (compared to a pure parallel hybrid) resulting from its need of a generator, a larger battery pack and more computing power to control the dual system.

Levels Of Hybrid Electric Vehicles

There are different levels of hybridization among HEVs on the market, all of which are defined by the role of the electric motor. The more the electric motor powers the vehicle, the less the ICE must run.

Exhibit 23 – Classification Of Electric Drive Vehicles By Function

Electric Drive Type	Functional Capabilities Provided by Battery
Micro Hybrid	Automatic start and stop plus regenerative braking
Mild Hybrid	Micro hybrid capabilities PLUS power assist to ICE
Full Hybrid	Mild hybrid capabilities PLUS electric launch
Plug-in Hybrid	Full hybrid capabilities PLUS electric range with grid-charged electricity
Battery Electric	Entirely electric power and propulsion energy (grid-charged)

Source: Electric Power Research Institute

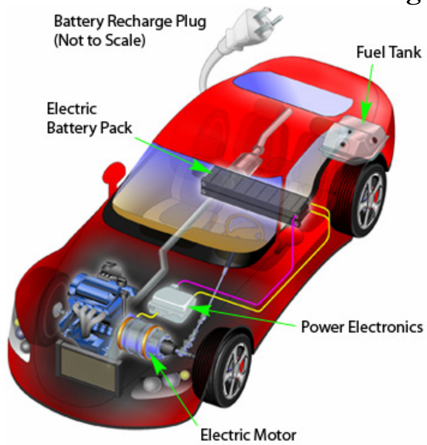
Micro hybrid: A micro hybrid incorporates stop-start technology (i.e., the ICE is switched off when the vehicle is at rest and switched on when propulsion is needed) and regenerative braking, but is not capable of using the electric motor to propel the vehicle without help from the ICE. A micro hybrid costs less than a full hybrid, but fuel savings are also less. The system uses a 42V electrical motor and battery package. Fuel savings range between 8% and 15% over conventional vehicles.

Mild hybrid: A mild hybrid uses 144V to 158V batteries that provide engine stop-start, regenerative braking and power assist. Like a micro hybrid, a typical mild hybrid is not capable of propelling the vehicle from a stop using the motor alone. Examples of medium hybrids include the Honda Insight, Civic and Accord. Fuel economy improvement ranges between 20% and 25% over conventional vehicles.

Full hybrid: A full hybrid offers engine stop-start, regenerative braking and the ability to propel the vehicle using the electric motor alone. Fuel economy savings range between 30% and 50% over conventional vehicles. Examples of full hybrids include the Toyota Prius and the Ford Escape.

Plug-in hybrid (PHEV): A PHEV is a full hybrid with larger batteries and the ability to recharge from an electric power grid. They are equipped with a power socket that allows the batteries to be recharged when the engine is not running. While PHEVs are currently not yet in mass production, several automakers have announced plans to introduce new models or plug-in versions of existing HEV models in the 2010-2012 time frame. This segment of the hybrid consumer vehicle market is seeing the most frenetic activity: **Toyota** has committed to commercial availability of a plug-in Prius by 2010, while **General Motors** plans to introduce the much touted Chevy Volt, the car upon which its future is supposed to hinge. Additionally, both Chrysler and Ford have promised to introduce more fuel efficient cars, including plug-in hybrids, to the domestic market as part of a turnaround. Another plug-in hybrid that has been in the news is the Fisker Karma. Slated for commercial availability in 4Q09, the Fisker Karma is powered by an electrical drivetrain called the Q Drive, which was designed by Quantum Fuel Systems Technologies.

Exhibit 24 – Schematic Of A Plug-In Hybrid Vehicle



Source: National Renewable Energy Laboratory

Exhibit 25 – Toyota Prius Plug-In Hybrid

Source: Thomas Weisel Partners LLC

Exhibit 26 – The Fisker Karma Plug-In Hybrid

Source: Thomas Weisel Partners LLC

The Fisker Karma is a four-door sedan, plug-in hybrid developed by **Fisker Automotive**, a joint venture between **Fisker Coachbuild, LLC** and Quantum. The power train for the Karma has been developed by Quantum and features a turbo-charged 2.0L 260hp GM Ecotec gasoline engine, a 22.6kWh lithium ion battery pack, two electric motors that deliver a combined 408hp and vehicle level control software. The car can accelerate from 0 to 60mph in 5.8 seconds and has a top speed of 125mph that is electronically limited. The battery gives the car an all-electric range of 50 miles, after which the gasoline ICE kicks in to extend this limit.

The car will be assembled by **Valmet Automotive** of Finland, which currently also produces the Porsche Boxster and Porsche Cayman. It is scheduled to begin delivery in November 2009 with a base price of $87,900. Fisker is targeting production of 7,500 vehicles in 2010 and 15,000 vehicles in 2011. Production is sold out until mid-2010. The automobile received a great deal of buzz and press attention at the recent North American International Auto Show in Detroit.

Battery packs will be supplied by **Advanced Lithium Power** in Vancouver, of which Quantum owns about 15%.

Fisker has also announced a new concept vehicle called the Sunset, or Karma S, a four-seat hard-top convertible based on the same plug-in hybrid system as the Karma.

Exhibit 27 – Fisker Karma S Concept

Source: Thomas Weisel Partners LLC

China Takes The Early Lead In Mass Production Of Plug-In Hybrids In BYD's F3 DM; Warren Buffet Buys Into The BYD Story

In a sign of the intense activity taking place to develop the next generation of automobiles, **BYD** (Build Your Dream), a Chinese lithium ion battery provider to the electronics industry, took the world by surprise when it beat established automakers like Toyota and GM in introducing the first mass-produced plug-in hybrid car. **BYD** entered the automotive industry in 2003 by acquiring the Tsinchuan Automobile Company, which it has since renamed BYD Auto.

The F3 DM (DM stands for dual mode) plug-in hybrid compact sedan, which went on sale in China in December 2008, is powered by a BYD produced lithium ion battery. The car has an all electric range of 62 miles with a top speed of 100mph. The 330V, 40Ah lithium ion battery pack has life of more than 2,000 cycles according to BYD, and a full recharge takes 8-9 hours on a standard household 220V electric outlet. The company also says that the battery pack can achieve a 50% recharge in 10 minutes using a special high power charger. The car's range can be extended by a further 237 miles with a three cylinder, 1.0 liter 50kW aluminum engine. The car went on sale in China for about 150,000 Yuan, or about $22,000. BYD plans to sell as many as 10,000 units in 2009. The company has plans to enter the U.S. market in 2010. It also plans to mass market in China an all electric vehicle that can go 300km (188 miles) on a single charge.

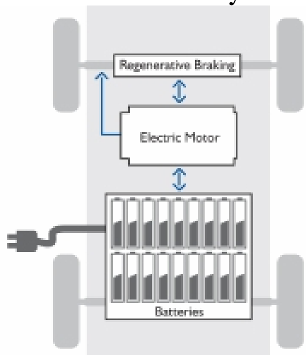
We note that **Berkshire Hathaway**, through its **MidAmerican Energy Holdings Company** subsidiary, has taken a 10% interest in BYD Company. This stake is valued at about 1.8 billion HK dollars, or USD $230 million.

MOVING ON TO ALL-ELECTRIC VEHICLES

Battery Electric Vehicles (BEVs) – The Most Dependent Electric Vehicle Category On Advanced Battery Technology

A BEV uses only electric power in the form of a large battery pack that powers one or more electric motors to turn the drive wheels. The batteries must be recharged from an external power source. This technology is used for passenger cars, forklifts, urban buses, airport ground support equipment and off-road industrial equipment. BEVs are zero-emissions vehicles (ZEVs) because they do not directly pollute the air. The only pollution associated with BEVs is the result of generating the electricity to charge the batteries. Even accounting for emissions associated with electricity generated to charge batteries, BEVs are significantly cleaner than the cleanest ICE powered vehicle.

Exhibit 28 – Battery Electric Vehicle



Source: Electric Drive Transportation Association

Depending on the vehicle and battery technology, batteries may be recharged from either a 110V or 220V wall outlet, or using a specialized charger.

The GM EV1 was the first modern production electric vehicle from a major automaker. It was also the first purpose-built electric car produced by **General Motors** in the United States. The car was introduced in 1996 in California and Arizona with a limited 3 year/30,000 mile lease-only agreement. That vehicle was discontinued after 1999 and subsequently removed from the road in 2003. GM stated that it could not sell enough vehicles to be profitable on its investment as the required breakthrough in battery technology was not coming through on time.

While BEVs are most commonly associated with golf carts, several sophisticated consumer vehicles powered solely by batteries are running on the streets today. BEVs are becoming more attractive with the advancement of new battery technologies that have higher power and energy density. We believe that the future of BEVs, which have floundered in recent years, is dependent on the availability of reliable and economical advanced battery technologies that can meet the energy density, cycle life and deep discharge requirements of the extended ranges.

Some of the most common applications today are neighborhood electric vehicles (NEVs) and low speed vehicles (LSVs). These are smaller electric vehicles with maximum speeds of 25-35mph and a limited range of 30-50 miles on a full charge. These vehicles are best suited to urban areas with high population and traffic density, characterized by short commutes and low speed limits, as well as to secluded communities and resorts. The market for these vehicles is supported by several manufacturers, including **Dynasty Electric Car Corp., Global Electric Motorcars, Miles Automotive, Reva Electric Car Company,** and **ZENN Motor Company**. Other useful EVs in niche applications include electric scooters and bikes.

We also note that Norwegian electric car maker **Think Global** offers a highway-capable, two-seater battery electric car called the Think City, offered to customers with a choice of lithium ion (**A123** and **EnerDel**) and sodium ZEBRA (**MES-DEA**) batteries. The car has a range of about 112.5 miles with a maximum speed of about 60mph.

Advantages: BEV propulsion systems have fewer moving parts than a conventional vehicle and therefore maintenance expenses are reduced. They also enjoy the advantage of noise-free propulsion, zero emissions and lower fuel costs.

Exhibit 29 – Th!nk City Car Powered By EnerDel Li ion Battery Pack And The ZENN Electric Car

Source: Thomas Weisel Partners LLC

Source: ZENN Motor Company

Battery electric drives are also being popularized by companies like **Smith Electric Vehicles** (subsidiary of the **Tanfield Group**) for applications such as commercial delivery vehicles, vans, refrigerated vehicles and shuttle buses. Smith's vehicles boast of driving ranges in excess of 100 miles on a full charge and a maximum speed of 50-70mph.

Exhibit 30 – Smith Electric Commercial Vehicles Powered By Valence Technology Li Ion Battery Pack

Source: Thomas Weisel Partners LLC

One of the much publicized new BEVs is the Tesla Roadster by **Tesla Motors**. The all-electric vehicle is priced at $109,000; Tesla has shipped over 50 units to date. The vehicle uses a large lithium ion battery pack that provides a range of over 220 miles on a full charge and has enough power to accelerate from 0-60mph in less than 4 seconds. The battery pack, which is rated at 53kWh, is composed of 6,831 individual cylindrical 18650 lithium ion cells and weighs 992lbs, including battery management systems. The 18650 cell, which gets its nomenclature from its dimensions (18.3mm diameter and 65mm height), is commonly found in laptop battery packs. While **Tesla** sources its cells from third parties, it assembles the battery pack in-house. The car is assembled by British sports car maker **Lotus,** while the power train installation and assembly takes place at the company's Menlo Park, CA site. **Assuming $800 per kWh of battery cost, it is apparent that the largest driver of the car's sticker price is the battery pack (at about $40,000).**

According to the company, the battery is expected to maintain good driving performance for five years or 100,000 miles, whichever comes first.

Tesla also plans to target the luxury sedan market in the future. We note that the company has applied for about $400 million in loans from the $25 billion package set aside by the federal government so automakers' can retool their factories to produce more fuel efficient cars. According to the company, the proceeds will be used for developing advanced batteries as well as its all electric sedan Model S.

Exhibit 31 - The Tesla Roadster

Source: Thomas Weisel Partners LLC

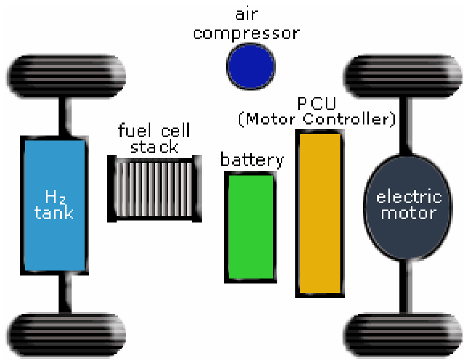
We note that **Lotus** is developing an extended range electric vehicle similar in technology to that of **GM's** Chevy Volt, which will feature a gas tank and a small ICE to extend the car's range.

Another partnership that is receiving widespread attention is Canada-based **ZENN Motor Company's** association with Texas-based **EEStor**. **EEStor** is developing a new ceramic-based ultracapacitor that would, per the company, exceed the abilities of any advanced battery technology today and at a much lower cost. This new ultracapacitor potentially could give an all-electric vehicle a driving range of up to 300 miles, with recharging taking only a few minutes using a specialized charger. The technology, however, is still subject to third-party review of permittivity data and successful prototype production.

Fuel Cell Electric Vehicles (FCEVs) – We See A Long-Term Future, But Prohibitive Costs And Infrastructure Continue To Hamper Mass Market Adoption

Fuel cell vehicles use a completely different propulsion system than conventional vehicles. An FCEV uses the electricity produced by a fuel cell to power motors that drive the vehicle's wheels. FCEVs can be fueled with pure hydrogen gas stored directly on the vehicle or extracted from a secondary fuel such as methanol, ethanol or natural gas that carries hydrogen. These secondary fuels must first be converted into hydrogen gas by an onboard device called a reformer. FCEVs fueled with pure hydrogen emit no pollutants, only water and heat. Vehicles that use secondary fuels and reformers produce small amounts of air pollutants.

Exhibit 32 – Schematic Of A Fuel Cell Vehicle



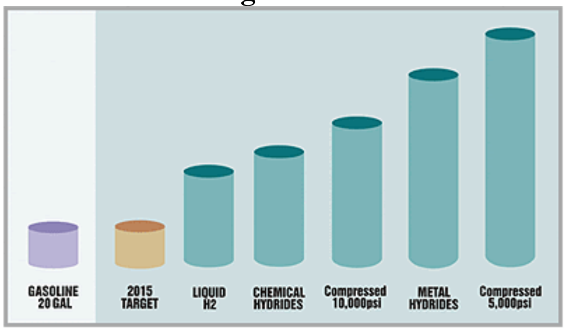
Source: National Renewable Energy Laboratories

Advantages: Fuel cell powered vehicles offer several advantages over conventional vehicles, including zero tailpipe emissions, 2-3x more efficiency than combustion engines, reduced fuel costs and operating costs due to fewer moving parts, noise reduction, and improved performance.

Disadvantages: Because FCEVs require a completely new vehicle propulsion system and new fueling infrastructure, many deployment issues can only be addressed by integrating and evaluating the components in complete systems, which increases the cost of a FCEV due to the high level of customization involved. Many other obstacles need to be overcome before FCEVs become a truly viable option for personal transportation.

- **Storage:** Because hydrogen is a gas, a larger volume of it is needed to travel the same distance as with a tank of gasoline.
- **Weight and size:** The weight and size of fuel cells need to be reduced to improve overall fuel efficiency.
- **Start-up time:** Fuel operates best at a fixed moderate temperature. Vehicles must be equipped with systems that allow for quick reactions when cold and to changing operating conditions.
- **Infrastructure:** FCEVs require an infrastructure that can supply hydrogen needs and/or clean operating reformers.

Exhibit 33 – Relative Volume Needed For Hydrogen Storage To Achieve More Than 300 Mile Range



Source: Hydrogen.gov

Most automakers are actively researching fuel cell transportation technologies and testing prototype passenger vehicles. In addition, many cities are testing fuel cell powered transit buses. For example, BC Transit has contracted with Canadian bus OEM **New Flyer Industries**, San Diego based electric drive integrator **ISE**, and fuel cell stack manufacturer **Ballard Power Systems** to work together to build 20 fuel cell buses for use during and after the 2010 Olympics and Paralympic Winter Games. We believe that contracts like these are an indicator of the broad interest in clean burning fuel technologies for mass transport; however, we continue to see fuel cell powered buses priced at $1-2 million versus about $200,000 for conventional buses, a price premium that is prohibitive for most fleets.

Exhibit 34 - GM Chevy Equinox Fuel Cell Vehicle

Source: Thomas Weisel Partners LLC

OTHER ALTERNATIVE FUELS AND ADVANCED VEHICLES

Natural Gas Vehicles (NGVs) – Key Advantages Are Emissions Reduction And Domestic Reserves

Compressed natural gas (CNG) and liquefied natural gas (LNG) are considered alternative fuels under the Energy Policy Act of 1992. Natural gas vehicles (NGVs) are either fueled exclusively with CNG or LNG (mono-fuel or dedicated NGVs) or are capable of natural gas and gasoline fueling (bi-fuel NGVs). In general, mono-fuel NGVs demonstrate better performance and have lower emissions than bi-fuel NGVs because their engines are optimized to run on natural gas. Also, the vehicle does not have to carry two types of fuel, freeing up cargo capacity and reducing weight.

Light duty NGVs work much like gasoline powered vehicles with spark-ignited engines. Some heavy-duty NGVs use spark-ignited natural gas systems, but other systems exist as well. High pressure direct injection engines burn natural gas in a compression-ignition (diesel) cycle. Heavy-duty engines can also burn diesel or natural gas in a dual-fuel system.

To provide adequate driving range, CNG must be stored onboard a vehicle in tanks at high pressure of up to 3,600psi. A CNG powered vehicle gets about the same fuel economy as a conventional gasoline vehicle on a gasoline gallon equivalent (GGE) basis. A GGE is the amount of alternative fuel that contains the same amount of energy as a gallon of gasoline. A GGE is about 5.7lbs of CNG.

To store more energy onboard a vehicle in a smaller volume, natural gas can be liquefied. To produce LNG, natural gas is purified and condensed into liquid by cooling to -260°F. At atmospheric pressure, LNG occupies only 1/600 the volume of natural gas in vapor form. A GGE equals about 1.5 gallons of LNG. Because it must be kept at such cold temperatures, LNG is stored in double-wall, vacuum-insulated pressure vessels. LNG fuel systems are typically used only with heavy-duty vehicles.

The interest in natural gas as an alternative fuel stems from its clean burning properties, its domestic resource base and its widespread commercial availability.

Compared with vehicles fueled with conventional diesel and gasoline, NGVs produce significantly lower amounts of harmful emissions. The driving range of NGVs generally is less than that of comparable diesel and gasoline fueled vehicles because of the lower energy content of natural gas. Extra storage tanks can increase driving range but they also increase weight and can displace payload capacity. NGV horsepower, acceleration and cruise speed are comparable with those of an equivalent conventional vehicle.

Advantages of NGVs:

- Natural gas is a domestically available resource with an existing distribution infrastructure in the form of transmission pipelines.
- Natural gas is a much cleaner burning fuel than gasoline or diesel. For example, the U.S. EPA calculated that using CNG versus gasoline in light duty vehicles can reduce CO emissions by 90-97%, CO_2 emissions by 25% and NOx emissions by 35-60%, while emitting little or no particulate matter and fewer toxic and carcinogenic materials.

- Even allowing for the lower energy content of CNG versus gasoline and diesel, CNG is a cheaper fuel.

Exhibit 35 – October 2008 Overall Average Fuel Prices On Energy-Equivalent Basis

	Nationwide Avg. Price in Gasoline Gallon Eqvt.	Nationwide Avg. Price in Diesel Gallon Eqvt.	Nationwide Avg. Price in Dollars per Million Btu
Gasoline	$3.04	$3.39	$26.33
Diesel	$3.27	$3.65	$28.38
CNG	***$2.01***	***$2.24***	***$17.37***
Ethanol (E85)	$3.99	$4.44	$34.53
Propane	$4.67	$5.21	$40.46
Biodiesel (B20)	$3.69	$4.11	$31.94
Biodiesel (B2-B5)	$3.45	$3.85	$29.89
Biodiesel (B99-B100)	$4.58	$5.10	$39.66

Source: U.S. Department of Energy Clean Cities Alternative Fuel Price Report October 2008 issue

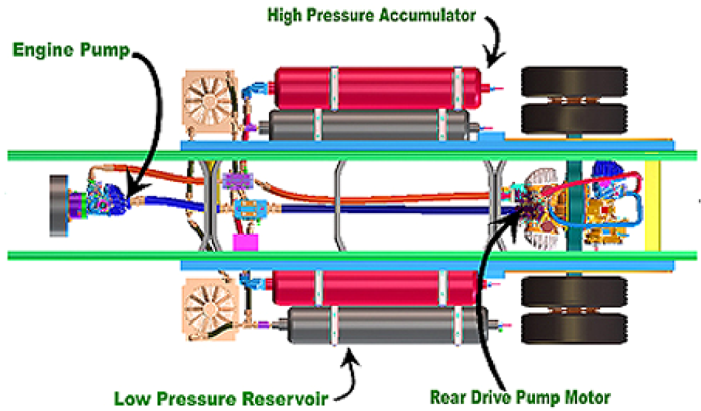
Disadvantages of NGVs: Despite the advantages of natural gas, the use of NGVs faces certain limitations such as fuel storage, infrastructure available for delivery and distribution at gasoline fueling stations. Also, natural gas must be stored in cylinders usually located in the vehicle's trunk, reducing the space available for other uses.

The Honda Civic GX is the only NGV commercially available in the United States. Europe continues to be a significantly larger market for NGVs with automakers such as Audi, Citroen, Fiat, Ford, Mercedes Benz, Peugeot, Renault, Volkswagen and Volvo offering CNG or CNG/gasoline bi-fuel versions of popular models. In addition, there is a large after market for the retrofitting of gasoline powered vehicles to handle CNG, particularly with companies like **Fuel Systems Solutions** that have an installed base of 4.5 million vehicles using its systems and components.

Hybrid Hydraulic Vehicles (HHV) – Best Suited To Medium To Heavy-Duty Vehicles In Stop-And-Go Traffic

Hybrid hydraulic vehicles (HHVs) function in the same way as HEVs except that energy for the alternative power source is stored in tanks of hydraulic fluid under pressure rather than batteries. Also, instead of electric motors, these vehicles have a hydraulic propulsion system, which can power the vehicle itself. The system captures energy during braking and uses that energy when the vehicle is accelerating.

Exhibit 36 –Hybrid Hydraulic Vehicle Schematic



Source: U.S. EPA

The main components in HHVs are:

- The **high pressure accumulator** stores energy as a battery would in a HEV using hydraulic fluid to compress nitrogen gas.
- The **low pressure reservoir** stores the low pressure fluid after it has been used by the pump/motor.
- The **rear drive pump/motor** converts the pressure from the hydraulic fluid into rotating power for the wheels, and it recovers braking energy that is stored in the high pressure accumulator.
- The **engine pump/motor** pressurizes and transfers hydraulic fluid to the rear drive pump/motor and/or high pressure accumulator.
- The **hybrid controller** monitors the driver's acceleration and braking, and commands the hybrid system components.

The three key features that enable improvement in fuel efficiency are:

- **Regenerative braking:** When stopping the vehicle, the hybrid controller uses energy from the wheels by pumping fluid from the low pressure reservoir into the high pressure accumulator. This stored energy is then used for acceleration. Typically energy recovery rates in hydraulic regenerative braking approach 70% versus 30% in hybrid electric vehicles.
- **Optimum engine control:** The engine pump pressurizes and transfers fluid from the low pressure reservoir to the rear drive pump/motor and, under certain operating conditions, to the high pressure accumulator. In the full series hydraulic, there is no conventional transmission and driveshaft connecting the engine to the wheels, freeing the engine to operate at its maximum efficiency to achieve optimum fuel economy.
- **Engine start/stop:** Using engine start/stop technology, the hybrid controller can determine when the engine needs to switch on and off, which increases fuel economy in stop-and-go traffic.

The use of hybrid hydraulic technology is best suited to larger and heavier vehicles because it can handle the high braking power and acceleration requirements. Hybrid hydraulic systems have a much higher power density than their electric counterparts and, thus, suffer in comparison in energy density. Given the low energy density of a hybrid hydraulic system, it may not be feasible to downsize the ICE with the intention of using stored hydraulic energy to give it a boost when required. For this reason, the ICE used must match the full power requirement of the vehicle.

Regenerative braking and engine start/stop make the technology best suited to commercial delivery vehicles, transit buses, garbage trucks and light duty work trucks that use frequent braking during normal operations.

In smaller passenger vehicles, hybrid hydraulic is impractical with the tighter space restriction, in particular due to the size of the accumulator tanks. In addition, hybrid hydraulic systems tend to be noisy, making them ill-suited to consumer car applications.

The EPA has been able to improve city fuel economy of a UPS package car by 70% and reduce CO_2 greenhouse gas emissions by 40%, while reducing brake wear by 75%. The EPA estimates that the additional costs of the technology manufactured in high volume has the potential to be less than 15% of the price of the base vehicle with a payback period of 2-3 years.

ENERGY STORAGE TECHNOLOGIES – NO SILVER BULLET SOLUTION FOR ELECTRIFICATION OF AUTOMOBILES; DIFFERENT SOLUTIONS FOR DIFFERENT APPLICATIONS

We devote an entire section of this white paper to energy storage technologies because advanced battery development has historically been the biggest stumbling block to the electrification of automobiles. In fact during 1900-1910, electric and gasoline propulsion were competing for the domestic and business transport market, and it was the electric vehicle's restricted range and slow refueling that resulted in the domination of the internal combustion engine. The restricted range of the electric car is caused by the limited amount of energy that can be stored in a battery; for example, the typical lead acid battery has an energy density of 35Wh/kg versus useful energy density of more than 2,000Wh/kg for gasoline.

Technological improvements to the tried and tested lead acid battery, as well as developments in nickel metal hydride and lithium ion batteries and ultracapacitors, however, mean that there is a solution for automobiles (as well as for heavier duty commercial and transit vehicles) irrespective of the degree of the electrification of the drivetrain.

Before we delve into battery technologies, it is important to highlight the different purposes that the battery serves in a conventional ICE powered vehicle and in a HEV or BEV. In an ICE powered vehicle, the battery's purpose is to provide a short powerful burst of power to start the engine. This type of battery is called the **SLI (Starting, Lighting and Ignition) battery** and it is designed to give a lot of current during starting, then to be recharged immediately by the car's alternator. A starting battery is also found in HEVs in addition to a high voltage battery, which can provide power for propulsion either alone or in combination with the ICE. In a BEV, there is no need for a starting battery. BEVs not only need high power and high voltage batteries (100-600V), they also need batteries that can be totally discharged and recharged often. This requirement is called **deep cycling**. Although these batteries tend to have less instant power than a starting battery, they can deliver electrical energy for longer periods of time and go through many deep cycles.

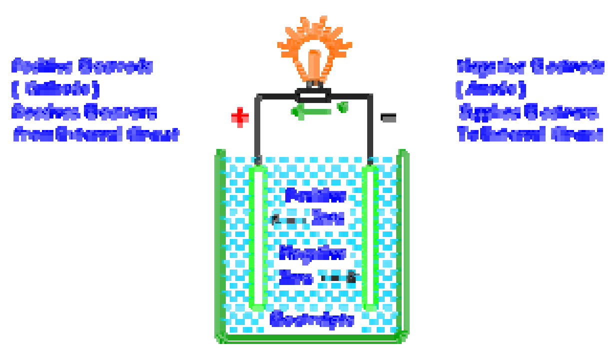
Basic Battery Theory

A battery is a device that converts chemical energy into electrical energy. A battery stores DC voltage and releases it when it is connected to a circuit.

The basic building block of a battery is the electrochemical cell. A cell has two types of electrodes or plates: one of the plates has an abundance of electrons (negative plate) and the other has a lack of electrons (positive plate). The negatively charged electrons are attracted to the positive terminal through an external circuit when connected; this results in the flow of electric current. If there is no external circuit, there is no movement of electrons and hence no flow of current, although there is a voltage between the positive and negative plates.

The plates are surrounded by an electrolyte, a chemical solution that reacts with the metals used to construct the plates, and are separated by a membrane called the separator, which electrically isolates the positive and negative electrodes while allowing for the free movement of ions. It is the chemical reactions between the electrolyte and plates that causes a lack of electrons on the positive electrode and an excess of electrons on the negative electrode. When connected to a circuit, the electrons move out of the negative terminal (anode) through the circuit and into the positively charged terminal (cathode), thus neutralizing the positive charge. The chemical reactions continue to provide electrons for current flow until the circuit is opened or the chemicals inside the battery become weak. At the time, either the battery has run out of electrons or all of the protons are matched with an electron. Recharging simply moves the electrons that moved to the positive electrode back to the negative electrode. A battery is made up of individual electrochemical cells.

Exhibit 37 – Battery Cell Schematic



Source: NASA

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Some Basic Battery Metrics To Set The Context

Power and energy: Power and energy are frequently confused. Energy is the capacity to do work and is measured in joules. One joule is equal to 1 watt-second and 1kWh is equal to 3.6 megajoules. Power is the rate at which energy is used or generated and is measured in watts. One watt of power is one joule of energy per second. In an electrical circuit, power is expressed as voltage (measured in volts) multiplied by current (measured in amperes).

Open circuit voltage: This is the voltage or potential difference measured across the battery terminals when there is no load on the battery.

Ampere-hour rating: This is a commonly used capacity rating defined as the amount of steady current that a fully charged battery can supply for 20 hours at 80°F without the cell's voltage dropping below a predetermined threshold. For example, if a 12V battery can be discharged for 20 hours at a rate of 4.0A before its voltage drops to 10.5V, it would be rated at 80 ampere-hours or 80AH. A 100AH battery would provide 1A for 100 hours or 10A for 10 hours.

Watt-hour rating: This rating is determined at 0°F because the battery's capacity changes with temperature and is calculated as the product of the battery's ampere-hour rating and voltage. Thus, if a battery can deliver 5AH at 200V, it would be rated at 1kWh.

Cold cranking amps: The cold cranking amps (CCA) rating is the most common method of rating automotive starting batteries. It is determined by the load, in amperes, that a battery is able to deliver for 30 seconds at 0°F without its voltage dropping below a predetermined level. For a 12V battery, that level is set at 7.2V. The normal range for a passenger car and light truck batteries is 300-600CCA, although some batteries have ratings as high as 1100CCA.

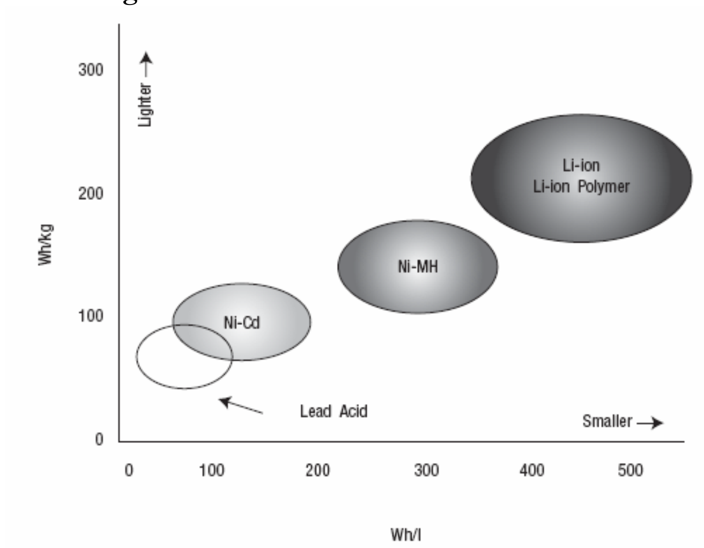
Cranking amps: The cranking amps (CA) rating is similar to CCA and is a measured at 32°F rather than at 0°F. This rating is commonly used in climates that are not subject to extremely cold weather. Typically, the CCA rating of a battery is about 20% less than its CA rating.

Reserve capacity: The reserve capacity (RC) rating is determined by the length of time, in minutes, that a fully charged starting battery at 80°F can be discharged at 25A before voltage drops below 10.5V. This rating gives an indication of how long the vehicle can be driven with the headlights on, if the charging system fails. A battery with a RC of 120 would be able to deliver 25A for 120 minutes before its voltage drops below 10.5V.

Energy density: This measures the energy storage capability of a battery and can be expressed relative to the mass of the battery in watt-hours per kilogram or Wh/kg (specific energy density) or relative to the battery's volume in watt-hours per liter or Wh/l. Thus, the energy density determines how far a vehicle can travel before the battery is fully discharged.

Power density: This measures how rapidly power can be drawn from the battery and, therefore, the maximum current that can be supplied to the electric motor to accelerate the vehicle. Power density is measured in watts per kilogram or W/kg. Note that high power density reduces available energy density significantly in most battery types and, therefore, reduces vehicle range. **As a result, EVs or BEVs are fitted with high energy density batteries to maximize range, while HEVs are fitted with high power density batteries that can discharge and recharge rapidly to provide quick power bursts to assist the ICE.**

Exhibit 38 – Comparison Of Energy Density Of Rechargeable Battery Technologies



Source: National Institute of Standards and Technology

Exhibit 39 – Battery Technology "Cheat Sheet"

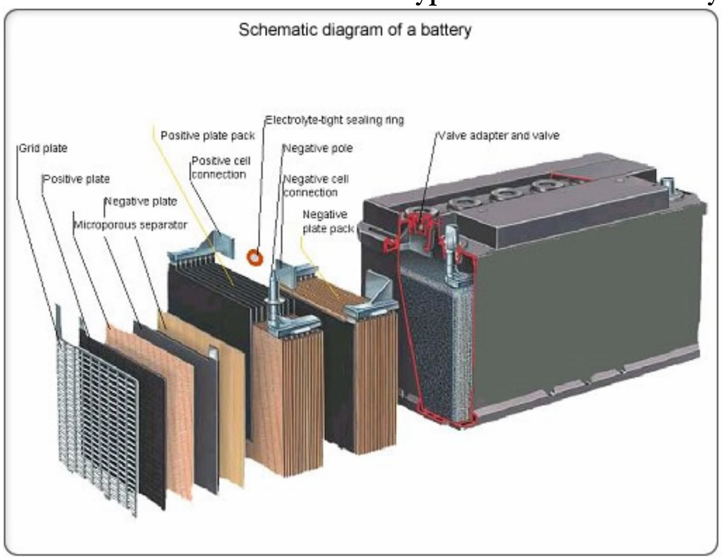
Battery Type	Anode Material	Cathode Material	Electrolyte Composition	Open-Circuit Voltage	Max. energy density (Wh/kg)	Max. power density (W/kg)	Charging time (full)	Operating Temp	80% discharge cycles before replacement	Self Discharge Per Month	Commercial Status	Applications
Lead acid	PbO_2	Pb	H_2SO_4	2.1	35	150	-	Ambient	1,000	3%-4%	Globally commercial Over $40bn in all applications	Transportation, motive power, deep cycling stationary applications, back-up power, short-duration power quality and peak reduction
Advanced lead acid	PbO_2	Pb	H_2SO_4	2.1	45	250	-	Ambient	1,500	-		
VRLA	PbO_2	Pb	H_2SO_4	2.1	50	150+	8.0 hr	Ambient	700+	-		
NiCd	Ni	Cd	KOH	1.2	50	200	-	Ambient	2,000	20%	Globally commercial Over $1bn in all applications	Aerospace, utility grid support, stationary rail, telecom back-up, low-end consumer goods
NiMH	Ni	Metal hydride	KOH	1.23	70-80	200	1.5 hr	Ambient	2,000+	30%	Globally commercial for small electronics, emerging market for larger applications	EVs, HEVs, small low-current consumer goods
Sodium Sulphur	S	Na	βAl_2O_3	2.1	110	150	-	350°C	1,000	-	Recently commercial (2002) in Japan. Estimated $0.4bn in industrial/utility applications	Utility grid-integrated renewable generation support, utility T&D system optimization, C&I peak shaving and back-up
Sodium Nickel Chloride	NiCl	Na	βAl_2O_3	2.1-2.2	100	150	-	300°C	700+	0%	Globally commercial for traction applications	EVs, HEVs, locomotives, peak shaving
Lithium polymer	Li	V_6O_{13}+ acetylene black	$(PEO^*)_{12}$ $LiClO_4$	2.0-2.5	150-200	350	-	80-120°C	1,000	10%		Back-up power, EVs, HEVs, mobile phones
Lithium ion	Carbon intercalation	Varies	Organic	3.6	120-150	120-150	6.0 hr	Ambient	1,000	10%	50% of global small portable market	EVs, HEVs, small consumer goods
Aluminum air	Al	O_2	KOH	1.5	220	30	-	Ambient	-	-		EVs, HEVs, back-up power, military
Zinc air	Zn	O_2	KOH	1.65	200	80-140	-	Ambient	200	-		

Source: The Electric Car; Development and future of battery, hybrid and fuel-cell cars by Michael H. Westbrook, BatteryUniversity.com, Sandia National Laboratories and Thomas Weisel Partners LLC

Lead Acid Batteries – The Dominant And Cost-Effective Technology For Conventional Vehicles, Capable Of Meeting Energy Needs Of Mild Hybrids Today; Potential To Address Full Hybrids Market

The lead acid battery has been around for 150 years and is the most commonly used energy storage devices for electrical traction applications. The lead acid battery, a low-cost version of which is used as the starter battery in ICE powered vehicles, uses lead and lead oxide paste plates with a dilute sulphuric acid electrolyte.

Exhibit 40 – Construction Of A Typical Lead Acid Battery



Source: Eurobat.org

A lead acid battery consists of grids, positive and negative plates, separators, elements, an electrolyte, a container, cell covers, vent plugs and cell containers. The grids form the basic framework of the battery plates and are the lead alloy framework that supports the active material of the plate. Plates are typically flat, rectangular components that are either positive or negative, depending on the active material they hold. **The positive plate has a grid filled with lead peroxide as its active material while the negative plate has sponge lead deposited on the grid.** Both plates are very porous and allow the liquid electrolyte to penetrate freely.

Each battery contains a number of elements, which are groups of positive and negative plates. The plates are formed into a plate group, which holds a number of plates of the same charge. The like charged plates are welded to a lead alloy post or strap. The plate groups are then alternated within the battery with separators inserted between them to prevent them from touching each other. Separators are porous plastic, electrically insulating sheets that allow for transfer of ions between plates.

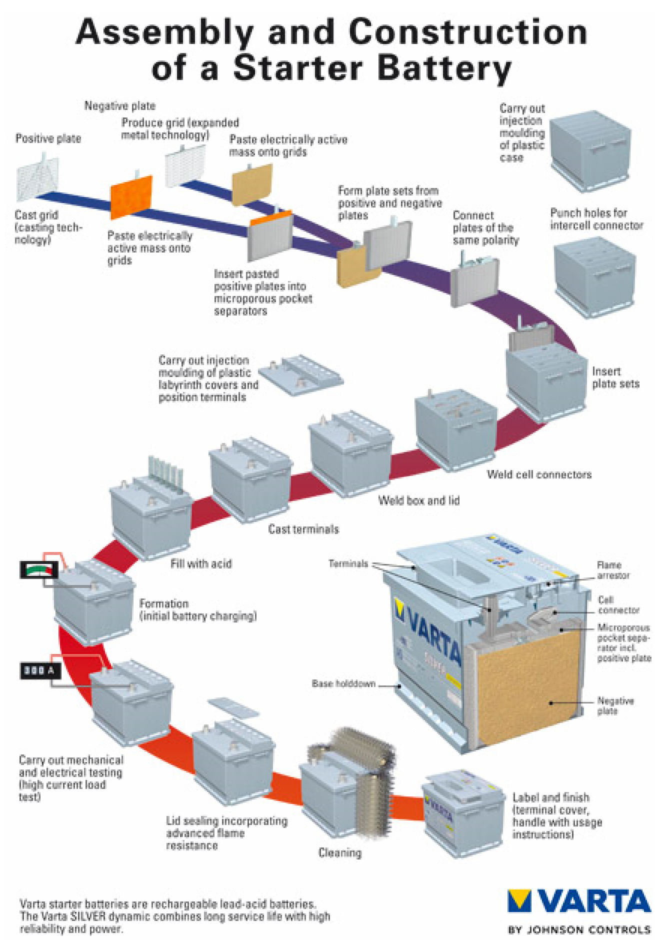
When the element is placed inside the battery case and immersed in electrolyte, it becomes a cell. A 12V battery has six cells connected in series, each of which has an open circuit voltage of 2.1V.

The electrolyte is 65% water and 35% sulphuric acid. The sulphuric acid supplies sulfate, which chemically reacts with the lead and the lead peroxide to release electrical energy and serves as the carrier for the electrons as they travel inside the battery. Available voltage decreases when the percentage of acid in the electrolyte decreases.

The container or shell of the battery is usually a one-piece molded assembly of polypropylene, hard rubber or plastic. The case has a number of individual cell compartments. Cell connectors are used to join all cells of a battery in series. The top of the battery is encased by a cell cover that must have vent holes to allow hydrogen and oxygen gases formed during charging and discharging to escape.

Conventional lead acid batteries with lead antimony grids suffer from gassing (i.e., the release of hydrogen and oxygen during charging and discharging). Therefore, an unsealed battery gradually loses water due to its conversion into hydrogen and oxygen, which escape into the atmosphere through the vent caps. If the water is not replaced, the level of the electrolyte falls below the top of the plates, resulting in a high concentration of sulphuric acid and potential permanent failure due to drying and hardening of the exposed material. Electrolyte level in the battery, thus, must be frequently checked.

Exhibit 41 – Lead Acid Battery Construction Steps



Source: Johnson Controls, Inc.

Lead Acid Battery Designs

A lead acid battery can be designed as a starting battery or a deep-cycle battery. A deep-cycle battery has thicker and fewer plates than a starting battery. The exact chemical composition of lead acid batteries also depends on the designed purpose of the battery. However, all lead acid batteries are based on the reaction of lead and acid.

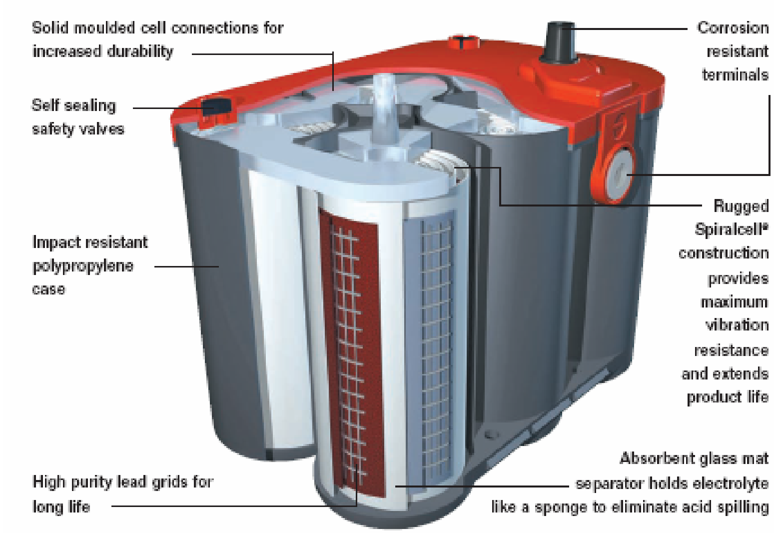
Maintenance-free and low-maintenance batteries: The majority of batteries installed in vehicles today are either low-maintenance or maintenance-free batteries. A low-maintenance battery is a heavy-duty version of a normal lead acid battery. Many of the components are of thicker construction and more durable. It comes with vent holes and caps, which allow water to be added to the cells, although it will require additional water much less often than a conventional lead acid battery. Low-maintenance batteries tackle the gassing problem by using calcium in the plate grid alloy and decreasing the amount of antimony. A maintenance-free battery experiences little gassing during charge and discharge cycles. Therefore, it does not come with external holes or caps, but small gas vents are provided to prevent gas pressure buildup inside the case. Water never needs to be added to maintenance-free batteries.

Valve regulated lead acid (VRLA): The flooded lead acid batteries described previously are vented so that any gases generated above the liquid electrolyte are released into the atmosphere. This design has two major disadvantages: (1) these batteries require periodic maintenance to replace lost water and (2) they can be operated only in an upright position. The VRLA battery overcomes these problems. The two major types of VRLA batteries are as follows:

- **Absorbed glass mat (AGM) batteries:** An AGM battery is a sealed valve regulated lead acid battery design with an absorbent glass microfiber separator between the battery plates. The electrolyte is absorbed into this material. The separator is 90-95% saturated with the electrolyte, so there are pockets where gas can reside in the separator material. These pockets allow liberated oxygen gas to travel from the positive plate to recombine with the negative plate, thus, preventing excessive gas pressure buildup in the battery case. Because oxygen gas recombines during battery cycling, AGM batteries are known as recombinant batteries. Since an AGM does not lose electrolyte due to gassing, it does not require periodic addition of distilled water to the cells. Also the absorbent material used between the plates retains the electrolyte and makes the battery leak resistant and spill proof. This allows AGM batteries to be used in many different positions, making them much better suited for portable applications. AGM batteries are often used in applications where the auxiliary battery is located in the passenger compartment.

  AGM batteries are constructed with either flat plates as in conventional flooded lead acid batteries or with cylindrical cells. The plates are built on grids made of a lead-tin calcium alloy, with porous lead dioxide as the active material pasted on the positive plates and sponge leads on the negative plates. The battery comes with a one-way valve that will release excess gas pressure and prevent bursting of the case if the battery is overcharged.

Exhibit 42 – Absorbed Glass Mat Battery



Source: Johnson Controls, Inc.

- **Gel batteries:** Gelled electrolyte batteries, also known as gel batteries, are a type of VRLA battery that has silica added to the electrolyte. The silica causes the electrolyte to become a gel, making the battery leak proof and spill proof when housed in a sealed case. The gel battery uses a recombinant process and is built similar to an AGM battery. The primary difference is in the plate separator and how the electrolyte is immobilized. While the gel battery is less efficient than an AGM battery, one area in which it excels is in high temperature operation. Because the gelled electrolyte makes good contact with the battery case, it is able to reject heat better and therefore handle higher heat conditions.

The following exhibit is a summary of the main advantages and disadvantages of lead acid batteries.

Exhibit 43 – Lead Acid Batteries Pros and Cons

Advantages	*Disadvantages*
- Inexpensive and simple to manufacture - Mature, reliable and well understood - Low self discharge rate, among the lowest in rechargeable battery systems - Low maintenance requirements - Good power density, capable of high discharge rates for quick power burst	- Low energy density limits applications to vehicle starting applications and micro hybrids - Deep discharge shortens battery life considerably - Lead and electrolyte are environmentally unfriendly - Performance impacted at low temperatures below 10°C requiring auxiliary battery heating and insulation - Cannot be stored in a discharged condition - Restrictions on transportation and storage

Source: Thomas Weisel Partners LLC

Exhibit 44 – Lead Acid Battery Manufacturers

Lead Acid Battery Manufacturers

	Transportation	***Motive Power***	***Network Power***
BAE			X
C&D Technologies		X	X
Crown Battery	X	X	X
East Penn Manufacturing	X	X	X
EnerSys		X	X
Exide	X	X	X
Fiamm Group	X	X	X
GS/Yuasa	X	X	X
Hoppecke	X	X	X
Johnson Controls	X		
MIDAC	X	X	X
Ritar Power	X	X	X
Shinkobe	X		X

Source: Thomas Weisel Partners LLC

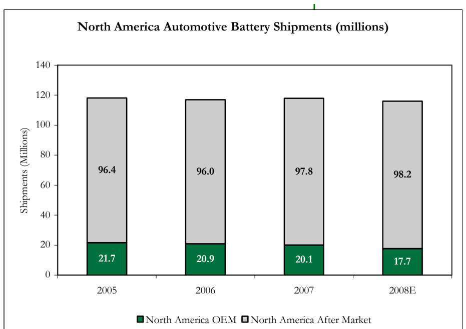
Although lead acid batteries do not currently meet the energy density requirements for full hybrid vehicles, sufficient advancements have been made to make them the ideal solution for micro/mild hybrid electric vehicles today. Until the cost of advanced battery chemistries comes down, we see the micro/mild hybrid sub-segment as best positioned near term in the HEV market as a more affordable alternative solution to conventional vehicles versus full hybrids. However, we also note that large incumbent lead acid producers, such as Exide, are devoting significant R&D budgets to further the lead acid chemistry, making them capable of competing with the current nickel metal hydride technology that powers most of today's full hybrids like the Toyota Prius.

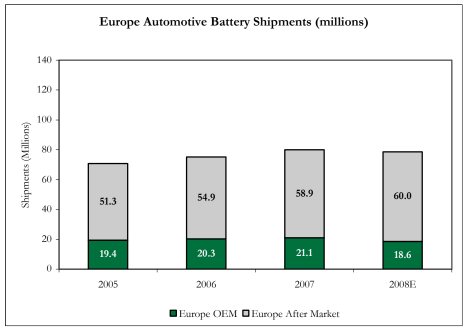
Lead Acid Automotive Battery Market Characteristics

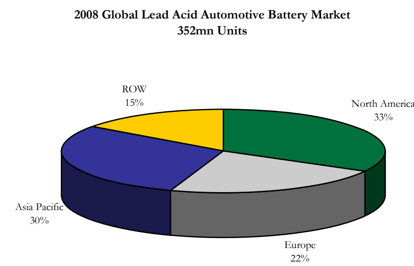
As seen in the following exhibit, lead acid battery shipments are driven primarily by the after market (i.e., replacement channel rather than the auto OEM channel). This is because the typical life of a lead acid battery is 3-5 years. We also note that demand in the after market channel tends to be inelastic, as battery replacement is not a discretionary purchase item such as a new vehicle.

In the near term, we believe that the grim economic backdrop will drive low-single-digit volume growth in the United States and Europe and will moderate growth expectations in Asia Pacific. However, we believe emerging markets like China and India will continue to grow at rates of 5-7%, driven by a burgeoning middle class.

Exhibit 45 – Lead Acid Automotive Battery Key End Markets







Source: Company reports, EUROBAT and Thomas Weisel Partners LLC estimates

Nickel Cadmium Batteries – Toxicity Of Cadmium, Memory Effect And Low Energy Density Hinder Applicability To Vehicles

The NiCd battery was invented at the turn of the nineteenth century. The materials used were expensive compared to other battery types available at the time, and its use was limited to special applications. It was not until 1947 that the modern sealed version of the NiCd battery became available. The NiCd design is also known as **alkaline** battery because of the alkaline nature of its electrolyte.

The NiCd battery uses a positive electrode of nickel hydroxide and a negative electrode of metallic cadmium metal commonly divided by a highly porous nylon separator. The electrolyte is aqueous potassium hydroxide. Typical voltage of a NiCd cell is 1.2V. During discharge, nickel oxyhydroxide combines with water to produce nickel hydroxide and a hydroxide ion, and cadmium hydroxide is produced at the negative electrode. When the cell is recharged, the chemical reactions are reversed, restoring the battery to its original state. During charging, some oxygen is formed at the positive electrode and some hydrogen at the negative electrode, requiring some venting, but far less than a lead acid battery.

NiCd batteries suffer from the **"memory effect,"** which occurs when a battery is not fully discharged and then recharged. If the battery is consistently being recharged after it is only partially discharged, at say 50%, the battery will eventually accept and hold only a 50% charge.

Because of their high charge and discharge rates, NiCd batteries have been of some interest to electric vehicle developers. However, their low energy density, memory effect and toxicity of Cadmium make them a far from ideal choice for electric vehicles. NiCd though remains a popular choice for applications such as two-way radios, emergency medical equipment, professional video cameras and power tools because of their high reliability, low price, long life and low maintenance.

Exhibit 46 – NiCd Pros And Cons

Advantages	*Disadvantages*
- Low manufacturing cost - Mature, reliable and well understood - Good low temperature performance - Long shelf life and cycle life - Low maintenance requirements - Capable of taking high charge and discharge rates	- Relatively low energy density vs. newer techologies - Memory effect necessitates periodic full discharge - Cd is environmentally unfriendly - Relatively high self discharge, needs to be recharged after storage

Source: BatteryUniversity.com and Thomas Weisel Partners LLC

Nickel Metal Hydride Batteries – The Predominant Choice For HEVs Today

Another alkaline battery design is the NiMH battery. The NiMH battery is very similar in construction to a NiCd battery in that it uses nickel hydroxide for the positive electrode and potassium hydroxide for the electrolyte. The big difference is in the materials used for the negative electrodes, which is a hydrogen storage alloy also known as a metal hydride. Much of the research being done in NiMH batteries relates to design and materials for the negative electrode. The most commonly used hydrogen-absorbing alloys used are compounds of titanium, vanadium, zirconium, nickel, cobalt, manganese and aluminum. An alloy formed by the combination of two or three of these metals has the ability to absorb and store hydrogen. The amount of hydrogen that can be stored is many times greater than the actual volume of the alloy.

During battery charging, hydrogen ions travel from the positive to the negative electrode where they are absorbed into the metal hydride material. The electrolyte does not participate in the reaction and acts only as a conduit for the hydrogen ions to travel through. When the battery is discharged, the process is reversed, with the hydrogen ions traveling from the negative to the positive electrode. The density of the electrodes changes somewhat during the charge-discharge process, but this is kept to a minimum as only protons are exchanged during battery cycling. Due to minimal density changes, electrode stability is one of the reasons why the NiMH battery has a very good cycle life.

The nominal voltage of a NiMH cell is similar to a NiCd cell at 1.2V.

NiMH Battery Cell Designs

NiMH batteries come in **cylindrical** and **prismatic** designs. The **cylindrical** type has the cell's active materials made in long ribbons and arranged in a spiral fashion inside a steel cylinder. The negative electrode is wound in parallel with the positive electrode, and the separator material holding the electrolyte is placed between them. The negative electrode is connected to the battery steel case, while the positive electrode is attached to the positive terminal at the top of the battery.

Cylindrical cells are often connected in a series of six to form a battery module with 7.2V output. Groups of these modules can be connected in a series to form a high voltage battery pack for electric vehicles.

The **prismatic** type is a box-like design with the active materials formed into rectangular flat plates like lead acid batteries. The positive and negative electrodes are placed alternately in the battery case with tabs used to connect the plate groups. Separator material is placed between the plates to prevent them from touching while allowing electrolyte to flow freely.

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The prismatic design requires less storage space, provides a more flexible form factor, possesses superior heat dissipation, and enables more reliable cell interconnects. Prismatic cells have no venting system and are susceptible to "bulging" due to pressure buildup, which can cause cell failure; as a result, they require heavier gauge metal and stronger welding.

Cooling

As high temperatures can lower performance and cause damage to NiMH batteries, all current production HEVs use air cooling to control HV battery pack temperature. Cabin or fresh air is circulated over the battery cells using an electric fan and ducting inside the vehicle.

State-Of-Charge (SOC) Management

The battery can overheat if its SOC rises above 80% or if the battery is placed under a load when its SOC is below 20%. In order to prevent overheating and maximize service life, the battery's SOC must be carefully managed.

One Company, Ovonic Battery Company, Owns Global Rights To The Technology

The **Ovonic Battery Company** (a subsidiary of **Energy Conversion Devices, Inc.**) has been the major supplier of NiMH battery technology and has developed particular expertise in its application to electric vehicles as a result of being awarded a major contract by the U.S. Advanced Battery Consortium in 1992. The company has since licensed the proprietary materials and technology for NiMH batteries to all significant NiMH battery manufacturers throughout the world.

In 2001, **ECD Ovonics** established a 50:50 joint venture with Chevron, **Cobasys LLC**, for the continued development and commercialization of its proprietary technology and has since expanded the scope of its licenses granted to Cobasys to prismatic NiMH batteries.

Cobasys develops fully integrated battery packs with plug and play adaptability for electric vehicles. Cobasys battery systems are used in **GM's** Saturn VUE Green Line SUV. The company also develops integrated solutions for all electric vehicles and stationary applications.

Exhibit 47 – NiMH Pros And Cons

Advantages	*Disadvantages*
- 30%-40% higher capacity over standard NiCd - Less prone to memory effect than NiCd - Environmentally friendly - Durable as electrolyte does not react with active materials - Simple storage and transportation, not subject to regulatory control	- High rate of self-discharge especially at high temperatures, about 50% higher than NiCd - High cost vs. lead acid and NiCd - Limited service life if repeatedly deep cycled - More complex charge algorithm needed as NiMH generates more heat during charge and requires longer charge time than NiCd. - Requires full discharge to prevent crystalline formation

Source: BatteryUniversity.com and Thomas Weisel Partners LLC

Very Few NiMH Battery Producers Today; Sanyo And Panasonic Merger Would Distort Competition Further

Automakers are reticent to disclose their major battery suppliers, but it is apparent that there are a very limited number of major NiMH battery suppliers as compared to lead acid. This number is set to go down even further with the ongoing merger discussions between Panasonic and Sanyo. **We believe that should Panasonic's acquisition of Sanyo go ahead as planned, the new entity would control over 90% of global NiMH production and a considerable share of lithium ion battery production.**

Exhibit 48 – Major Automotive NiMH Battery Producers

Automotive NiMH Battery Manufacturers

Manufacturers	Comments
Panasonic EV (Toyota and Matsushita JV)	- Key supplier for Toyota hybrids, legacy supplier Honda Civic and Insight Subsequently announced plans to build new 300,000 NiMH unit faciility by 2011 and a Li ion facility by 2010
Cobasys (JV between Ovonic and Chevron)	- Key supplier for GM's Saturn VUE Green Line SUV
Sanyo Energy	- Supplier for Ford Escape hybrid, key supplier to Honda
Johnson Controls	- JCI has been developing NiMH batteries for over 15 years, products are in use in vehicles all over the world

Source: Thomas Weisel Partners LLC

Lithium Ion Batteries – The Most Promising Technology For Electric Vehicles Today; Very Little Commercial Production For Vehicles Currently, But Majority Of Auto OEMs Testing The Technology

The most promising battery technology for electric vehicles today is the Li ion battery, which has excellent open circuit voltage (3.6V) and energy density that is twice as high as that of NiCd. In addition, Li ion batteries do not suffer from the memory effect and are environmentally friendlier. The promise of Li ion is evidenced by the number of automakers announcing joint development and manufacturing ventures with established Li ion players (see Exhibit 53).

Li ion batteries evolved from non-rechargeable lithium batteries such as those used in watches and hearing aids. The first rechargeable lithium batteries used lithium metal for the negative electrode and an intercalation compound with a lattice structure to absorb lithium ions as the positive electrode. Because lithium is the lightest metal and provides the highest energy density of all metals, it is very well suited to energy storage; however, lithium is also a very unstable metal that oxidizes very rapidly in air and water and, therefore, is highly flammable and slightly explosive. Lithium metal is also very corrosive. With this design, during recharging, the metallic lithium can reform unevenly at the negative electrode, forming spiky structures called "dendrites" that are unstable and reactive, and can pierce the separator, causing an explosion.

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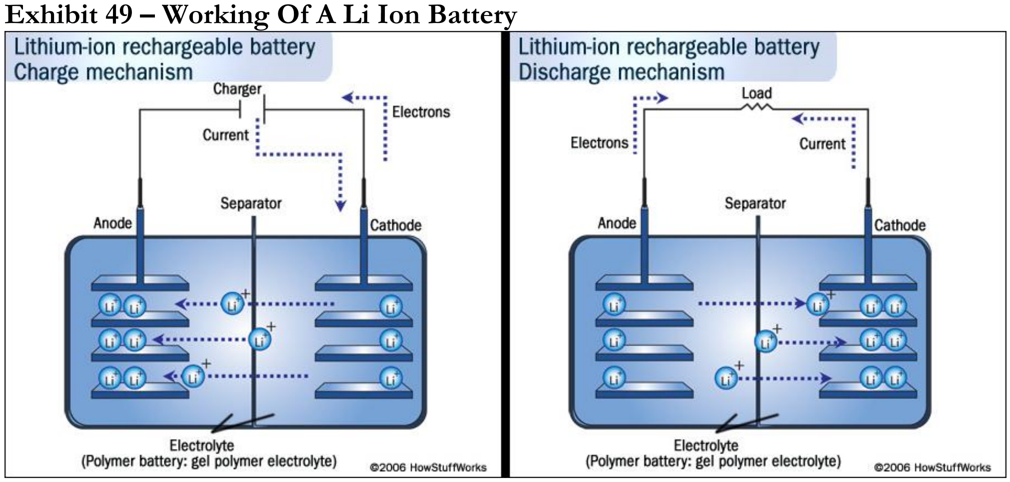
As a result, research shifted to a non-metallic lithium battery using lithium ions. Although slightly lower in energy density than lithium metal, the Li ion battery is safe, provided certain precautions are taken during charging and discharging. In 1991, Sony commercialized the first Li ion battery. Today, the Li ion battery is the fastest growing technology in everyday commercial products, accounting for 70% of the $7 billion market for portable rechargeable batteries, and is the most promising for electric vehicles.

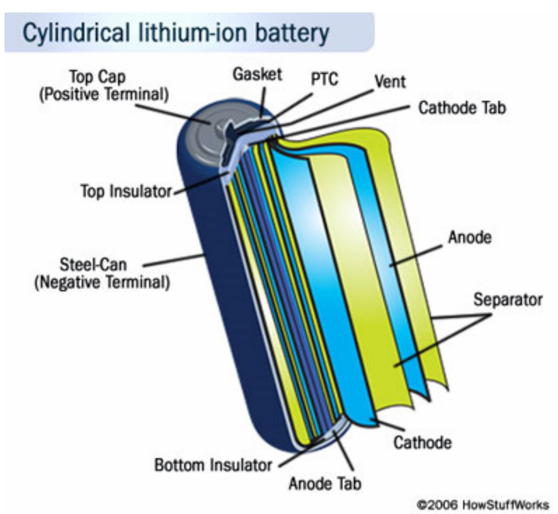
The negative electrode is made of graphite, a form of carbon, and the positive electrode is mostly composed of graphite and a lithium alloy oxide. The electrolyte is made from a lithium salt in an organic solvent. Porous polyethylene membranes are used to separate the plates to allow the flow of ions while blocking the flow of electrons. When the battery charges, lithium ions move through the electrolyte from the positive to the negative electrode and attach to the carbon. During discharge, the lithium ions move back to the lithium alloy oxide.

Exhibit 49 – Working Of A Li Ion Battery



Source: HowStuffWorks.com

Exhibit 50 – Construction Of A Cylindrical Li Ion Battery



Source: HowStuffWorks.com

Exhibit 51 – Li Ion Pros And Cons

Advantages	*Disadvantages*
- High energy density, as much as 2x NiCd	- Safety and stability
- High open circuity voltage of 3.6V means fewer cells to be interconnected for a HV battery system	- Requires complex battery monitoring system to control charging and discharging
- Low self discharge rate, less than half that of NiCd and NiMH	- Expensive to manufacture
- No memory effect	- Subject to aging, even if not in use
- Low maintenance	

Source: BatteryUniversity.com and Thomas Weisel Partners LLC

To develop a high energy density and safe battery, both the cathode materials as well as the electrolyte have been areas of intense research over the past several years. The batteries commonly used in today's mobile phones and laptops still use cobalt dioxide as the positive electrode. But because cobalt oxide is more costly and reactive, it is inappropriate for electric vehicle use. A summary of primary Li ion chemistries follows:

- **Nickel-cobalt-manganese:** NCM Li ion batteries are somewhat easier to make than cobalt dioxide. Substituting nickel and manganese for some of the cobalt raises the electrical potential only slightly, but it is enough to tune the cell either for higher power or energy density. It is less susceptible to thermal runaway than cobalt dioxide. Its long-term durability is still unclear. Manufacturers include **Hitachi, Panasonic** and **Sanyo**.
- **Nickel-cobalt-aluminum:** NCA is similar to NCM with cheaper aluminum replacing the manganese. Companies manufacturing NCA cells include **Toyota** and **Johnson Controls-Saft**, the joint venture between **Johnson Controls** and **Saft**.
- **Manganese oxide spinel:** LMO offers higher power at a lower cost than cobalt because its three-dimensional crystalline structure provides more surface area, permitting more ion flow between the electrodes. According to Ener1, manganese spinel powder costs about 25% less than lithium iron phosphate, 50% less than lithium nickel cobalt oxide, and 67% less than lithium cobalt oxide. LMO also offers better stability but worse energy density. **GS Yuasa, LG Chem** through its **Compact Power International** subsidiary, **NEC-Lamilion Energy** and **Samsung** offer cells with LMO cathodes.
- **Lithium titanate:** These batteries use manganese cathodes like LMO, but instead of using graphite, they use titanate anodes. These batteries deliver higher power, excellent stability, longevity and low temperature performance, but slightly lower energy density than LMO. LTO batteries also are more cost effective, avoiding the use of more expensive Nickel or Cobalt. Companies commercializing LTO/LMO technology include **Altair Nano, Ener 1** and **Toshiba**.
- **Iron phosphate:** LFP cathodes appear to solve many of the stability and safety problems associated with cobalt dioxide and manganese spinel batteries. The compound is inexpensive, and because the bonds between the iron, phosphate and oxygen atoms are far stronger than those between cobalt and oxygen atoms, the oxygen is much harder to detach when overcharged. Therefore when it fails, it does so without overheating. However, iron phosphate does not conduct well; thus, engineers have to add dopants to compensate. Even so, the cells work at lower voltages than cobalt, so more cells need to be interconnected for a

given voltage, which increases interconnection and battery monitoring requirements. One way to work around this is the use of nanostructures, which effectively increases the active surface area of the electrode so more ions can travel. Companies that have commercialized iron phosphate technology for automotive applications include **A123** and **Valence**.

Exhibit 52 – United States Advanced Battery Consortium (USABC) Classifications For HEV Chemistry

Cathode Group	Group A (Nickel base)	Group B (Iron Base)	Group C (Mn base)	Group C-1 (Mn Base) -Gen 1	Group C-2 (Mn Base) -Gen 2
Cathode	LiNiCoxO	$LiFePO_4$	$LiMn_2O_4$	$LiMn_2O_4$	$LiMn_2O_4$
Anode	Graphite	Graphite	Graphite	Hard Carbon	LTO
Advantages	Capacity	Safety Cost	Cost Power	Power Longevity Low Temp Safety	Power Longevity Low Temp Safety
Disadvantages	Safety Price Cold Temp	High Temp Volatge Cold Temp	High Temp Longevity Cold Temp	Energy Efficiency	Lower Energy Density
Manufacturers	Hitachi JCI/Saft Panasonic EV Sanyo	A123 BYD Valence	GS Yuasa LG Chemicals NEC-Lamilion Samsung	Ener1	Altair Nano Ener1 Toshiba

Source: Ener1, Inc.

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Exhibit 53 – Primary Li Ion Battery Suppliers And Customers

Supplier	Chemistry	Company Location	Factory Location	Customers	Comments
A123	Lithium Iron Phosphate	USA	China	Think Global, BAE	One of three battery options in the Think City model. Think, however, has temporarily halted production while it seeks additional capital to fund working capital A123 batteries were tested for GM's Chevy Volt, but GM decided to go with LG Chem for cells. Also working with BAE Systems on hybrid drivetrains for heavy duty vehicles.
AESC	Lithium Manganese	Japan	Japan	Nissan, Subaru	JV between NEC and Nissan. Initial output from plant set at 13,000 units when plant opens in Spring 2009 with capacity increasing to 65,000 units by 2010. In addition the companies plan to invest an additional 100bn Yen to build another plant in 2011 or later to support production of 200,000 units for HEVs and Evs.
Altair Nano	Lithium Titanate, Lithium Manganese	USA	China	Phoenix Motorcars, ISE	Shipped battery packs to Phoenix Motorcars primarily for demonstration vehicles Also shipped to ISE for integration into heavy duty hybrid vehicle drivetrains
BYD	Lithium Iron Phosphate	China	China	BYD	BYD, a Chinese Li ion battery producer, has built the first Chinese HEV, with plans to introduce the car to the U.S. in 2011. Warren Buffett's Berkshire Hathaway, through its MidAmerican Energy Holdings subsidiary, has agreed to purchase a 10% stake in BYD for $230mn.
Electrovaya	Lithium Polymer	Canada	Canada	Phoenix Motorcars, Tata Motors/Miljo Grenland	Begun work on battery pack design and production program for Phoenix Motorcars all-electric SUVs and SUTs. Licensed battery technology to Tata Motors subsidiary Miljo for four-door electric vehicles
Ener1	Lithium Titanate, Lithium Manganese	USA	USA	Think Global	$70mn contract with Think, one of three battery options in the Think City model. Think has, however, temporarily halted production while it seeks additional capital to fund working capital.
Evonik/Li-Tec		Germany	Germany	Daimler	Daimler and Evonik have established a JV for the development and production of Li ion batteries. As part of the agreement, Daimler also takes over a 49.9% stake in Evonik's Li-Tec subsidiary. The capacity avilable at Li-Tec and the JV will initially concentrate on Daimler's needs. Beyond that, the sale of cells and battery systems to third parties is planned.
GS Yuasa		Japan	Japan	Mitsubishi, Honda	GS Yuasa and Mitsubishi set up a JV in 2007 to produce batteries for the iMiEV Honda announced in December 2008 it has agreed to set up a Li ion JV with GS Yuasa with plans to equip its hybrid vehicles with batteries from the factory from 2012.
Hitachi	Li Thionyl Chloride, Lithium Manganese	Japan	Japan	GM	Hitachi's Li ion batteries to be installed annually in more than 100,000 GM HEVs, scheduled to launch in North America in 2010.
Johnson Controls-Saft	Lithium Nickel Cobalt Aluminum	USA/France	France	BMW, Daimler, Ford, GM, Azure Dynamics	Selected by Ford for first series production PHEV to be introduced in 2012 and for initial 20 vehicle rollout of Ford Escape PHEV by end of 2009. Also selected by Daimler for Mercedes S Class 400 hybrid and by BMW for 7 Series Active Hybrid car. Signed 5-year agreement to supply Li ion batteries to Azure Dynamics for commercial vehicles in North America. Also has contracts with Chrysler for Dodge Sprinter PHEV test fleet and with GM to design and test Li ion batteries for Saturn VUE Green Line plug-in hybrid SUV.
LG Chem	Lithium Manganese	Korea	Korea	GM	LG Chem will supply the cells to GM for its Chevy Volt from 2010-2015. GM will assemble battery packs from the cells in-house at a new facility. LG Chem subsidiary Compact Power will provide assembled battery packs for prototype Volts until the GM battery plant is up.
Panasonic EV	Lithium Nickel Cobalt Oxide	Japan	Japan	Toyota	JV between Panasonic and Toyota, primary NiMH supplier for Toyota hybrids. Plans to build a Li ion battery plant with production starting in 2010 have been announced
Samsung	Lithium Manganese	Korea	Korea	None announced	Samsung and Robert Bosch GmbH announced an agreement to set up a JV to design and produce Li ion batteries for automotive applications, named SB LiMotive Co. Ltd.
Sanyo		Japan	Japan	Volkswagen	Sanyo has agreed on joint Li ion battery development with Volkswagen AG planning to build a factory by 2010 and Volkswagen plans to introduce a car with Li ion batteries the same year
SK Energy	Lithium Polymer	Korea	Korea	None announced	Primarily produces batteries for mobile devices, developing batteries for EV, HEV and PHEV applications.. Formed alliance with Hyundai Motor, LG Chem and SB LiMotive.
Valence Technology	Lithium Iron Phosphate, Lithium Vanadium Phosphate	USA	China	Tanfield Group, Wrightbus, PVI, Brammo, Oxygen	Contract worth up to $70mn with Tanfield Group's Smith Electric Vehicles. Signed $2mn contract with Oxygen for Cargoscooters. Also signed agreements with Brammo for Enertia all-electric motorcycles and PVI for electric buses and trucks

Source: Ener1, Inc. and Thomas Weisel Partners LLC

Thermal Runaway Explained; New Chemistries Improve Stability And Safety Of Lithium Ion Chemistry

Of all the battery chemistries, the lithium ion battery is the most susceptible to a phenomenon known as "thermal runaway," which manifests itself in the form of overheated laptop batteries that have on occasion exploded or caught fire. A one-in-200,000 failure rate triggered the recall of six million Li ion battery packs used in laptops manufactured by **Apple** and **Dell**. Thermal runaway refers to a situation in which an increase in temperature changes the conditions in a way that causes a further increase in temperature, leading to a destructive result.

As explained previously, lithium is an unstable metal that reacts violently when exposed to air or water. For this reason, researchers developed the non-metallic lithium battery using lithium ions. **Sony**, the maker of the lithium ion batteries that caught fire, says that on rare occasion microscopic metallic particles find their way into the cells and may pierce the separator, leading to a short circuit within the cell, causing the cells to expend their electrical energy in the form of heat. Although battery manufacturers strive to minimize the presence of metallic particles, complex assembly techniques make the elimination of all metallic particles impossible. Energy-dense cells with ultra thin separators are more susceptible to impurities.

A mild short will only cause an elevated self-discharge. Little heat is generated because the discharging energy is very low. However, if enough microscopic metal particles converge on one spot, a major short can develop, causing a large current to flow between the positive and negative plates, which in turn causes the temperature to rise. The high heat of the failing cell then propagates to the neighboring cell, causing it to become thermally unstable and triggering a chain thermal reaction that leads to destruction of the battery pack. To increase safety, packs are fitted with dividers to protect the failing cell from spreading to neighboring cells.

Another situation that could lead to thermal runaway is overcharging. Overcharging causes plating of metallic lithium on the anode and the cathode material becomes an oxidizing agent; losing stability and releasing oxygen in an exothermic reaction. If unattended, the cell could vent with flame.

Lithium ion cells with cobalt cathodes, same as the recalled batteries, should never rise above 130°C. At 150°C the cell becomes thermally unstable. By using alternative cathode chemistries such as manganese dioxide spinel and ferrous phosphate and anode materials like lithium titanate as described previously, the thermal stability of lithium ion batteries can be improved.

Thermal Characteristics Of Li Ion Cells Necessitate Use Of Intricate Protection Mechanisms At Battery Pack Level

Due to thermal characteristics of lithium ion cells, battery packs come with multiple levels of safety controls. For example, separators are designed to melt at a certain temperature threshold, thus, shutting their pores to prevent the flow of ions and electrically isolating the bad cell from the rest of the battery pack. In addition, built into each battery pack is a protection circuit that limits the peak voltage of each cell during charge and prevents the cell voltage from dropping too low on discharge. In addition, the maximum charge and discharge current is limited, and cell temperature is monitored to prevent extreme temperatures. When this technology, used in today's laptops, is scaled up to electric vehicle applications, the complexity of the monitoring and control circuitry and software increases exponentially. **It is for this reason that the battery pack assembly and battery monitoring and control systems can account for up to 50% of the cost of a complete battery pack integrated into a vehicle, with the Li ion cells accounting for the remainder of the cost.**

Exhibit 54 – Multiple Levels Of Redundant Safety Measures In A Li Ion Battery Pack

System Software	Systems Hardware	Cell Hardware
Measurement of battery system characteristics - Cell/pack voltage - Temperature - Current - Device feedback - Sensor validity - If fault or failure is detected appropriate control action is taken	**Electronics Hardware** - Over voltage protection - Over temperature - Cell balancing circuitry - Fusing for over current - Contactors - High voltage service disconnect **Mechanical Hardware** - Optimized thermal management - Structural protection	**Key Design Features** - Pressure vent - Current interrupt device - Separator materials - The system structure is also designed to contain any vented materials

Source: Johnson Controls, Inc.

Lithium Polymer Battery; Good Energy Density Characteristics, However, More Expensive To Manufacture And Higher Operating Temperature Requirements

The Li poly battery was developed through continuous research on the Li ion battery. The electrolyte used in Li poly cells is not a liquid; rather, the lithium salt is held in a solid polymer composite such as polyacrylonitrile. The dry polymer design also serves as the separator between the plates. The design offers simplification with respect to fabrication, ruggedness, safety and thin-profile geometry.

The Li poly, however, suffers from poor conductivity due to high resistance of the dry electrode and therefore cannot deliver bursts of current for heavy loads. Heating the cell to 140°F (60°C) or higher increases its efficiency. The voltage of a Li poly cell is 4.23V when fully charged. The cells must be protected from overcharge. However, these cells are more resistant to overcharging than Li ion cells and there is much less chance of electrolyte leakage.

Li poly cells are expensive to manufacture and have a higher cost to energy ratio than Li ion, NiMH and NiCd batteries. Offsetting these disadvantages is the fact that Li poly cells are lighter and can be packaged in many ways because they do not use a metal case.

In some Li poly cells, a gelled electrolyte has been added to enhance ion conductivity; these cells are known as lithium-ion-polymer cells.

Exhibit 55 – Lithium Polymer Pros And Cons

Advantages	***Disadvantages***
- Flexible form factor - manufacturers are not bound by standard cell formats - Light weight - gelled rather than liquid electolytes enable simplified packaging, eliminating the metal shell - Improved safety - more resistant to overcharging than Li ion and less chance of electrolyte leakage	- Lower energy density and decreased cycle count compared to Li ion High temperature design, must be operated - between 176°F and 248°F - Expensive to manufacture, though potential for lower cost once mass produced

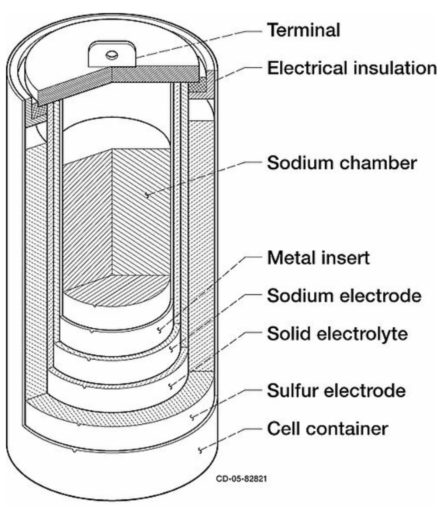
Source: BatteryUniversity.com and Thomas Weisel Partners LLC

Alternative Battery Chemistries; Early Days Yet And There Is Long-Term Promise; However, For Now We See Lead Acid, NiMH And Li Ion Dominating In The Foreseeable Future

Sodium-Sulfur Batteries – High Operating Temperature And Corrosive Nature Of Sodium Lend Technology Inappropriate For Vehicles, Although Well Suited To Large Grid Back-Up Applications

Sodium is an element that shows good promise as a negative electrode material for batteries. Like lithium, sodium has a low atomic mass and can produce relatively high voltage. Sulfur can work well as a positive electrode, and both sodium and sulfur are plentiful and cheap. However, sodium is highly reactive and must be used with a special ceramic electrolyte called beta alumina, which also serves as the separator. The NaS battery has a high energy density, high efficiency of charge/discharge and long cycle life. However, because of the high operating temperature of 350°C and the corrosive nature of the sodium polysulfides, such cells are best suited to large-scale, non-mobile applications such as grid backup. Another drawback of the technology is extreme sensitivity to overcharging, which in combination with the high operating temperature, created engineering problems that led to an extremely complex battery unit.

Exhibit 56 – Sodium Sulfur Battery



Sodium sulfur battery schematic

Source: NASA

Sodium-Nickel-Chloride (ZEBRA) Batteries – "Successor" To NaS Batteries; Being Used In Electric Vehicles Today

The ZEBRA battery is quite similar in construction to the NaS battery. The major difference is that the positive (sulfur) electrode is replaced with one made from nickel chloride or a combination of nickel chloride and ferrous chloride. The battery uses two different types of electrolyte: (1) the beta alumina similar to the NaS design and (2) another layer of electrolyte between the beta alumina and the positive electrode.

The battery operates at a slightly lower temperature (300°C) than NaS, has a similar energy density and the same maximum power density as NaS. If damaged, it is potentially less dangerous than NaS because of the relative harmless nature of the potential nickel chloride-sodium contact. Another advantage is that the cells fail to a short circuit condition rather than open circuit, and this does not cause complete failure of the battery.

ZEBRA batteries today are marketed primarily by **MES-DEA** of Switzerland and are currently in use in electric delivery vans sold by Modec, among others. These vans use 85kWh batteries. ZEBRA batteries are also being offered in the **Think City** electric car. ZEBRA battery packs are found in electric drive systems integrated by **ISE Corp** for heavy-duty vehicles. These drives feature one to three packs that can store 17.8-20kWhr of energy and provide up to 33kW of power.

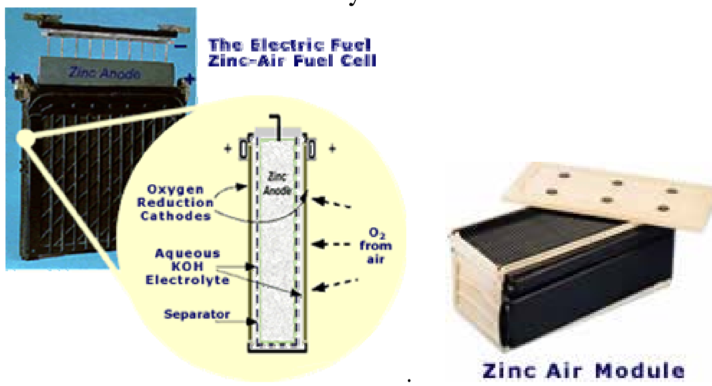
Zinc-Air Batteries – Good Energy Density, But Level Of Infrastructure Required Seems Stumbling Block

The zinc-air cell is commonly used in hearing aids but has been tested and modified for possible use in electric vehicles. The zinc-air design is a mechanically rechargeable battery powered by the oxidation of zinc with oxygen from the air. The design uses a positive electrode of gaseous oxygen and a sacrificial negative electrode made of zinc. The negative electrode is spent during the discharge cycle, and the battery is recharged by replacing the zinc electrodes. The rate at which the air-electrolyte exchange takes place determines the power density. Zinc-air batteries have maximum energy densities as high as 200Wh/kg and specific power of 90W/kg at 80% depth of discharge.

A major disadvantage is that zinc is a solid and cannot be handled and pumped with the convenience of a liquid. In addition, the technology would require a recycling infrastructure to recycle the zinc oxide waste into zinc. Decomposition of the electrolyte takes place upon prolonged exposure to the air and can be severely affected by varying humidity and carbon dioxide content. This makes it essential for the battery to be sealed against air ingress when in storage. It also makes it essential that in use the air is filtered, humidity controlled and the carbon dioxide content reduced by scrubbing.

The technology has been tested on all-electric heavy-duty buses and commercial vehicles in the U.S. and Germany in the past under public funding programs, which have since been discontinued. Though the technology is promising in terms of energy density for electric vehicles, we have not seen too many new developments in the field to suggest efforts to further the technology for transportation applications.

Exhibit 57 – Zinc Air Battery Cell And Module



Source: Electric Fuel Corp.

Ultracapacitors – Traditionally Used For Power Bursts, Technology Advances Are Bridging The Gap Between Power And Energy Density

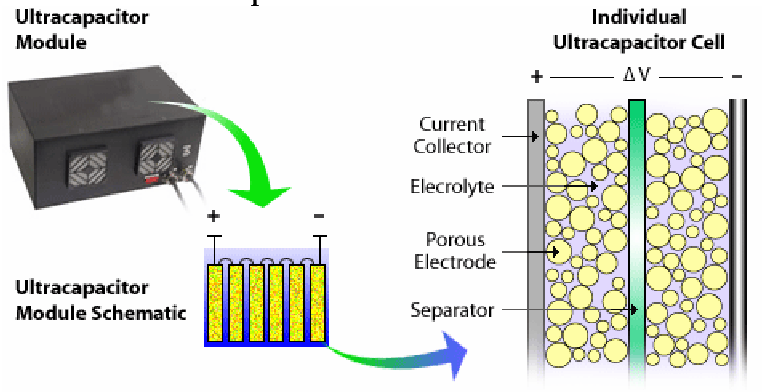
In order to understand ultracapacitors, it is first essential to understand what a capacitor is. A capacitor is an electrical device used to store and release electrical energy. While a battery stores energy chemically, a capacitor stores the energy in an electrostatic field created between a pair of electrodes separated by an insulating material called a dielectric. **There is no chemical reaction between the electrodes and the dielectric as in a battery; therefore, while a battery needs some time to charge and discharge but can provide continuous power, a capacitor can instantaneously release all of its energy.**

When voltage is applied to a capacitor, the two electrodes receive equal and opposite charges. The plate that is connected to the negative terminal of the power source accepts electrons and stores them on its surface. The other plate loses electrons to the power source. This action charges the capacitor. This energy is stored statically until the two terminals are connected together.

The ability of a capacitor to store an electric charge is called capacitance and is measured in farads (F). A one-farad capacitor can store one coulomb of charge or one ampere-second at one volt. The capacitance is directly proportional to the surface area of the electrodes and the insulating qualities of the dielectric; however, it is inversely proportional to the distance between the electrodes.

Ultracapacitors incorporate a large electrode surface area and a very small distance between the electrodes. These features give them very high capacitance, with some rated as high as 5000F. Rather than using a dielectric, ultracapacitors use an electrolyte and store electrical energy at the boundary between the electrodes and the electrolyte. No chemical reactions are involved in the storing of energy.

Exhibit 58 – Ultracapacitor Schematic



Source: National Renewable Energy Laboratory

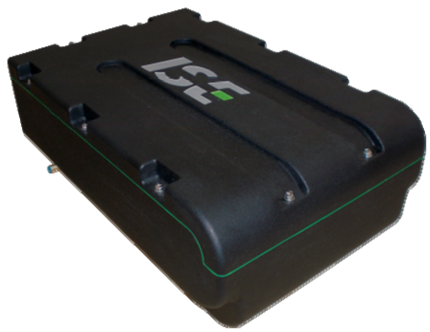
The electrodes are typically made of carbon but can also be made from a metal oxide or conducting polymers. The surface of the electrodes is very coarse in order to increase the effective surface area. An ounce of carbon provides nearly 13,500 square feet of surface area. The plates are immersed in an electrolyte, normally boric acid or sodium borate mixed in water and ethylene glycol or sugars to reduce chances of evaporation. When voltage is applied, the electrolyte becomes polarized. The charge of the positive electrode attracts the negative ions in the electrolyte, and the charge of the negative electrode attracts the positive ions. When the positively charged ions form a layer on the surface of the negative electrode, electrons within the electrode that are beneath the surface move to match up with them. The same occurs on the positive electrode and these two layers of separated charges form a strong static charge. A porous, ultra-thin dielectric separator is placed between the two electrodes to prevent the charges from moving between them. This small separator and the immense amount of surface area allow the ultracapacitor to have high capacitance. However, the thin insulator is also the reason cell voltage must be kept low.

The absence of chemical reactions between the electrodes and electrolyte allow for rapid charge and discharge times, making the ultracapacitor suitable for hybrid electric vehicle applications by providing power bursts for acceleration and quick recharging through regenerative braking.

Ultracapacitors have excellent cycle life without any degradation in performance. They are also able to operate over a wider temperature range and are not affected by low temperatures to the same degree as batteries. However, ultracapacitors suffer in energy density when compared to batteries.

Ultracapacitors are used commonly today to supplant battery power in vehicles. The Toyota Prius was the first automobile to use a bank of ultracapacitors. One of the leading ultracapacitor producers in the United States is **Maxwell Technologies**. **ISE**, a leading hybrid drive systems integrator for heavy-duty vehicles, has teamed up with Maxwell to develop integrated ultracapacitor packs. For example, two packs weighing 200kg can provide peak power of 200kW and 0.6kWh of energy storage, which is adequate to capture most available regenerative braking energy and to supply large amounts of supplementary power for brief periods. However, such energy is good to propel the vehicle for only a few hundred yards, necessitating the use of battery power. Maxwell's Boostcap ultracapacitors are also being integrated into China's Golden Dragon diesel-electric hybrid buses.

Exhibit 59 – ISE Integrated Ultracapacitor Pack Featuring Maxwell Ultracapacitors



Source: ISE Corporation

The ultracapacitor's use of ions and electrolytes rather than simply relying on static charges and the absence of a chemical reaction positions the ultracapacitor to potentially bridge the gap between power density and energy density, in other words, acceleration and range. A great deal of research has been performed to increase the energy content of ultracapacitors. For example, researchers at MIT are using nanoengineering to deposit a forest of carbon nanotubes, which could potentially push the ultracapacitor's capacity to 50% of a battery.

A Texas-based privately held company called **EEStor** is adopting a different strategy and has developed a new ultracapacitor using a barium titanate ceramic powder insulator, which would, per the company, exceed the abilities of any advanced battery technology today, potentially giving an all-electric vehicle a driving range of up to 300 miles with a full recharge in 3-6 minutes using a specialized charger, for the same cost as a lead acid battery with similar energy content. The company was recently granted a U.S. patent for its electrical-energy-storage-unit (EESU) product. The patent claims energy storage of at least 52.22kWh in a package that weighs 281.56 pounds. Third-party verification of permittivity data and prototype delivery were expected in 2008, but is now likely pushed out to 2009.

Exhibit 60 - EESU Vs. Battery Technologies

	EESU	NiMH	Lead Acid (Gel)	Ni-Z	Li ion
Weight (pounds)	286.56	1,716	3,646	1,920	752
Volume (inch^3)	4,541	17,881	43,045	34,780	5,697
Discharge rate/ 30 days	0.10%	5%	1%	1%	1%
Charging time (full)	*3-6 mins	1.5 hr	8.0 hr	1.5 hr	6.0 hr
Life reduced with deep cycle use	None	Moderate	High	Moderate	High
Hazardous materials	None	Yes	Yes	Yes	Yes

** charging time is restricted by the converter circuits, not the EESU*

Source: United States Patent – Weir et al., Patent Number US 7,466,536 B1

Electric car company **ZENN Motor Company** owns a 3.8% stake in **EEStor** with an option to increase its stake to 7%. **ZENN** owns exclusive rights to purchase EESUs for passenger cars for the small/mid-size vehicle market of which 40 million are sold annually. The company also owns non-exclusive rights on larger electric vehicles over 1,400kg and has the option to increase its stake in EEStor to 7%. The successful commercial production of the EESU is crucial to the prospects of ZENN's "Highway cityZENN" highway-capable electric vehicle with a 250 mile range and maximum speed of 80mph. EEStor is completing the build-out of a production facility in Austin, TX and first prototype deliveries are expected in 2009.

Regardless of whether ultracapacitors will replace batteries in automobiles, it is apparent that ultracapacitors are here to stay. For example, **AFS Trinity**, a developer of hybrid drivetrains, has been vocal about the benefits of using ultracapacitors in conjunction with Li ion batteries in its Extreme Hybrid drivetrain for plug-in hybrids. According to the company, using its proprietary technology can extend the life of Li ion batteries in plug-in hybrid vehicles to 150,000 miles versus 25,000 miles for conventional hybrids that are retrofitted with Li ion batteries for plug-in capability. We note that **Maxwell** working with Argonne National Laboratory arrived at much the same conclusion in a separate study. The principle driving the large improvement in battery life is that in conventional plug-ins without ultracapacitors the batteries are subjected to high current demands, such as during acceleration, which results in resistive heating that could further cause battery damage and reduce the number of miles that can be driven during the life of the battery. Instead, the ultracapacitor can be used to handle the high current events, allowing the battery to comfortably operate in its state of charge window. The company has successfully produced two prototype plug-in hybrid SUVs (modified Saturn VUEs) with a 40 mile all-electric range and fuel economy of 150mpg, and it is seeking $2.5 billion in federal loan funding from the U.S. Department of Energy under the $25 billion Advanced Technology Vehicle Manufacturing Incentive Program or the "green retooling fund". The company intends to use $2 billion to retool an existing factory of a major American car maker to produce plug-in hybrid SUVs using its Extreme Hybrid technology under a sub-contract arrangement. The remaining $500 million would be used by **AFS Trinity** and engineering partner **Ricardo** for technology transfer and engineering support for model redesign and retooling.

BATTERY MANUFACTURING COSTS – A CLOSELY GUARDED SECRET; NO DETAILS IN PUBLIC DOMAIN; BUT COST SHOULD REDUCE WITH VOLUME

Incumbent advanced battery manufacturers are very reticent to discuss their manufacturing costs for competitive reasons. As a result, there is very little detail on battery costs and battery material usage in the pubic domain by established battery players like **Hitachi, Sanyo** and **Panasonic**. In addition, lithium ion batteries for automotive applications are generally not in commercial production, thus, it is very hard to estimate costs. Studies were conducted by Argonne National Laboratory in 2000 and Electric Power Research Institute Battery in 2005 to explore the topic further.

The following exhibit provides a comparison of projected battery pack costs in terms of dollars per kWh of energy for NiMH and Li ion batteries based on vehicle type. It is evident that costs depend on production volume, materials and whether the design is for high energy (PHEVs and BEVs) or for high power (HEVs). For high power applications, cost per kWh increases as the cells and battery pack become smaller, while electrode surface area increases, the design uses thinner plates and relative material composition changes. However, on a per kW basis, costs reduce.

Exhibit 61 – Estimated Costs Of NiMH And Li Ion Batteries

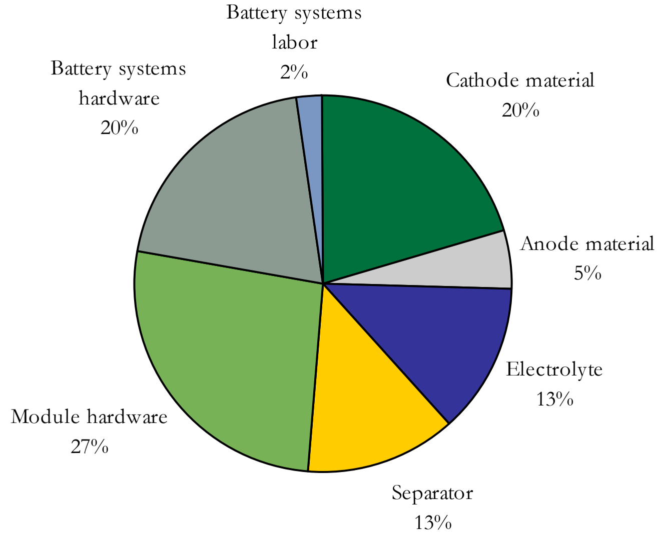
Estimated Costs of NiMH Battery Packs						
	Full HEV		PHEV 20		BEV	
Battery Capacity (kWh)	1.5	1.5	6	6	30	30
Annual unit production	20,000	100,000	20,000	100,000	20,000	100,000
Cost per kWh	n.e.	$750	$625	$500	n.e.	$300
Battery pack cost	n.e.	$1,125	$3,750	$3,000	n.e.	$9,000

Estimated Costs of Li ion Battery Packs						
	Full HEV		PHEV 20		BEV	
Battery Capacity (kWh)	1.5	1.5	6	6	30	30
Annual unit production	20,000	100,000	20,000	100,000	20,000	100,000
Cost per kWh	$1,250	$850	$550	$380	$400	$280
Battery pack cost	$1,875	$1,275	$3,300	$2,280	$12,000	$8,400

Source: Electric Power Research Institute

For a quick reality check, if we take what we believe to be volume selling prices on Li ion batteries in the $500-800/kWh range and apply the 30% gross margin range that **Valence Technology**, one of the few commercial ferrous phosphate based Li ion automotive battery producers, expects it can make at its newly expanded production facility, we come up with battery pack production costs of $350-560/kWh, in line with the ranges presented above.

Exhibit 62 – High Energy Li Ion Battery Estimated Cost Components



Source: Electric Power Research Institute

DO HYBRIDS PAY BACK THE INITIAL PREMIUM VS. CONVENTIONAL VEHICLES? DEPENDS ON BATTERY COSTS, VEHICLE DESIGN, GASOLINE PRICING, DRIVING BEHAVIOR, MILEAGE AND FEDERAL/STATE INCENTIVES

As seen in the following exhibit, today's hybrid offerings provide a payback of less than 10 years on the initial purchase premium compared with that of the conventional vehicle. The largest drivers of payback are gasoline pricing and improvement in fuel efficiency or mileage. For our purposes, we have assumed $4 per gallon of gas and not the sub-$2 per gallon recession-driven levels. At $4 per gallon of gas, the payback period on the Camry hybrid is 3.4 years; this decreases to 2.7 years at $5 per gallon of gas and increases to 4.5 years at $3 per gallon of gas. In addition, our analysis does not take into account pricing outside the United States. For example, gas prices in Europe, Asia and South America are significantly higher than in the United States, further reducing payback time.

The payback is also determined by the design of the vehicle and whether the electrical motor substitutes for a portion of ICE power or simply supplements ICE power (i.e., a "muscle hybrid"). In the case of the Toyota Highlander for example, the ICE has not been downsized in the hybrid version. As a result, the premium on the hybrid is over $5,000, leading to a longer payback period of over seven years.

Another key determinant of payback is the presence of a federal or state tax incentive for the purchase of hybrid vehicles. The federal tax credit on Toyota hybrid models, for example, was $2,600 but then phased out to $0 once vehicle sales crossed 60,000. The $2,100 tax credit on Honda hybrids has also been phased out. The tax credits on Ford and GM hybrids remain, however. For example, the 2009 Ford Escape comes with a $3,000 tax credit on the hybrid model.

Exhibit 63 – Payback In Years On Current Models Of Hybrid Electric Vehicles

	Hybrid	Regular
Toyota Model	Camry Hybrid 2.4L 4-cyl ECVT	Camry LE 2.4L 4-cyl 5AT
Max Suggested Retail Price	$26,870	$23,960
Premium	$2,910	
Federal tax credit *	$0	
Effective premium	$2,910	
Fuel economy - city (mpg)	33	19
Fuel economy - highway (mpg)	34	28
Annual miles	15,000	15,000
Annual gallons of gasoline	448	663
Gasoline price per gallon	$4.00	$4.00
Annual gasoline costs	$1,791	$2,650
Annual savings	$859	
Payback time without tax credit	***3.4***	
Payback time with tax credit	***0.4***	

** Tax credit of $2,600 phased out*

	Hybrid	Regular
Toyota Model	Highlander 4WD-i Hybrid	4WD Highlander (3.5L V6 5AT)
Max Suggested Retail Price	$34,700	$29,390
Premium	$5,310	
Federal tax credit *	$0	
Effective premium	$5,310	
Fuel economy - city (mpg)	27	17
Fuel economy - highway (mpg)	25	23
Annual miles	15,000	15,000
Annual gallons of gasoline	578	767
Gasoline price per gallon	$4.00	$4.00
Annual gasoline costs	$2,311	$3,069
Annual savings	$758	
Payback time without tax credit	***7.0***	
Payback time with tax credit	***3.6***	

** Tax credit of $2,600 phased out*

	Hybrid	Regular
Honda Model	2009 Civic Hybrid	2009 Civic Sedan EX 5-Spd AT
Max Suggested Retail Price	$23,650	$20,775
Premium	$2,875	
Federal tax credit *	$0	
Effective premium	$2,875	
Fuel economy - city (mpg)	40	25
Fuel economy - highway (mpg)	45	36
Annual miles	15,000	15,000
Annual gallons of gasoline	354	508
Gasoline price per gallon	$4.00	$4.00
Annual gasoline costs	$1,417	$2,033
Annual savings	$617	
Payback time without tax credit	***4.7***	
Payback time with tax credit	***1.3***	

	Hybrid	Regular
Ford Model	2009 Escape Hybrid FWD	2009 Escape XLT FWD V6
Max Suggested Retail Price	$29,645	$25,920
Premium	$3,725	
Federal tax credit *	($3,000)	
Effective premium	$725	
Fuel economy - city (mpg)	34	18
Fuel economy - highway (mpg)	31	26
Annual miles	15,000	15,000
Annual gallons of gasoline	463	705
Gasoline price per gallon	$4.00	$4.00
Annual gasoline costs	$1,850	$2,821
Annual savings	$970	
Payback time without tax credit	***3.8***	
Payback time with tax credit	***0.7***	

Source: Ford Motor Co., American Honda Motor Co., Toyota Motor Sales U.S.A. and Thomas Weisel Partners LLC estimates

For the next generation of plug-in hybrids and plug-in electric vehicles, things are not so clear. The key variable is battery pricing, which remains largely outside the public domain and is the primary driver of incremental cost versus conventional vehicles. **Price estimates for NiMH batteries range from $800 to $1,200/kWh of energy, while lithium ion batteries range from $500 to $800/kWh in volume production, versus about $1000/kWh today.** In comparison, the U.S. Advanced Battery Consortium, a government-funded consortium of the Big 3 automakers, has published long-term, high-volume battery cost goals of $500-1,000 for a power-assist HEV battery pack, approximately $240/kWh for plug-in hybrids with 10 mile and 40 mile electric range (at 100k unit volume), and a minimum goal for commercialization of $150/kWh for electric vehicle battery packs with a longer term goal of $100/kWh (at 25,000 unit volume).

We believe the lower energy density of NiMH batteries make them impractical to meet the high energy needs of plug-in hybrids and electric vehicles. As a result, we look to lithium ion batteries to meet the needs of PHEVs and BEVs. We believe NiMH batteries will continue to feature in mild and full HEVs with their lower energy and higher power needs.

Based on the rough price ranges above, we have attempted to estimate the payback on HEVs, PHEVs with 10 mile and 40 mile electric range, and BEVs. We note that, for the most part, automotive lithium ion battery mass production has not really taken off yet, but it is apparent that battery pricing will need to come down significantly to meet U.S. ABC goals. We believe that a major portion of battery cost reduction will come from higher volume manufacturing, and also from better material utilization and lower cost materials, although we are not convinced that achieving less than $150/kWh for BEV battery packs is feasible.

We have attempted to differentiate payback with and without federal tax incentives. As part of the financial bailout bill that was passed into law in 2008, plug-in hybrid and electric vehicles won a federal tax credit. For vehicles less than 10,000lbs and with batteries storing at least 4kWh of energy, the tax credit is a base of $2,500 and $417 per kWh in excess of 4kWh, capped at $7,500. GM's Chevy Volt, the Tesla Roadster and the Fisker Karma would qualify for the maximum credit of $7,500. The stimulus bill further builds on the existing plug-in electric drive tax credit, by changing the tax credit phase-out trigger of cumulative vehicle sales from 250,000 to 200,000 vehicles per manufacturer.

As discussed previously, for the purposes of our model, we assumed $4 per gallon gasoline. While today's average gasoline prices of below $2 per gallon is a long way off from 2008's summer peak of approximately $4-5 per gallon, we believe that gasoline prices will cross previous highs as economic activity picks up emerging out of a global recession. In addition, gasoline pricing is substantially higher outside the United States; for example, when gasoline in Europe was $8 per gallon, it was only $4 per gallon in the United States. This impacts payback periods very favorably.

From the analysis below, it is apparent that:

- At today's battery pricing, federal tax incentives are a must to get single-digit payback periods versus conventional vehicles on extended range PHEVs and BEVs.
- The (fuel) cost to operate an automobile reduces with the degree of electrification from $0.13 per mile for a conventional vehicle to $0.03 per mile for a BEV.

Exhibit 64 – HEV, PHEV And BEV Payback Analysis

Assumptions		
Gas price per gallon	$4.00	
Annual Miles	12,000	
Conventional vehicle milage	30	mpg
HEV mileage	50	mpg
Wh per mile of battery reqd.	300	
Mileage (per kWh)	4.0	miles
Electricity cost per kWh	$0.12	

	Conventional	HEV	PHEV 10	PHEV 40	HEV
Miles driven electric mode	-	-	3,650	9,000	12,000
Miles driven hybrid mode	-	12,000	8,350	3,000	
Federal tax credit *	$0	$0	$0	$5,836	$7,500
Annual fuel costs	$1,600	$960	$778	$510	$360
Annual fuel cost savings	$0	$640	$823	$1,090	$1,240
Fuel cost per mile	**$0.13**	**$0.08**	**$0.06**	**$0.04**	**$0.03**

Assuming today's NiMH technology at $800-$1,200 per kWh

	HEV	PHEV 10	PHEV 40	BEV
Battery kwh	1	3	12	30
Cost per kwh (mid-point)	$1,000	$1,000	$1,000	$1,000
Battery cost	$1,000	$3,000	$12,000	$30,000
Other incremental cost	$1,500	$2,000	$2,200	$0
Total incremental cost	$2,500	$5,000	$14,200	$30,000
Payback without tax credit	***3.9***	***6.1***	***13.0***	***24.2***
Payback with tax credit	***3.9***	***6.1***	***7.7***	***18.1***

Assuming Li ion technology at $800 per kWh

	HEV	PHEV 10	PHEV 40	BEV
Battery kwh	1	3	12	30
Cost per kwh	$800	$800	$800	$800
Battery cost	$800	$2,400	$9,600	$24,000
Other incremental cost	$1,500	$2,000	$2,200	$0
Total incremental cost	$2,300	$4,400	$11,800	$24,000
Payback without tax credit	***3.6***	***5.3***	***10.8***	***19.4***
Payback with tax credit	***3.6***	***5.3***	***5.5***	***13.3***

Assuming Li ion technology at $500 per kWh

	HEV	PHEV 10	PHEV 40	BEV
Battery kwh	1	3	12	30
Cost per kwh	$500	$500	$500	$500
Battery cost	$500	$1,500	$6,000	$15,000
Other incremental cost	$1,500	$2,000	$2,200	$0
Total incremental cost	$2,000	$3,500	$8,200	$15,000
Payback without tax credit	***3.1***	***4.3***	***7.5***	***12.1***
Payback with tax credit	***3.1***	***4.3***	***2.2***	***6.0***

Assuming Li ion technology at USABC targets

	HEV	PHEV 10	PHEV 40	BEV
Battery kwh		3	12	30
Cost per kwh		$240	$240	$150
Battery cost	$500	$720	$2,880	$4,500
Other incremental cost	$1,500	$2,000	$2,200	$0
Total incremental cost	$2,000	$2,720	$5,080	$4,500
Payback without tax credit	***3.1***	***3.3***	***4.7***	***3.6***
Payback with tax credit	***3.1***	***3.3***	***NA***	***NA***

** Federal tax credit of $2,500 plus $417 per kWH in excess of 4kWH applies to first 200,000 vehicles per manufacturer*

Source: American Council for an Energy Efficient Economy, Ricardo, Inc. and Thomas Weisel Partners LLC estimates

Sensitivity To Fuel Prices

In order to account for fuel price swings, we have attempted a sensitivity analysis for cost per mile and payback periods to changes in gasoline prices; the results are presented below. We conclude that at current expectations of volume battery pricing:

- Even at $1 gasoline, the fuel cost per mile to drive an electrified vehicle is as good if not better than that to drive a conventional vehicle.
- At $2 gasoline, single-digit payback periods are feasible on HEVs and PHEVs.
- $3 gasoline yields single-digit payback periods on BEVs.
- Every $1 increase in gasoline pricing can reduce payback periods by 20-40% on average.

Exhibit 65 – Sensitivity To Fuel Prices

Gasoline	Est. Fuel Cost per Mile				
Price	Conventional	HEV	PHEV 10	PHEV 40	BEV
$1.00	$0.03	$0.02	$0.02	$0.03	$0.03
$2.00	$0.07	$0.04	$0.04	$0.03	$0.03
$3.00	$0.10	$0.06	$0.05	$0.04	$0.03
$4.00	**$0.13**	**$0.08**	**$0.06**	**$0.04**	**$0.03**
$5.00	$0.17	$0.10	$0.08	$0.05	$0.03
$6.00	$0.20	$0.12	$0.09	$0.05	$0.03
$7.00	$0.23	$0.14	$0.11	$0.06	$0.03
$8.00	$0.27	$0.16	$0.12	$0.06	$0.03

Gasoline	Est. Payback Time with Incentives			
Price	HEV	PHEV 10	PHEV 40	BEV
$1.00	12.5	28.3	33.8	187.5
$2.00	6.3	9.8	5.8	17.0
$3.00	4.2	5.9	3.2	8.9
$4.00	**3.1**	**4.3**	**2.2**	**6.0**
$5.00	2.5	3.3	1.7	4.6
$6.00	2.1	2.7	1.3	3.7
$7.00	1.8	2.3	1.1	3.1
$8.00	1.6	2.0	1.0	2.6

** Assumes $500/kWh Li ion battery pack*

Gasoline	Est. Payback Time without Incentives			
Price	HEV	PHEV 10	PHEV 40	BEV
$1.00	12.5	28.3	117.1	375.0
$2.00	6.3	9.8	20.0	34.1
$3.00	4.2	5.9	10.9	17.9
$4.00	**3.1**	**4.3**	**7.5**	**12.1**
$5.00	2.5	3.3	5.7	9.1
$6.00	2.1	2.7	4.6	7.4
$7.00	1.8	2.3	3.9	6.1
$8.00	1.6	2.0	3.3	5.3

** Assumes $500/kWh Li ion battery pack*

Source: Thomas Weisel Partners LLC

A more encompassing way to look at economics of a conventional vehicle versus an electrified vehicle is to compare **total cost of ownership** (i.e., purchase price as well as fuel costs over the anticipated ownership life of the vehicle). For our modeling, we assumed a base conventional vehicle price of $20,000, incremental purchase price for electrified drivetrains per the figures in Exhibit 64, ownership of over 10 years and annual mileage of 12,000 miles. Given the reliability of Toyota Prius batteries that continue to show acceptable performance after more than 100,000 miles of driving, we assumed no replacement of batteries required past the 10 year horizon.

Our analysis indicates that:

- With federal tax credits, even at $2 gasoline, an HEV or PHEV has economics at par or better than conventional vehicles. At $3 gasoline, BEVs make more economic sense than conventional vehicles.
- In the absence of incentives, it would take $3 gasoline for PHEVs to make economic sense and $5 gasoline for BEVs to make economic sense.

Exhibit 66 – Sensitivity Of Total Cost Of Ownership To Fuel Prices

Gasoline Price	Est. 10 Year Total Cost of Ownership per Mile (with incentives): Conventional	HEV	PHEV 10	PHEV 40	BEV
$1.00	$0.20	$0.20	$0.22	$0.21	$0.26
$2.00	$0.23	$0.22	$0.23	$0.22	$0.26
$3.00	$0.27	$0.24	$0.25	$0.22	$0.26
$4.00	**$0.30**	**$0.26**	**$0.26**	**$0.23**	**$0.26**
$5.00	$0.33	$0.28	$0.27	$0.23	$0.26
$6.00	$0.37	$0.30	$0.29	$0.24	$0.26
$7.00	$0.40	$0.32	$0.30	$0.24	$0.26
$8.00	$0.43	$0.34	$0.32	$0.25	$0.26

Gasoline Price	Est. 10 Year Total Cost of Ownership per Mile (without incentives): Conventional	HEV	PHEV 10	PHEV 40	BEV
$1.00	$0.20	$0.20	$0.22	$0.26	$0.32
$2.00	$0.23	$0.22	$0.23	$0.27	$0.32
$3.00	$0.27	$0.24	$0.25	$0.27	$0.32
$4.00	**$0.30**	**$0.26**	**$0.26**	**$0.28**	**$0.32**
$5.00	$0.33	$0.28	$0.27	$0.28	$0.32
$6.00	$0.37	$0.30	$0.29	$0.29	$0.32
$7.00	$0.40	$0.32	$0.30	$0.29	$0.32
$8.00	$0.43	$0.34	$0.32	$0.30	$0.32

Assumptions:
Ownership over 10 years, 12,000 miles per year
Conventional vehicle purchase price of $20,000
Li ion battery pricing of $500/kWh
No replacement of Li ion battery required in the first 10 years of ownership
Does not include insurance or maintenance costs

Source: Thomas Weisel Partners LLC

GRID CAPACITY AND CHARGING INFRASTRUCTURE CONCERNS; OUR TAKE – SUFFICIENT GRID CAPACITY, BUT SMART CHARGING INFRASTRUCTURE DEVELOPMENT NEEDED

Several doubts have been raised about the ability of the power grid to handle a surge in demand from the charging of PHEVs and BEVs. Although the U.S. power grid is antiquated and can struggle to meet peak demand of the 850GW order, we believe that off-peak capacity remains an under-utilized asset that is more than sufficient to meet demand from hybrid and electric vehicles for several years. For example, a study by Pacific Northwest National Laboratory found that off-peak electricity production and transmission capacity could fuel 73% of the U.S. light duty vehicle (LDV) fleet, or 158 million vehicles, assuming they were replaced with plug-in hybrids with a 33 mile electric range while average residential electricity consumption would increase by 30-40%. As long as there is intelligence in the grid and the vehicle to prevent vehicle charging during peak demand and allow charging only to "fill the valleys", we do not see grid-related issues for electric vehicle penetration. This is where Smart Grid technology comes in.

Smart Grid technology, already used today to effect two-way communication between the utility and the home and to implement price-based demand response programs, can also be used to manage power flow to and from electric vehicles. This would allow utilities to manage the one-way flow of electricity to PHEVs, within parameters set by plug-in owners, thus, adapting the charging to grid conditions (e.g., slow during high demand and increasing with the availability of renewable energy).

Eventually the battery in the PHEV can be viewed as a source of electricity itself and can be used to return power to the grid (V2G) during peak demand or return power to the home (V2H) during grid outages. Smart grid companies such as **GridPoint** are working with utilities and auto OEMs to make this vision of the future a reality.

We also highlight that base load sources of capacity such as coal power plants, by their very nature, cannot be simply shut down overnight even though demand on the grid is much lower then. As such, the base load capacity runs underutilized at such times, but having electric vehicles charging would improve the utilization as well as the economics of base load capacity.

Building The Charging Infrastructure Of Tomorrow Today

Despite the promise of electricity as an alternative fuel source, the reality is that there is a shortage of locations for vehicle owners to plug in and recharge their batteries. So while the idea of the battery being charged overnight in the owner's garage makes sense, there are only 54 million garages for the 247 million registered cars in the United States. As a result, many cars are either parked curbside or in parking lots, especially in crowded urban areas. In addition, most plug-in car owners would want to charge their car more than once a day.

California start-up **Project Better Place** is aggressively addressing this market gap through an innovative business model in which an electric vehicle owner subscribes to a charging plan much like a cell phone plan, except that the owner purchases miles instead of minutes. Car owners then pay to access a network of smart charging spots and battery exchange stations powered by renewable energy. The idea is to manage a combination of battery recharging stations that let owners "top off" their batteries for shorter trips and to have automated battery switching stations for trips longer than 100 miles. Ideally the batteries will be charged using renewable energy such as in Australia, Denmark and California where there is excess wind power overnight, which would otherwise go to waste. The company's first target mass market is Israel, where in partnership with Nissan-Renault and the Israeli government that will offer tax incentives to customers, the company will build and operate an Electric Recharge Grid of over 500,000 charging spots. The company is also partnering with the governments of Australia, Denmark and Japan as well as local governments in California and Hawaii to establish electric car recharging networks.

Start-up **Coulomb Technologies** is also addressing this market gap providing networked "Smartlet" smart charging stations to municipalities and other parking lot owners as capital equipment. **Coulomb** markets its products through dealers and contractors that typically sell and install streetlights and traffic light controllers. Under this business model, **Coulomb** provides a recurring revenue stream to the parking lot property owner in the form of rent and remits a share of charging revenue to the purchaser of the charging stations until their purchase and installation costs have been paid back. **Coulomb** will also pay the property owner for the electricity costs. The plug-in driver must subscribe to access electricity from the charging stations and has the ability to tailor his or her subscription plan much like cell phone plans. Each charging station performs bi-directional energy metering and control, user authentication and enables a "pay for what you use" model through wireless communication with a data center. The first of these charging stations are now up and running in San Jose and provide charging capability ranging from 110V/15A to 220V/80A AC charging to 120kW DC.

Exhibit 67 – Coulomb Technologies ChargePoint

Source: Thomas Weisel Partners LLC

Exhibit 68 – Energy Storage Solutions Providers

Company	Location	Ticker	Market Cap ($ mn)	Technology	Description
A123 Systems	Waltham, MA	NA	NA	Lithium ion (ferrous phosphate)	A123 Systems is a leading supplier of high power lithium ion batteries using patented Nanophosphate™ technology. The company's primary customers are DeWALT and Black & Decker for portable power tool applications. The company is commercializing its technology for vehicle and grid stabilization applications, and is one of three battery options in the Think City car. A123 currently is shipping multi-MW battery systems for grid storage applications to AES.
Advanced Battery Power	China	ABAT	$138	Lithium polymer	Advanced Battery Technologies, founded in September 2002, develops, manufactures and distributes rechargeable Polymer Lithium-Ion (PLI) batteries. The company's products include rechargeable PLI batteries for electric automobiles, motorcycles, mine-use lamps, notebook computers, walkie-talkies and other electronic devices. ABAT's batteries combine high-energy chemistry with state-of-the-art polymer technology to overcome many of the shortcomings associated with other types of rechargeable batteries
Altair Nanotechnologies	Reno, NV	ALTI	$101	Lithium ion (lithium manganese/lithium titanate spinel)	Altair Nano produces high power lithium titanate based battery products for automotive, grid back up and military applications. The company has shipped its batteries to Phoenix Motorcars and to ISE, an integrator of hybrid drivetrains for heavy duty vehicles. Altair was recently chosen by DeignLine International, a bus OEM to supply four 44kWh demo battery packs. The company is also developing multi MW systems for grid storage with AES.
Axion Power	New Castle, PA	AXPW	$27	Lead acid	Axion is developing advanced batteries and an energy storage product based on its patented lead carbon battery (PbC™) technology. Whereas conventional lead-acid batteries use negative electrodes made of sponge lead pasted onto a lead grid current collector, Axion's technology uses negative electrodes made of microporous activated carbon with very high surface area. The result is a battery-supercapacitor hybrid that uses less lead. Axion is producing prototype PbC batteries in small quantities at its plant in New Castle and believes this new battery technology is the only class of advanced battery that can be assembled on existing lead-acid battery production lines throughout the world without significant changes to production equipment and fabrication processes.
China BAK Battery	Shenzhen, China	CBAK	$96	Lithium ion (ferrous phosphate)	China BAK produces prismatic lithium-ion cells for cellular phone replacement battery manufacturers and OEMs and lithium polymer cells for use in portable consumer electronics. The Company has recently expanded its product offerings to include high-power, lithium phosphate cells for use in cordless power tools, hybrid electric vehicles and medical devices.
China Ritar Power	Shenzhen, China	CRTP	$36	Lead acid	Ritar designs, develops, manufactures and markets environmentally friendly lead-acid batteries with a wide range of capacities and applications, including telecommunications, UPS devices, Light Electrical Vehicles (LEV), and alternative energy production (solar and wind power)
Electrovaya	Ontario, Canada	ca;EFL	$17	Lithium ion SuperPolymer	Electrovaya is a developer and manufacturer of portable power solutions with its proprietary Lithium Ion SuperPolymer® battery technology. Its goal is to become the preferred provider of portable power for aerospace, defense and wireless sectors, and the developer of alternative energy applications including UPS, stand-by power, plug-in hybrids and Zero-Emission Vehicle.
EEStor	Cedar Park, TX			Ultracapacitor (Barium Titanate)	EEStor is developing a new ceramic-based ultracapacitor that would, per the company, exceed the abilities of any advanced battery technology today at much lower cost, potentially giving an all-electric vehicle a driving range of up to 300 miles with recharging in a few minutes using a specialized charger. The technology is still subject to third party review of permittivity data and successful prototype production. ZENN Cars owns a 3.8% stake in the company.
Ener1	Indianapolis, IN	HEV	$539	Lithium ion (lithium manganese/lithium titanate)	Ener1 develops and manufactures compact, high performance lithium-ion batteries to power the next generation of hybrid and electric vehicles. The company is led by an experienced team of engineers and energy system experts at its EnerDel subsidiary located in Indiana. EnerDel has developed proprietary battery systems based on technology originally pioneered with the assistance of the Argonne National Lab. Ener1 is seeking to become the first company to mass-produce a cost-competitive lithium-ion battery for hybrid and electric vehicles
Exide	Alpharetta, GA	XIDE	$302	Lead acid	Exide Technologies, with operations in more than 80 countries, is one of the world's largest producers and recyclers of lead-acid batteries. The company's four global business groups – Transportation Americas, Transportation Europe and Rest of World, Industrial Energy Americas and Industrial Energy Europe and Rest of World – provide a comprehensive range of stored electrical energy products and services for industrial and transportation applications. Exide recently agreed to acquire Canada based lithium ion battery maker, Mountain Power Inc.
Firefly Energy	Peoria, IL			Lead acid	Firefly is a private company seeded from the R&D laboratory of Caterpillar. Firefly's technology seeks to eliminate the limitations of conventional lead acid battery chemistry by replacing conventional lead grids with micro-cellular-based carbon-graphite foam grids with much greater surface areas, thus increasing active material utilization levels from the historical 20-50% up to 70-90%.
Johnson Controls	Milwaukee, WI	JCI	$9,577	Lead acid and Lithium ion	Johnson Controls is a global leader in automotive experience, building efficiency and power solutions. The company provides innovative automotive interiors that help make driving more comfortable, safe and enjoyable. For buildings, it offers products and services that optimize energy use and improve comfort and security. Johnson Controls also provides batteries for automobiles and hybrid-electric vehicles, along with systems engineering and service expertise. The company is the global market leader in lead acid automotive batteries, and through its JV with Saft, produces NiMH and Li ion batteries based on lithium nickel cobalt aluminum chemistry.
Maxwell Technologies	San Diego, CA	MXWL	$111	Ultracapacitor	Maxwell is a leading developer and manufacturer of innovative, cost-effective energy storage and power delivery solutions such as ultracapacitors for applications in consumer and industrial electronics, transportation and telecommunications, high-voltage grading and coupling capacitors to ensure the safety and reliability of electric utility infrastructure and other applications involving transport, distribution and measurement of high-voltage electrical energy, and radiation-mitigated microelectronic products for aerospace applications.
Valence Technologies	Austin, TX	VLNC	$192	Lithium ion (ferrous phosphate)	Valence Technology is an international leader in the development of lithium phosphate energy storage solutions. The company has redefined lithium battery technology and performance by marketing the industry's first safe, reliable and rechargeable lithium phosphate battery. Customers include Smith Electric Vehicles, Wrightbus, Brammo, Oxygen and PVI.

Source: Thomas Weisel Partners LLC

Exhibit 69 – Electric Drivetrain Systems Developers And Integrators

Company	Location	Ticker	Market Cap ($ mn)	Description
Allison Transmission	Indianapolis, IN	NA	NA	Allison Transmission is a leader in the design, manufacture and sales of commercial-duty automatic transmissions, hybrid propulsion systems, and related parts and services for on-highway trucks and buses, off-highway equipment and military vehicles. Having literally invented the category, today the company continues to dominate with an 80% market share of all medium- and heavy-duty commercial fully automatic transmissions produced. Allison used to be a division of General Motors until 2007 and developed the original "2-Mode" hybrid transmission for commercial buses and trucks.
Azure Dynamics	Detroit, MI	ca;AZD	$15	AZD has developed proprietary electric and hybrid electric drive technology for the light to heavy duty commercial vehicle categories. AZD has expertise in the areas of vehicle controls software, power electronics, electric machine design, vehicle systems engineering and vehicle integration. The company's vehicles are in operation for major fleet owners like AT&T, Con Edison, FedEx and Purolator.
BAE Systems	Rockville, MD	NA	NA	BAE Systems is primarily an aerospace and defense company, but it is also a developer of hybrid drive trains. BAE's HybriDrive system is used by transit agencies in New York, San Francisco, Houston, London, Toronto, and Ottawa
Eaton Corp.	Cleveland, OH	ETN	$8,008	Eaton is a major automotive, truck, and hydraulic systems supplier with 2007 sales of $13.4 billion. The company manufactures components for hydraulic systems on vehicles and elsewhere in the industry, as well as parts such as safety systems and transmissions for vehicles. Eaton is also active in both electric- and hydraulic-hybrid systems for Class 3-8 commercial vehicles.
Enova Systems	Torrance, CA	ENA	$10	Enova focuses on electric drive systems for pure electric, fuel cell powered and hybrid vehicles. It offers primary-drive systems, including a motor controller and traction motor in 90, 120 and 240kW sizes, in series, pre-transmission parallel and post-transmission parallel configurations. Customers include Smith Electric Vehicles, Optare and Navistar subsidiary, IC Bus.
ISE	San Diego, CA	NA	NA	ISE is a systems integrator of electric-drive systems focusing on traction motors and accompanying electric power storage for major bus and truck manufacturers . While the company offers both gasoline and diesel hybrid solutions, as well as battery electric and fuel cell powered solutions, its main product is series hybrids. ISE also sells individual subsystems and components, including integrated battery and ultracapacitor packs, motive drive subsystems (as well as individual motors and inverters), auxiliary power units, electrically-driven accessories, and hybrid vehicle control systems. End-customers include transit agencies in Long Beach, San Diego, Los Angeles, and British Columbia.
UQM Technologies	Frederick, CO	UQM	$45	UQM is a developer and manufacturer of power dense, high efficiency electric motors, generators and power electronic controllers for the automotive, aerospace, medical, military and industrial markets. A major emphasis of the company is developing products for the alternative energy technologies sector including propulsion systems for electric, hybrid electric and fuel cell electric vehicles, under-the-hood power accessories and other vehicle auxiliaries and distributed power generation applications.
ZENN Motor Co.	Toronto, CA	ca;ZNN	$91	ZENN Motor Company (ZMC) is engaged in the development, assembly and distribution of electric vehicles and drive trains. The company assembles and distributes a low speed electric vehicle called the Zero Emission, No Noise (ZENN). ZMC owns a 3.8% stake in EEStor, which is developing a potentially disruptive ultracapacitor technology called the EESU that could replace advanced batteries as well as gasoline engines in vehicles. ZMC owns exclusive rights to purchase EESUs for passenger cars under 1,400kgs and non-exclusive rights for vehicles over 1,400kgs. The company's planned highway capable "cityZENN" car is expected to have a range of 250 miles, powered by the EEStor technology

Source: Thomas Weisel Partners LLC

Exhibit 70 – Natural Gas-Based System Providers

Company	Location	Ticker	Market Cap ($ mn)	Description
Fuel Systems Solutions	Santa Ana, CA Cherasco, Italy	FSYS	$473	Fuel Systems Solutions designs and manufactures advanced products and systems to enable internal combustion engines to run on clean burning gaseous fuels such as natural gas and propane. Its BRC subsidiary based in Italy focuses on the light duty and automobile sector, while its IMPCO Technologies subsidiary based in Santa Ana, CA focuses on the heavy duty, industrial, power generation and stationary engines sectors. The company is expanding its automotive focus to the North American market in 1Q09. Transportation OEM customers include BMW, Fiat, Ford, Mitsubishi, Peugeot, Toyota, and Volvo. Industrial OEM customers include Caterpillar, Cummins, Hyundai, Kohler, Linde, Toyota, and Yamaha.
Westport Innovations	Vancouver, Canada	WPRT	$628	Westport is a leading provider of natural gas engine systems to the medium and heavy duty vehicle market. The company has a worldwide installed base of over 17,000 natural gas fueled engines in 19 countries and offers the only heavy duty natural gas system with diesel equivalent performance. Westport also has a 50:50 JV with diesel engine manufacturer Cummins, called Cummins Westport, which targets the medium duty vehicle market.

Source: Thomas Weisel Partners LLC

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