The US government announced a series of major loans and grants in early August to accelerate the development of a new generation of electric vehicles. But, as John L Petersen wrote, ahead of the award announcements, the question of what type of battery will be needed is still a matter of debate.

Why advanced lead acid batteries will dominate HEV markets

While the differences between HEV technologies have always been important to automobile manufacturers, the public's understanding of those differences is limited.

That dynamic is about to change following US president Barack Obama's decision to accelerate the effective date of federal fuel economy standards. These require manufacturers to increase fuel efficiency by approximately 40% over the next seven years, and will also eliminate fleet-wide averaging and force each class of vehicles to carry a fair share of the fuel economy burden.

The most cost-effective way to meet the new goals will be the widespread adoption of HEV technology across all classes of cars and light trucks. The new rules are not an HEV mandate, but they have put HEV technologies on a regulatory fast track that will rapidly drive revenue growth across the entire spectrum of battery manufacturers.

A critical issue that most people fail to recognize is the profound difference between hybrid electric vehicles (HEVs) that use electric drive to support an internal combustion engine and plug-in electric vehicles (PHEVs) that use an internal combustion engine to support electric drive.

Micro, mild, and full hybrids are "power applications" that use relatively small battery packs to:

- Stop and start the internal combustion engine when the vehicle stops and starts;
- Provide moderate amounts of power to launch the vehicle from a stop and improve acceleration;
- Recover all or part of the energy that is normally lost in braking to recharge the batteries; and
- Power accessories like heat and air conditioning while the internal combustion engine is off.

They need a battery pack that can accept a fast charge over a brief braking interval, deliver that stored electricity over a brief acceleration interval and repeat the process hundreds of thousands of times over the life of the vehicle.

In comparison, they are PHEBs "energy applications". They use much larger battery packs to:

- Power the vehicle in electric-only mode for a distance of 10 to 40 miles before starting the internal combustion engine;
- Recover all or part of the energy that is normally lost in braking to recharge the batteries;
- Stop and start the internal combustion engine when the vehicle stops and starts; and,
- Power accessories like heat and air conditioning while the internal combustion engine is off.

Since power is rarely an issue in larger battery packs, the critical requirement for PHEVs is a battery pack that can deliver substantially all of its stored energy over the time required to drive 10 to 40 miles and repeat that process once or twice a day for the life of the vehicle.

Most people find that battery comparisons based on energy densities are confusing because they do not provide a meaningful context for the raw numbers. The following table re-states the most common energy density values in familiar weight and volume terms and shows what energy density actually means for the principal HEV and PHEV configurations. For the purposes of the table, energy densities of 30 Wh/kg and 50 Wh/l for advanced lead-acid batteries and 100 Wh/kg and 150 Wh/l for lithium-ion batteries were used as the starting point.

Battery cost

In a July 2008 report on its Solar Energy Grid Integration Systems — Energy Storage (SEGIS-ES) program, Sandia National Laboratories estimated the current cost of advanced

Fuel Efficiency and Battery Size Trade-offs For Principal HEV Configurations

	Fuel savings	Battery capacity	Li-ion weight advantage	Li-ion volume advantage
Micro-hybrid	10%	0.50 kWh	26 pounds	0.2 cubic feet
Mild-hybrid	20%	1.00 kWh	51 pounds	0.5 cubic feet
Full-hybrid	40%	1.50 kWh	77 pounds	0.7 cubic feet
PHEV-10	55%	5.00 kWh	257 pounds	2.4 cubic feet
PHEV-40	100%	16.00 kWh	821 pounds	7.5 cubic feet

Battery Cost Trade-offs For Principal HEV Configurations

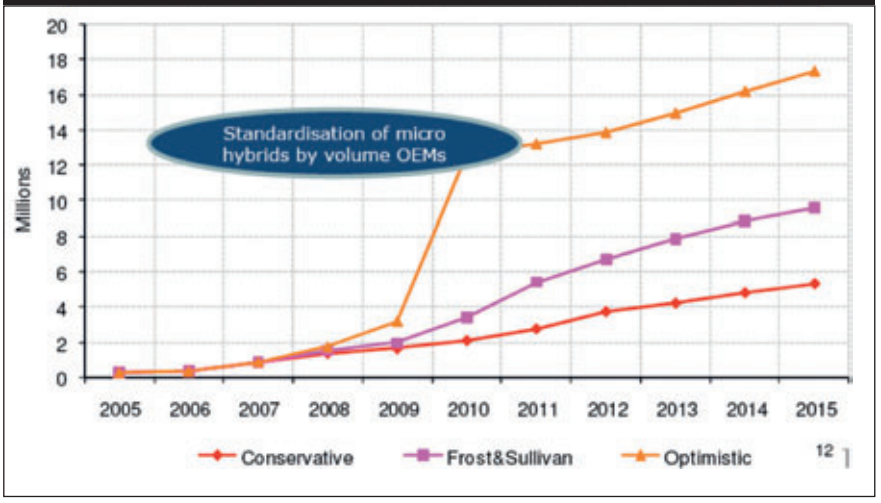
	Battery capacity (kWh)	Li-ion battery cost	Advanced lead-acid battery	Federal tax credits	Advanced Lead-acid battery cost advantage
Micro-hybrid	0.50	$667	$250		$417
Mild-hybrid	1.00	$1,333	$500		$833
Full-hybrid	1.50	$2,000	$750		$1,250
PHEV-10	5.00	$6,665	$2,500	($2,500)	$4,165
PHEV-40	16.00	$21,328	$8,000	($7,500)	$13,328

lead-acid batteries at $500 per kWh and the current cost of lithium-ion batteries at $1,333 per kWh.

I'm aware of PR claims and forward looking statements that suggest lithium-ion battery costs may be lower, but I've not been able to confirm lower prices based on published price lists from first tier manufacturers or quantify the meaning of terms like significant and substantial.

So while I'm not entirely comfortable that the Sandia values are right, I've not been able to find other numbers that are better. The following table compares the estimated cost of using advanced lead-acid and lithium-ion batteries in each of the principal HEV configurations.

Frost & Sullivan Scenario Analysis for Global HEV Market



Total vehicle cost

For most US consumers, the most important number will be the incremental cost of an HEV over a comparable car with an internal combustion engine powertrain. The following table compares the estimated cost premium for each of the principal HEV configurations using advanced lead-acid and lithium-ion batteries.

Since power is rarely an issue in larger battery packs, the critical requirement for PHEVs is a battery pack that can deliver substantially all of its stored energy over 10 to 40 miles and repeat that process once or twice a day for the life of the vehicle.

Market forecast

Global market forecasts for HEVs vary widely and are evolving rapidly in response to new laws and regulations. In an October 2008 AW Briefing on The Global Oil Paradox: Transforming the Automotive Industry, Anil Valsan of Frost & Sullivan presented a slideshow that included two highly informative graphs.

The first graph showed three growth scenarios for the global HEV market. The second graph showed the breakdown of the global market for each of the principal HEV configurations.

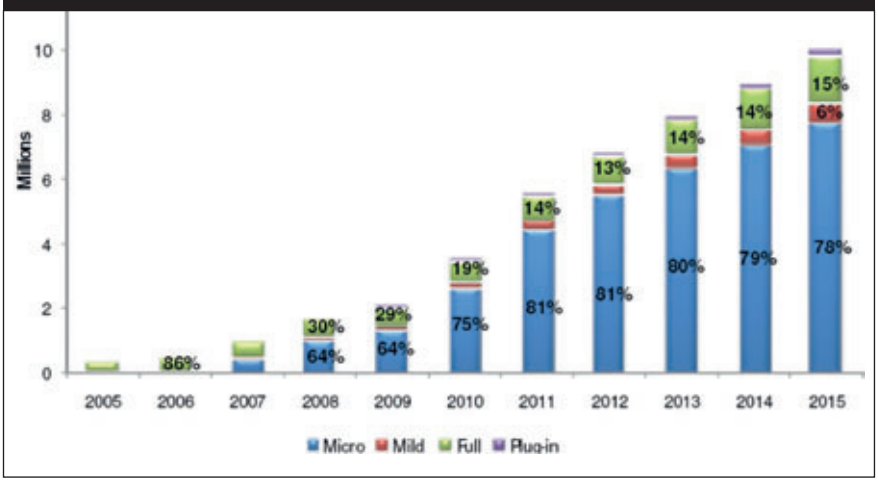
Last October, the biggest unknown was the automobile industry's response to EU legislation that requires manufacturers to reduce average CO2 emissions from the current level of 160 g/km to 120 g/km by 2012. Eight months later, it's clear that the industry response has been a concerted effort to standardize micro and mild hybrid technologies throughout Europe.

The Obama administration's decision to accelerate CAFE standards by

Fuel Savings and Battery Cost Trade-offs For Principal HEV Configurations

	Fuel savings	Basic ICE vehicle cost	HEV premium using advanced lead-acid batteries	HEV premium using Li-ion batteries
Micro-hybrid	10%	$18,000	$750	$1,167
Mild-hybrid	20%	$18,000	$1,500	$2,333
Full-hybrid	40%	$18,000	$2,250	$3,500
PHEV-10	55%	$18,000	$2,000	$6,165
PHEV-40	100%	$18,000	$2,500	$15,828

Frost & Sullivan Scenario for Hybrid Vehicles — Global



five years can only serve to increase the rate of standardization for micro and mild hybrid technologies. Under current conditions, it looks like Frost & Sullivan's "optimistic" view from last October will probably fall well short of the emerging reality.

Despite all the media hype over PHEVs, I'm convinced that cars with plugs will not be a material segment of the HEV market for the foreseeable future and the major business opportunity is in micro, mild and full HEVs.

In combination, the regulatory changes from Brussels and Washington DC have fundamentally altered market dynamics in the HEV sector and increased the critical importance of five facts.

- Aggressive CO2 emission standards will increase the rate of HEV standardization in the EU;
- Acceleration of CAFE standards will increase the rate of HEV standardization in the US;
- The EU standards will be implemented before most proposed lithium-ion battery plants can be built;
- Since adequate supplies of lithium-ion batteries will not be available during the 2009 to 2012 EU phase-in window, most major automobile manufacturers will turn to advanced lead-acid batteries for a substantial portion of their micro, mild and full hybrid product lines; and,
- Once advanced lead-acid batteries earn the first mover advantage in Europe, it will be very difficult, if not impossible, for lithium-ion batteries to overcome an entrenched and cheaper alternative.

I have consistently argued that budget conscious consumers would prefer cheap lead-acid batteries to smaller, lighter and more expensive lithium-ion batteries, particularly for HEV applications. The timing of the new EU regulations has put automakers in a position where they can't afford to wait for the battery of tomorrow.

Instead they have to go to work immediately and meet the CO2 emission standards with batteries they can buy today from established manufacturers. Under those circumstances, I'm convinced that advanced lead-acid batteries will dominate the HEV markets until a clearly superior battery technology is developed.

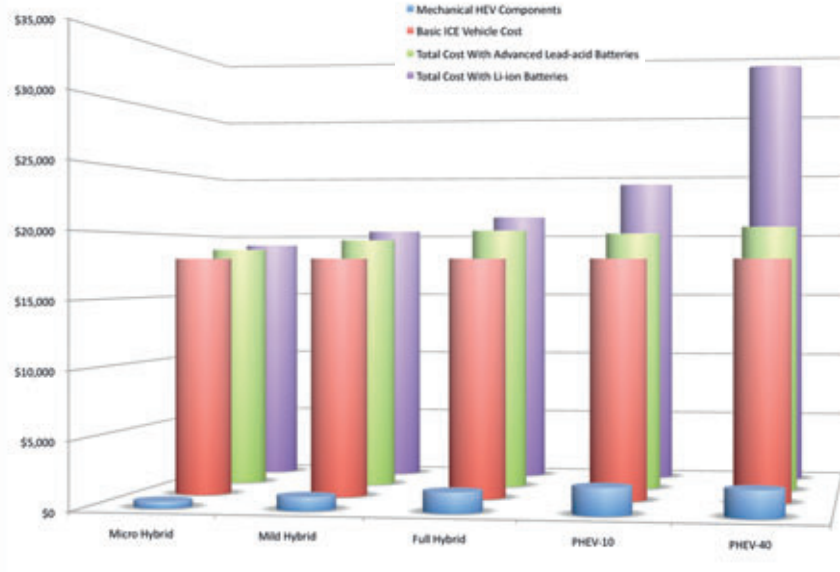
The market dynamic may change over the long-term if PHEVs become a dominant hybrid configuration. It may also be impacted by future changes in the relative price advantage of advanced lead-acid batteries.

For the foreseeable future, however, the lion's share of the revenue gains from the HEV revolution will flow to companies like Johnson Controls, Enersys, Exide and C&D Technologies that have substantial existing manufacturing capacity in both Europe and the US, and from technology-driven newcomers like Axion Power International (OTC: AXPW) that can rapidly and inexpensively expand their production capacity to satisfy soaring demand from the HEV market. ■

The timing of the new EU regulations has put automakers in a position where they can't afford to wait for the battery of tomorrow.

John L Petersen, is a US lawyer based in Switzerland who works as a partner in the law firm of Fefer Petersen & Cie and represents North American, European and Asian clients, principally in the energy and alternative energy sectors. More of his thoughts can be found on http://seekingalpha.com/author/john-petersen

Total cost comparison of HEV's using advanced lead-acid ad Li-ion batteries



	Micro Hybrid	Mild Hybrid	Full Hybrid	PHEV-10	PHEV-40
Mechanical HEV Components	$500	$1,000	$1,500	$2,000	$2,000
Basic ICE Vehicle Cost	$18,000	$18,000	$18,000	$18,000	$18,000
Total Cost With Advanced Lead-acid Batteries	$18,750	$19,500	$20,250	$20,000	$20,500
Total Cost With Li-ion Batteries	$19,167	$20,333	$21,500	$24,165	$33,828