Micro hybrid, HEV, P-HEV and EV market 2012-2025

Impact on the battery business

Christophe PILLOT
Director, AVICENNE ENERGY

November 2013

Presentation Outline
- The rechargeable battery market in 2012/2013
- The x-EV market worldwide in 2012
- 2012-2025 Trends & forecasts
- Conclusions
AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

HEV powered by Lithium ion battery forecasts from 2008 to 2012

EV sold, in million units, worldwide, 2010 - 2020

THE BATTERY MARKET IS REALLY DYNAMIC

Cellular Phones sold per Year (Million)

Tons of Li-ion Cathode per year

Portable PC sold per Year (Million)

Li-ion 18650 cell price ($/Wh)

Source: AVICENNE ENERGY Analyses 2013
THE WORLDWIDE BATTERY MARKET 1990-2012

Lithium Ion Battery: Highest growth & major part of industry investments

Source: AVICENNE ENERGY, 2013
THE WORLDWIDE BATTERY MARKET 1990-2012

Lithium Ion Battery: Highest growth & major part of the investments
Lead acid batteries: By far the most important market (90% market share)

Source: AVICENNE ENERGY, 2013
THE WORLDWIDE BATTERY MARKET
1990-2012

50 BILLION US$ in 2012
5% AVERAGE GROWTH PER YEAR (1990-2012)

Source: AVICENNE ENERGY Analyses 2013

1- Pack level
LI-ION IN 2012
MAIN APPLICATIONS: CELLULAR, NOTEBOOK

4 450 M cells – 32 000 MWh
10 500 M$

CAGR 2002/2012
+25 % per year in Volume
+14% per year in value

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Li-ion Battery sales,
MWh, Worldwide, 2000-2012

Li-ion Battery sales,
MWh, Worldwide, 2000-2012

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LI-ION IN 2012
MAIN APPLICATIONS: CELLULAR, NOTEBOOK

4 450 M cells – 32 000 MWh
10 700 M$ (cell level)

CAGR 2002/2012
+25 % per year in Volume
+14% per year in value

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HEV, P-HEV & EV DEFINITION & SEGMENTATION

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Note: Micro HEV are not in the HEV statistics & HEV forecast
HEV WORLDWIDE IN 2012
1.5 M HEV

HEV sold per year, M units, worldwide, 2000 - 2012

Penetration of hybrids in the global sales, 2000-2012

Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY

Micro hybrid not included
HEV WORLDWIDE IN 2012
BY CAR SUPPLIER

Total HEV Vehicles
+1,5 M in 2012

HEV sold per year, M units per car manufacturers, 2000-2012

Others: Nissan, Mercedes, Mazda, VW, Audi

Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY
Micro hybrid not included
HEV WORLDWIDE IN 2012 BY CAR SUPPLIER

TOP 3: TOYOTA, HONDA, HYUNDAI

OTHERS: FORD, GM, ...

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TOYOTA
HONDA
HYUNDAI

FORD
GM
HYUNDAI

Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY
Micro hybrid not included
HEV WORLDWIDE IN 2012 BY COUNTRY

Total HEV Vehicles
+1,5 M in 2012

HEV sold per year, M units per country, 2004-2012

Source: AVICENNE ENERGY Analyses 2013

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HEV WORLDWIDE IN 2012 BY COUNTRY

USA 29%
JAPAN 54%
EUROPE 10%
OTHERS 7%

Total HEV Vehicles +1,5 M in 2012

HEV sold per year, M units per country, 2004-2012

Source: AVICENNE ENERGY Analyses 2013

Micro hybrid not included
HEV FORECASTS 2012-2025

HEV MARKET: 2.5 Million units in 2015 – 5 M in 2020

Micro hybrid, HEV, P-HEV and EV market 2012-2025

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Micro hybrid not included

Source: AVICENNE ENERGY Analyses 2013
LI-ION BATTERY DEVELOPMENTS FOR HEV, P-HEV & EV

LIB >>> NiMH but
SAFETY & COST ISSUES

<table>
<thead>
<tr>
<th></th>
<th>PRIUS III NiMH</th>
<th>PRIUS x - Li-ion</th>
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<tbody>
<tr>
<td>Volts</td>
<td>201.6</td>
<td>201.6</td>
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<tr>
<td>Cells</td>
<td>168 (28*6)</td>
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<tr>
<td>Capacity</td>
<td>6.5 Ah</td>
<td>3.8 Ah</td>
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<tr>
<td>Energy</td>
<td>1310 Wh</td>
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<td>Weight</td>
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<td>T°C Range</td>
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<tr>
<td>Cyclability</td>
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<tr>
<td>Safety</td>
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<td>Cost</td>
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Recall slash battery profit

Operating profit/Revenue

<table>
<thead>
<tr>
<th>Year</th>
<th>Sanyo</th>
<th>MBI</th>
<th>BYD</th>
<th>SGS</th>
<th>Sony</th>
<th>NEC</th>
<th>Maxell</th>
<th>SDI</th>
<th>LGC</th>
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<td>2010</td>
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<table>
<thead>
<tr>
<th>SAFETY ISSUES</th>
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</thead>
<tbody>
<tr>
<td><strong>Li-ion and LMP are not thermally stable what raises serious safety concerns</strong></td>
</tr>
</tbody>
</table>

| Background | In the 80’s, lithium metal batteries were put into the markets (Moli Energy). Their further development has for a long time been slow because of a low cycle efficiency and safety issues: High chemical reactivity and a low melting point enable strong chemical reactions, even explosions. In the charging-discharging process, lithium metal can form dendrite and accumulate on electrodes. The growing lithium dendrite could puncture the separator and result in an internal short circuit. |
| **CONSEQUENCES:** Except BOLLORE, all the companies developing Li metal batteries cancelled their projects |

| Mobile | Li-ion batteries for mobile devices mostly used a Lithium Cobalt Oxide Cathode and liquid electrolyte. In case of overcharging or short-circuit (contact between anode & cathode) a chain reaction starts -> heating & gasing -> fire ("Thermal runaway") |
| **CONSEQUENCES:** In 2006, SONY had to recall millions of portable PCs for total costs of 400 million USD, more than there profit-to-date |

| Automotive | With new cathode chemistry, most of the automotive today on the markets experienced safety concerns: |
| (1) BYD Taxi in China with a lithium iron phosphate cathode |
| (2) GM Volt in the US with a LG Chemical battery using LMO cathodes (as a result of a crashed tested Chevrolet Volt caught three weeks after the testing !) |
| (3) PRIUS P-HEV in the US (converted from HEV Prius by a local engineering company without any authorisation by Toyota) |

| Aircraft | Boing 787: The fire that burned near the tail of a parked Boeing 787 in Boston was caused by an overheating Lithium ion battery pack. The battery fire could have been hot enough to melt the carbon-fiber reinforced plastic that makes up the plane’s shell. |
| **CONSEQUENCES:** All the 787 worldwide are grounded. Considerable losses for Boing. |
SAFETY IS A SINE-QUA-NON SELECTION CRITERIA FOR BATTERY TECHNOLOGIES

Some technologies are already out of the game due to stability issues

The lithium ion technologies that win will win partly on their safety argument, possibly sacrificing some energy density.
The largest share of the value (40%) comes from cell components. Cell manufacturers & OEM alliance may be the winning model but comes with high risk if the wrong cell manufacturer is selected. Tiers 1- cell manufacturers alliance: most of them disappear (eg. Saft-Johnson Controls, Bosch-Samsung, Enerdel-Delphi...) Tiers 1- OEM alliance on Battery are not successful. Panasonic and LG Chem, cell manufacturers develop raw -material in-house and make the pack integration for OEM. On a different scale, Toyota, BYD or BOLLORE are fully integrate.
LIB MANUFACTURING INVESTMENTS 2009-2015

10-12 B$ WORLDWIDE
>50 GWh in 2015

Total Investment (M$) made for LIB manufacturing

Source: AVICENNE ENERGY Analyses 2013

A123 Michigan Plant - Photo courtesy of A123 Systems

Liotech Plant, Novosibirsk – 1.5 GWh production capacity

Average Investments:
250 $ / kWh

Source: AVICENNE ENERGY Analyses 2013
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AVICENNE ENERGY - CONFIDENTIAL INFORMATION
LIB CELL BILL OF MATERIALS

NISSAN LEAF

BOLLORE BLUE CAR

GM VOLT

BMW ACTIVE HYBRID 5

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AVICENNE ENERGY - CONFIDENTIAL INFORMATION
LI-ION BATTERY COST 2011-2020

LIB cell average cost (EV design; NMC cathode)

LI-ION BATTERY PACK COST FOR EV

* For Production > 100 000 packs/year
TOTAL BATTERY DEMAND 2025 FORECASTS

EV, HEV & P-HEV Battery needs (MWh)
CAGR 2012-2025: +20%

Total battery demand (MWh)
CAGR 2012-2025: +12%

Source: AVICENNE ENERGY Analyses 2013

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Source: AVICENNE ENERGY Analyses 2013
35 MILLION MICRO-HYBRIDS CAR IN 2020

Micro-hybrids car market 2010-2020

![Micro-hybrid car sold per year](image)

Source: AVICENNE ENERGY Analyses 2013

Micro-hybrid batteries

- Powered today by Advanced lead acid batteries (sometimes in conjunction with super capacitors)
- LTO will also penetrate this market (Toshiba -> Suzuki)
- Panasonic develop new NiMH cell to adress the micro-hybrid market

Advantages of micro-hybrid compared to HEV

- Much more profitable than full HEV: 8 to 10 times less expensive than full HEV to save 5% gasoline instead of 20% (4 times less)
- Much more impact on CO2

<table>
<thead>
<tr>
<th></th>
<th>Micro-hybrid</th>
<th>Full HEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>Advanced lead acid</td>
<td>NiMH or LIB</td>
</tr>
<tr>
<td>Cost ($)</td>
<td>300</td>
<td>3000</td>
</tr>
<tr>
<td>Fuel saving (%)</td>
<td>5%</td>
<td>20%</td>
</tr>
<tr>
<td>Million Vehicle sold per year in 2020</td>
<td>35</td>
<td>3.5</td>
</tr>
</tbody>
</table>
HEV, P-HEV AND EV REALITY OF THE MARKET WILL BOOST MICRO HYBRID AND ADVANCED LEAD ACID BATTERIES

2010

STANDARD CAR 88.5%

MILD HEV 0.5%

FULL HEV 1%

2015

STANDARD CAR 44%

MICRO HYBRIDS 10%

ULTRA BATTERY

Li-ion

2020

STANDARD CAR 44%

MICRO HYBRID 50%

FULL HEV 4%

Li-Air, Li-S, Fuel Cells

Source: AVICENNE ENERGY Analyses 2013

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TAKEAWAYS

Battery Market 2010-2025
CAGR = +10%

- Li-ion battery is driven today by Portable PCs & electronic devices
- For HEV, the battery technology is today the NiMH
- In 2012, most of the car makers (except Toyota) switch to Li-ion
- P-HEV & EV will be powered by Li-ion: 6 B$ market in 2015 - 11 B$ in 2020 & 15 B$ in 2025
- EV expectations attract large Chemical companies
- New materials are needed to meet Automotive standards
- HEV will account for less than 5% of the automotive sales in 2020
- P-HEV & EV < 2% by 2020
- Micro-hybrid will achieve >50%
- Lead acid battery will be the first market in 2025 in volume & value
- A very small EV market in the automotive world will represent a huge market for batteries
- New LIB applications: UPS, Telecom, Forklift, Medical, Residential ESS, Grid ESS: CAGR > 15% in the next 15 years

RECHARGEABLE BATTERY MARKET WORLDWIDE
2000-2025

Other: Automatic handling equipment, forklifts, back-up, UPS, Telecom, medical devices, Residential ESS, Grid ESS, ...
THANK YOU

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