THE BATTERY MARKET FOR HEV, P-HEV & EV 2010 - 2020

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THE 28TH INTERNATIONAL BATTERY SEMINAR & EXHIBIT

Fort Lauderdale, Florida
Wednesday, March 16th 2011
1. THE RECHARGEABLE BATTERY MARKET IN 2010
2. ELECTRIC VEHICLE SEGMENTATION
3. HEV MARKET BY COMPETITOR AND BY AREA
4. FORECASTS BY 2020
5. IMPACT ON THE BATTERY BUSINESS
MAIN QUESTIONS

- Impact of the financial & economic crisis on the HEV market & the PHEV or EV developments?
- Will the HEV penetration continue? Where is the limit?
- Car suppliers strategy for HEV, PHEV & EV? Do they believe in those markets?
- What are the main market drivers & limiters?
- When will Li-ion appeared massively in HEV? NiMH Vs. Li-ion for HEV?
- Which Li-ion batteries for the future HEV, PHEV & EV?
- Cobalt, Lithium, Nickel or Phosphate future needs?
- Market for EV, PHEV & HEV batteries in 2015 & 2020?
- Who will be the main battery suppliers?
- Will high level investment result in a significant overcapacity in the future?
WHY EV?

Petroleum consumption worldwide 1960-2009

Price of the WTI barrel of oil, US $

CO₂ density in the atmosphere increase

Source: Energy Information Administration, US Government
Source: http://www.eia.doe.gov/emeu/steo/pub/contents.html

Petroleum consumption worldwide 1960-2009

Price of the WTI barrel of oil, US $

CO₂ density in the atmosphere increase

IPCC, Intergovernmental Panel on Climate Change, Climate Change 2007, Synthesis Report p38
**HEV, P-HEV & EV**

**DEFINITION & SEGMENTATION**

**HYBRID LEVELS:**

- MICRO HEV*
- MILD HEV
- MEDIUM HEV
- FULL HEV

**EV & HEV MARKET**

- EV 25 kWh
- HEV 0.6-2 kWh batteries
- P HEV 5 kWh batteries

**MICRO HEV**
- CITROEN C3
- GM Saturn Vue
- GM AURA
- GM MALIBU
- HONDA ACCORD

**MILD HEV**
- GM AURA
- GM MALIBU
- HONDA ACCORD

**MEDIUM HEV**
- TOYOTA PRIUS
- TOYOTA CAMRY
- FORD ESCAPE
- FORD FUSION
- MILAN
- GM YUKON
- GM TAHOE
- NISSAN ALTIMA

**FULL HEV**
- TOYOTA CAMRY
- TOYOTA PRIUS
- FORD FUSION
- FORD ESCAPE

**THE BATTERY MARKET FOR HEV, P-HEV & EV 2010 - 2020**

*Note: Micro HEV are not in the HEV statistics & HEV forecast*
THE RECHARGEABLE BATTERY MARKET IN 2010
VALUE IN M$

Battery for Automotive market in 2010: 11% of the battery market in value

Battery sales, M US$, Worldwide, 1995-2010

Battery sales, M US$, Worldwide, by application 2000-2010

SOURCE: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011

THE BATTERY MARKET FOR HEV, P-HEV & EV 2010 - 2020 - MARCH 2011
THE RECHARGEABLE BATTERY MARKET IN 2009
VOLUME IN MWH

The worldwide rechargeable battery market, MWh, 1995-2010

Battery for Automotive market in 2010: <5% of the battery market in Volume

The worldwide rechargeable battery market, MWh, 1995-2010

Source: The Rechargeable Battery Market 2010-2020, Avicenne, March 2011
NIMH IN 2010
MAIN APPLICATION: HEV

1 200 M NiMH cells – 3 500 MWh
1.65 B$

NiMH battery market worldwide in value
% for HEV application

NiMH battery by applications, worldwide, % in value, 2010

CAGR 2005/2010
+14% per year in Volume
+10% per year in value

SOURCE : THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
1.3% of vehicle sold worldwide in 2010 was Hybrid

HEV sold per year, M units, worldwide, 2000 - 2010

Penetration of hybrids in the global sales, 2000-2010

Note: Micro HEV are not in the HEV statistics & HEV forecast

SOURCE: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
HEV WORLDWIDE IN 2010

Total HEV Vehicles:
≈ 900,000 units in 2010

HEV sold per year, M units per car manufacturers, 2000-2010

SOURCE: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
HEV WORLDWIDE IN 2010

Total HEV Vehicles:
≈ 900 000 units in 2010

USA 30%
JAPAN 55%
EUROPE 11%
OTHERS 4%

Note: Micro HEV are not in the HEV statistics & HEV forecast

HEV sold per year, M units per country, 2000-2010

SOURCE: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
HEV FORECASTS UP TO 2015

HEV MARKET IN 2015 : 2,2 Million units (1)

Penetration of hybrids (2) in the global sales, 2000-2015

Penetration of hybrids (2) in the global sales, 2000-2015

(1) Assumptions:
- >75 M vehicle sold WW in 2015
- 3% Hybrids

(2) HEV & hybrid excluding micro hybrids

SOURCE : THE RECHARGEABLE BATTERY MARKET 2010-2020 , AVICENNE, MARCH 2011
NIMH BATTERY DEVELOPMENTS

NiMH Capacity is increasing
Exemple of AA NiMH
(index 100 in 1996)

NiMH cost per kWh is decreasing
(index 100 in 1996)

<table>
<thead>
<tr>
<th></th>
<th>PRIUS II</th>
<th>PRIUS III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>6.5 Ah</td>
<td>6.5 Ah</td>
</tr>
<tr>
<td>Cells</td>
<td>228 (38 * 6)</td>
<td>168 (28 * 6)</td>
</tr>
<tr>
<td>Voltage</td>
<td>273.6 v</td>
<td>201.6 v</td>
</tr>
<tr>
<td>Specific power</td>
<td>1000 W/kg</td>
<td>1300 W/kg</td>
</tr>
<tr>
<td>Specific energy</td>
<td>46 Wh/kg</td>
<td>46 Wh/kg</td>
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<tr>
<td>Total power/HEV</td>
<td>36 kW</td>
<td>37.8 kW</td>
</tr>
<tr>
<td>Total energy/HEV</td>
<td>1778 Wh</td>
<td>1310 Wh</td>
</tr>
</tbody>
</table>

SOURCE : THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
Thanks to TOYOTA, Panasonic EV, got more than 75% of the HEV battery market and a large know-how.

NiMH battery & Car makers relationships in 2009/2010

**Production**
- TOYOTA
- LEXUS
- HONDA
- FORD
- NISSAN
- GM
- BMW
- DAIMLER
- CHRYSLER

**Development**
- VW
- DAIMLER
- BMW
- PSA
- CHERY

SOURCE: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
LI-ION BATTERIES DEVELOPMENTS FOR HEV, P-HEV & EV

- Li-ion is THE solution for the future
  - BUT, SAFETY, LIFE TIME & COST issues
  - Lot of technical solutions (NMC, NCA, LFP, LCO...)
  - Lot of EXPENSIVE Developments...

So,
- Lot of JV, partnerships etc...

### JOINT VENTURE & STRONG PARTNERSHIP

<table>
<thead>
<tr>
<th></th>
<th>TOYOTA</th>
<th>NISSAN</th>
<th>HONDA</th>
<th>FORD</th>
<th>MITSUBISHI</th>
<th>DAIMLER</th>
<th>BYD AUTO</th>
<th>BOSCH</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>SB LiMotive</td>
<td></td>
</tr>
<tr>
<td>SAFT</td>
<td></td>
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<td>JV</td>
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<td>BYD</td>
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<td></td>
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<td></td>
<td>JV in China</td>
<td></td>
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<tr>
<td>ENAX</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HEV, EV</td>
<td></td>
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<tr>
<td>MAGNA</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Partner</td>
<td></td>
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<table>
<thead>
<tr>
<th>PRIUS III NiMH</th>
<th>PRIUS x - Li-ion</th>
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<tbody>
<tr>
<td>Volts</td>
<td>201.6</td>
</tr>
<tr>
<td>Cells</td>
<td>168 (28*6)</td>
</tr>
<tr>
<td>Capacity</td>
<td>6.5 Ah</td>
</tr>
<tr>
<td>Energy</td>
<td>1310 Wh</td>
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<tr>
<td>Weight</td>
<td>38 kg</td>
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<tr>
<td>T°C Range</td>
<td>+</td>
</tr>
<tr>
<td>Cyclability</td>
<td>+</td>
</tr>
<tr>
<td>Safety</td>
<td>++</td>
</tr>
<tr>
<td>Cost</td>
<td></td>
</tr>
</tbody>
</table>

TOYOTA, NISSAN, HONDA, FORD, MITSUBISHI, DAIMLER, BYD AUTO, BOSCH, CONTINENTAL, JC, PANASONIC, PEVE, NEC, AESC, GSY, LEJ (EV), SB LiMotive, JV, JV in China, Partner, HEV, EV, ENAX, MAGNA

THE BATTERY MARKET FOR HEV, P-HEV & EV 2010 - 2020 - MARCH 2011
# Li-Ion Batteries Developments

The battery market for HEV, P-HEV & EV 2010 - 2020 - March 2011

<table>
<thead>
<tr>
<th>Li-ion</th>
<th>Tiers 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sanyo</td>
<td></td>
</tr>
<tr>
<td>PEVE</td>
<td></td>
</tr>
<tr>
<td>AESC (Nec-Nissan)</td>
<td></td>
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<tr>
<td>EC SAFT</td>
<td></td>
</tr>
<tr>
<td>BEJ - Blue Energy Japan</td>
<td></td>
</tr>
<tr>
<td>A123</td>
<td></td>
</tr>
<tr>
<td>LiTec - Evonik</td>
<td></td>
</tr>
<tr>
<td>LG</td>
<td></td>
</tr>
<tr>
<td>LEI (GSY-Mitsubishi)</td>
<td></td>
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<tr>
<td>SB LiMotive (SDI-BOSCH)</td>
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<tr>
<td>ENAX - CONTINENTAL</td>
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<td>MAGNA</td>
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<tr>
<td>GAZA</td>
<td></td>
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<td>GSY</td>
<td></td>
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<tr>
<td>TOSHIBA</td>
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<tr>
<td>BYD</td>
<td></td>
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<tr>
<td>HITACHI</td>
<td></td>
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<tr>
<td>BATSCAP (BOLLORE-EDF)</td>
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<tr>
<td>SK Energy</td>
<td></td>
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<tr>
<td>TESLA</td>
<td></td>
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<tr>
<td>CONTINENTAL</td>
<td></td>
</tr>
<tr>
<td>ALP/E-One</td>
<td></td>
</tr>
<tr>
<td>Emerit (Delphi 28,9%)</td>
<td></td>
</tr>
<tr>
<td>RENAULT/AESC/CESA</td>
<td></td>
</tr>
<tr>
<td>Panasonic/Tesla</td>
<td></td>
</tr>
<tr>
<td>Sony</td>
<td></td>
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<tr>
<td>Lishen</td>
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</tr>
<tr>
<td>HITACHI MAXELL</td>
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</tr>
</tbody>
</table>

**ASIA**
- TIER 1: AESC (Nec-Nissan), EC SAFT, BEJ, Sanyo, LG, LG Chem, BYD, HITACHI, SK Energy, TESLA
- Other: A123, LiTec - Evonik, LEI (GSY-Mitsubishi), SB LiMotive (SDI-BOSCH), ENAX - CONTINENTAL, MAGNA, GAZA, GSY, TOSHIBA, BATSCAP (BOLLORE-EDF)

**USA**
- TIER 1: AESC (Nec-Nissan), EC SAFT, BEJ, Sanyo, LG, LG Chem, BYD, HITACHI, SK Energy, TESLA
- Other: A123, LiTec - Evonik, LEI (GSY-Mitsubishi), SB LiMotive (SDI-BOSCH), ENAX - CONTINENTAL, MAGNA, GAZA, GSY, TOSHIBA, BATSCAP (BOLLORE-EDF)

**EUROPE & AUTRES**
- TIER 1: AESC (Nec-Nissan), EC SAFT, BEJ, Sanyo, LG, LG Chem, BYD, HITACHI, SK Energy, TESLA
- Other: A123, LiTec - Evonik, LEI (GSY-Mitsubishi), SB LiMotive (SDI-BOSCH), ENAX - CONTINENTAL, MAGNA, GAZA, GSY, TOSHIBA, BATSCAP (BOLLORE-EDF)

**THE BATTERY MARKET FOR HEV, P-HEV & EV 2010 - 2020 - MARCH 2011**

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LI-ION BATTERY COST

LI-ION BATTERY COST
CELLS / PACK

LI-ION BATTERY PACK COST FOR EV
AVICENNE FORECASTS

Source: AVICENNE Compilation, March 2011

Short term*
2020**

* For Production > 100,000 packs/year
** USBAC Goal in 2020
LI-ION PENETRATION IN VARIOUS DEVICES
AVICENNE & OTHER ANALYSTS FORECAST

(1) AVICENNE HEV Forecasts, march 09, Relevant scenario
(2) AVICENNE HEV Forecasts, march 09, Li-ion Optimistic scenario
(3) IIT, TAKESHITA, March 08, THE 25th INTERNATIONAL BATTERY SEMINAR & EXHIBIT, Slide 8 & March 2009, 26th Battery Seminar, Slide 5
(4) AAB, Menahem ANDERMAN, Ph.D, Tampa, Florida, May 2009

SOURCE: AVICENNE COMPILATION, MARCH 2011
LONG TERM HEV FORECAST FROM 3 TO 8 M HEV IN 2020

HEV FORECASTS (Million)

SOURCE: AVICENNE COMPILATION, MARCH 2011
LONG TERM
HEV BATTERY FORECASTS

HEV market, million units, worldwide, 2005-2020

Number of HEV sold worldwide (Million)

0,0  0,5  1,0  1,5  2,0  2,5  3,0  3,5  4,0

% of Li-ion - Relevant Scenario

HEV battery market worldwide, million $ 2000-2020

0  500  1000  1500  2000  2500  3000

% of Li-ion battery in HEV

NiMH
Li-ion
Penetration of Li-ion in IHV (%)

Note: Micro HEV are not in the HEV statistics & HEV forecast

SOURCE: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
### HEV, P-HEV & EV Long Term Forecasts

**EV Energy Need: 25 More Than HEV!**

#### Average Wh per device

<table>
<thead>
<tr>
<th>Device</th>
<th>Average Wh</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV</td>
<td>25000</td>
</tr>
<tr>
<td>P-HEV</td>
<td>10000</td>
</tr>
<tr>
<td>HEV</td>
<td>1000</td>
</tr>
<tr>
<td>E-bikes</td>
<td>400</td>
</tr>
<tr>
<td>Power Tools</td>
<td>45</td>
</tr>
<tr>
<td>Portable PC</td>
<td>50</td>
</tr>
<tr>
<td>Mobile Phone</td>
<td>4</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of EV Sold (Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
</tr>
<tr>
<td>2013</td>
<td>4</td>
</tr>
<tr>
<td>2014</td>
<td>8</td>
</tr>
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<td>2015</td>
<td>16</td>
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<td>2016</td>
<td>32</td>
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<td>2017</td>
<td>64</td>
</tr>
<tr>
<td>2018</td>
<td>128</td>
</tr>
<tr>
<td>2019</td>
<td>256</td>
</tr>
<tr>
<td>2020</td>
<td>512</td>
</tr>
</tbody>
</table>

#### Sources
- IIT (March 2011)
- Deutsche Bank (2010)
- Roland Berger (2010)
- AVICENNE (March 2011)

**Source:** The Rechargeable Battery Market 2010-2020, AVICENNE, March 2011
Assumptions

200,000 EV in 2015
1M in 2020
100% Li-ion

0.1 M P-HEV in 2015
0.4 M in 2020
100% Li-ion

2.2 M HEV in 2015
3.5 M in 2020
35% Li-ion in 2020

EV, HEV & P-HEV Battery needs (M Wh)
2005 – 2020

EV, HEV & P-HEV Battery needs (M $)
2005 – 2020

SOURCE: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
LIB MANUFACTURING INVESTMENT 2009-2015
10-12 B$ WORLDWIDE / >50 GWH IN 2015

Total Investment (M$) made for LIB manufacturing

SOURCE: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
ANNOUNCED INVESTMENT WILL RESULT IN SIGNIFICANT OVERCAPACITY

**Assumptions**

- 200,000 EV in 2015
- 1M in 2020
- 100% Li-ion

- 0.1 M P-HEV in 2015
- 0.4 M in 2020
- 100% Li-ion

- 2.2 M HEV in 2015
- 3.5 M in 2020
- 35% Li-ion in 2020

**EV, HEV & P-HEV Battery needs (M Wh)**

- 2005 – 2020 (Scenario 2)

- Production capacity

**SOURCE**: THE RECHARGEABLE BATTERY MARKET 2010-2020, AVICENNE, MARCH 2011
TOTAL BATTERY DEMAND
2005-2020

Total battery demand (M Wh)
2005 – 2020

- EV 25 kWh
- P-HEV 10 kWh
- HEV 1 kWh
- Li-ion except Auto
- NiMH except Auto
- NiCd
The Hybrid vehicle is the only mass market choice for electric traction cars today

Toyota opened this market and earn money with HEV models

The hybrid vehicles is now a niche market: in 2015 we believe more than 2,1 million Hybrid cars will be sold worldwide

The battery technology is today the NiMH, we don’t expect the Li-ion to be significant on the HEV mass market

P-HEV & EV will be powered by Li-ion

1 M EV represent roughly 20 000 MWh, or 40 000 tones of cathode materials!

HEV, P-HEV & EV will change the gasoline dogma in the car Industry. In the next decade, we are expecting one of the world most important disruption in the car industry

Then, EV could change totally the battery market on a long term basis.
IMPACT OF A DISASTER

LIB MATERIALS
- Cathode market share
- Anode market share
- Separator market share
- Electrolyte market share

BATTERIES
- LIB market share
- NiMH market share
- NiCd market share

APPLICATIONS
- Batteries for HEV, PHEV, EV market share

THE BATTERY MARKET FOR HEV, P-HEV & EV 2010 - 2020 - March 2011
Thank you!

Christophe Pillot

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