Prime time for batteries

Forecasts vary on how many, and when, electrified vehicles will hit the streets, but auto and battery makers are ramping up efforts like there's no tomorrow.

by Patrick Ponticel

Batteries and battery cells are designed for either high energy, high power, or something in between. Shown here is A123 Systems' portfolio, with the gray prismatic pouch cell for high energy, the orange cylindrical cell for high power, the green cylindrical cell for in between, and the yellow cell for nonautomotive purposes.

Renault-Nissan CEO Carlos Ghosn has taken a strong and bold position on the future of electric vehicles. He and other stakeholders in the company can only hope that battery expert Menahem Anderman is terribly wrong in projecting a much less electrifying future.

Earlier this year at the Advanced Automotive Batteries Conference (which his consulting company, **Advanced Automotive Batteries**, administers every year), Anderman forecasted a global EV market of about 150,000 total vehicles in 2020. For Renault and Nissan, his forecast is 45,000 EV sales in 2020, a figure that he said is 10 times less than what Ghosn projects.

Anderman forecasts a combined EV and plug-in hybrid-electric vehicle (PHEV) market share that "is likely to stay well below 2% through 2020."

Although his projections for EVs and PHEVs are self-admittedly "conservative," Anderman did convey some optimism in his presentation by noting that lithium-ion batteries represent "a very significant growth industry" with sales climbing seven to eight times from 2010 levels to more than $10 billion in 2020—even if sales of EVs and PHEVs account for only 1.5% global market share. The $10 billion figure assumes a 4% market share for hybrid-electric vehicles using Li-ion batteries.

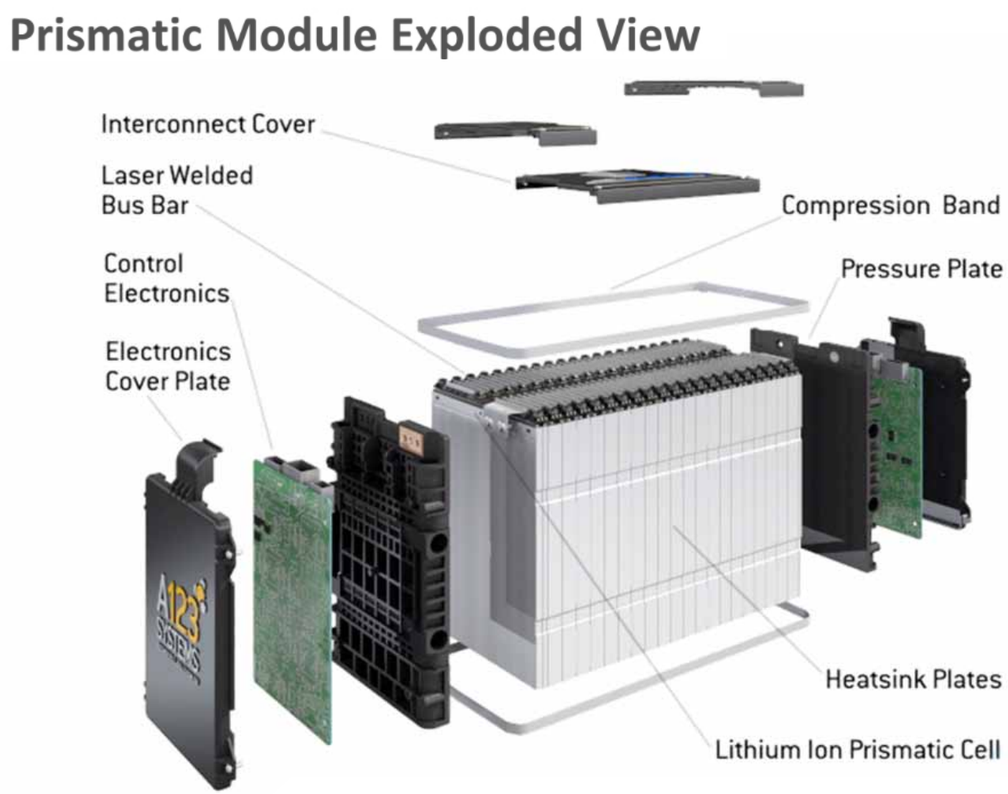
A market share of 2% for EVs and PHEVs is not out of the question, Anderman allowed. But of five "what will it take" keys, "most of them would have to happen, and I think many of them will not be easy to get." He did not identify which of the keys are easy or hard "gets."

One of the keys is actually two keys grouped under the single banner of technology/cost: 100% battery performance improvement and $300/kW·h battery cost. An oil price of $200/barrel before 2020 and "notable new gasoline taxation" comprise the one other key that involves hard numbers. Consumer interest, government subsidies, and reliability/safety of EVs and PHEVs are the other keys.

AABC conference organizer/moderator Menahem Anderman has a less optimistic outlook for electrified vehicles and batteries than do most, if not all, other analysts.

"The growth pattern after 2015 will depend on battery reliability and government policies," Anderman noted.

Among other projections Anderman shared at the January conference in Pasadena (the proceedings are available here and the 2011

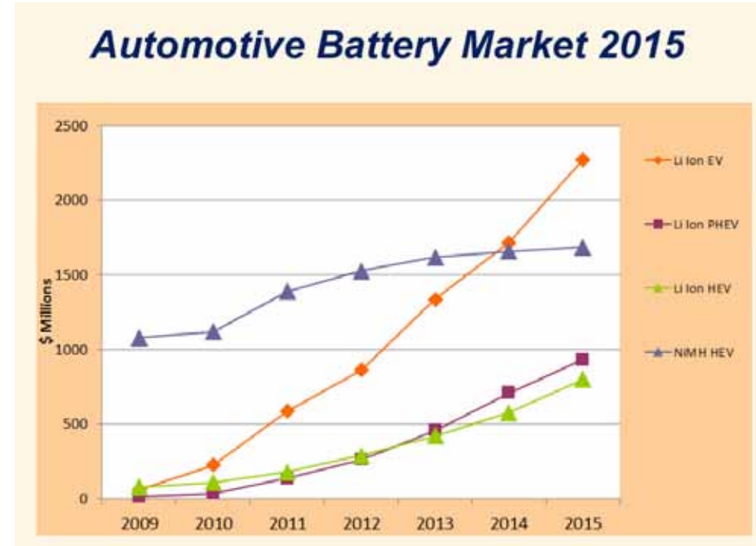


A123 Systems' scalable architecture for its 20 A·h prismatic pouch cells enables economies of scale in the non-cell components of the module. *(Click here to see animation of module construction.)*

Plug-In Hybrid and Electric Vehicle Opportunity Report is available here) is an HEV battery market reaching just over $1.7 billion by 2015, with Li-ion batteries growing market share from 10% currently to about 30% vs. nickel metal-hydride batteries.

Regarding the evolution of Li-ion battery types in 2015-2020, Anderman said he believes battery configuration will move toward prismatic and away from cylindrical, "and the question will be between metal can or pouch." He said he favors the metal can because "it's more reliable, it's proven, but the pouch will make it" because of, among other things, large current investment in the technology.

In terms of cell assembly, Anderman said there is no clear winner between winding, stacking, or Z-fold, and a determining factor will be whether the metal will eventually gain acceptance over the pouch.



Sales of lithium-ion batteries will overtake those of nickel metal-hydride in the next few years, according to AAB's Menahem Anderman.

Low-cobalt NMC (nickel manganese cobalt) is what most battery companies seem to prefer for the future, along with a cell capacity of between 15 and 40 A·h, Anderman said.

Regarding price, he predicts that in 2015 it will be about $12,000 to $15,000 for a 24-kW·h battery produced in a plant with a volume of at least 50,000 packs/year. Among the assumptions for this price is a battery that meets safety goals and has a 10-year life. There are companies offering better prices today, but they either don't meet the safety and life milestones or they are employing "future pricing" that will make it difficult for them to lower their prices in the future, according to Anderman.

Battery makers speak

Nobuaki Yoshioka, Executive Vice President of Automotive Energy Supply Corp. (**AESC**, a joint venture between **Nissan** and **NEC**), politely disagreed with the host of the AABC event. "Dr. Anderman seems very negative, very conservative about the spread of EVs, but I'm convinced there is a [brighter] future for them," he said. (See sidebar for various forecasts.)

Yoshioka also opined that reducing battery costs is the industry's biggest priority. He predicted a steep decline in the coming few years, although he did not offer hard figures. Once the price has come down, the emphasis will be on delivering higher energy density, which could lead to smaller batteries, he said.

The Japanese government seems to share Yoshioka's more positive outlook for EV acceptance, having announced support for the eventual installation of up to 2 million regular ac charging stations and up to 5000 dc quick-charge stations throughout the country, Yoshioka said.

The presentation by **A123 Systems**' Global Director of Marketing, Jeff Kessen, involved no sales projections, although he did note that the company will have invested $1

Safe, low-cost manufacturing can be achieved only via proven processes, said Boston Power's Per Onnerud.

billion in new Li-ion battery capacity between 2009 and 2012. He used much of his time to highlight A123's particular type of lithium-iron-phosphate technology (see the battery materials feature in this edition for more detail) as well as to describe the company's methodology for sorting through the many variables in determining which type of cell best fits the application.

"Every battery manufacturer has a variety of cells designed for different types of applications, some focusing on energy, some on power," said Kessen. But it's not always appropriate that power cells are used for hybrid-electrics, nor energy cells for EVs. He cited a hybrid bus program slated for production later this year. A123's energy cell will be used "for the reason that it has good power for that application and it fits best in the duty cycle that the customer brought to us," he said.

Similarly, **Ohio State University** used A123 System cells last summer to set a new land speed record for EVs, reaching 308 mph (496 km/h). That's not a typical duty cycle for system design, "but in that case it made sense to use a high-power cell for what they were trying to accomplish," said Kessen.

"In the end, I think it's important for battery manufacturers to have enough systems engineering competence and experience so the best cell can be chosen for the application and the analysis of what can be expect-

Bullish on batteries (and the vehicles they go in)

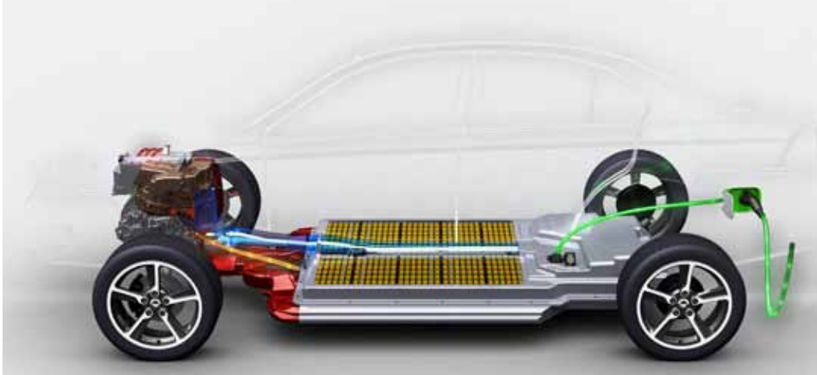
Advanced Automotive Batteries President Manahem Anderman may be the industry's most conservative analyst regarding the future of electrified vehicles. He forecasts a global EV market of about 150,000 total vehicles in 2020 and a combined EV and PHEV market share that "is likely to stay well below 2% through 2020."

In comparison, **Strategy Analytics** on May 3 released an estimate that 1.1 million EV's will be manufactured in 2018, in addition to 6.5 million mild, full, and plug-in hybrid-electric vehicles. The company based its forecast on, among other things, the following trends among automakers: widening deployment to models built on the same platform and to the mass-produced compact segments; increasing flexibility to suit different requirement of different consumers; simplifying design to reduce costs and bring about localized production; and increased competition between suppliers.

Pike Research estimated May 6 that 1.3 million plug-ins (PEVs, including battery EVs and PHEVs) will be purchased for corporate and government fleets between 2010 and 2015—almost 400,000 purchased annually by 2015. Pike Senior Analyst Dave Hurst noted that automakers are looking to fleets in these early years of PEV sales to bolster production and reduce overall vehicle costs. "As a result, passenger cars will be the leading segment in the PEV fleet market over the next five years, representing more than 80% of total sales in 2015."

The analyst firm **Verify Markets** told *SAE VE* on May 4 that it expects 5 million EVs to be sold annually by 2015, more than 1 million in North America.

Research and Markets forecast May 9 that HEVs, PHEVs, and EVs will constitute 35% of the cars made in 2025—probably 25% hybrids and 10% pure EVs with a chance that EVs by then will be even more popular than HEVs. "Any motor manufacturer without a compelling lineup of electric vehicles is signing its death warrant," the company stated.



Coda is among the start-ups planning to launch an electric vehicle.

Lux Research on April 12 projected that energy-storage technologies for EVs is set to grow from $13 billion in 2011 to $30 billion in 2016.

Roland Berger told *SAE VE* on May 10 that it expects EVs to have gained about 5% share in all major markets. In a technical paper delivered at last year's SAE Convergence conference, **IHS Automotive** did not provide a vehicle-sales forecast but did project that the number of individual nameplates globally with some form of electrification—from start-stop to battery-electric—will total almost 800 compared with only about 300 in 2011.

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Costs and Payback Period for Advanced Technologies

Technology	Technical cost, $	Payback years at fuel price per gallon of, $		
		3	6	8
Gasoline turbo with start-stop	1000	5.4	2.7	2.0
Parallel hybrid	3000	8.2	4.1	3.1
EV with range extender	10,000	6.4	2.9	2.2
Pure battery EV	20,000	14.7	6.2	4.5

IHS Automotive

EV Cell and (24kWh) Pack Price*

Based on:168 40-Ah cells; 302V nominal

Volume	Cell Materials	Cell Cost	Cell price	Pack cost	Pack Price
k per year	$/kWh	$/kWh	$/kWh	$/kWh	$/kWh
5	250 - 350	500 - 700	600-800	800 - 1100	850 - 1300
50	180 - 260	270- 400	**330 - 425**	440 - 600	**475 -675**

Price of a 24-kWh battery for a plant producing 50,000 packs/ year is on the order of $12,000-$15,000

Advanced Automotive Batteries

ed in terms of life is done in a complete and professional manner."

Boston Power Chief Technology Officer Per Onnerud noted in his AABC presentation that the industry is starting to see more of a mix in which types of cells are used for which applications. More specifically, he said, "I think we will see that energy cells will come into play more and more, whereas you see some systems today are essentially using power cells for an energy situation."

Onnerud hit on one of Anderman's main industry priorities in his brief description about the company known best for supplying batteries for **Hewlett-Packard** laptops. "I just want to emphasize that when we design for technology, we start with safety and then we design the other attributes."

That is true of the company's Swing 4400 cell, Onnerud said. "We believe that [it] has improved reliability due to some of the safety factors that the cell has. The cell has current-interrupt devices that will interrupt if you overcharge the cell. The cell has venting devices if you were to heat up the cell from some kind of external factor, and we have Six Sigma manufacturing systems today that meet the industry standards."

The Swing has an energy density of 180 W·h/kg, 420 W·h/L, and achieved more than 1000 cycles at 100% depth of charge (DOD)—more than 2000 cycles at 90% DOD.

"This is really where the rubber hits the road," Onnerud said. Fast-charge capability is 80% in 30 min "due to a very nice mechanical envelope, where the stack pressure of the cell is reduced compared to cylindrical cells. And that allows us to not lose significant cycle life when you fast-charge the system, which actually makes it very suitable for automobile applications."

The oval prismatic lithium cobalt manganese Swing cell is being used in **Saab**'s 9-3 ePower EV concept. It's a 35.5 kW·h unit for which Boston Power is also managing the power electronics.