The Rechargeable Battery Market and Main Trends 2014-2025

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Presentation Outline
• The rechargeable battery market in 2014
• The Li-ion battery value chain
• Li-ion battery material market
• Forecasts & conclusions
AGENDA

The market in 2014 by technology, applications & battery suppliers

Li-ion battery value chain
  - Raw materials market
  - Supplier / customer relationship
  - Raw material cost
  - New entrants strategy
  - Raw material road map 2000-2030

xEV market in 2013/2014

xEV forecasts up to 2025

Could Lithium ion replace lead acid for industrial applications?

Rechargeable battery market forecasts up to 2025
AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

HEV powered by Lithium ion battery forecasts from 2008 to 2014

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

THE BATTERY MARKET IS REALLY DYNAMIC

Cellular Phones sold per Year (Million)

Million Units / year

0 500 1000 1500 2000

2000 2014

Li-ion
NiMH

Portable PC sold per Year (Million)

Million Units / Year

0 100 200 300 400 500

2000 2014

Li-ion

230 M Tablets
170 M Portable PCs

Tons of Li-ion Cathode per year

Tons of cathode / Year

0 20000 40000 60000 80000 100000 120000

2000 2014

Li-ion 18650 cell price ($/Wh)

$/Wh

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

2000 2014

Source: AVICENNE ENERGY Analyses 2015
THE WORLDWIDE BATTERY MARKET
1990-2015

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

Source: AVICENNE ENERGY, 2015
2015: Estimations
THE WORLDWIDE BATTERY MARKET
1990-2015

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, 2015
2015: Estimations
THE WORLDWIDE BATTERY MARKET 1990-2015

60 BILLION US$ in 2014 – Pack level
5% AVERAGE GROWTH PER YEAR (1990-2014)

SLI: Start light and ignition batteries for cars, truck, moto, boat etc...
PORTABLE: consumer electronics (cellular, portable PCs, tablets, Camera, ...), data collection & handy terminals,
POWER Tools: power tools but also gardening tools
INDUSTRIAL
- MOTIVE: Forklift (95%), others
- STATIONARY: Telecom, UPS, Energy Storage System, Medical, Others (Emergency Lighting, Security, Railroad Signaling, Diesel Generator Starting, Control & Switchgear,
AUTOMOTIVE: HEV, P-HEV, EV
OTHERS: Medical: wheelchairs, medical carts, medical devices (surgical power tools, mobile instrumentation (x-ray, ultrasound, EKG/ECG, large oxygen concentrators
1- Pack: cell, cell assembly, BMS, connectors – Power electronics (DC DC converters, invertors...) not included

Source: AVICENNE ENERGY, 2015
THE WORLDWIDE BATTERY MARKET IN 2014: US $ 60 BILLION

Battery market in 2014 (M$)

1- Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC DC converters, invertors...) not included

Source: AVICENNE ENERGY, 2015
The worldwide rechargeable battery market, Million cells, 1995-2015

Which cell are we talking about?

2015: estimation data

GS Yuasa International / Lithium Energy Japan

Front Edge Technology, Inc
The worldwide rechargeable battery market, in volume, MWh, 1995-2015

2004-2014(CAGR): +16%
NiCd: -2% per year
NiMH: +6 per year
Li-ion: +21% per year

MWh

- 10 000
- 20 000
- 30 000
- 40 000
- 50 000
- 60 000
- 70 000


2015: estimation data
The worldwide rechargeable battery market, in value, M$, 1995-2015

2004 – 2014 CAGR):+12%
NiCd: -6% per year
NiMH: + 9% per year
Li-ion: +14% per year

Note: Cell level
### EACH BATTERY TECHNOLOGY HAS ITS SPECIFIC ABSOLUTE ADVANTAGES

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<th>Advantage of ...</th>
<th>Lead Acid</th>
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<th>Conventional</th>
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**Absolute advantages**

- Higher cyclability
- Price
- Volumetric energy density
- Operating temperature range
- Self discharge rate
- Voltage output
- Design characteristics

**EACH BATTERY TECHNOLOGY HAS ITS SPECIFIC ABSOLUTE ADVANTAGES**

- Gravimetric energy density
- Volumetric energy density
- Operating temperature range
- Self discharge rate
- Design characteristics

**EACH BATTERY TECHNOLOGY HAS ITS SPECIFIC ABSOLUTE ADVANTAGES**

- Higher cyclability
- Price
- Safety
- Recyclability

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- Operating temperature range
- Higher cyclability
- Price

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JAPANESE, CHINESE & KOREAN MARKET SHARE

Japanese market share (value) decreasing: from 82% of the market in 2001 to < 40% in 2014

(1) Excluding lead acid batteries
**CYLINDRICAL LI-ION BATTERY**

Cylindrical LIB market Company market share in 2014 in volume: 1925 Million cells (+3%)

- **SANYO-PANASONIC** 39%
- SAMSUNG 29%
- LG 18%
- SONY 7%
- OTHERS 7%

**Key success factor**
- Production speed (→ cost)
- Performances
- Customer (Portable PCs) access

**Production Speed: 18650 – 2,8Ah cells**

- PANASONIC: 350 ppm
- SDI: 400 ppm
- LG: 400 ppm

*Note: 1 ppm: piece per minutes*

**Assumptions:** TESLA sold 35 kEV in 2014, 55 kEV in 2015 and 100 kEV in 2016

**SANYO-PANASONIC, SDI & LG will share the market**

**Cylindrical cells (M) by mfg.**

*Source: Interviews with LG, SAMSUNG, SANYO-PANASONIC*
PRISMATIC LI-ION BATTERY

Prismatic LIB market Company market share in 2014 in volume: 1200 Million cells (-5%)

Prismatic cells (M) by Mfg.:
SAMSUNG is leading

Source: AVICENNE ENERGY Analyses 2015
LI-LAMINATE BATTERY

Laminate battery market
Company market share in 2014 in volume: 2 220 Million cells (+32%)

Pouch cells (M) by Mfg. SONY, ATL and SAMSUNG are leading this market

Source: AVICENNE ENERGY Analyses 2015
LI-ION IN 2014
MAIN APPLICATIONS: CELLULAR, NOTEBOOK

5 400 M cells – 46 000 MWh
13 600 M$ (2)

CAGR 2004/2014
+21 % per year in Volume
+14% per year in value

**Graph:** Li-ion Battery sales, MWh, Worldwide, 2000-2014

**Graph:** Li-ion Battery sales, MWh, Worldwide, 2000-2014

*2015 estimation data*
LI-ION IN 2014
MAIN APPLICATIONS: CELLULAR, NOTEBOOK

5 250 M cells – 45 000 MWh
13 300 M$ (2)

CAGR 2004/2014
+20 % per year in Volume
+14% per year in value

**Note:** (1) 2013: Avicenne Forecasts (2) Cell level

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**Graphs:**
- Li-ion Battery sales, M$, Worldwide, 2000-2014 (1)
- Li-ion Battery sales, M$, Worldwide, 2000-2014 (1)
CELLULAR PHONES MARKET
> 1980 M LIB CELLS IN 2014

+1800 M cell phones sold in 2013 (+7% CAGR)

**CELLULAR PHONES MARKET**

- **1980 M LIB CELLS IN 2014**
- **+1800 M cell phones sold in 2013 (+7% CAGR)**

**Graph:**
- Comparison of cellular phone sales from 2000 to 2013 for Nokia, Motorola, Samsung, Apple, LG, RIM, ZTE, and Others.
- Nokia, Samsung, and Apple have dominated the market.
- Samsung Galaxy & iPhone change the game.

**Statistical Data:**
- **2010:**
  - 1400 M Phones
  - Nokia: 33%
  - Samsung: 20%
  - Others: 29%
  - Apple: 3%
  - ZTE: 4%
  - RIM: 3%
  - LG: 8%
- **2013:**
  - 1800 M Phones
  - Nokia: 14%
  - Samsung: 25%
  - Others: 42%
  - Apple: 4%
  - ZTE: 4%
  - Huawei: 3%
  - LG: 8%

**Chart:**
- Comparison of market share for standard and smartphones in 2013.
- Samsung leading with a +13% increase from 2012/2013 growth.
- Nokia: -23%
- Apple: +13%
- Huawei: +67%
- LG: +25%

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CELLULAR PHONES/LIB SUPPLIERS RELATIONSHIPS

2013 Cellular Phone makers / battery suppliers relation

Smartphones ie laminate LIB increasing

APPLE needs in 2013

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PORTABLE PC MARKET
990 M LIB CELLS IN 2014

195 M portable PCs sold
2012/2013: -3%

Market outlook 2014

- Uncertain macro & weakness in both consumer & commercial growth
- No sign for end-customer demand recovery
- Decrease due to cannibalization by tablets
- Small overall decrease only thanks to Emerging market growth

Increase of Ultra-thin Portable PCs

Note: Excluding Tablets
TABLET MARKET
> 550 M CELLS IN 2013

Tablets sold (Million)
Apple leadership

Source: Gartner, IDC, Display search – 2013: AVICENNE Estimation

ASP tablets drop
From $636 in Q4 2010 to $335 in Q4 2013

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LIB BATTERY SHORT TERM TRENDS
Higher capacity, thinner battery, Pouch cells have the highest growth

18650 battery capacity*

Cellular phones battery capacity

Cylindrical/Prismatic/Laminates in 2013

Li-ion cylindrical: “Tesla impact”: 150 M cells in 2013, 300M in 2014, 600 M in 2015
BATTERY PRICE IS DECREASING DRASTICALLY

In 10 Years 80% price decreasing despite a fluctuating Co price

Production capacity 2009/2011: from 150 to 250 M cells/month

18650 oversupply ratio is decreasing thanks to TESLA

Note - Q4 2013: Cylindrical: 0,17 $/Wh ; Laminates: 0,3$/Wh

Source: LME

- Standard Demand
- TESLA
- Production Capacity
- Oversupply ratio

The Rechargeable Battery Market and Main Trends 2014-2025

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March 9, 2015
LI-ION VALUE CHAIN – MARKET DEMAND

CATHODE
105 000 T in 2014
Revenues: 2.5 B$
CAGR 04/14: +16%

ANODE
57 000 T
Revenues: 0.8 B$
CAGR 03/13: +14%

ELECTROLYTE
44 000 T
Revenues: 0.68 B$
CAGR 04/14: 20%

SEPARATOR
695 M m²
Revenues: 1.15 B$
CAGR 04/14: 18%

BINDER
7 100 Tons
Revenues: 0.2 B$
CAGR 08/13: 15%

ANCILLARY
Revenues: 0.7 B$

CELL MANUFACTURERS
Revenues: 13.6 B$
Gross margin: <10%

PACK MANUFACTURERS
Revenues: 19.6 B$
Gross margin: <10%

OEMs
CATHODE ACTIVE MATERIALS NEEDS BY CHEMISTRY

Cathode active materials for LIB in Tons, 2000-2014 (Demand)

- LFP
- LMO
- NCA
- NMC
- LCO

Supply

LCO – >45 KT (2014)

- Nichia 13%
- Umicore 16%
- B&M 10%
- Reshine 6%
- Easpring 10%
- Internal 3%
- ShanShan 10%
- Other China 8%

NMC¹ – > 35 KT (2014)

- Umicore 24%
- Nichia 11%
- SUMITOMO 16%
- Others 5%
- Internal 11%
- TODA 4%
- Other China 8%
- Reshine 3%
- ShanShan 8%

LMO – > 18 KT (2014)

- Nichia 7%
- Nippon Denko 8%
- Other 5%
- Other China 31%
- Reshine 16%
- Qyanyun 11%
- ShanShan 9%
- JGC 16%

LFP – > 10 KT (2014)

- Tatung 12%
- Aleees 18%
- Others 30%
- Valence 6%
- Formosa 8%
- A123 10%
- Other Japan 5%
- Other China 31%

NEW ENTRANTS ON THE FIELD:

LEADERS:

umirole
NICHIA
EASPRING
SHANSHANTECH

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CATHODE ACTIVE MATERIAL FORECASTS 2000-2025

Cathode active materials 2000-2025 - Tons

Cathode active materials in 2014: 105 000 Tons

Cathode active materials in 2025: > 350 000 Tons

ASSUMPTIONS:

- Portable devices:
  2013-2025: +11% per year in volume

- HEV
  4.8 M HEV/year in 2020 - 35% LIB
  6.8 M HEV in 2025 90% LIB

- P-HEV
  0.4 M P-HEV/year in 2020, 0.7 M in 2025
  100% LIB

- EV
  1M EV/year in 2020, 1.5M/year in 2025
  100% LIB

- Industrial & stationary
  2013-2025: +16% per year

Assumption: Tesla keep NCA chemistry and have a relative success
(200 000 EV sold per year in 2025 – TESLA forecast 500 000)
ANODE ACTIVE MATERIALS
57 000 TONS IN 2014

LIB Anode Materials

Source: A. Jossen, IRES 2007

Source: Hitachi Chemical

LIB Anode market, (Tons)

Source: Sanyo, March 2011
ANODE FOR LIB IN 2014

Natural graphite become a commodity

![Graph showing percentage of materials](image)

**Carbon for LIB anodes by type (2013)**

- **Others**: 0%
- **A123**: 20%
- **BAK**: 40%
- **ATL**: 60%
- **Maxell**: 80%
- **Lishen**: 100%
- **BYD**: ARTIFICIAL
- **LGC**: MCMB
- **SDI**: NATURAL
- **PANASONIC**: Amorphous
- **SONY**: METAL
- **SANYO**: Natural

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**Hard Carbon**
- Capacity (/g): 400 mAh/g
- Capacity (/cc): ++
- Power: ++
- Stability: ++
- Cyclability: ++
- Precursors: Petroleum Pitch, Resin, cellulose, wood, coconuts...
- COST: 30 -> 25 $/kg
- SUPPLIERS: KUREHA

**Soft Carbon**
- Capacity (/g): 250 mAh/g
- Capacity (/cc): 0
- Power: +
- Stability: +
- Cyclability: +
- Precursors: Petroleum coke
- COST: 25->20 $/kg
- SUPPLIERS: HITACHI

**Graphite**
- Capacity (/g): 325-375 mAh/g
- Capacity (/cc): +
- Power: 0
- Stability: 0
- Cyclability: 0
- Precursors: Natural or petroleum coke
- COST: 15 -> 10 $/kg
- SUPPLIERS: HITACHI

**NEW ENTRANTS ON THE FIELD:**

- **LEADERS:**
  - Hard Carbon: 325-375 mAh/g
  - Soft Carbon: 250 mAh/g
  - Graphite: 325-375 mAh/g

**Note:** MCMB: Mesocarbon Microbeads

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**THE RECHARGEABLE BATTERY MARKET AND MAIN TRENDS 2014-2025**

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LIB SEPARATOR MARKET 2014

LIB separator market, M$, CAGR 2004/2014: +17%

LIB Separator supplier, market share in 2014

LEADERS:
- Asahi Kasei
- Celgard
- Evonik
- TEIJIN
- HIFUTURE

NEW ENTRANTS ON THE FIELD:
- UBE
- MAXELL
- DUPONT
- LG Chem
- MITSUBISHI

Others: TDK/Nitto Denko, Foshan Jinhui Hi-Tech, Shenzhen Senior Technology Material, Xinxiang Green next Energy, Dupont, TDK, LG Chem, Mitsubishi,…

The Rechargeable Battery Market and Main Trends 2014-2025

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ELECTROLYTE SUPPLIERS/CUSTOMERS
44 000 TONS IN 2014

LIB electrolyte market, Tons, CAGR 2004/2014: +23%

LIB electrolyte supplier, market share in 2014

Note: (1) GTHR: Zhangjiagang Guotai-Huarong
LIB ELECTROLYTE MARKET 2014

Electrolyte Battery makers & suppliers relation in 2014

Electrolyte maker sales 2005-2013

(1) Full electrolyte formulation in-house

(2) Panax-Etec bought Samsung Chiel activities in 2010
BATTERY MARKET FORECASTS
2014-2025

Applications covered

- Portable PCs, net-book, Ultra-book
- Cellular Phones, Smart-phones
- Tablets
- Camcorders
- Cordless Tools, Gardening tools
- Digital Camera
- Games, MP3
- Cordless Phones
- Shavers, Toothbrush,
- RC Cars
- E-bikes
- Power tools
- Security lighting
- Vehicles: HEV, P-HEV, EV
- Industrial motive (forklift)
- Industrial stationary (UPS, Telecom)
- Medical
- Energy Storage (Small / large)

Parameters analysis

- Main segment trends
- Power need trends (volume, weight, capacity, running time)
- Penetration rate for each Chemistry, each form factor,
- 2013 -2025 Forecasts
- OEM strategies and positions
- Main drivers & limiters
Cellular phones demand (M Units) CAGR 2010-2025: +6%

Cellular Phones market Drivers

- Emergent market
- Renewal ratio increase
- Smartphone penetration increase

LIB cells demand 2014-2025
Polymer penetration: 50% -> 75%

LIB cells for cellular phones trends

- Laminates ratio increase
- Increase of Thickness
- Increase of >1400 mAh capacity

Source: AVICENNE ENERGY Analyses
PORTABLE ELECTRONIC DEVICES FORECASTS 2010-2025

Portable PCs demand (M Units) 2010-2025 CAGR: +4%

- 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

LIB cells demand 2010-2025
Polymer penetration: 7% -> 28%

- Thinner cells
- Polymer penetration increasing from 7% in 2010 to 28% in 2025
- > 2800 mAh for Premium/corporate
- 2.2 Ah for consumer, emerging market

Source: IDC, Gartner, AVICENNE Energy

Source: AVICENNE ENERGY Analyses

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2025 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

2000-2025 LIB market, MWh, by application (3C)

- Others
- Household
- Toys
- MP3
- Video Games
- Digital Camera
- Camcorders
- Cordless Phones
- Tablets
- Portable PCs
- Cellular Phones

Source: AVICENNE ENERGY Analyses

2000-2025 LIB market, M cells, by form factor (3C)

Source: AVICENNE ENERGY Analyses

(1) Source: Takeshita, Battery Japan 2013 BJ-3 conference – Slide p 4
X-EV MARKET

Why x-EV ?

Definition & segmentation

X-EV worldwide in 2013
  - By country
  - By car makers
  - By battery chemistry

X-EV forecasts
  - AVICENNE ENERGY & other analyst forecasts
  - Battery chemistry forecasts
  - Battery cost forecasts

X-EV battery forecasts
SAFETY ISSUES

Li-ion and LMP are not thermally stable what raises serious safety concerns

**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

- Most of the BMS function is to manage the safety of the cell & the battery pack:
  - Overcharge management
  - Over voltage management

- Use “safer” material in the pack:
  - Flame retardant,
  - High shock resistance

- Thermal management improve both the safety and the life time

The lithium ion technologies that win will win partly on their safety argument, possibly sacrificing some energy density.

(1) Low energy density: mostly developed for stationary applications, or LV start light & ignition batteries
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 2013

$/kWh
The Rechargeable Battery Market and Main Trends 2014-2025

32nd INTERNATIONAL BATTERY SEMINAR & EXHIBIT
March 9, 2015

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

AVICENNE ENERGY - CONFIDENTIAL INFORMATION
LI-ION BATTERY COST 2013-2020

LIB cell average cost (36Ah pouch) (EV design ; LMO/NMC cathode)

LI-ION BATTERY PACK COST FOR EV

(1) Active materials only

* For Production > 100 000 packs/year
HEV FORECASTS 2000-2020

HEV MARKET: 2.5 Million units in 2015 – 5 M in 2020 – 7 M in 2025

Micro hybrid not included

Source: AVICENNE ENERGY Analyses 2013
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 2013
Micro hybrid not included
X 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
The Rechargeable Battery Market and Main Trends 2014-2025

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**XEV 2025 FORECASTS**

**HEV, P-HEV & EV market forecasts up to 2025**

**LIB penetration in HEV 2010-2025**

- EV
- P-HEV
- HEV

- NiMH
- LIB

Million cars

- 0,9
- 2,5
- 0,37
- 0,15
- 0,5
- 1
- 1,5
- 7
- 0,65

2010 2015 2020 2025
TOTAL BATTERY DEMAND FOR AUTO FORECASTS

EV, HEV & P-HEV Battery needs (MWh)
CAGR 2013-2020: +23%

Rechargeable battery market for Auto\(^{(1)}\), M$ for x-EV 2000-2025
CAGR 2014-2020: +14%

Source: AVICENNE ENERGY Analyses 2013

(1) Pack level
35 MILLION MICRO-HYBRIDS CAR IN 2020

Micro-hybrids car market 2010-2020

Advantages of micro-hybrid compare to HEV

- Powered by Advanced lead acid batteries
- 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

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<thead>
<tr>
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<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%
- MICRO HYBRIDS 10%
- MILD HEV 0.5%
- FULL HEV 1%

2015
- Advanced Lead acid
- Standard Lead acid Batteries
- Lead acid

2020
- STANDARD CAR 44%
- MICRO HYBRID 50%
- FULL HEV 4%

AFTER
- ULTRA BATTERY
- Li-ion
- Li-Air, Li-S, Fuel Cells
THE WORLDWIDE BATTERY MARKET
1990-2013

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

Lead Acid Batteries
330 GWh for US $ 30 Billion

Industrial Batteries
54 GWh for US $ 10 Billion

Source: AVICENNE ENERGY, 2014
The Rechargeable Battery Market and Main Trends 2014-2025

BATTERY FOR OTHER APPLICATION
US$ 18 BILLION\(^1\) MARKET

Battery market in 2013 (M$)

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<th>M$</th>
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<tbody>
<tr>
<td>Power Tools</td>
<td>1400</td>
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<tr>
<td>E-bikes</td>
<td>2290</td>
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<td>Forklifts</td>
<td>3570</td>
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<tr>
<td>Others</td>
<td>180</td>
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<tr>
<td>TOTAL MOTIVE</td>
<td>3750</td>
</tr>
<tr>
<td>Telecom back-up</td>
<td>2900</td>
</tr>
<tr>
<td>UPS</td>
<td>2400</td>
</tr>
<tr>
<td>Misc. Standby</td>
<td>315</td>
</tr>
<tr>
<td>ESS</td>
<td>450</td>
</tr>
<tr>
<td>Seismic (1)</td>
<td>210</td>
</tr>
<tr>
<td>Other Stationary</td>
<td>1090</td>
</tr>
<tr>
<td>Total STATIONARY</td>
<td>7370</td>
</tr>
<tr>
<td>TOTAL INDUSTRIAL</td>
<td>11120</td>
</tr>
</tbody>
</table>

| Medical Cart            | 150 |
| Wheelchair              | 47  |
| Medical Device (1)      | 1150|
| Marine                  | 450 |
| Others                  | 1000|
| TOTAL                   | 17600|

\(^1\) 500 M$ for Li-ion - Source: Zprime 2011

1- Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC DC converters, invertors...) not included

Source: AVICENNE ENERGY, 2014
THE WORLDWIDE BATTERY MARKET IN 2013: US $ 54 BILLION

Battery market in 2013 (M$)

1- Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC DC converters, invertors...) not included

Source: AVICENNE ENERGY, 2014
TOTAL POTENTIAL MARKET ANALYZED IN THE SURVEY (M$, PACK LEVEL¹)

Application details

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US$ 18 Billion in 2013

Source: AVICENNE ENERGY 2013

1- Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC DC converters, invertors...) not included

2- Other App: Military, aerospace, Oil & Gas, Railways, Aviation, Utility metering,...
“OTHER APPLICATIONS”

10 B$ POTENTIAL MARKET

Battery market in 2012 (M$)

- Other Applications
- Marine
- Medical devices
- Wheelchair
- Medical Cart
- Other Stationary
- Seismic
- ESS
- Other Stand-by
- UPS
- Telecom
- Other Motive
- Forklift
- Power Tools
- E-Bikes

Battery market in 2020 (M$)

- Lead Acid
- LIB

CAGR: +4%
CAGR: +15%

For Power tools, NiCd batteries are used rather than lead acid batteries.

Source: AVICENNE ENERGY, 2013

March 9, 2015

CONTACT
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LI-ION CELL & PACK MARKET DETAILS

2013 - 2025

Portables: from 28 to 83 GWh
Automotive: from 6 to 50 GWh
« Others »: from 5 to 30 GWh

Li-ion cell market (B$)

Li-ion Pack market\(^1\) (B$)

1- Pack: cell, cell assembly, BMS, connectors – Power electronics (DC DC converters, invertors...) not included
2- Others: Batteries for Power tools, E-bikes, Industrial, medical...

Source: AVICENNE ENERGY Analysis 2014
**TAKEAWAYS**

**Battery Market 2010-2025**

**CAGR = +10%**

- Li-ion battery is driven today by Portable PCs & electronic devices (smartphones, tablets)
- 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
- In 2020, Energy storage will represent less than 5% of the total battery market

**RECHARGEABLE BATTERY MARKET WORLDWIDE 2000-2025**

(MWh)

- **2000**
  - Others
  - LIB
  - NiMH
  - NiCd
  - Lead Acid
- **2025**
  - Others
  - LIB
  - NiMH
  - NiCd
  - Lead Acid

(Pack level)

- **2000**
  - Lead Acid (+4%)
  - NiCd (-5%)
  - LIB for 3C (+3%)
- **2010**
  - Lead Acid (+4%)
  - NiCd (-5%)
  - LIB for 3C (+3%)
- **2015**
  - Lead Acid (+4%)
  - NiCd (-5%)
  - LIB for 3C (+3%)
  - LIB for Others* (+16%)
- **2020**
  - Lead Acid (+4%)
  - NiCd (-5%)
  - LIB for 3C (+3%)
  - LIB for Others* (+16%)
- **2025**
  - Lead Acid (+4%)
  - NiCd (-5%)
  - LIB for 3C (+3%)
  - LIB for Others* (+16%)

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

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Phone: +33 1 47 78 46 00
Mobile: + 33 6 88 82 79 49
About
AVICENNE ENERGY
Information for Growth - Powering your company’s market strategy with in-depth research

- Creation: 1992, by Ali MADANI
- Headquarter: Paris
- Liaison Office: Japan, USA
- AVICENNE Energy Director: Christophe Pillot

5 consultants
- A Madani
- C Pillot
- JP Salvat
- X Zhang
- A Yassari
OUR BUSINESS STORY

- **1992**: AVICENNE Creation
- **1994**: AVICENNE advised French Industry Ministry on the European battery business opportunities
  - AVICENNE open its office in JAPAN
- **1999**: « BATTERIES » congress 1st edition in Paris
- **2003**: AVICENNE work on the due diligence process for the sales of SAFT by ALCATEL
- **2008**: AVICENNE: expert witness in the NTT-Hydro Quebec conflict
- **2009**: AVICENNE presented its market forecasts to industrials (CIAPS) in Beijing – China
- **2010**: Avicenne developed partnership with BATTERY JAPAN
  - 20th Edition of “The rechargeable battery market worldwide 2010-2020
- **2011**: AVICENNE Energy division is created
  - 13th Edition of BATTERIES Congress
- **2014**: 23rd Edition of our Battery Market Syrvey
  - 16th Edition of BATTERIES Congress in NICE, France
  - 1 month mission in China: Qinghai EV Rally, CIBF, 50 companies visited
OUR METHODOLOGY

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<td></td>
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QUALITATIVE

Quantitative

Strategic

INFORMATION COLLECTION

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<tr>
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DEMAND SIDE

MARTK & STRATEGIC ANALYSIS

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QUALITATIVE

Quantitative

Strategic
The Rechargeable Battery Market and Main Trends 2014-2025

METHODOLOGY: EXTENSIVE FIELD RESEARCH TO RETRIEVE & CROSS CHECK INFORMATION

- Top management contact network > 19,000 contacts
- In Depth analysis Of applications
- Conferences & Exhibitions
- Cross Check Analysis

- Battery Makers
- OEM
- Raw materials suppliers
- Substitution technologies
- BMS Electronics
- Environment & recycling

32nd INTERNATIONAL BATTERY SEMINAR & EXHIBIT
March 9, 2015

CONTACT
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+ 33 1 47 78 46 00
c.pillot@avicenne.com

www.avicenne.com

INFORMATION FOR GROWTH

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CUSTOMIZED & MULTICLIENT SURVEY FOR ALL THE VALUE CHAIN

Raw Materials
Materials
Cells
Pack
OEM

Source: Photo from BASF
MORE THAN 200 REFERENCES WORLDWIDE

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3M
A123
AIR LIQUEIDE
AIR PRODUCT
AHLSTROM
ALCATEL
AMPEREX (ATL)
APPLIED MATERIALS
ARKEMA
AROS SECURITIES
ARC
ASHLAND
AT AMPEREX
AT KEARNY
AUSTRIAN INSTITUTE OF TECHNOLOGY
AXEON
BAIN
BASF
BATTERY ASSOCIATION OF KOREA
BAYER
BLACK & DECKER
BH BILITON
BRAND LICENSING PARTNERS (BLP)
BOURNS
BOSCH
BOOZ
BRUCKNER
BUHLER GMBH
BYD
CEBON
CALL2RECYCLE
CAP X
CATELLA
CARBONE LORRAINE
CARLYLE
CATELLA
CATERPILLAR INC.
CDN COBALT
CEA/LITEN
CELLARD
CHEMTELL
CHEMISHE FABRIK BUDENHEIM
CIBA
CIAPS CHINA
COGEMA
CONOCO PHILIPS
CRU GROUP
CSC CHALLENGE STRATEGY CHANGE
DELTA
DGA
DIALOG SEMICONDUCTOR
DOW CHEMICAL
DOW CORNING
DUPONT
DURACELL
EDF
ELECTRO ENERGY
ENER 1
ENERGIZER
EOLITE
EPICOS OHG
ERAMET
ETC AB
FACOM
FALCON BRIDGE
FAIRCHILD SEMICONDUCTOR
FAMEART
FIST
FLORIDENNE DE CHIMIE
FMC
FORTU POWER CELL
FRANCE TELECOM
FREUDENBERG VIESSTOFFE SE & CO
FRAUNHOFER INSTITUTE
FULTON INNOVATION
GAIA
GIL IMPORT BATTERIES LTD.
GS MELCOTEC
HC STARCK
HILTI
HITACHI MAXELL
HOLLINGSWORTH & VOSE CIE
HONEYWELL
HPL (HIGH POWER LITHIUM)
HUTCHINSON
ICC NEXERGY
IEC
IGL EXPORT.
INTERNATIONAL COMPONENT CORP.
INTERNATIONAL RECTIFIER
INTEL
INTEL
INTER
INCO
ISRAEL CONSULTING
ITRI
ITS
JBC
JETRO
JOHNSON CONTROLS
JOHNSON MATTHEY
KODAK
KRUGER
LAZARD
LECLANCHE
LEGRAND
LG CHEMICAL
LION CELLS
LITTLE FUSE
LILIPUCIAN
LYNAS CORP
MATSUSHITA
MICROSOFT
MTI MICRO FUEL CELLS
MOLTECH
MOLYCORP
MOMENTIVE
MOSAID TECHNOLOGIES
MOTOROLA
MUNSTER UNIVERSITY
NANOCYL
NEOPLUS - RUSSIA
NEC
NITECH
NNKPC
NORILSK NICKEL
NOVALED
NTK POWERDEX
OLIVER WYMAN
OMG INC
ORANGE
OSKR
PANASONIC
PHILIPS
PHOTON
PK & WISE
PLEXTRONICS
POWER GENIX
PRAYON
PRISMARK
PSA
RAYOVAC
RECHARGE
RENAULT
RHODIA
ROLAND BERGER
ROSISK INFORMATION SERVICES
SAFT
SAGENTIA
SAINT GOBAIN
SAGITAR
SAMSUNG SDI
SANIK
SCHRODER VENTURE
SCOTENT ENTREPRISE
SEPCELL
SFZ
SHENZHEN HIGH POWER TECHNOLOGY
SCHOTT AG
SKC
SQM
SVE - DASSAULT
SOLVAY
SONY
STIBAT
STORCK
STRATEGY ANALYSIS
TERRAROSSA CAPITAL
TIGER GLOBAL
TODA KOGYO
TOTAL
TOTAL WIRELESS SOLUTION
TOYO
TOYOTA
TREOFAN
TYCO
UMICORE
UNIROSS
URAL ELEMENT
US NAVY
VARTA
VOLTRAC
WACKER CHEMIE AG
WARBURGPIINCUS
WILDCAT
WORLD INDUSTRIAL INFORMATION CENTER
WR GRACE & CIE
YASLAMEN
ZEBRA
ZPOWER
SPEAKER, CHAIRMAN OR WORKSHOP MODERATOR

*Tens of INTERNATIONAL CONFERENCES per year*

- Extended Battery Life Working Group on battery technology development for mobile devices Meeting Tokyo Japan, Dec 2014 – 1h30 Presentation “The battery market for mobile 2013-2025”
- INTERNATIONAL Li-ion BATTERY SUMMIT – Dec 2013, Shenzhen, China “The Li-ion battery raw materials market 2012-2020”
- THE INTERNATIONAL BATTERY SEMINAR - FLORIDA Fort Lauderdale, Florida, March 2014 – 2h tutorial “HEV, PHEV & EV market 2010-2020 ; Battery is the key” (From 2004 to 2014)
- EVER 2009, 2011, MONACO “Challenges for EV market in Europe”
- EVS 2011, 2013 “Battery market for automotive industry”
- CIAPS (China Industrial Association of Power sources), BEIJING, Dec 2009 “Advanced battery market & raw materials worldwide”
AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

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

BATTERIES 2015

www.batteriesevent.com

- 3 days congress in France (Paris, Nice, Cannes)
- 500 attendees
- 40 Booths
  Battery makers, raw materials suppliers, IC & BMS suppliers, tests, machining, coating,
- 80 international experts:
  Researchers, industrial process, marketing, financials,
SUMMARY

- A small team dedicated on the battery industry since almost 20 years

- Working with large group worldwide: FMC, Umicore, Dupont, Dow, Panasonic, LG, Samsung, JCI, Nokia, Bosch, Siemens, Toyota, Renault, ...

- Synthetic presentation to management & CEO of major groups

We will help and support your growth

- Flexibility
- Expert Network
- Methodology
- Knowledge

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