The worldwide battery market 2011-2025

Christophe PILLOT
Director, AVICENNE ENERGY

Presentation Outline
- The rechargeable battery market in 2011
- The Li-ion battery value chain
- Li-ion battery material market
- Forecasts & conclusions
<table>
<thead>
<tr>
<th>24th October</th>
<th>25th October</th>
<th>26th October</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Keynotes</strong></td>
<td><strong>Car Makers</strong></td>
<td><strong>Safety</strong></td>
</tr>
<tr>
<td>AVICENNE</td>
<td>FORD</td>
<td>NATUREO</td>
</tr>
<tr>
<td>HP</td>
<td>PSA</td>
<td>FINANCES</td>
</tr>
<tr>
<td>TOYOTA</td>
<td>RENAULT</td>
<td>GS YUASA</td>
</tr>
<tr>
<td>SB LIMOTIVE</td>
<td>DAIMLER</td>
<td>SAFT</td>
</tr>
<tr>
<td>BAR ILAN UNIV.</td>
<td>TOSHIBA</td>
<td>LECLANCHE</td>
</tr>
<tr>
<td>GTAI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J. PETERSEN</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>R&amp;D</strong></td>
<td><strong>Raw Mat.</strong></td>
<td><strong>Manu-facturing</strong></td>
</tr>
<tr>
<td>TOYOTA</td>
<td>UMICORE</td>
<td>MEGTEC</td>
</tr>
<tr>
<td>FRAUNHOFER INST.</td>
<td>PRAYON</td>
<td>POLYTYPE</td>
</tr>
<tr>
<td>US DOE</td>
<td>BASF</td>
<td>EIRICH</td>
</tr>
<tr>
<td>R. BRODD</td>
<td>CLARIANT</td>
<td>SOVEMA</td>
</tr>
<tr>
<td>IFP</td>
<td>TODA KOGYO</td>
<td></td>
</tr>
<tr>
<td>CEA</td>
<td>QINGDAO</td>
<td></td>
</tr>
<tr>
<td>SHMUEL DE-LEON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWEL</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Portable</strong></td>
<td><strong>Raw Mat.</strong></td>
<td><strong>Manu-facturing</strong></td>
</tr>
<tr>
<td>TI</td>
<td>DOW</td>
<td>KROENERT</td>
</tr>
<tr>
<td>INTEL</td>
<td>DUPONT</td>
<td>PEC</td>
</tr>
<tr>
<td>ST ERICSSON</td>
<td>DREAM WEAVER</td>
<td>SCHENK</td>
</tr>
<tr>
<td>CALL2RECYCLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Battery Managmt.</strong></td>
<td><strong>Raw Mat.</strong></td>
<td><strong>Future</strong></td>
</tr>
<tr>
<td>CHE EV</td>
<td>FMC</td>
<td>ROLANDBERGER</td>
</tr>
<tr>
<td>INTERTEK</td>
<td>HITACHI</td>
<td>ELEMENT ENERGY</td>
</tr>
<tr>
<td>RWTH AACHEN</td>
<td>ARKEMA</td>
<td>MANZ TUBINGEN</td>
</tr>
<tr>
<td>HEL</td>
<td>JSR</td>
<td>BUHLER</td>
</tr>
<tr>
<td>LITHIUM BALANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Battery</strong></td>
<td><strong>Safety</strong></td>
<td><strong>Battery</strong></td>
</tr>
<tr>
<td></td>
<td>SAE</td>
<td>BASF-OVONIC</td>
</tr>
<tr>
<td></td>
<td>PSA</td>
<td>POWERGENIX</td>
</tr>
<tr>
<td></td>
<td>RENAULT</td>
<td>IKERLAN</td>
</tr>
<tr>
<td></td>
<td>DAIMLER</td>
<td>ILZRO-ALABC</td>
</tr>
<tr>
<td></td>
<td>TOSHIBA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RESERVE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The worldwide Battery market 2011-2025

**BATTERIES 2012**
October 24-26, 2012
Nice, FRANCE

**CONTACT**
Christophe PILLOT
+ 33 1 47 78 46 00
c.pilot@avicenne.com
AVICENNE PROFILE

Information for Growth - Powering your company’s market strategy with in-depth research

- Creation: 1992
- Headquarter: Paris
- Liaison Office: Japan, USA
- AVICENNE Energy Director: Christophe Pillot
- 4 consultants in Paris
METHODOLOGY: EXTENSIVE FIELD RESEARCH TO RETRIEVE & CROSS CHECK INFORMATION

Top management contacts network > 17 000 contacts

Conferences & Exhibitions

In Depth analysis Of applications

Cross Check Analysis

Battery Makers

Battery Users, OEM

Substitution technologies: SuperCap, Fuel cells

Safety

Raw materials suppliers

Environment & recycling

The worldwide Battery market 2011-2025

BATTERIES 2012
October 24-26, 2012
Nice, FRANCE

CONTACT
Christophe PILLOT
+ 33 1 47 78 46 00
c.pilot@avicenne.com
MORE THAN 180 REFERENCES WORLDWIDE

A123, AIR LIQUIDE, AIR PRODUCT, AHLSTROM, ALCATEL, AMPEREX (ATL), APPLIED MATERIALS, AROS SECURITIES, ARC, ASHLAND, ATOFINA - ARKEMA, AT KEARNEY, AXEON, BAIN, BASF, BATTERY R&D ASSOCIATION OF KOREA, B&D, BHP BILLITON, BRAND LICENCING PARNERS (BLP), BOURNS, BOSCH, BUHLER GMBH, BYD, CAP X, CATELLA, CARBONE LORRAINE, CARLYLE, CATELLA, CATERPILLAR INC., CDN COBALT, CEA/LITEN, CELGARD, CHEMETALL, CHEMISHE FABRIK BUDENHEIM, CIBA, CIAPS CHINA, COGEMA, CONOCO PHILIPS, CRU GROUP, CSC CHALLENGE STRATEGY CHANGE, DCN, DELTA, DGA, DIALOG SEMICONDUCTOR, DOW CHEMICAL, DOW CORNING, DUPONT, DURACELL, EDF, ELECTRO ENERGY, ENER 1, ENERGIZER, EOLITE, EPCH OHG, ERMET, ETC AB, FACOM, FALCON BRIDGE, FAIRCHILD SEMICONDUCTOR, FAMEART, FIST, FLORIDIENNE DE CHIMIE, FMC, FORTU POWER CELL, FRANCE TELECOM, FULTON INNOVATION, GAIA, GIL IMPORT BATTERIES LTD., GS MELCOTEC, HC STARCK (BAYER), HILTI, HITACHI MAXELL, HOLLINGSWORTH & VOSE CIE, HONEYWELL, HPL (HIGH POWER LITHIUM), HUTCHINSON, IER, IGL EXPORT, INTERNATIONAL COMPONENT CORP., INTERNATIONAL RECTIFIER, INTEK, INTEL, INTERSIL, INCO, ITRI, ITS, JBC, JETRO, JOHNSON CONTROLS, KODAK, KRUGER, LAZARD, LECLANCHÉ, LEGRAND, LG CHEMICAL, LION CELLS, LITTLE FUSE, LILIPUCIAN, LYNAS CORP, MATSUHITA, MICROSOFT, MTI MICRO FUEL CELLS, MOLTECH, MOLYCORP, MOMENTIVE, MOTOROLA, MUNSTER UNIVERSITY, NANOYCL, NCCP - RUSSIA, NITECH, NKKPC, NORILSK NICKEL, NOVALED, NTK POWERDEX, OMG INC, PANASONIC, PHILIPS, PHOTON, PK & WISE, POWER GENIX, PRAYON, PRISMARK, PSA, RAYOVAC, RECHARGE, RENAULT, RHODIA, ROLAND BERGER, SAFT, SAGENTIA, SAINT GOBAIN, SAKTI, SAMSUNG SDI, SANIK, SCHRODER VENTURE, SCOTENT ENTREPRISE, SFPZ, SHENZHEN HIGH POWER TECHNOLOGY, SCHOTT AG, SKC, SVE - DASSAULT, SOLVAY, SONY, STIBAT, STORCK, STRATEGIE ANALYSIS, TERRAROSSA CAPITAL, TIGER GLOBAL, TODA KOGYO, TOTAL, TOTAL WIRELESS SOLUTION, TOYO, TOYOTA, TYCO, UMICORE, UNIROSS, URALELEMENT, US NAVY, VARTA, VOLTRACK, WARBURGPINCUS, WORLD INDUSTRIAL INFORMATION CENTER, WR GRACE & CIE, YASLAMEN, ZEBRA, ZPOWER
AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

HEV powered by Lithium ion battery forecasts from 2008 to 2011

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

OUTLINE

- THE RECHARGEABLE BATTERY MARKET IN 2011/2012
- LIB VALUE CHAIN
- LIB RAW MATERIAL MARKET
- 2020 & 2025 FORECASTS
- CONCLUSIONS
THE BATTERY MARKET IS REALLY DYNAMIC

Cellular Phones sold per Year (Million)

- 2000
- 2011

Million Units / year

Li-ion
NiMH

Portable PC sold per Year (Million)

- 2000
- 2011

Million Units / Year

Li-ion
NiMH

Tons of Li-ion Cathode per year

- 2000
- 2011

Tons of cathode / Year

Li-ion 18650 cell price ($/Wh)

- 2000
- 2011

$/Wh
THE WORLDWIDE BATTERY MARKET 1990-2010

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

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

![Graph showing worldwide battery market from 1990 to 2010.](image)
LI-ION IN 2011
MAIN APPLICATIONS: CELLULAR, NOTEBOOK

>4 200 M cells – 28 000 MWh
9 700 M$

CAGR 2006/2011
+21% per year in Volume
+13% per year in value

Li-ion Battery sales,
MWh, Worldwide, 2000-2011

Li-ion Battery sales,
MWh, Worldwide, 2000-2011

- 2 000
- 4 000
- 6 000
- 8 000
- 10 000
- 12 000


M Wh

Cellular Phones Portable PCs Others

Tablets Digital Camera Toys E-bikes

Power Tools Video Games Auto Others Camcorders MP3 Household devices

The worldwide Battery market 2011-2025

BATTERIES 2012
October 24-26, 2012
Nice, FRANCE

CONTACT
Christophe PILLOT
+ 33 1 47 78 46 00
c.pilot@avicenne.com
LI-ION IN 2011
MAIN APPLICATIONS: CELLULAR, NOTEBOOK

> 4 200M cells – 28 000 MWh
9 700 M$

CAGR 2006/2011
+21% per year in Volume
+13% per year in value
LI-ION VALUE CHAIN

- **CATHODE SUPPLIERS**
  - 63,000 T in 2011
  - Revenues: 1.8 B$
  - CAGR 06/11: +13%

- **ANODE SUPPLIERS**
  - 32,200 T
  - Revenues: 0.55 B$
  - CAGR 06/11: 9%

- **ELECTROLYTE SUPPLIERS**
  - 21,000 T
  - Revenues: 0.4 B$
  - CAGR 06/11: 17%

- **SEPARATOR SUPPLIERS**
  - 440 M m²
  - Revenues: 0.8 B$
  - CAGR 06/11: 15%

- **BINDER SUPPLIERS**
  - 4,800 Tons
  - Revenues: 0.15 B$
  - CAGR 06/11: 12%

- **ANCILLARY**
  - Revenues: 0.5 B$

**CELL MANUFACTURE RS**
- Revenues: 9 B$
- Gross margin: <10%

**PACK MANUFACTURE RS**
- Revenues: 11 B$
- Gross margin: <10%

**OEMs**
CATHODE ACTIVE MATERIALS NEEDS BY CHEMISTRY

Cathode active materials for LIB in Tons, 2000-2011

Cathode active materials for LIB, % of volume, 2011
CATHODE ACTIVE MATERIAL FORECASTS 2000-2020

Cathode active materials 2000-2020 - Tons

- **ASSUMPTIONS:**
  - Portable devices: 2010-2020: +11% per year in volume
  - HEV: 3,7 M HEV/year in 2020, 35% LIB
  - P-HEV: 0,4 M P-HEV/year in 2020, 100% LIB
  - EV: 1M EV/year in 2020, 100% LIB

Cathode active materials in 2011: 63,000 Tons

Cathode active materials in 2020: 250,000 Tons
ANODE FOR LIB IN 2011

Natural graphite is more & more used

Note:
MCMB: Mesocarbon Microbeads
LIB SEPARATOR MARKET 2011

LIB separator market, M$, CAGR 2001/2011: +19%

LIB Separator supplier, market share in 2011

- CELGARD 26%
- ASAHI 25%
- TDK/Nitto Denko 17%
- TORAY-TONEN 21%
- SK 12%
- UBE 7%
- ENTEK 3%
- SUMITOMO 1%
- Others 5%

Others: TDK/Nitto Denko, Foshan Jinhui Hi-Tech, Shenzhen Senior Technology Material, Xinxiang Green next Energy, Dupont, …
ELECTROLYTE SUPPLIERS/CUSTOMERS
21 200 TONS IN 2011

LIB electrolyte market, Tons,
CAGR 2001/2011: +19%
TIME TO MARKET FOR NEW MATERIALS IN LIB INDUSTRY

The research and development in this industry is very long and time consuming.

Time to market to commercialize a new material is long. Remember that the first Li-ion battery was launch by Sony in 1991 with LCO cathode, graphite, LiPF6 electrolyte & polyolefin membrane. It was 20 years ago.

LTO was invented by Matsushita in 1993 (19 years ago)

Lithium iron phosphate was invented in 1995 (15 years ago).

So, it take between 10 & 20 years to commercialized a new material in the battery industry.
BATTERY MARKET FORECASTS
2011-2025

Applications covered

- Portable PCs, net-book
- Cellular Phones, Smartphones
- Tablets
- Camcorders
- Cordless Tools, Gardening tools
- Digital Camera
- Games, MP3
- Cordless Phones
- Shavers, Toothbrush,
- RC Cars
- E-bikes
- Security lighting
- Vehicles: HEV, P-HEV, EV
- Energy Storage
- Others

Parameters analysis

- Main segment trends
- Power need trends (volume, weight, capacity, running time)
- Penetration rate for each Chemistry, each form factor
- 2011 -2020 Forecasts
- OEM strategies and positions
- Main drivers & limiters
PORTABLE ELECTRONIC DEVICE FORECASTS 2011-2020

Cellular phone demand (M Units)
CAGR 2010-2020: +6%

Cellular Phone market Drivers
- Emergent market
- Renewal ratio increase
- Smartphone penetration increase

LIB cells demand 2010-2020
Polymer penetration: 16% -> 33%

LIB cells for cellular phone trends
- Pouch cell ratio increase
- Increase of Thickness
- Increase of >1400 mAh capacity
PORTABLE ELECTRONIC DEVICES FORECASTS 2011-2020

Portable PC demand (M Units)
2010-2020 CAGR: +10%

- Mature market stable or decreasing
- Growth driven by Emerging market
- Ultrabook is increasing (20\(^{(1)}\) to 60% in 2013\(^{(2)}\))
- ASP decreasing (<499$ Portable PCs increase from 25% in 2010 to 33% in 2012

(1) Samsung & AVICENNE (2) Intel

LIB cells for portable PC trends
- Thinner cells
- Pouch cells penetration increasing from 7% in 2010 to 23% in 2020
- > 2800 mAh for Premium/corporate
- 2.2 Ah for consumer, emerging market
2025 LIB FORECASTS EXCEPT AUTOMOBILE

2000-2025 LIB market, MWh, by application (except Auto)

2000-2025 LIB market, M cells, by form factor (Except Auto)

(1) Source: Battery Japan 2012 BJ-1 conference – Slide p 10
LONG TERM HEV FORECAST FROM 3 TO 8 M HEV IN 2020

AVICENNE ENERGY FORECASTS ARE REALISTIC COMPARE TO OTHER ANALYSTS

Source: AVICENNE ENERGY Compilation, February 2012
LI-ION PENETRATION IN VARIOUS DEVICES: AVICENNE & OTHER ANALYSTS FORECAST

Li-ion penetration in electronic devices & HEV

HEV powered by LIB forecasts from 2008 to 2011


---

(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,
(4) AAB, Menahem ANDERMAN, Ph.D, Tampa, Florida, May 2009
LIB BUSINESS
RECALL SLASH BATTERY PROFIT

- More & more incidents & accidents
- All the battery makers and the OEM are concerned
- Recall cost impact drastically the battery business and the profitability

Operating profit/Revenue

2002 2003 2004 2005 2006 2007 2008 2009 2010

0% 10% 20% 30%

-50% -40% -30% -20% -10% 0%

Sanyo MBI BYD SGS NEC Maxell LGC SDI Average

More & more incidents & accidents
All the battery makers and the OEM are concerned
Recall cost impact drastically the battery business and the profitability

Operating profit/Revenue

2002 2003 2004 2005 2006 2007 2008 2009 2010

0% 10% 20% 30%

-50% -40% -30% -20% -10% 0%

Sanyo MBI BYD SGS NEC Maxell LGC SDI Average
LIB MANUFACTURING INVESTMENTS
2009-2015

10-12 B$ WORLDWIDE
>50 GWh in 2015

The worldwide Battery market 2011-2025

LIB MANUFACTURING INVESTMENTS
2009-2015

10-12 B$ WORLDWIDE
>50 GWh in 2015

The worldwide Battery market 2011-2025

LIB MANUFACTURING INVESTMENTS
2009-2015

10-12 B$ WORLDWIDE
>50 GWh in 2015

The worldwide Battery market 2011-2025

LIB MANUFACTURING INVESTMENTS
2009-2015

10-12 B$ WORLDWIDE
>50 GWh in 2015

The worldwide Battery market 2011-2025
LIB BATTERY COST

Costs analysis

- Raw material cost (Co, Mn, Ni, Al, Cu, ...)
- Anode, cathode, Electrolyte, separator, binders, Cu & Al foil, etc...
  - cost structure:
    - CAPEX,
    - labor cost,
    - R&D
    - Marketing, Adm, Overhead, margin)
- Raw material needs / mAh
- Electrode process Yield
- Assembly Process Yield
- Cell manufacturing cost
- Module manufacturing cost
- Pack assembly cost
- ...

Battery price in 2011
$/kWh
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
EV FORECASTS 2011-2020

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

EV impact on the LIB & raw material market is HUGE

IIT, March 2011 Fort Lauderdale
IIT, March 2010 Fort Lauderdale
Deutsche Bank, Electric Cars: Plugged In 2 – Nov 2009
Roland BERGER, Oct 2011, Batteries 2011 Cannes
AAB, AABC Europe, Mainz, June 2011
TOTAL BATTERY DEMAND 2011-2020

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

Total battery demand (MWh) 2000 – 2025
HEV, P-HEV AND EV REALITY OF THE MARKET WILL BOOST MICRO HYBRID AND ADVANCED LEAD ACID BATTERIES

2010
- STANDARD CAR: 88.5%
- MICRO HYBRIDS: 10%
- MILD HEV: 0.5%
- FULL HEV: 1%

2015
- STANDARD CAR
- Lead acid
- Standard
- Lead acid (+EDLC)
- Advanced Lead acid
- NiMH

2020
- STANDARD CAR: 54%
- MICRO HYBRID: 40%
- FULL HEV: 4%

AFTER
- ULTRA BATTERY
- Li-ion
- Li-Air, Li-S, Fuel Cells
TAKEAWAYS

Battery Market 2010-2020
CAGR = +8%

- Li-ion battery is driven today by Portable PCs & electronic devices
- For HEV, the battery technology is today the NiMH
- LIB begin really to compete in 2012
- P-HEV & EV will be powered by Li-ion: 5 B$ market in 2015 & 9 B$ in 2020
- 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 40%
- Lead acid battery will be the first market in 2020 in volume & value

RECHARGEABLE BATTERY MARKET WORLDWIDE 2000-2020

- Lead Acid
- NiCd
- NiMH
- LIB
- Others
THANK YOU

Christophe PILLOT  
AVICENNE ENERGY  
c.pillot@avicenne.com  
Phone: +33 1 47 78 46 00  
Mobile: + 33 6 88 82 79 49