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32<sup>nd</sup> INTERNATIONAL BATTERY  
SEMINAR & EXHIBIT

March 9, 2015

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# The Rechargeable Battery Market and Main Trends 2014-2025

**Christophe PILLOT**

Director, AVICENNE ENERGY

**Presentation Outline**

- The rechargeable battery market in 2014
- The Li-ion battery value chain
- Li-ion battery material market
- Forecasts & conclusions



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# 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



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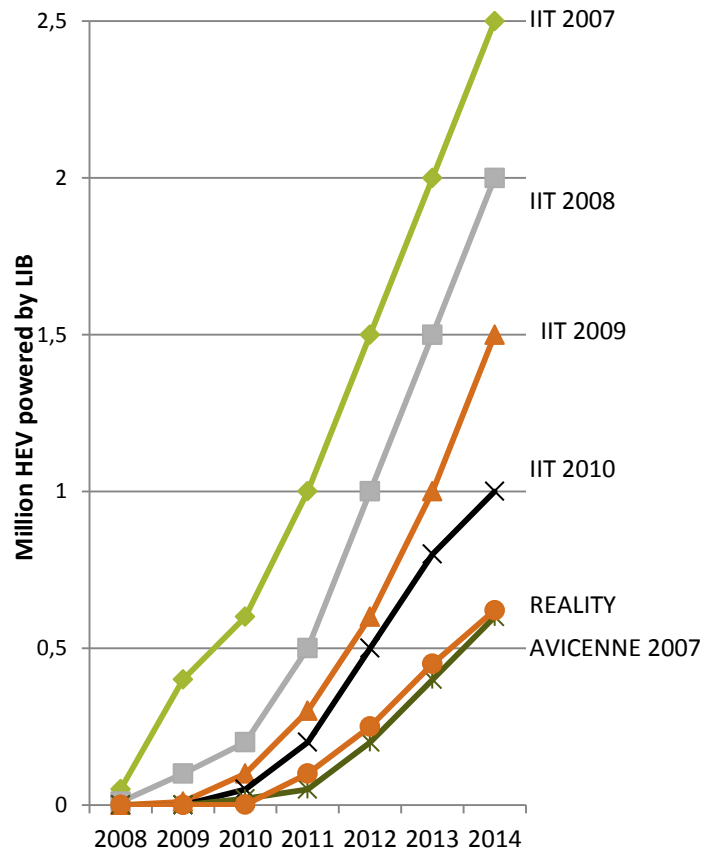
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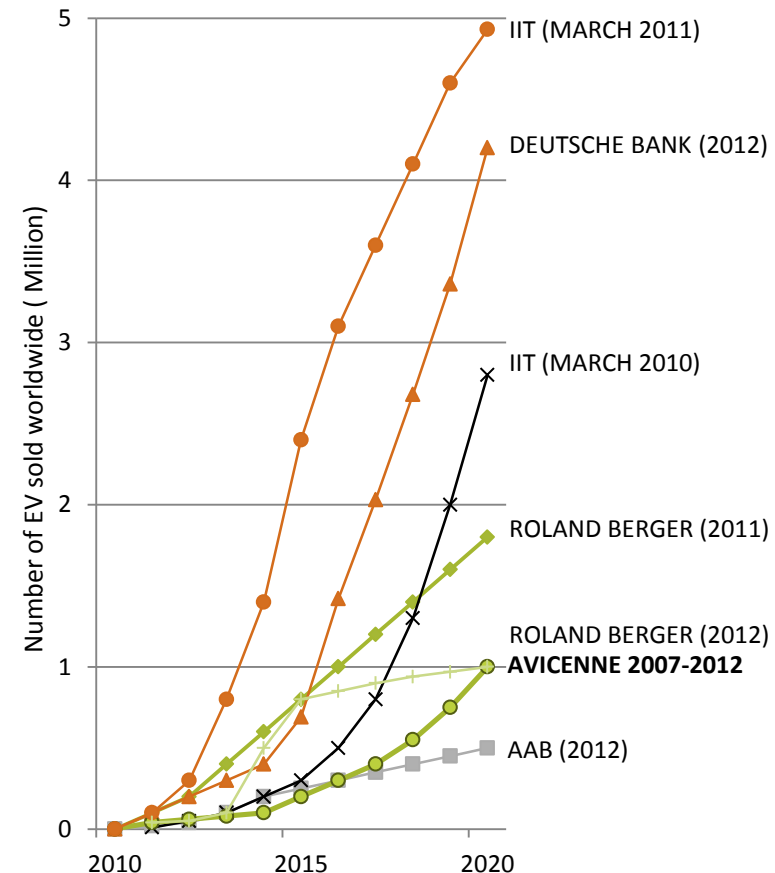
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# AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

HEV powered by Lithium ion battery  
forecasts from 2008 to 2014



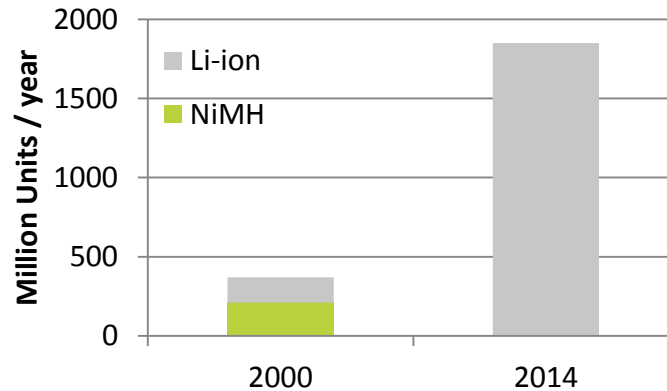
EV sold, in million units, worldwide,  
2010 - 2020



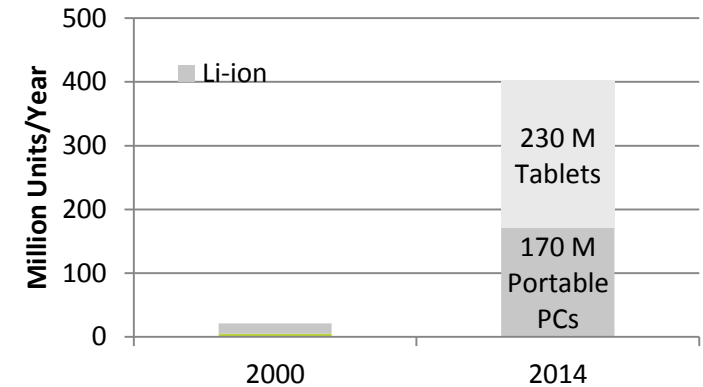
Source : International Battery Conference, Fort Lauderdale 2007, 2008, 2009, 2010 & 2011

# THE BATTERY MARKET IS REALLY DYNAMIC

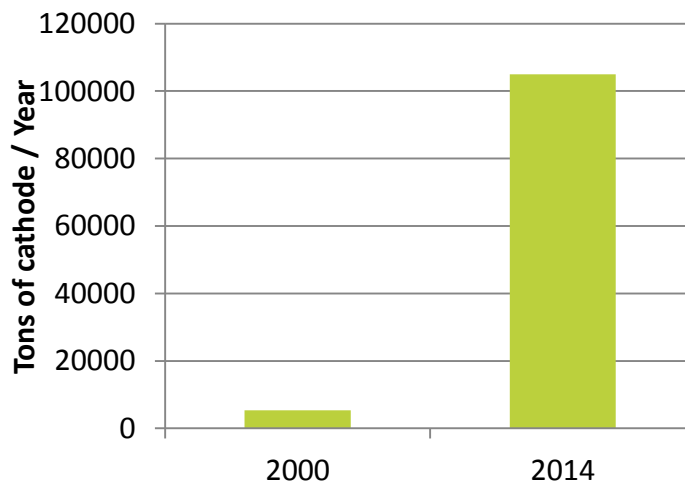
**Cellular Phones sold per Year (Million)**



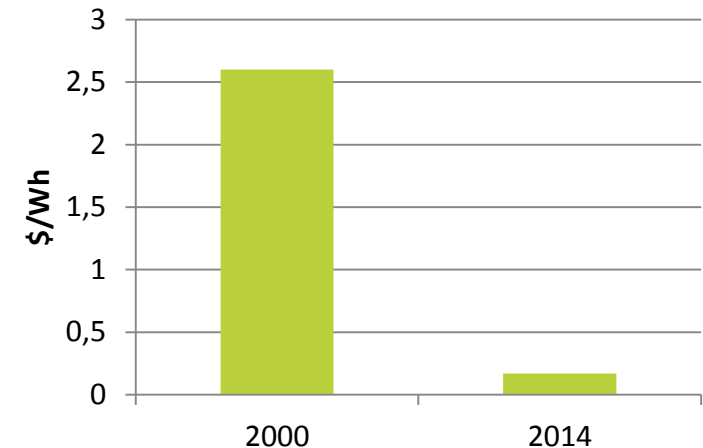
**Portable PC sold per Year (Million)**



**Tons of Li-ion Cathode per year**



**Li-ion 18650 cell price (\$/Wh)**



Source: AVICENNE ENERGY Analyses 2015



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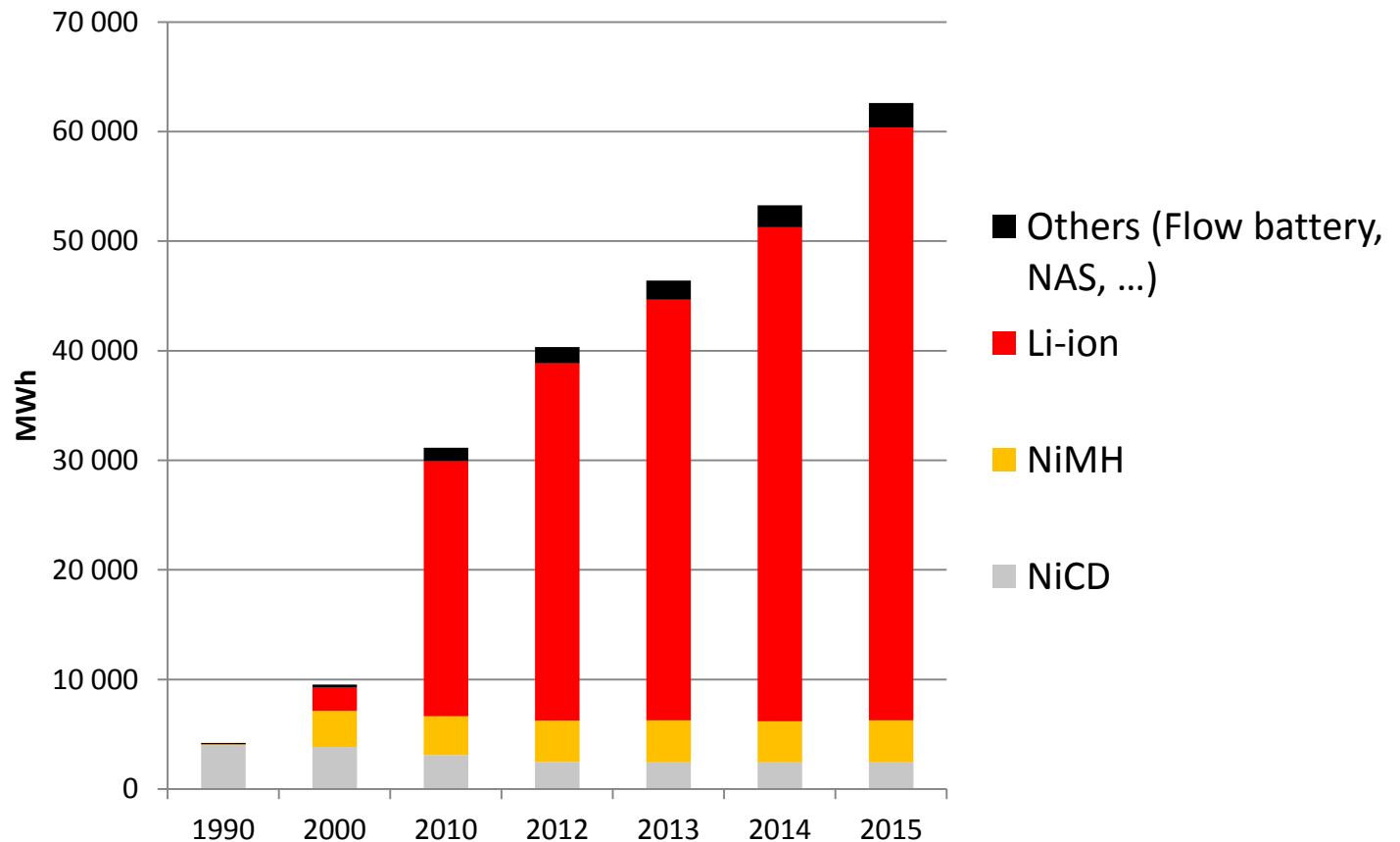
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# THE WORLDWIDE BATTERY MARKET 1990-2015

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



Source: AVICENNE ENERGY, 2015

2015: Estimations



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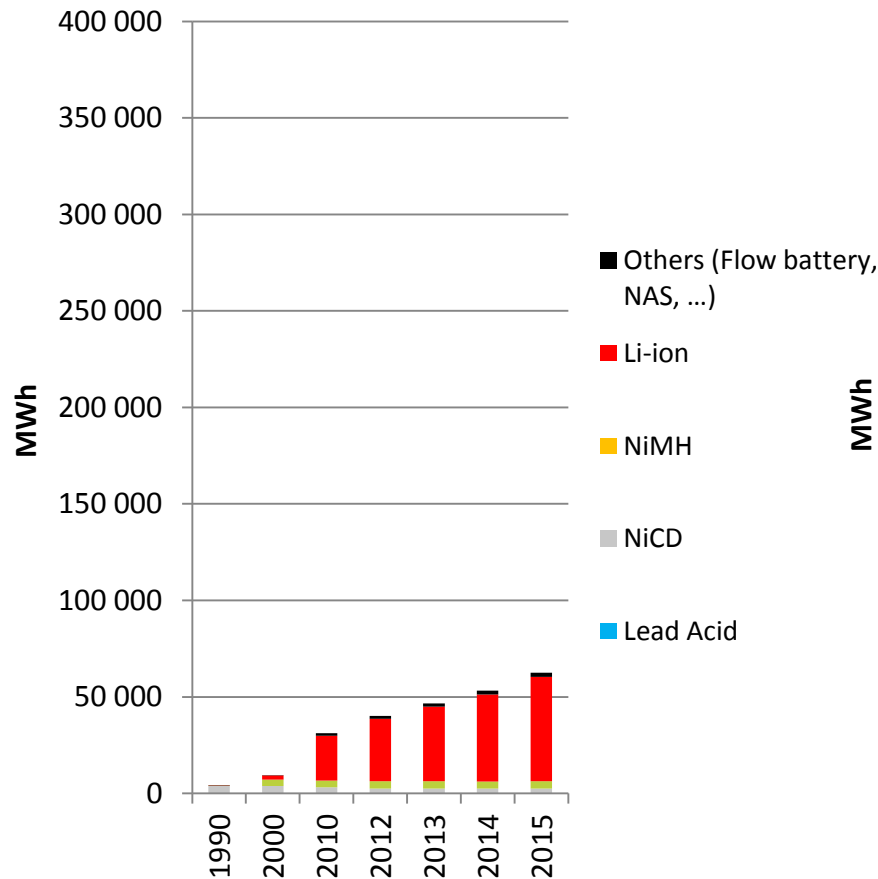
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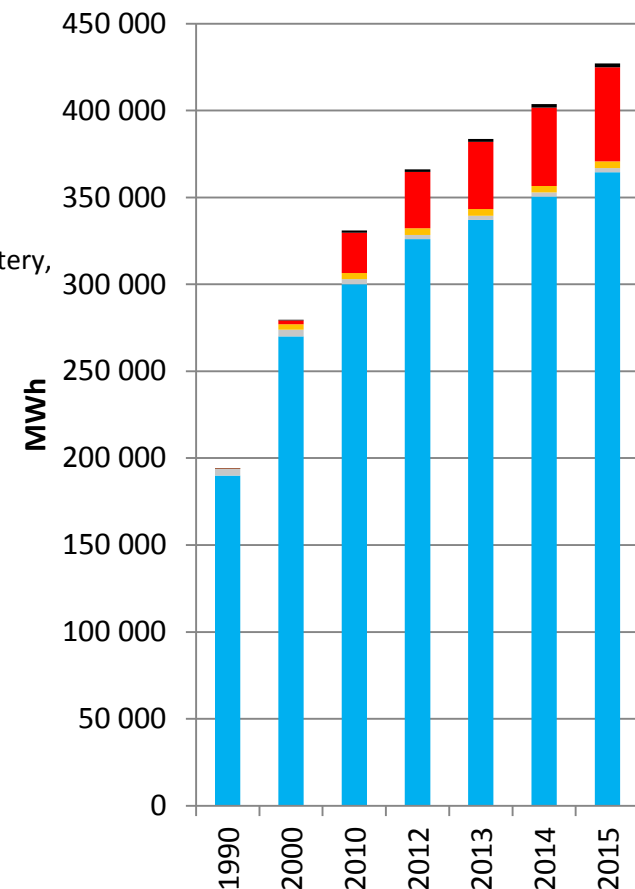
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# THE WORLDWIDE BATTERY MARKET 1990-2015

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

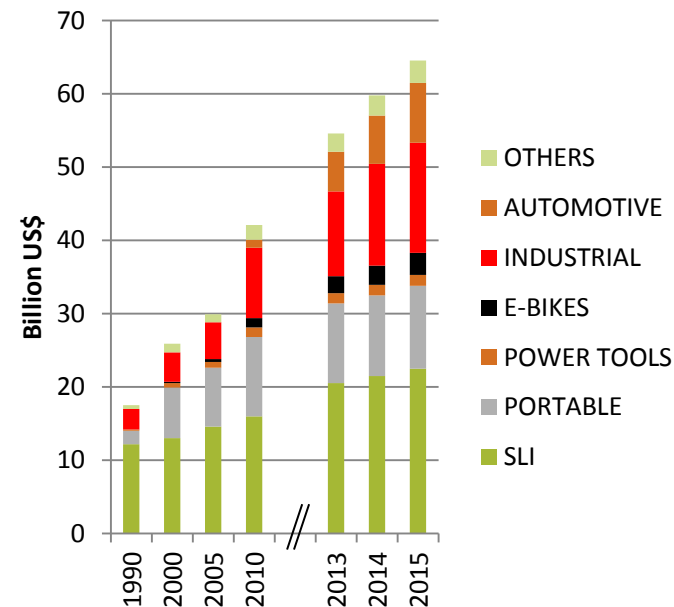
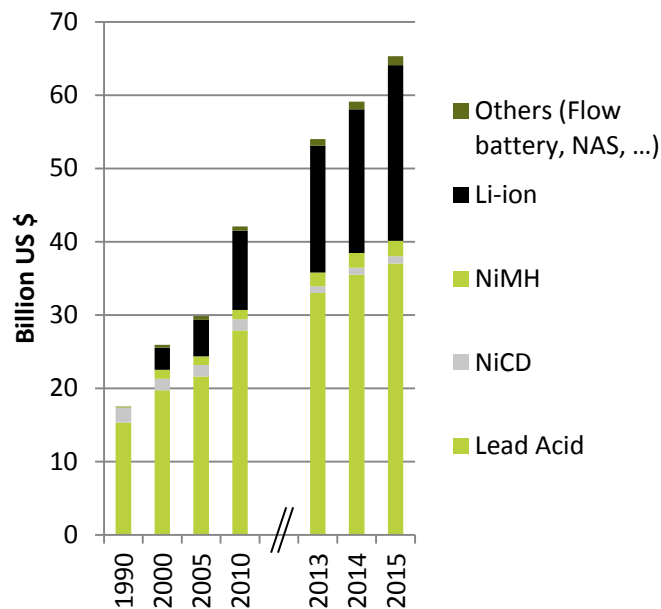


2015: Estimations

# THE WORLDWIDE BATTERY MARKET 1990-2015

60 BILLION US\$ in 2014 – Pack level<sup>1</sup>

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*

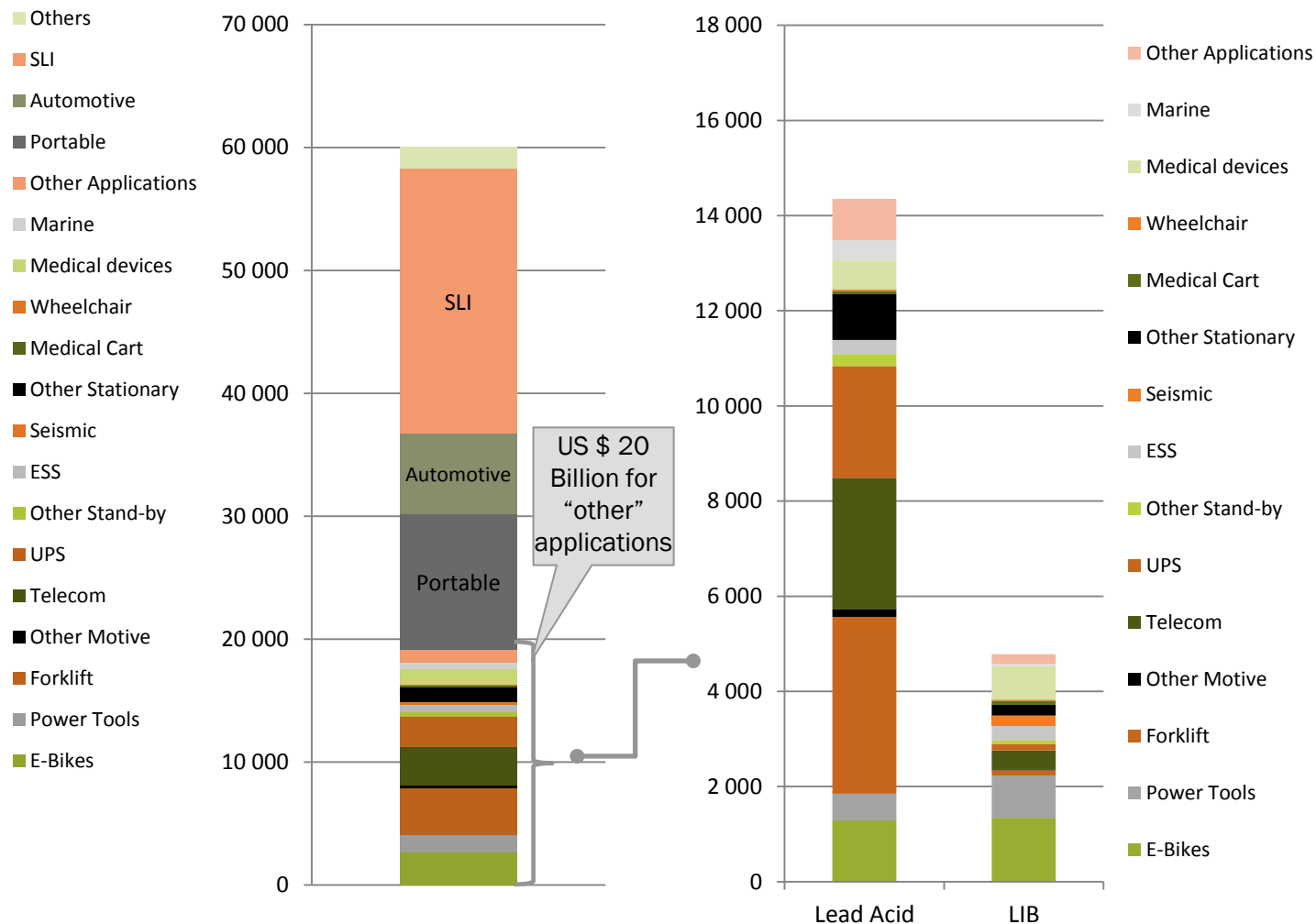
*OTHERS: Medical: wheelchairs, medical carts, medical devices (surgical power tools, mobile instrumentation (x-ray, ultrasound, EKG/ECG, large oxygen concentrators*

*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





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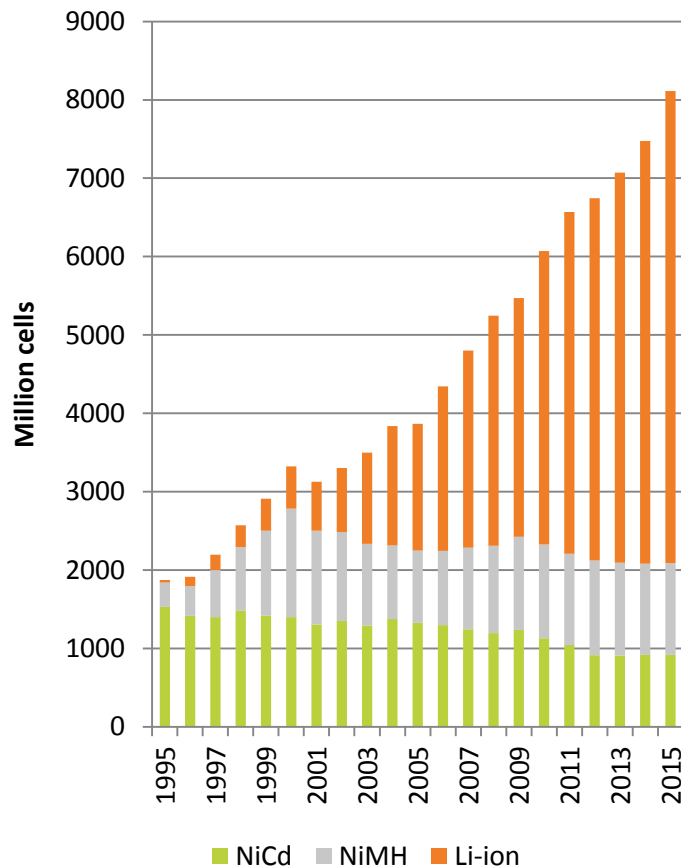
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# WORLDWIDE BATTERY SALES BY CHEMISTRY, UNITS, 1995-2015

The worldwide rechargeable battery  
market, Million cells, 1995-2015



2015: estimation data

Which cell are we talking about?



Front Edge Technology, Inc



GS Yuasa International / Lithium Energy Japan



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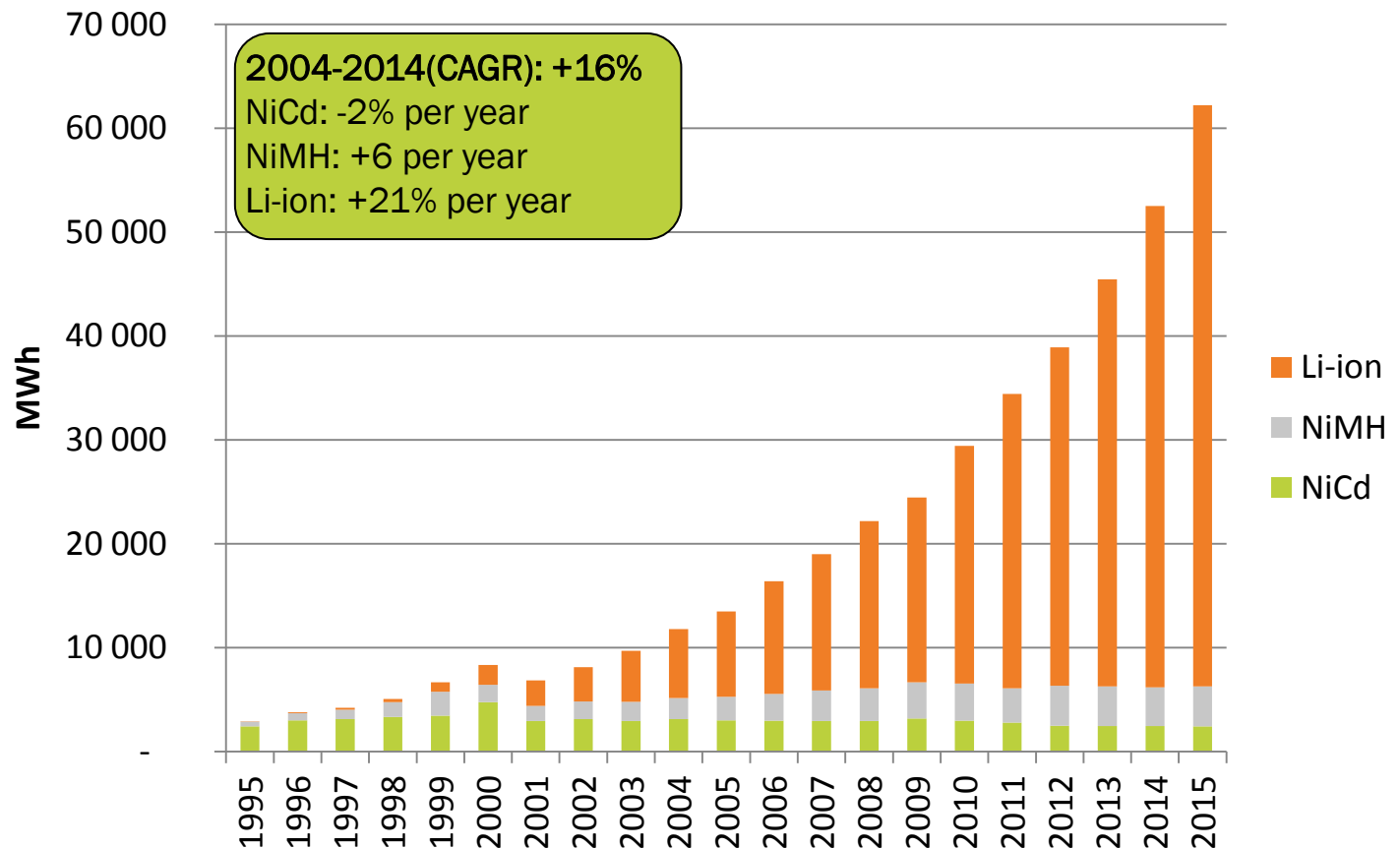
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# WORLDWIDE BATTERY SALES BY CHEMISTRY, MWh, 1995-2015

The worldwide rechargeable battery market, in volume,  
MWh, 1995-2015



2015: estimation data



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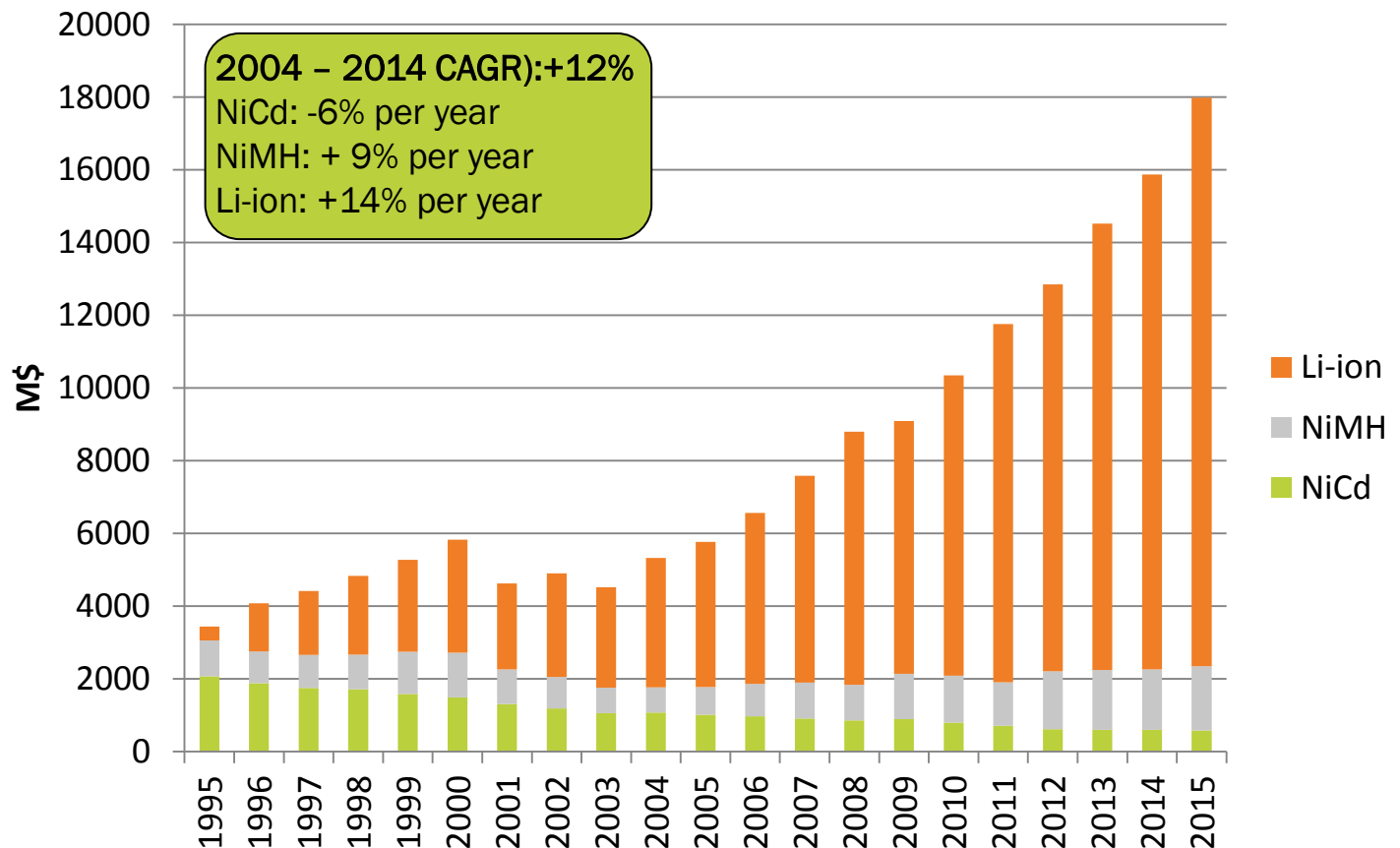
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# WORLDWIDE BATTERY SALES BY CHEMISTRY, M\$, 1995-2015

The worldwide rechargeable battery market, in value, M\$,  
1995-2015



Note: Cell level

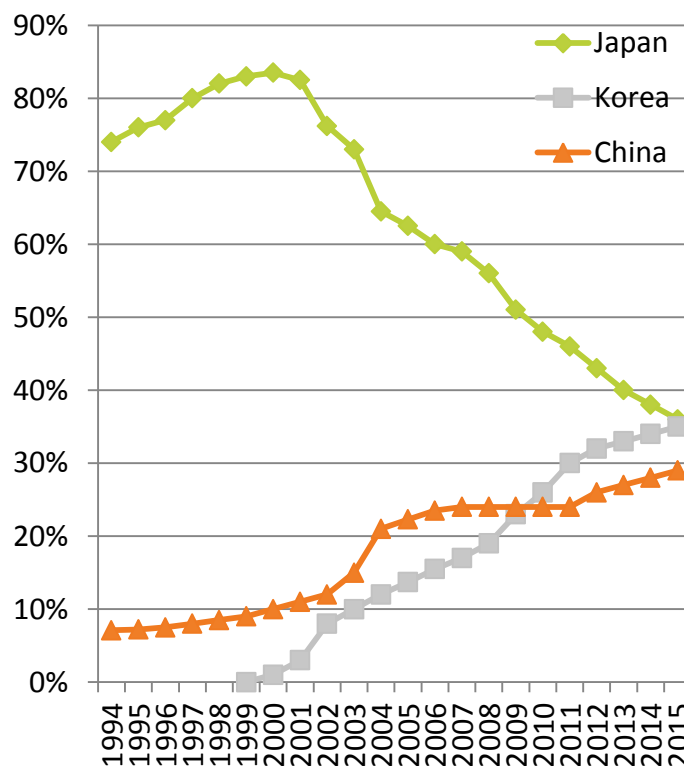
# EACH BATTERY TECHNOLOGY HAS ITS SPECIFIC ABSOLUTE ADVANTAGES

Advantage of ... ...On		Lead Acid	Nickel Cadmium NiCd	Nickel Metal Hydride NiMH	Lithium-Ion	
					Conventional	Laminate
Lead Acid			<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Operating temperature range</li> <li>Self discharge rate</li> <li>Reliability (progressive extinction)</li> </ul>	<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Self discharge rate</li> </ul>	<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Voltage output</li> <li>Self discharge rate</li> </ul>	<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Self discharge rate</li> <li>Design characteristics</li> </ul>
Nickel Cadmium NiCd		<ul style="list-style-type: none"> <li>Higher cyclability</li> <li>Voltage output</li> <li>Price</li> </ul>		<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> </ul>	<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Voltage output</li> <li>Self discharge rate</li> </ul>	<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Self discharge rate</li> <li>Design characteristics</li> </ul>
Nickel Metal Hydride NiMH		<ul style="list-style-type: none"> <li>Higher cyclability</li> <li>Voltage output</li> <li>Price</li> </ul>	<ul style="list-style-type: none"> <li>Operating temperature range</li> <li>Higher cyclability</li> <li>Self discharge rate</li> <li>Price</li> </ul>		<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Operating temperature range</li> <li>Higher cyclability</li> <li>Voltage output</li> <li>Self discharge rate</li> </ul>	<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Operating temperature range</li> <li>Self discharge rate</li> <li>Design characteristics</li> </ul>
Lithium-Ion	Conventional	<ul style="list-style-type: none"> <li>Higher cyclability</li> <li>Price</li> <li>Safety</li> <li>Recyclability</li> </ul>	<ul style="list-style-type: none"> <li>Operating temperature range</li> <li>Higher cyclability</li> <li>Price</li> <li>Safety</li> <li>Recyclability</li> </ul>	<ul style="list-style-type: none"> <li>Price</li> <li>Safety</li> <li>Discharge rate</li> <li>Recyclability</li> </ul>		<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density (potentially)</li> <li>Design characteristics</li> <li>Safety</li> <li>Price</li> </ul>
	Laminate	<ul style="list-style-type: none"> <li>Higher cyclability</li> <li>Price</li> </ul>	<ul style="list-style-type: none"> <li>Operating temperature range</li> <li>Higher cyclability</li> <li>Price</li> </ul>	<ul style="list-style-type: none"> <li>Volumetric energy density</li> <li>Higher cyclability</li> <li>Price</li> </ul>	<ul style="list-style-type: none"> <li>Operating temperature range</li> <li>Higher cyclability</li> </ul>	
Absolute advantages		<ul style="list-style-type: none"> <li>Higher cyclability</li> <li>Price</li> </ul>	<ul style="list-style-type: none"> <li>Operating temperature range</li> <li>Price</li> </ul>	<ul style="list-style-type: none"> <li>Volumetric energy density</li> </ul>	<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Self discharge rate</li> <li>Voltage output</li> </ul>	<ul style="list-style-type: none"> <li>Gravimetric energy density</li> <li>Volumetric energy density</li> <li>Self discharge rate</li> <li>Voltage output</li> <li>Design characteristics</li> </ul>

# JAPANESE, CHINESE & KOREAN MARKET SHARE

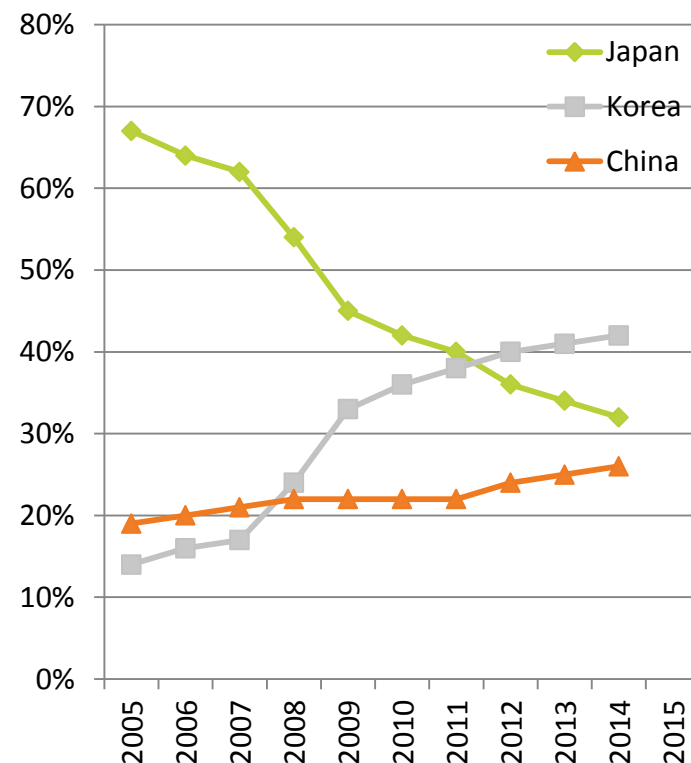
Japanese market share (value) decreasing: from 82 % of the market in 2001 to < 40% in 2014

**Rechargeable battery<sup>(1)</sup> market by country**



(1) Excluding lead acid batteries

**LIB market by country**





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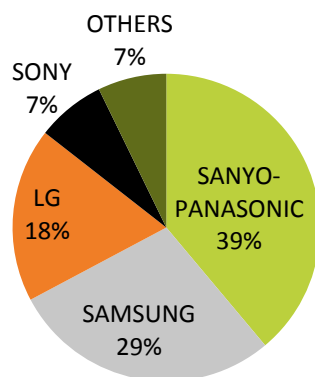
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# CYLINDRICAL LI-ION BATTERY

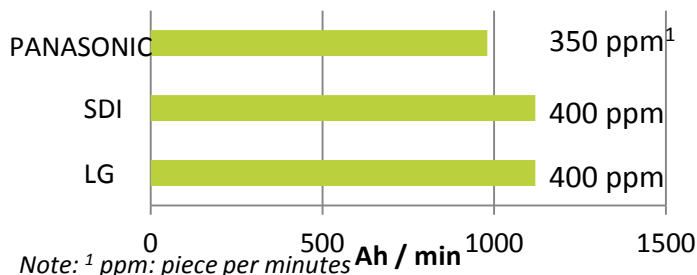
Cylindrical LIB market Company  
market share in 2014 in volume:  
1925 Million cells (+3%)



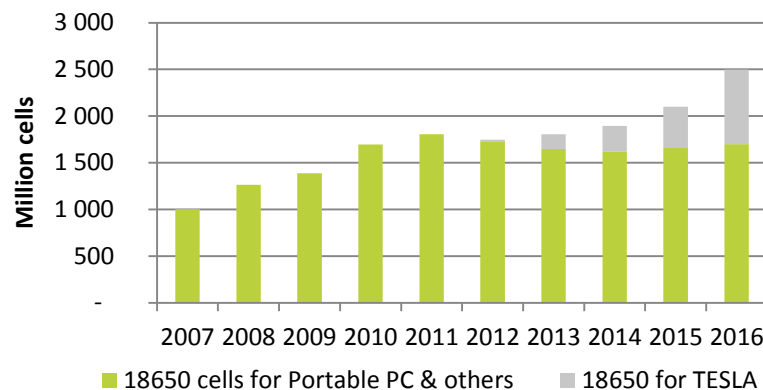
## Key success factor

- Production speed (-> cost)
- Performances
- Customer (Portable PCs) access

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

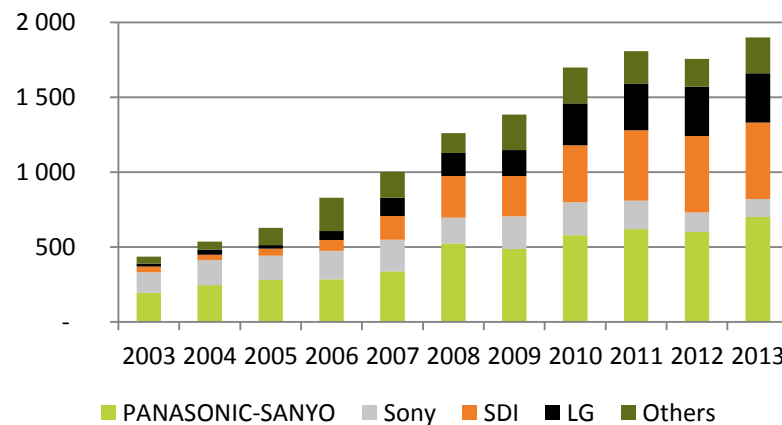


SANYO-PANASONIC, SDI & LG  
will share the market



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

## Cylindrical cells (M) by mfg.



Source: Interviews with LG, SAMSUNG, SANYO-PANASONIC 14



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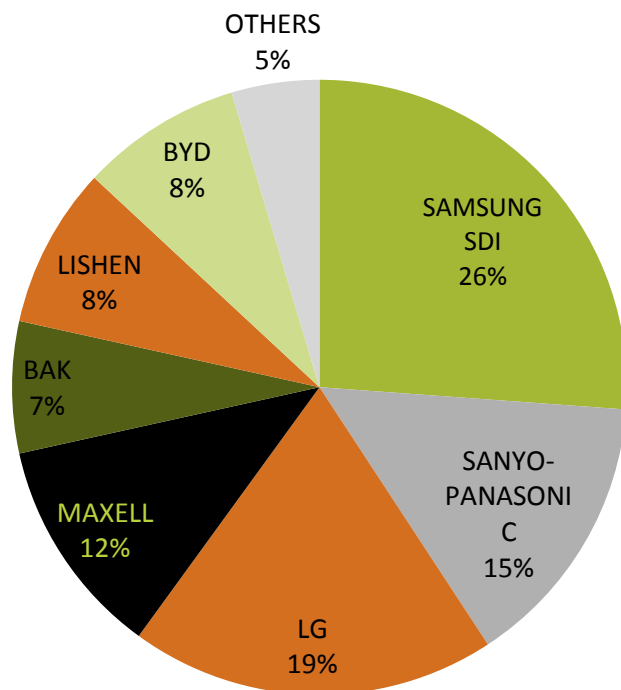
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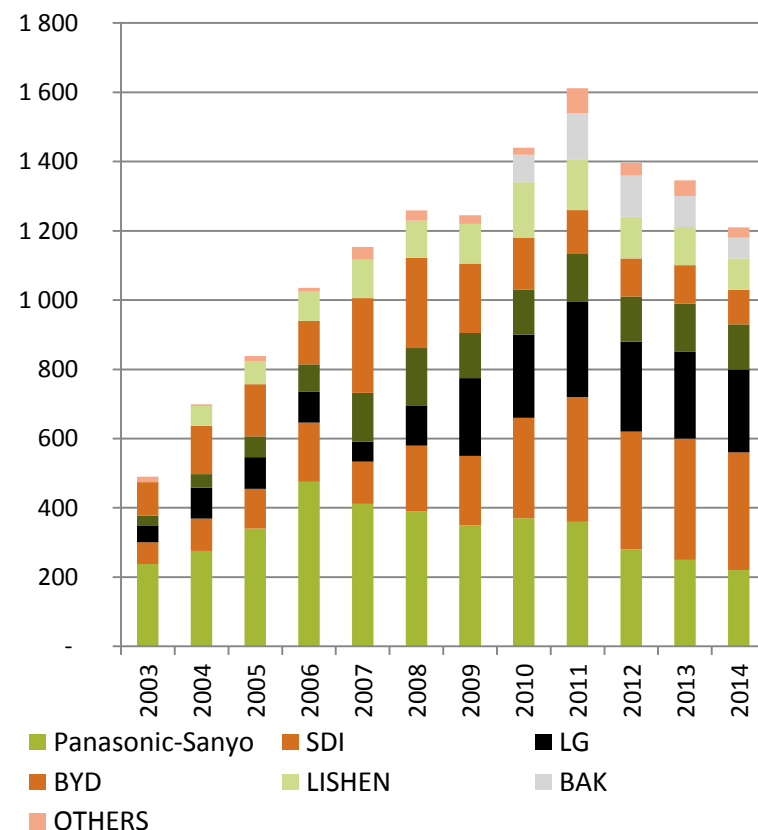
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# PRISMATIC LI-ION BATTERY

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



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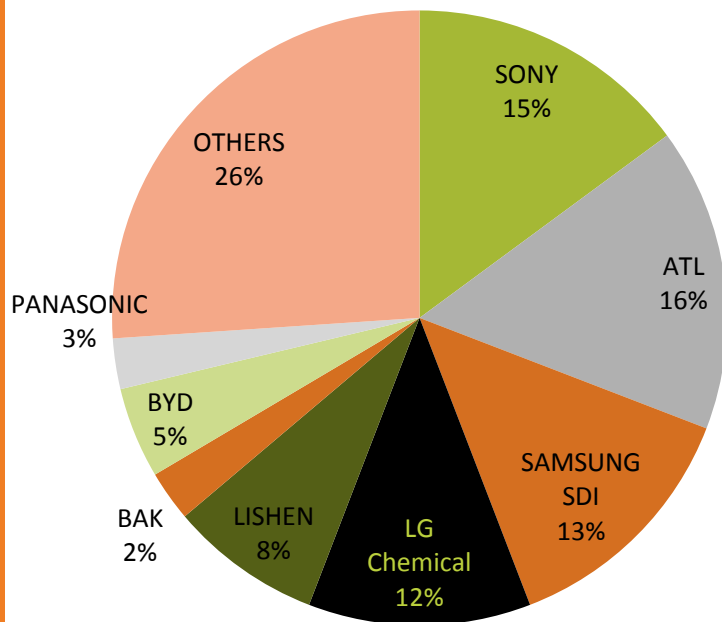
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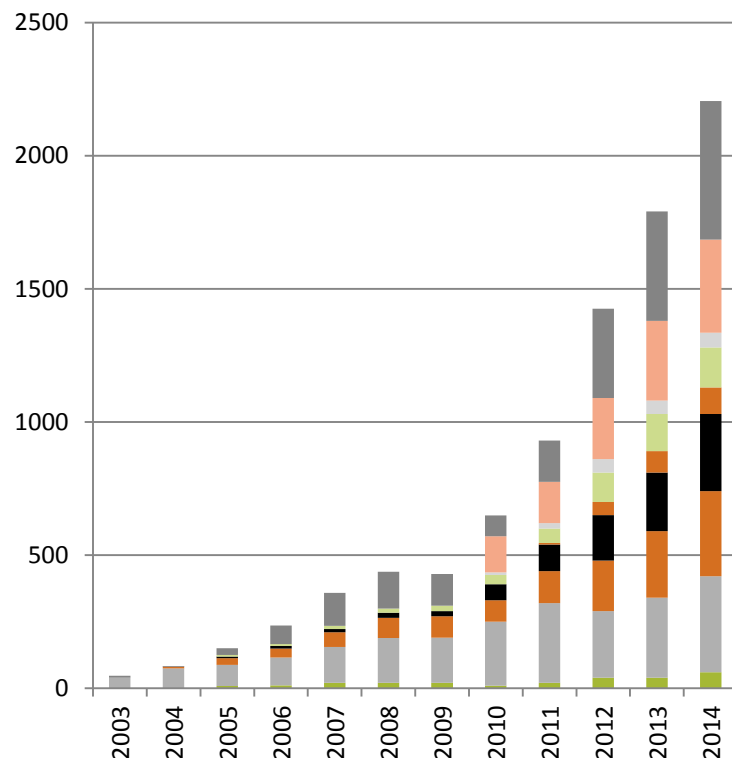
# LI-LAMINATE BATTERY

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



Source: AVICENNE ENERGY Analyses 2015

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



Panasonic-Sanyo  
LG  
LISHEN  
Sony  
MAXELL  
BAK  
SDI  
BYD  
ATL





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# LI-ION IN 2014

## MAIN APPLICATIONS: CELLULAR, NOTEBOOK

5 400 M cells – 46 000 MWh

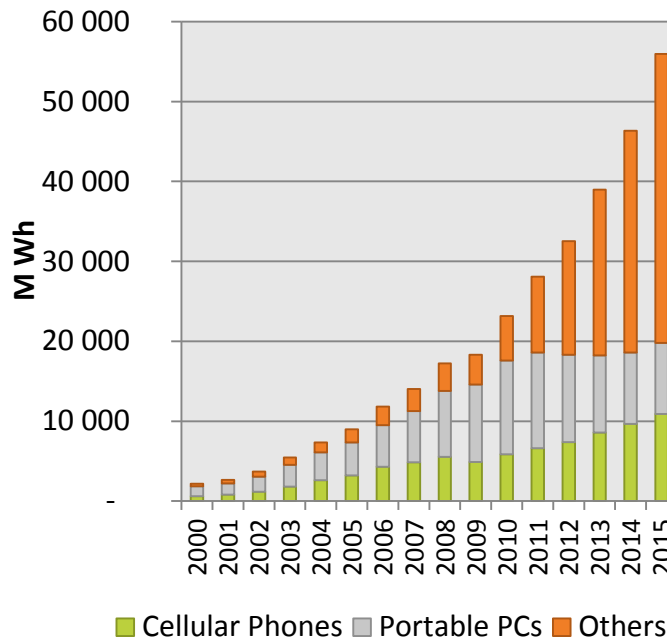
13 600 M\$ (2)

CAGR 2004/2014

+21 % per year in Volume

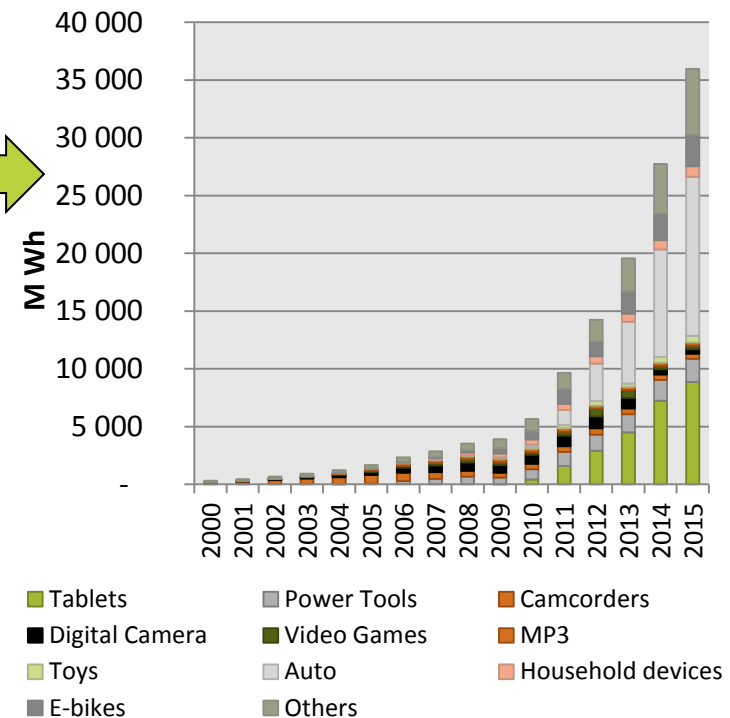
+14% per year in value

Li-ion Battery sales,  
MWh, Worldwide, 2000-2014



2015 estimation data

Li-ion Battery sales,  
MWh, Worldwide, 2000-2014





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# LI-ION IN 2014

## MAIN APPLICATIONS: CELLULAR, NOTEBOOK

5 250 M cells – 45 000 MWh

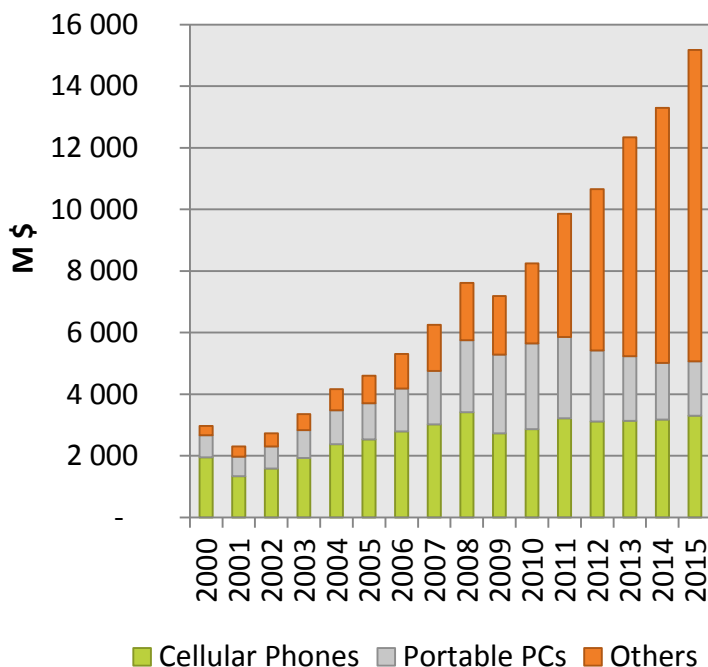
13 300 M\$ (2)

CAGR 2004/2014

+20 % per year in Volume

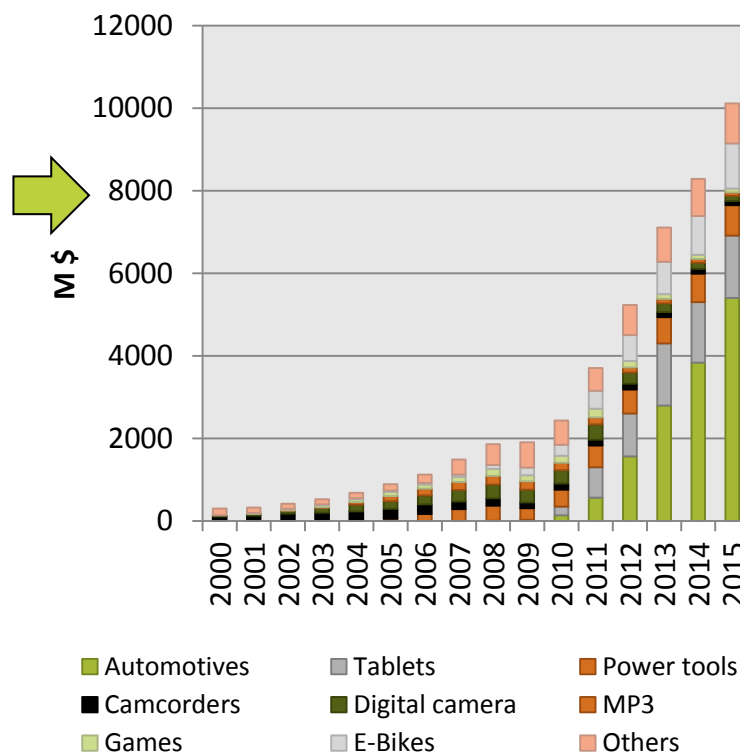
+14% per year in value

Li-ion Battery sales,  
M\$, Worldwide, 2000-2014 (1)



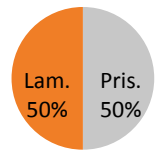
Note: (1) 2013: Avicenne Forecasts (2) Cell level

Li-ion Battery sales,  
M\$, Worldwide, 2000-2014 (1)



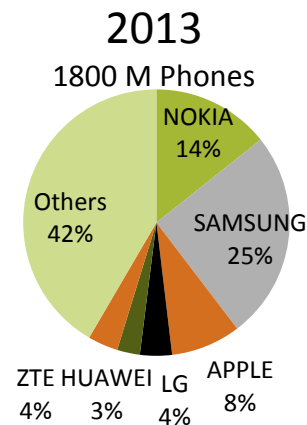
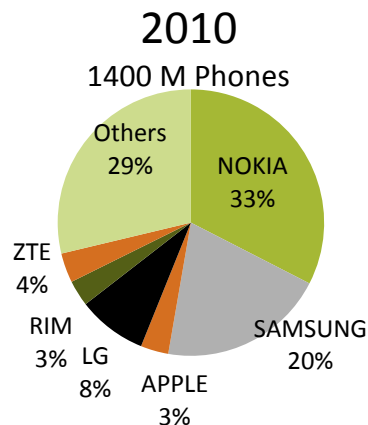
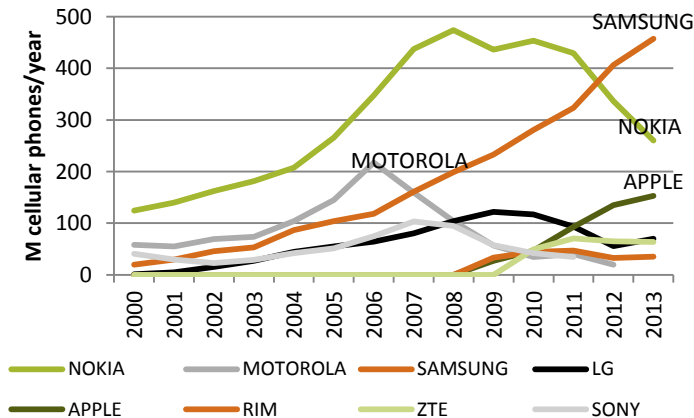
# CELLULAR PHONES MARKET

## > 1980 M LIB CELLS IN 2014

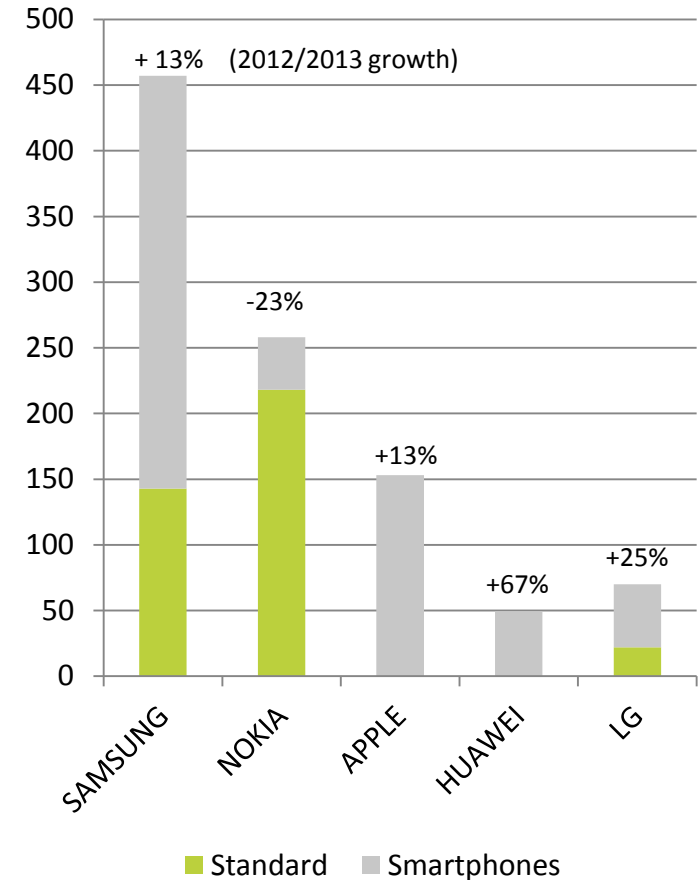


LIB cell format  
(Volume) 2013

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



Samsung Galaxy & I-phone  
change the game





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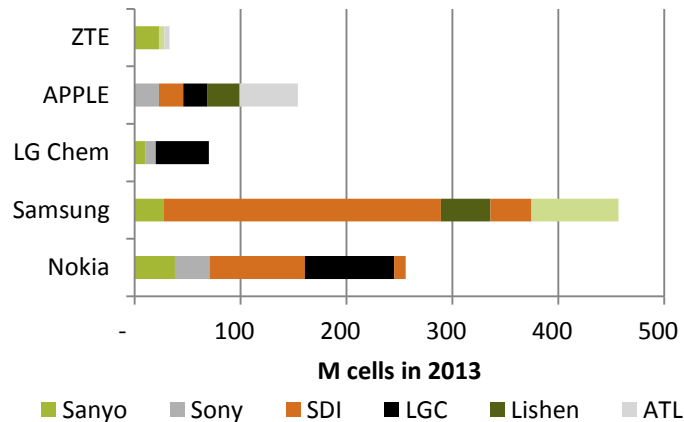
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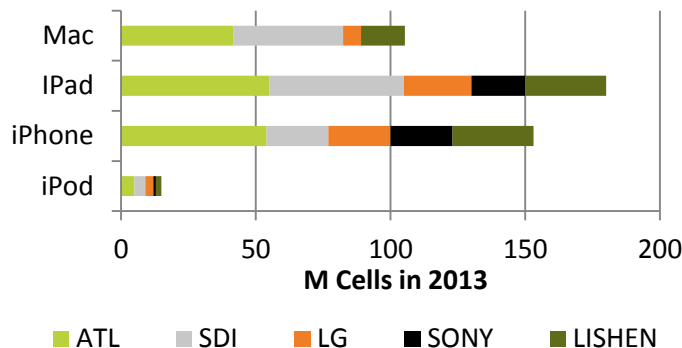
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# CELLULAR PHONES/LIB SUPPLIERS RELATIONSHIPS

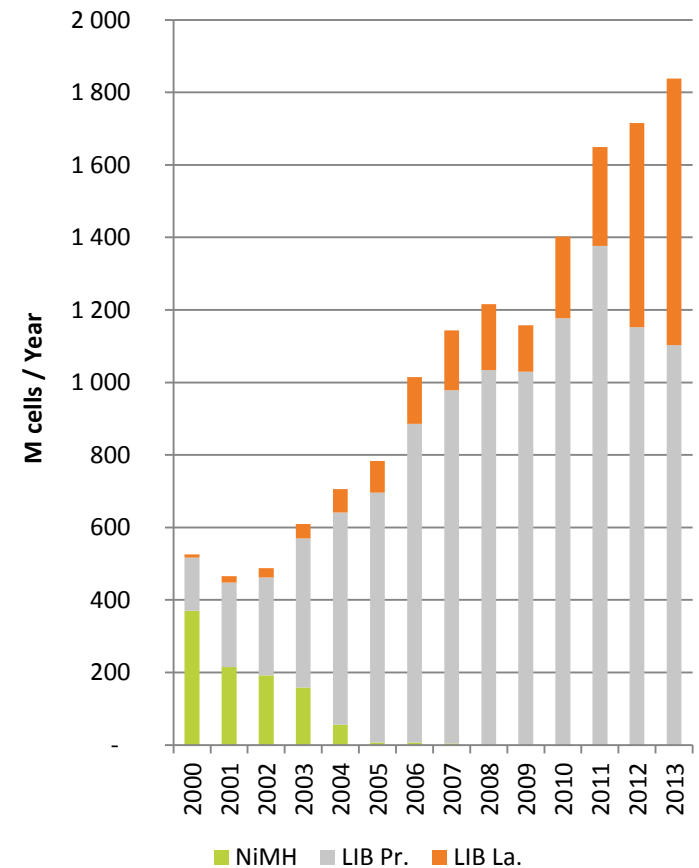
## 2013 Cellular Phone makers / battery suppliers relation



## APPLE needs in 2013

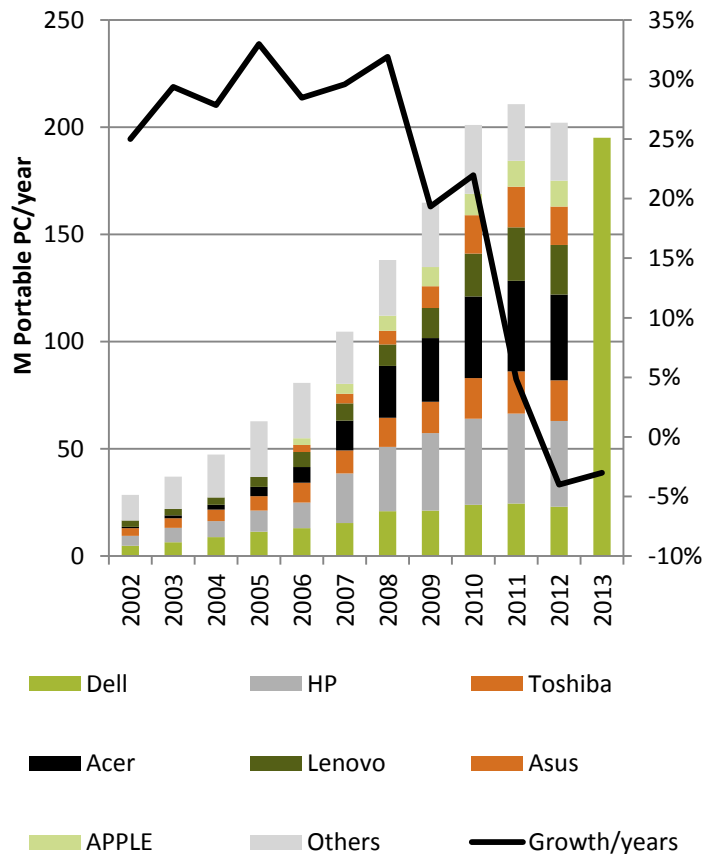


## Smartphones / ie laminate LIB increasing

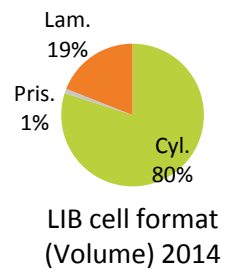


# PORTABLE PC MARKET 990 M LIB CELLS IN 2014

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



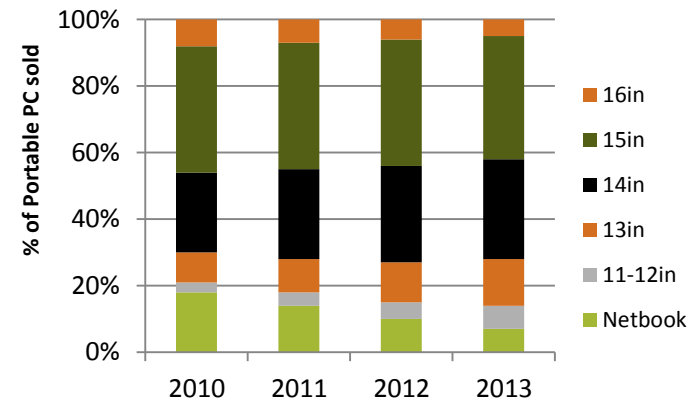
Note: Excluding Tablets



## 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

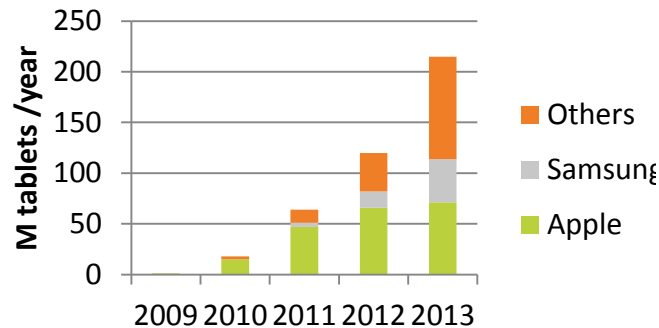
## Increase of Ultra-thin Portable PCs



# TABLET MARKET > 550 M CELLS IN 2013

## Tablets sold (Million)

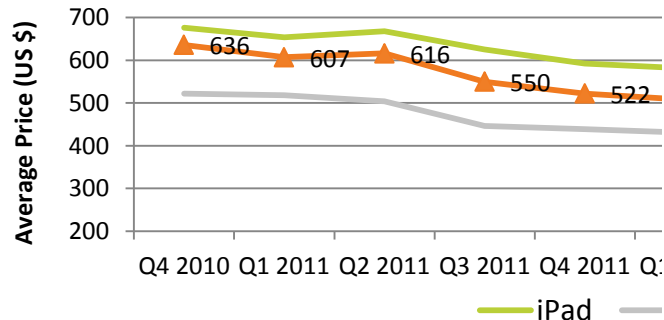
### Apple leadership



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

## ASP tablets drop

From \$636 in Q4 2010 to \$335 in Q4 2011





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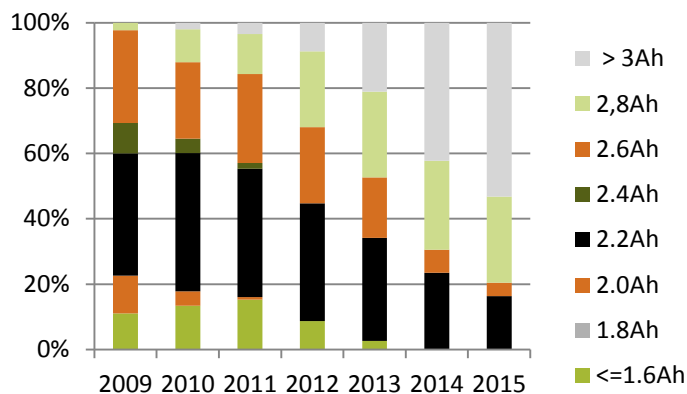
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# LIB BATTERY SHORT TERM TRENDS

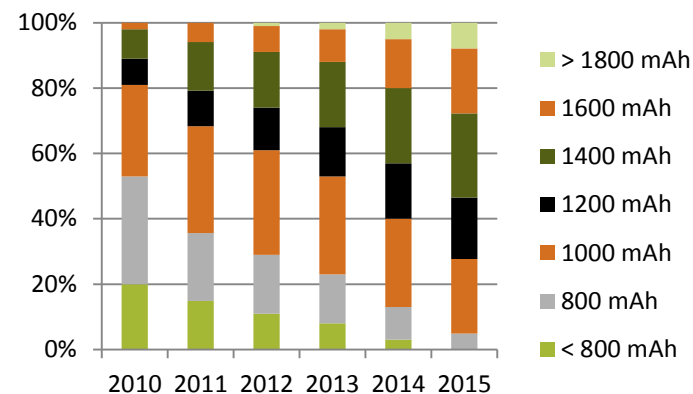
Higher capacity, thinner battery, Pouch cells have the highest growth

## 18650 battery capacity\*

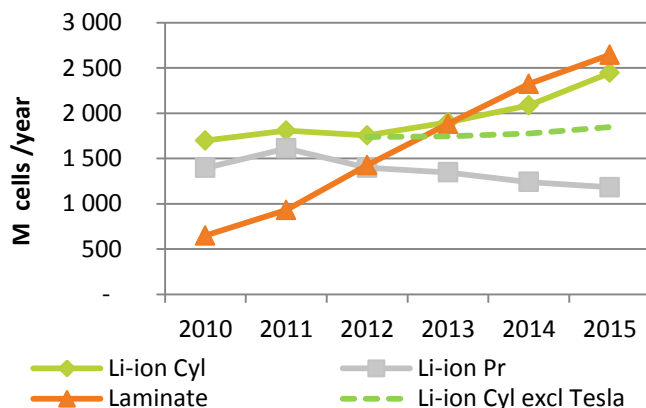


\*1C rate or laptop type 18650 cells

## Cellular phones battery capacity

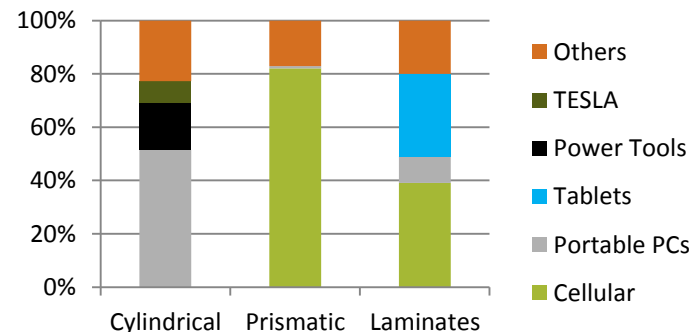


## Cylindrical/Prismatic/Laminates



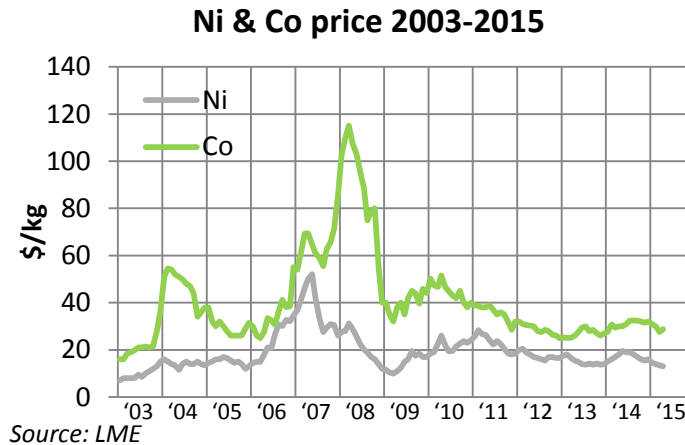
Li-ion cylindrical: "Tesla impact": 150 M cells in 2013, 300M in 2014, 600 M in 2015

## Cylindrical/Prismatic/Laminates in 2013

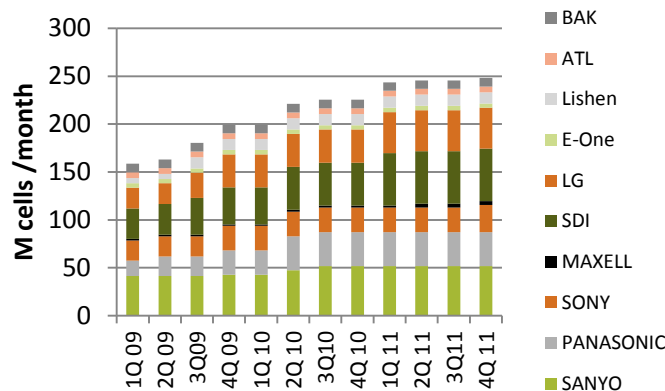


# BATTERY PRICE IS DECREASING DRASTICALLY

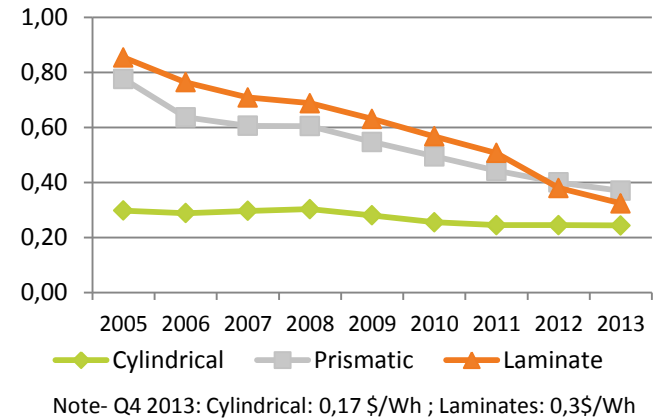
In 10 Years 80% price decreasing  
despite a fluctuating Co price



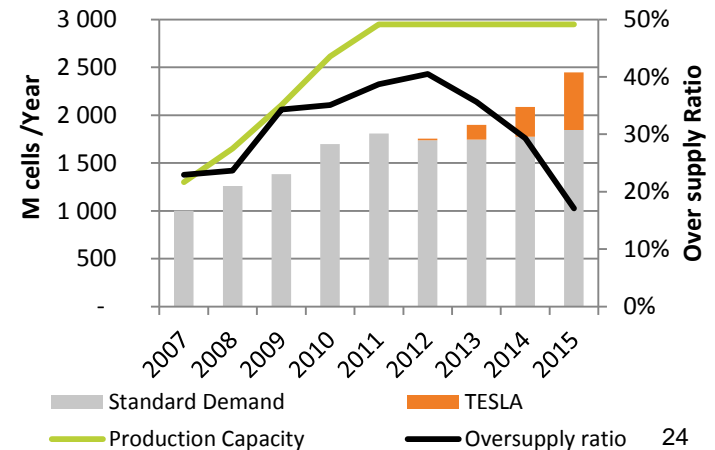
Production capacity 2009/2011:  
from 150 to 250 M cells/month



Average LIB cell price (\$/Wh)

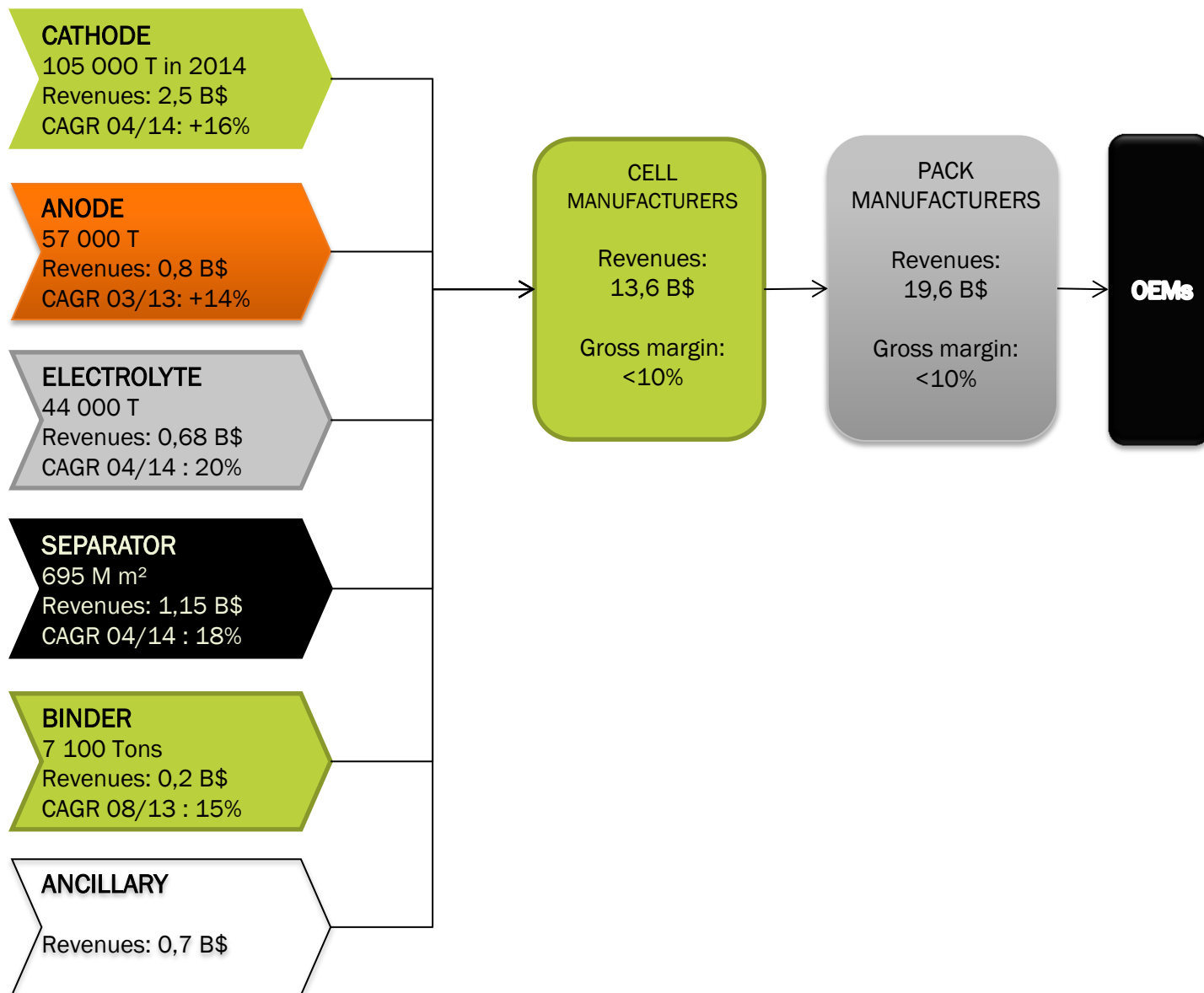


18650 oversupply ratio is  
decreasing thanks to TESLA



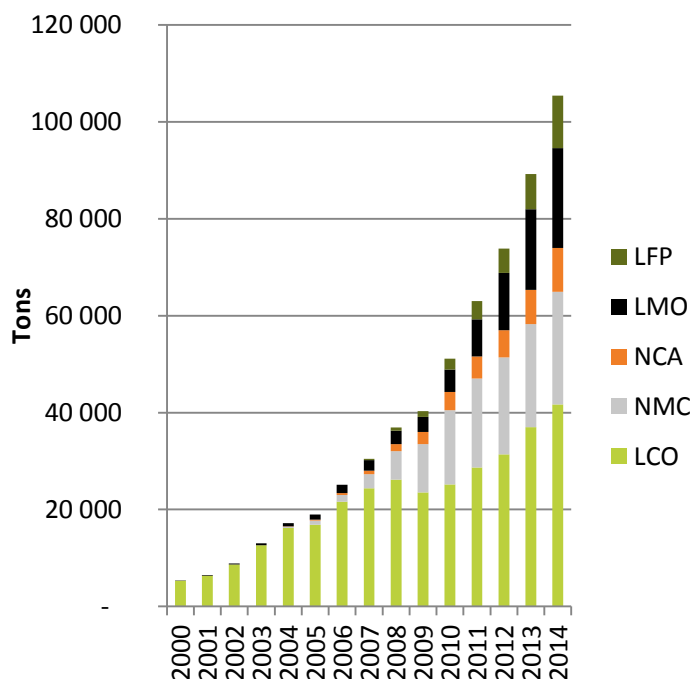


# LI-ION VALUE CHAIN – MARKET DEMAND



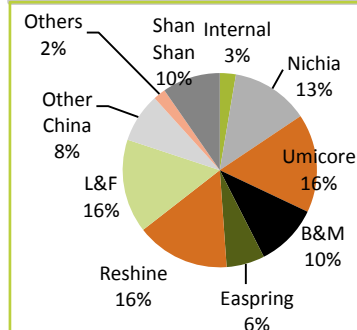
# CATHODE ACTIVE MATERIALS NEEDS BY CHEMISTRY

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

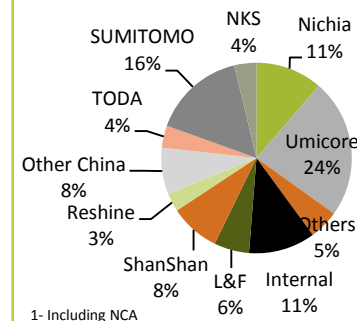


## SUPPLY

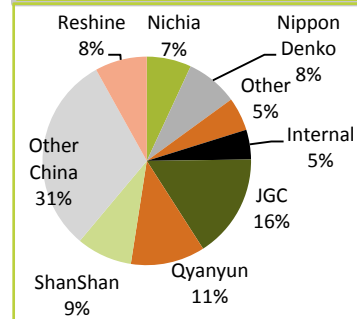
### LCO – >45 KT (2014)



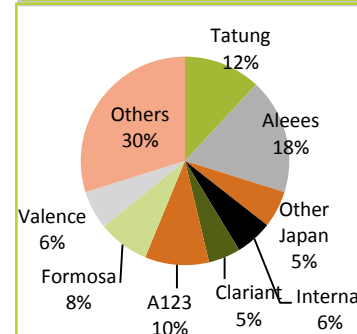
### NMC<sup>1</sup> – > 35 KT (2014)



### LMO – > 18 KT (2014)



### LFP – > 10 KT (2014)



### LEADERS:



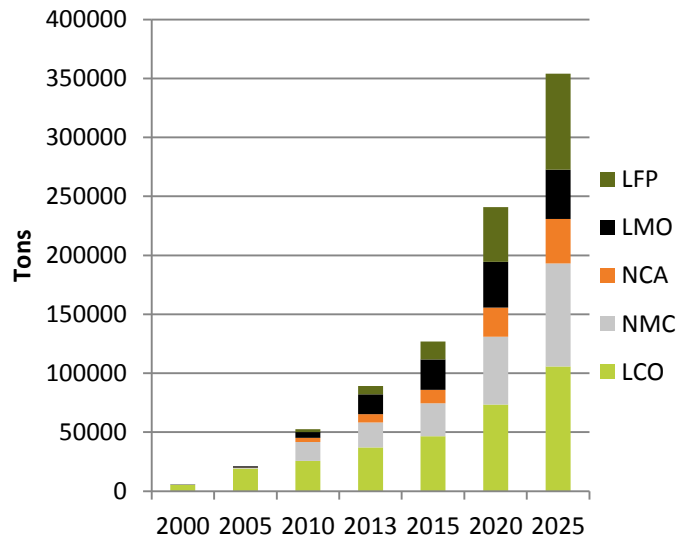
### NEW ENTRANTS ON THE FIELD:



(...)

# CATHODE ACTIVE MATERIAL FORECASTS 2000-2025

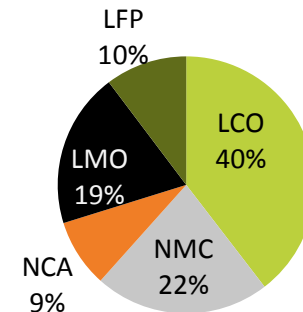
## Cathode active materials 2000-2025 - Tons



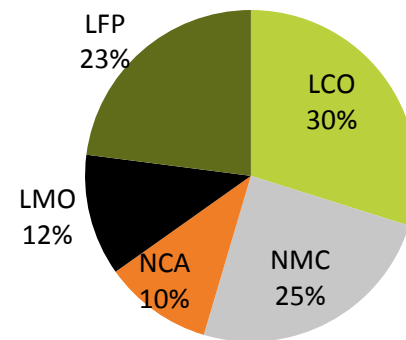
### ASSUMPTIONS:

- 🔋 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

## Cathode active materials in 2014: 105 000 Tons



## Cathode active materials in 2025: > 350 000 Tons

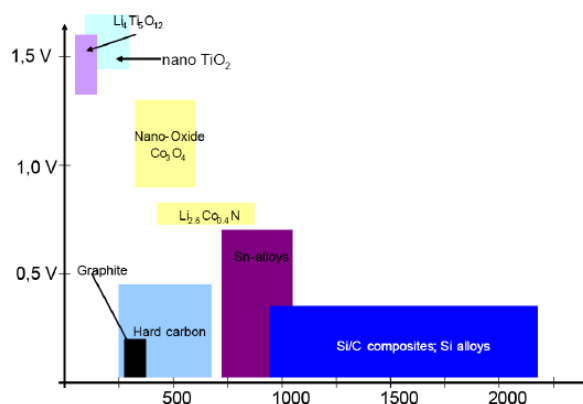


Assumption: Tesla keep NCA chemistry and have a relative success  
(200 000 EV sold per year in 2025 – TESLA forecast 500 000)

# ANODE ACTIVE MATERIALS

## 57 000 TONS IN 2014

### LIB Anode Materials

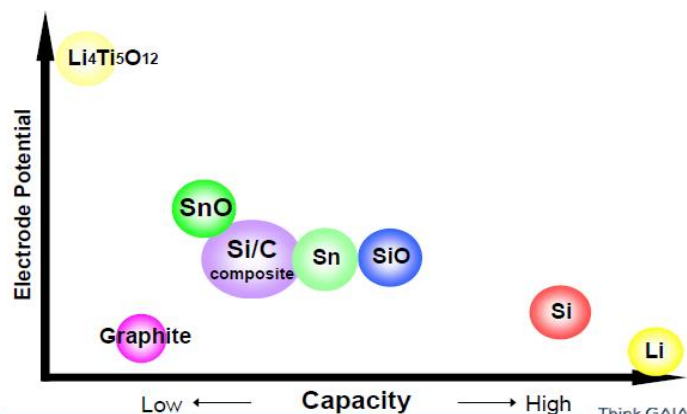


Source: A. Jossen, IRES 2007



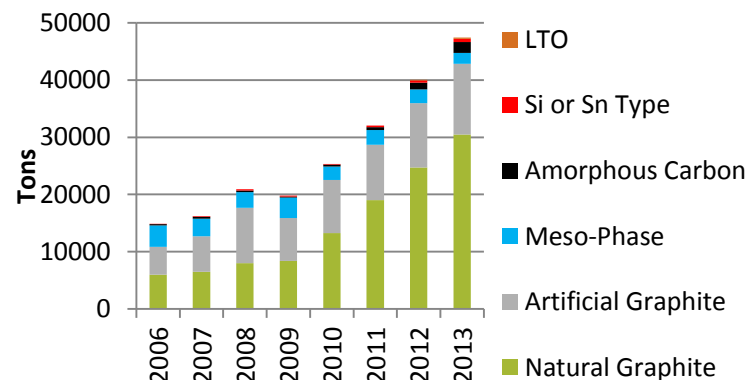
Source: Hitachi Chemical

### LIB Anode Materials



Source: Sanyo, March 2011

### LIB Anode market, (Tons)





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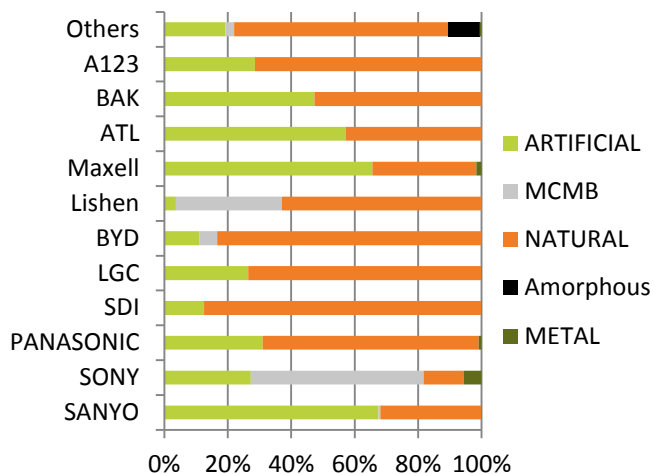
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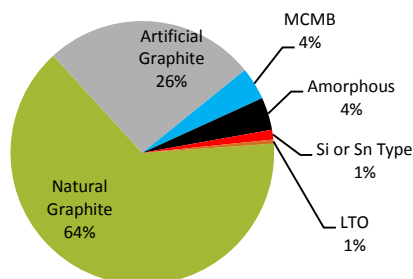
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# ANODE FOR LIB IN 2014

## Natural graphite become a commodity



Carbon for LIB anodes by type (2013)



Note: MCMB: Mesocarbon Microbeads

	Hard Carbon	Soft Carbon	Graphite
Capacity (/g)	400 mAh/g	250 mAh/g	325-375 mAh/g
Capacity (/cc)	++	0	+
Power	++	+	0
Stability	++	+	0
Cyclability	++	+	0
Precursors	Petroleum Pitch, Resin, cellulose, wood, coconuts...	Petroleum coke	Natural or petroleum coke
COST 2012->2020	30 -> 25 \$/kg	25->20 \$/kg	15 -> 10 \$/kg
SUPPLIERS	KUREHA	HITACHI	HITACHI BTR & many others

### LEADERS:



### NEW ENTRANTS ON THE FIELD:



(...)



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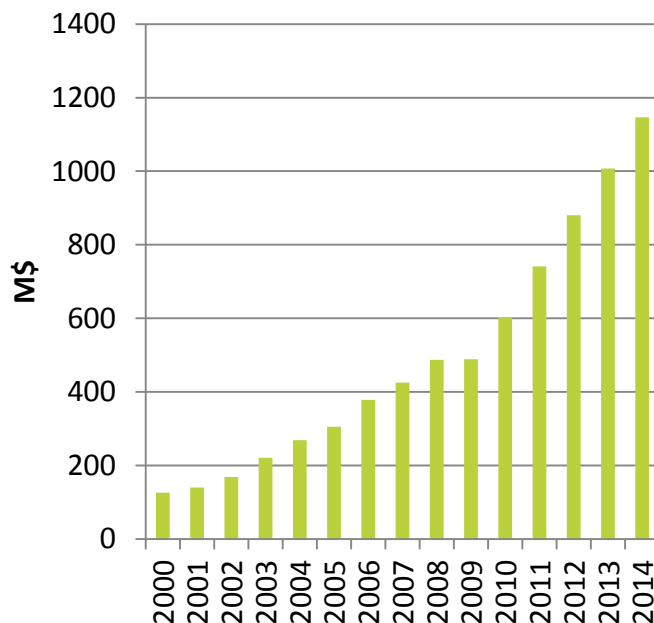
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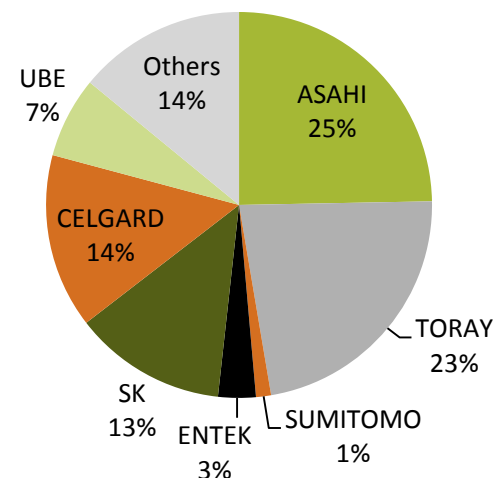
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# LIB SEPARATOR MARKET 2014

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



LIB Separator supplier, market  
share in 2014



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

LEADERS:

AsahiKASEI



UBE



TORAY

NEW ENTRANTS ON THE FIELD:



LG Chem

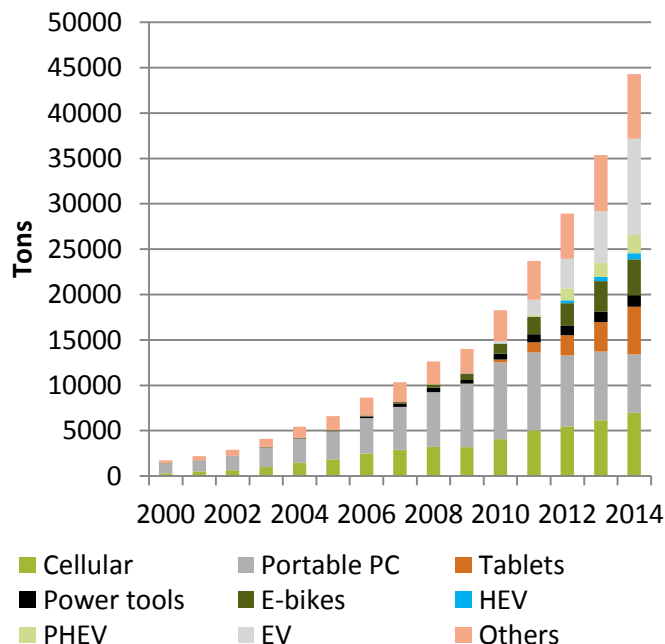


MITSUBISHI

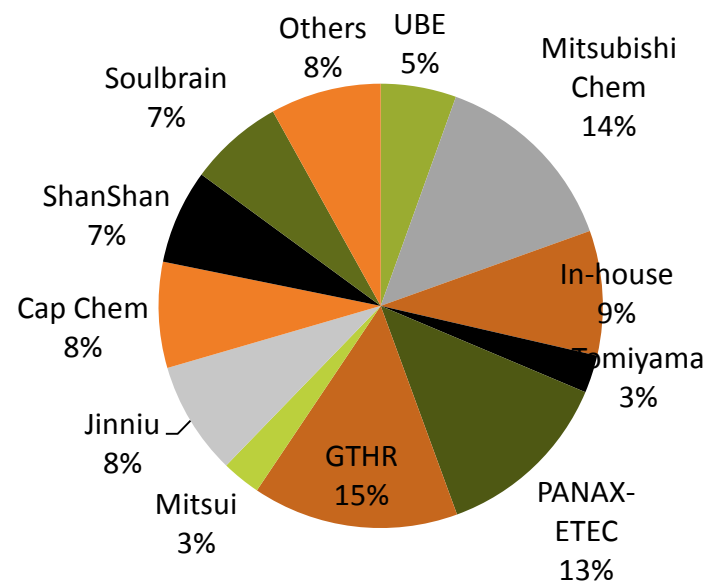
Evonik, TEIJIN,  
HIFUTURE, UBE-MAXELL (...)

# ELECTROLYTE SUPPLIERS/CUSTOMERS 44 000 TONS IN 2014

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



LIB electrolyte supplier, market  
share in 2014



## LEADERS:



Zhangjiagang  
Guotai-Huang



JINNIU



SHANSHANTECH



新宙邦  
GAPCHEM

## NEW ENTRANTS ON THE FIELD:



LG Chem



The Chemical Company



UBE  
UBE INDUSTRIES LTD.



Note: (1) GTTH: Zhangjiagang Guotai-Huarong



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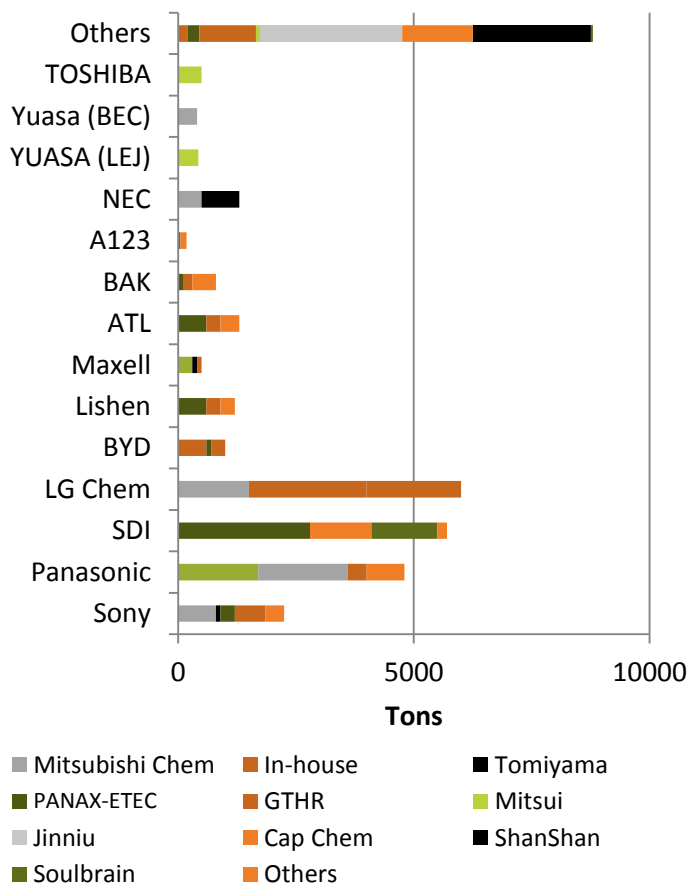
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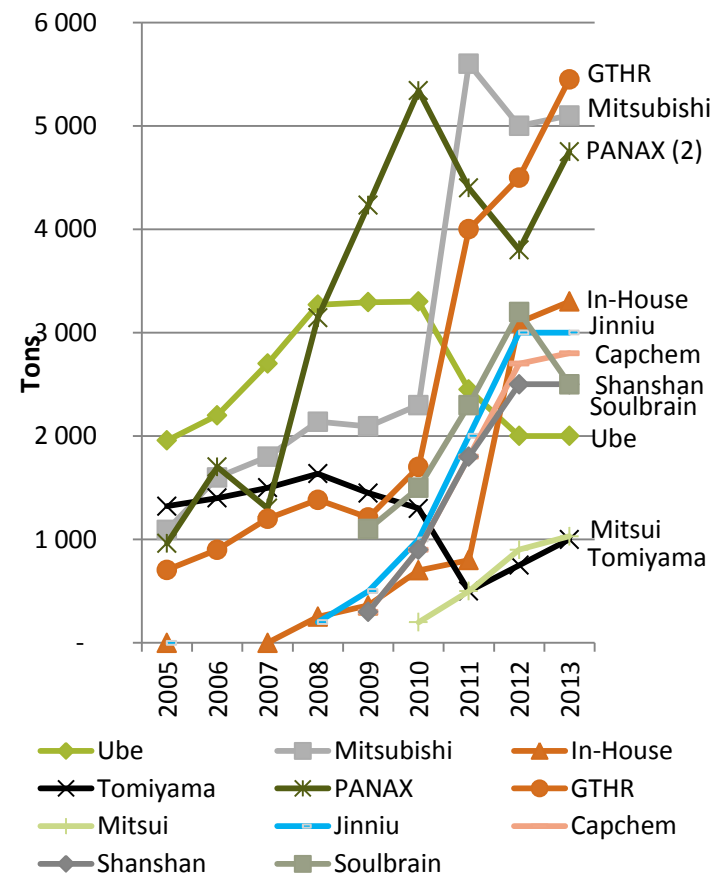
# LIB ELECTROLYTE MARKET 2014

## Electrolyte Battery makers & suppliers relation in 2014



(1) Full electrolyte formulation in-house

## Electrolyte maker sales 2005-2013



(2) Panax-Etec bought Samsung Chiel activities in 2010



# BATTERY MARKET FORECASTS 2014-2025

## Applications covered

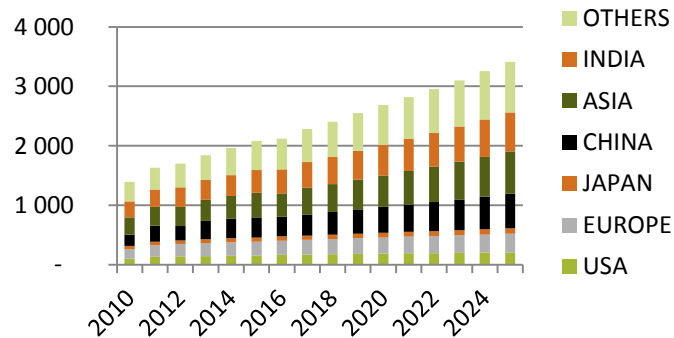
- 🔋 Portable PCs, net-book, Ultra-book
- 🔋 Cellular Phones, Smart-phones
- 🔋 Tablets
- 🔋 Camcorders
- 🔋 Cordless Tools, Gardening tools
- 🔋 Digital Camera
- 🔋 Games, MP3
- 🔋 Cordless Phones
- 🔋 Shavers, Toothbrush,
- 🔋 RC Cars
- 🔋 E-bikes
- 🔋 Power tools
- 🔋 Security lighting
- 🔋 Vehicles: HEV, P-HEV, 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

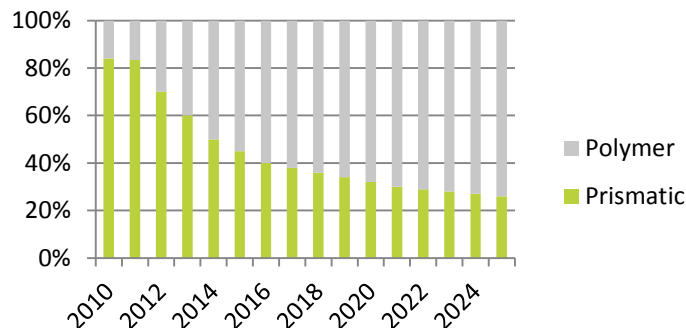
# CELLULAR PHONES FORECASTS 2010-2025

Cellular phones demand (M Units)  
CAGR 2010-2025: +6%

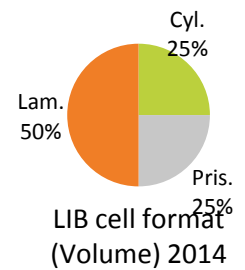


LIB cells demand 2014-2025

Polymer penetration: 50% -> 75%



Source: AVICENNE ENERGY Analyses



Cellular Phones market Drivers

- Emergent market
- Renewal ratio increase
- Smartphone penetration increase



LIB cells for cellular phones  
trends

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



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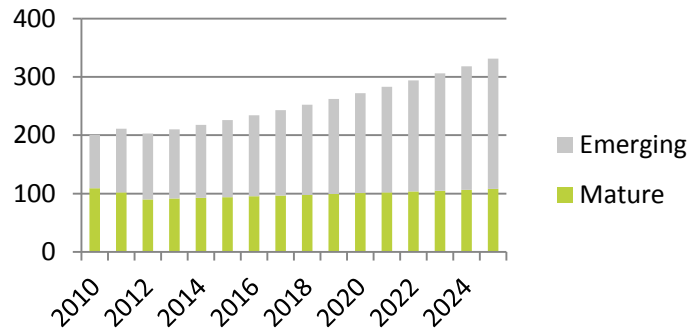
March 9, 2015

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# PORTABLE ELECTRONIC DEVICES FORECASTS 2010-2025

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



Source: IDC, Gartner, AVICENNE Energy

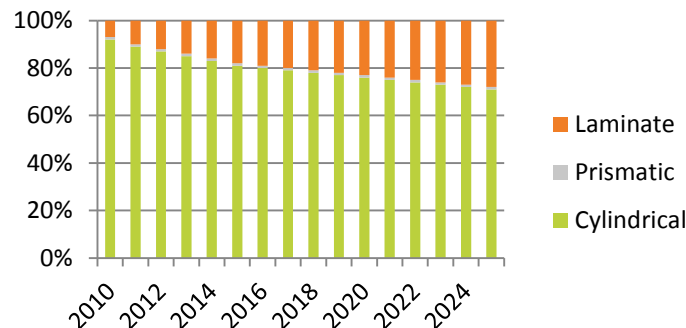
## Portable PCs market trends

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

(1) Samsung & AVICENNE (2) Intel

## LIB cells demand 2010-2025

Polymer penetration: 7% -> 28%



Source: AVICENNE ENERGY Analyses

## LIB cells for portable PCs trends

- 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



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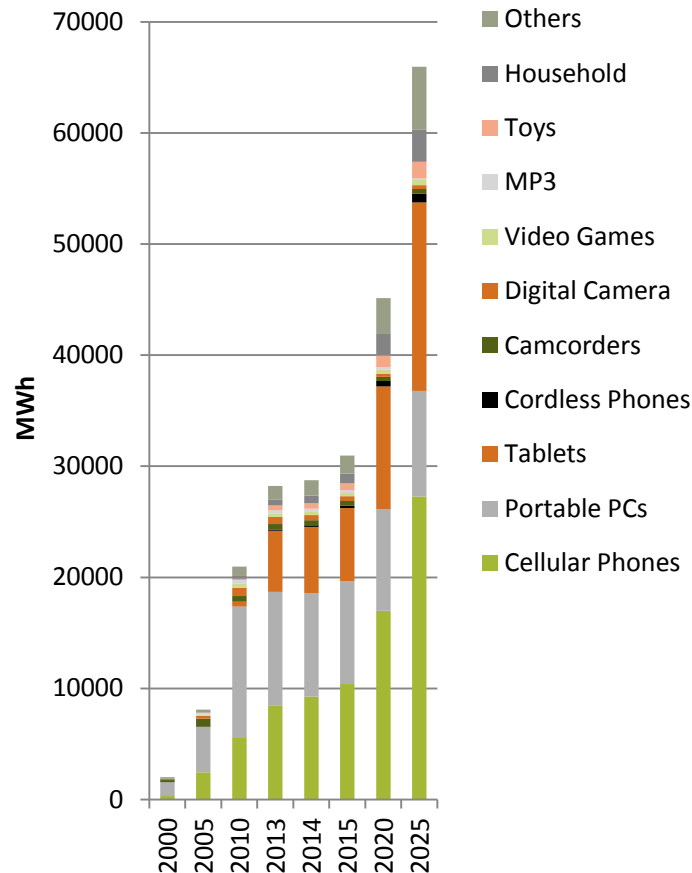
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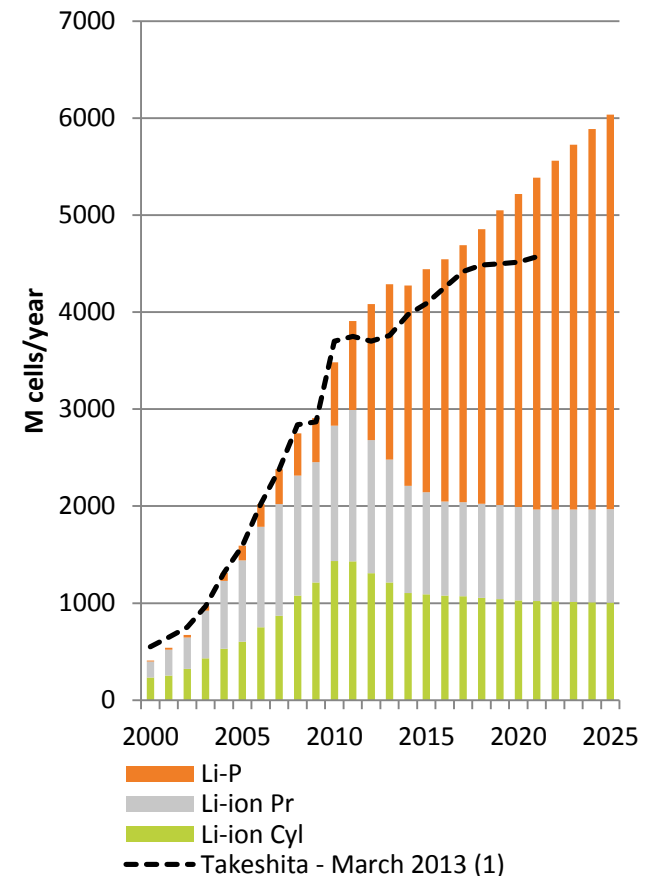
# 2025 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

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



Source: AVICENNE ENERGY Analyses

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



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



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# 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



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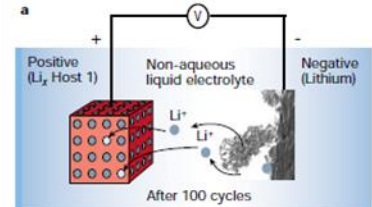
# SAFETY ISSUES

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 their 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






Boeing 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 Boeing.













# SAFETY IS A SINE-QUA-NON SELECTION CRITERIA FOR BATTERY TECHNOLOGIES

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

Cathode		LCO	NMC	LMO	LFP	High V	Sulfur
SAFETY							?
xEV ?		NO	YES	YES	YES	?	?

Anode		Graphite	Hard Carbon	Soft Carbon	LTO	Si/C	Li Metal
SAFETY							
xEV ?		YES	YES		No (1)	?	?

Electrolyte		Liquid	+ Additive	Gel Polymer	5 V	Polymer membrane	Solid
SAFETY					?		
xEV ?		NO	YES	YES	No	YES	> 2025

Separator		PE, PP membrane	+ coating	Non woven	Polymer membrane	Solid
SAFETY						
xEV ?		YES	YES	YES	YES	> 2025

BMS	<ul style="list-style-type: none"> <li>Most of the BMS function is to manage the safety of the cell &amp; the battery pack: <ul style="list-style-type: none"> <li>Overcharge management</li> <li>Over voltage management</li> </ul> </li> </ul>
-----	--

Packaging	<ul style="list-style-type: none"> <li>Use "safer" material in the pack: <ul style="list-style-type: none"> <li>Flame retardant,</li> <li>High shock resistance</li> </ul> </li> </ul>
-----------	--

Thermal	<ul style="list-style-type: none"> <li>Thermal management improve both the safety and the life time</li> </ul>
---------	--

 Very Safe       Unsafe

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

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



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& EXHIBIT

March 9, 2015

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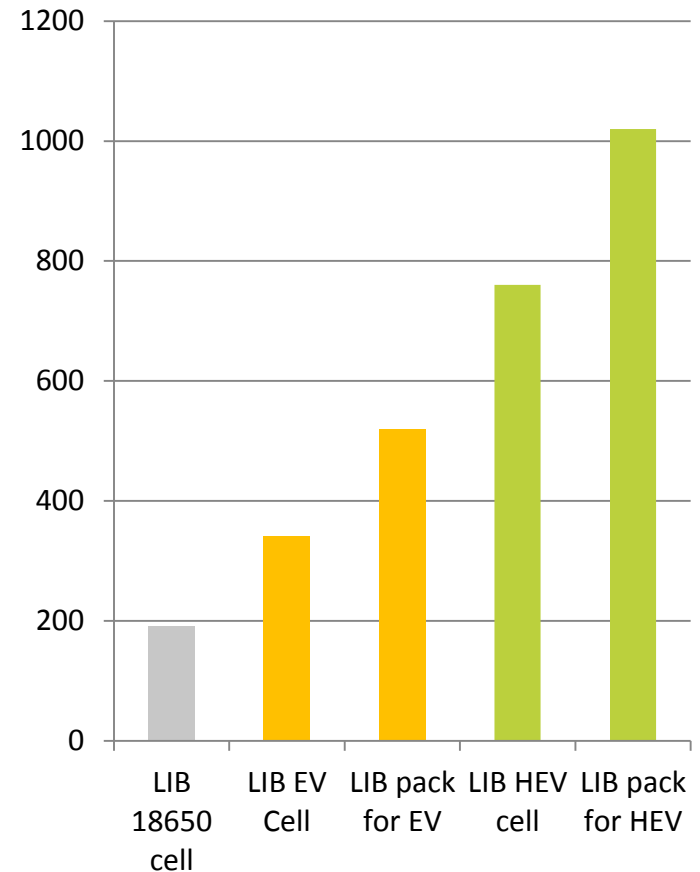
Christophe PILLOT  
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[c.pillot@avicenne.com](mailto:c.pillot@avicenne.com)

# 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





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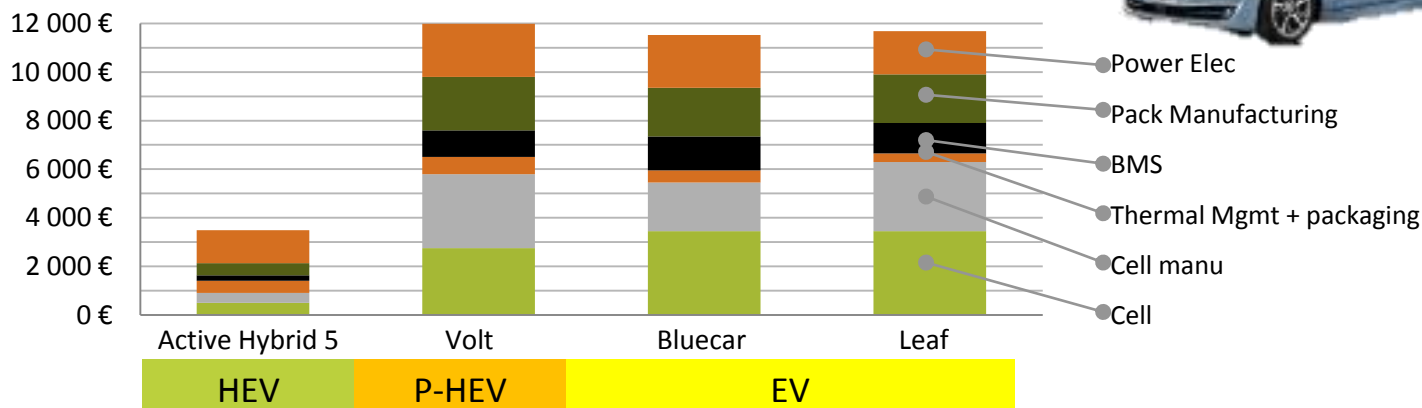
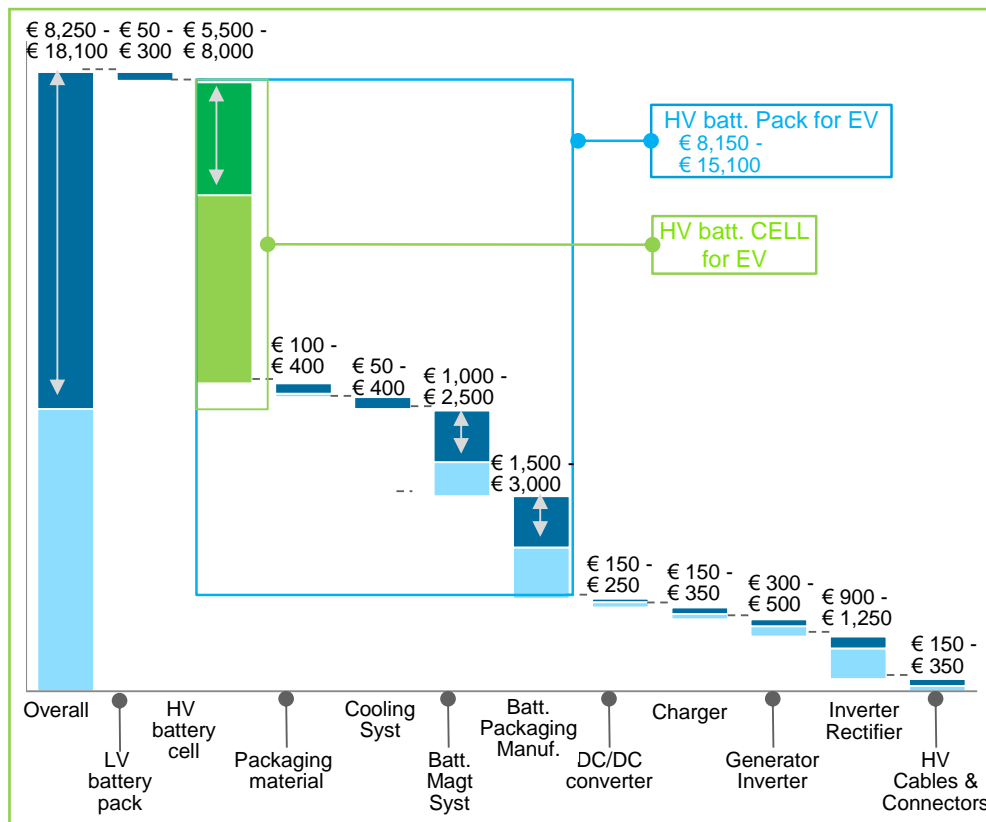
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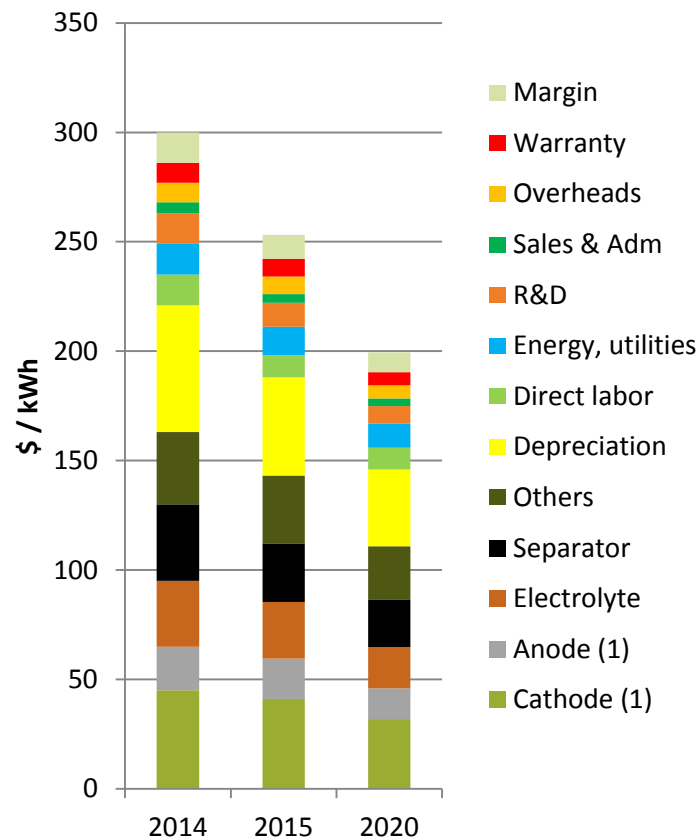
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c.pillot@avicenne.com

# BATTERY & POWER ELEC. COST IN EV



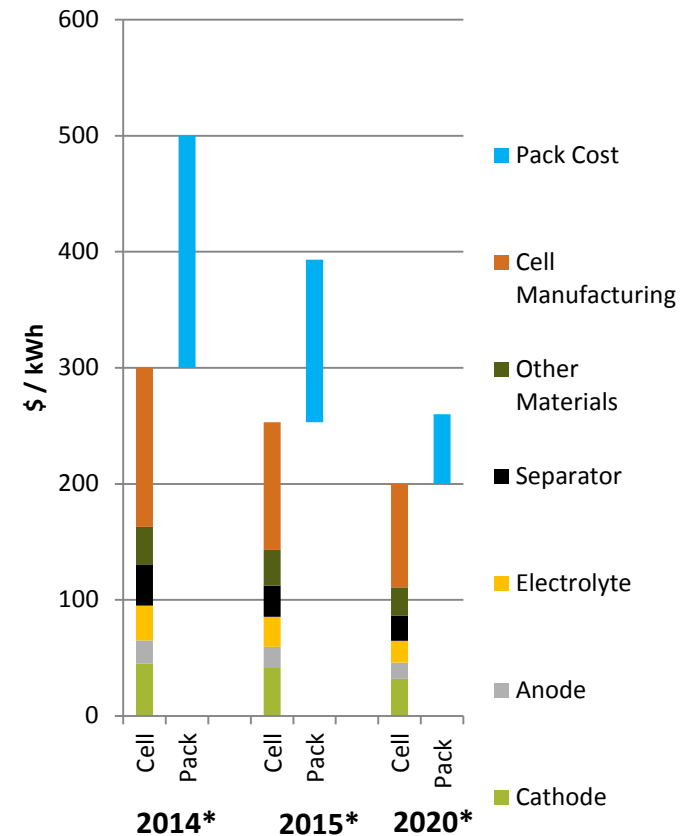
# LI-ION BATTERY COST 2013-2020

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



(1) Active materials only

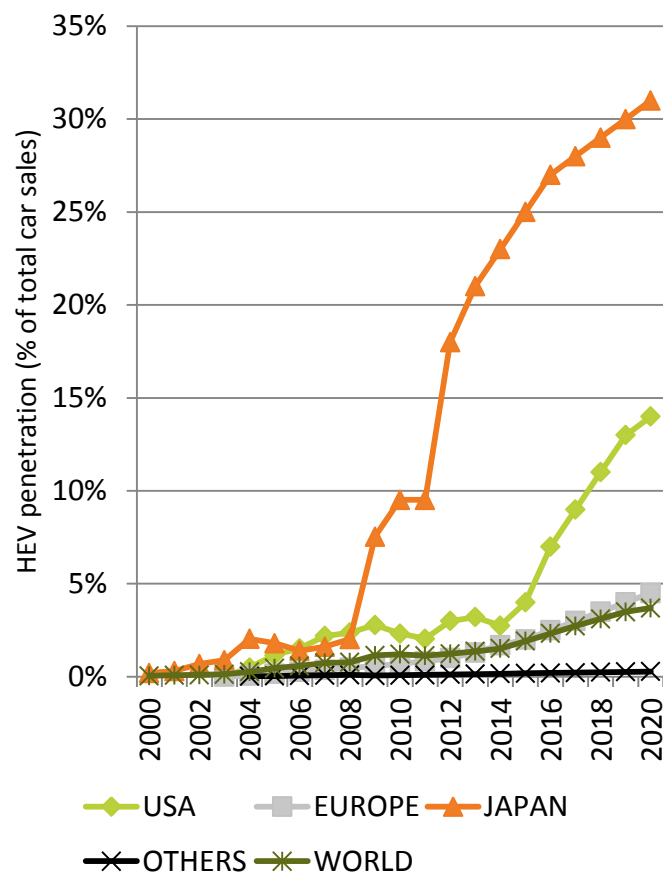
LI-ION BATTERY PACK COST  
FOR EV



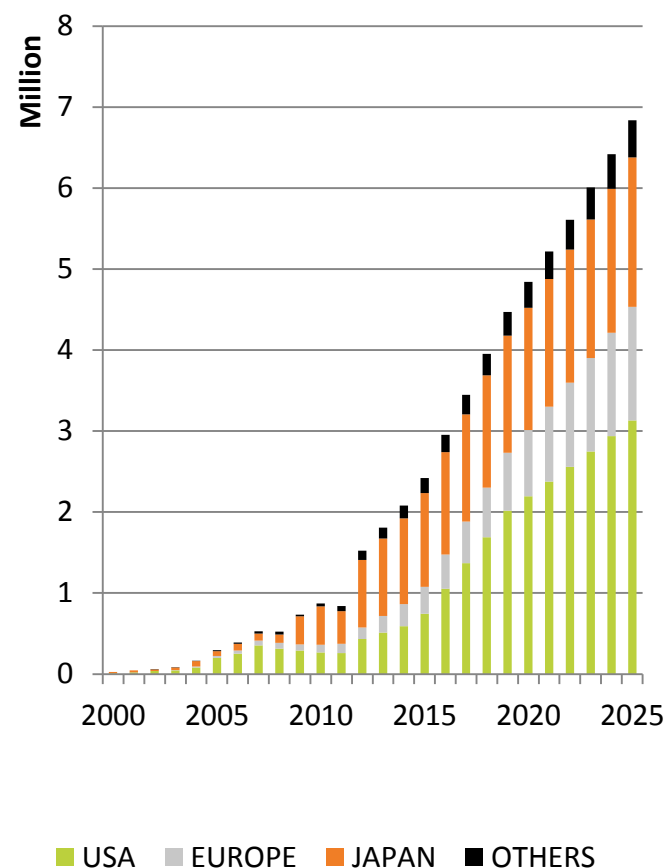
\* For Production > 100 000 packs/year

# 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



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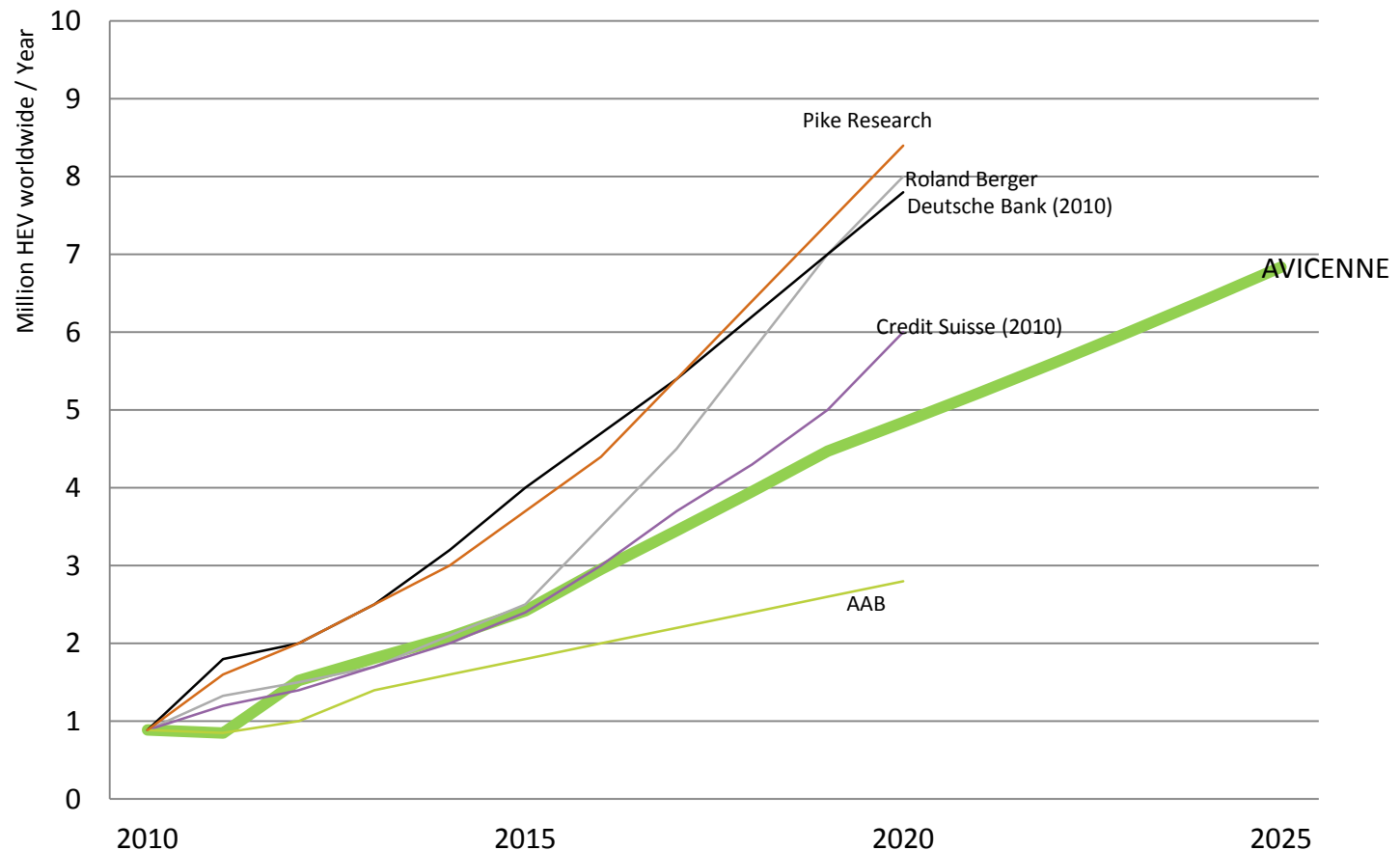
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# LONG TERM HEV FORECAST FROM 3 TO 8 M HEV IN 2020

## AVICENNE ENERGY FORECASTS ARE REALISTIC COMPARE TO OTHER ANALYSTS

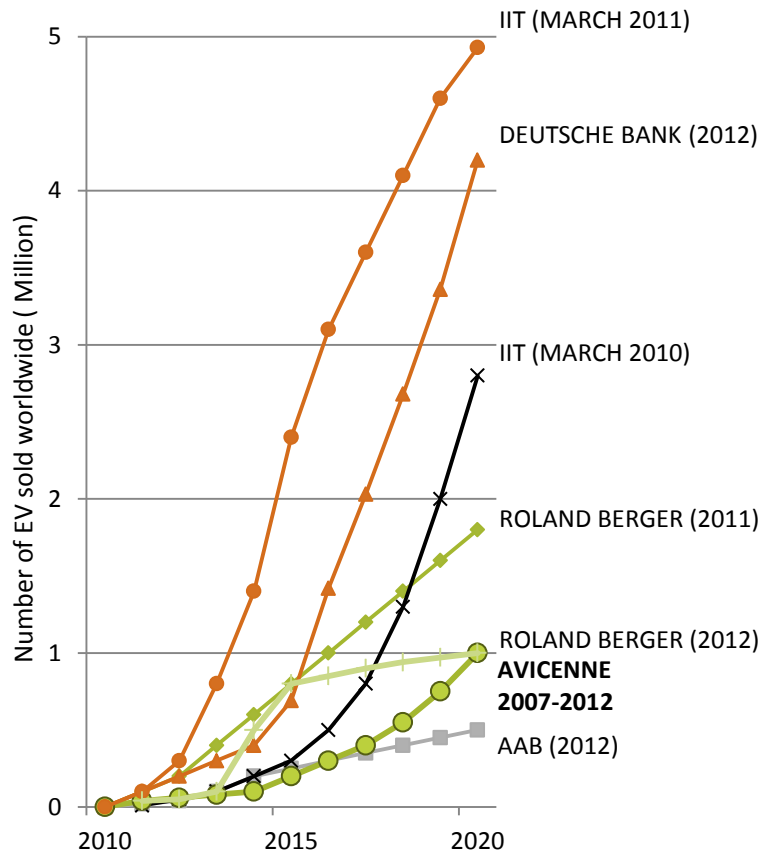


Source: AVICENNE ENERGY Compilation, February 2013

Micro hybrid not included

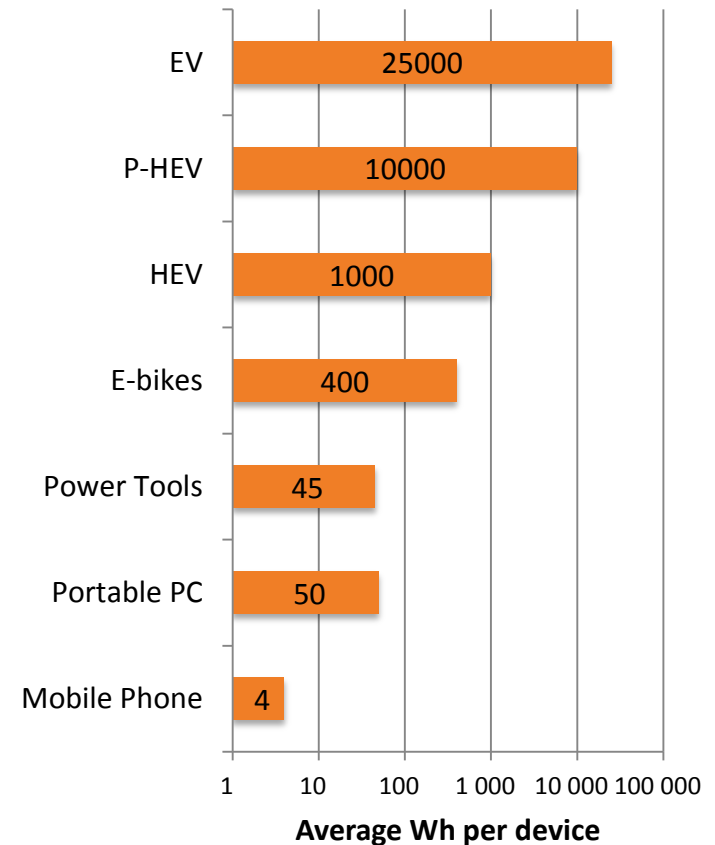
# X EV FORECASTS 2011-2020

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



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

EV impact on the LIB & raw  
material market is HUGE





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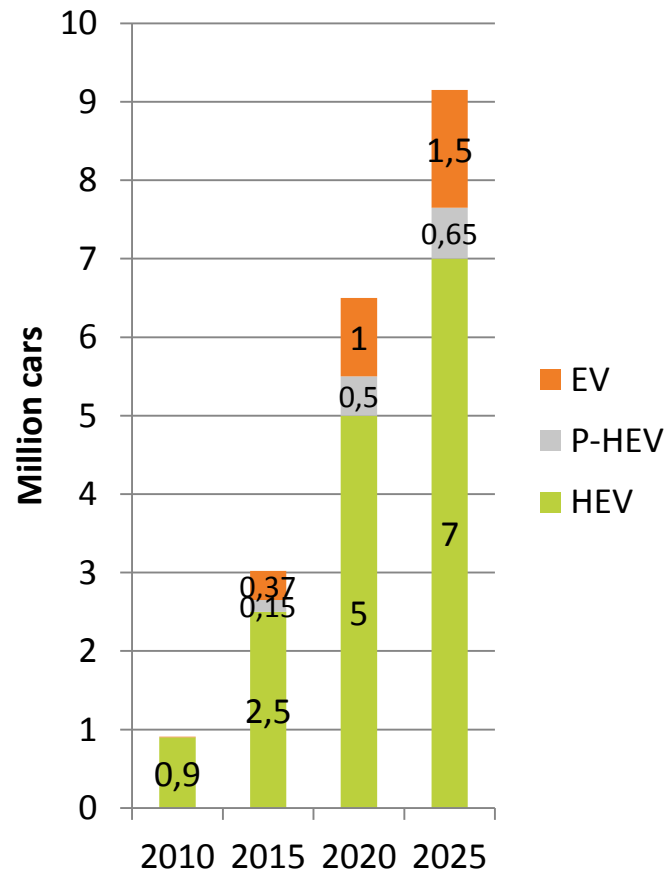
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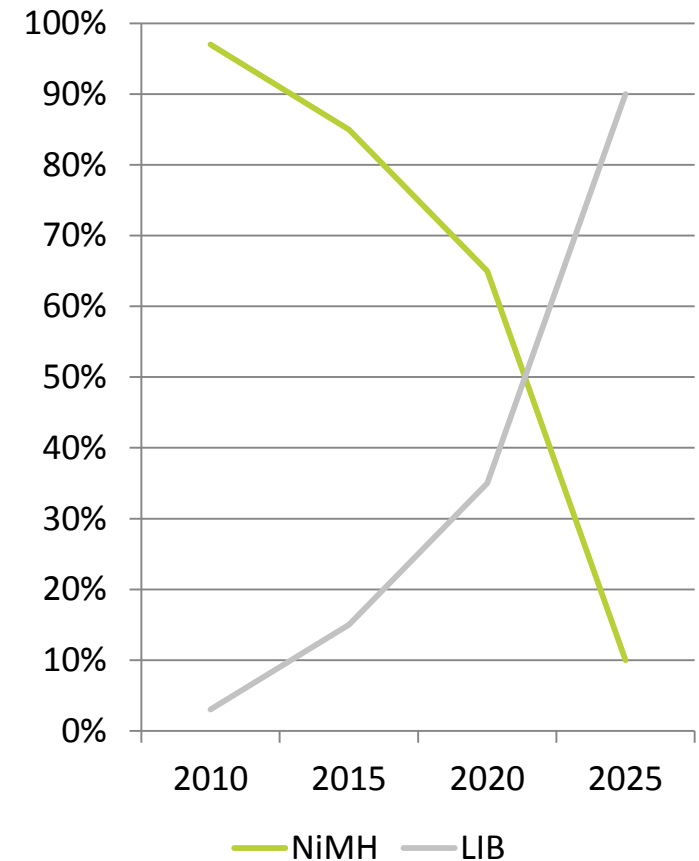
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# XEV 2025 FORECASTS

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



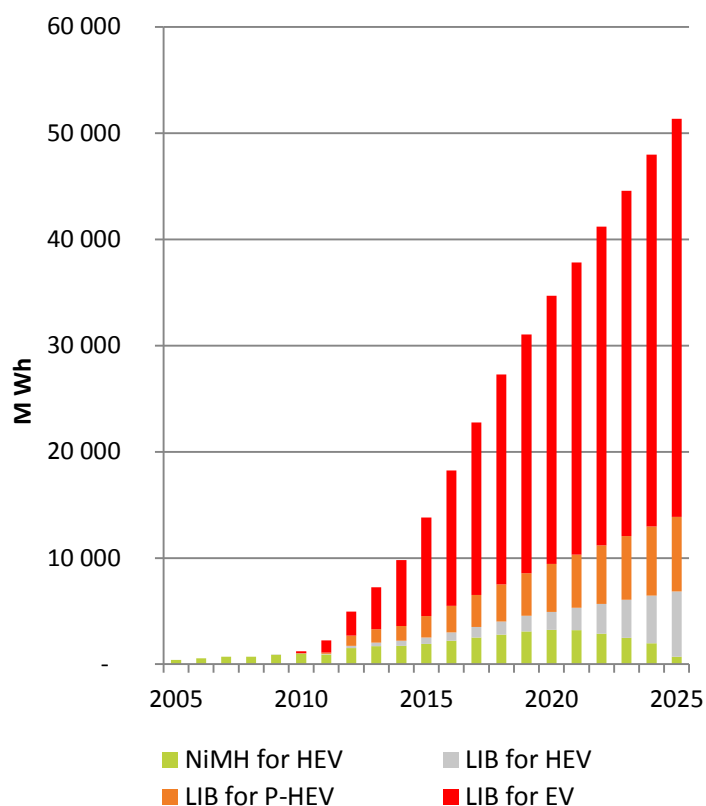
## LIB penetration in HEV 2010-2025



# TOTAL BATTERY DEMAND FOR AUTO FORECASTS

EV, HEV & P-HEV Battery  
needs (MWh)

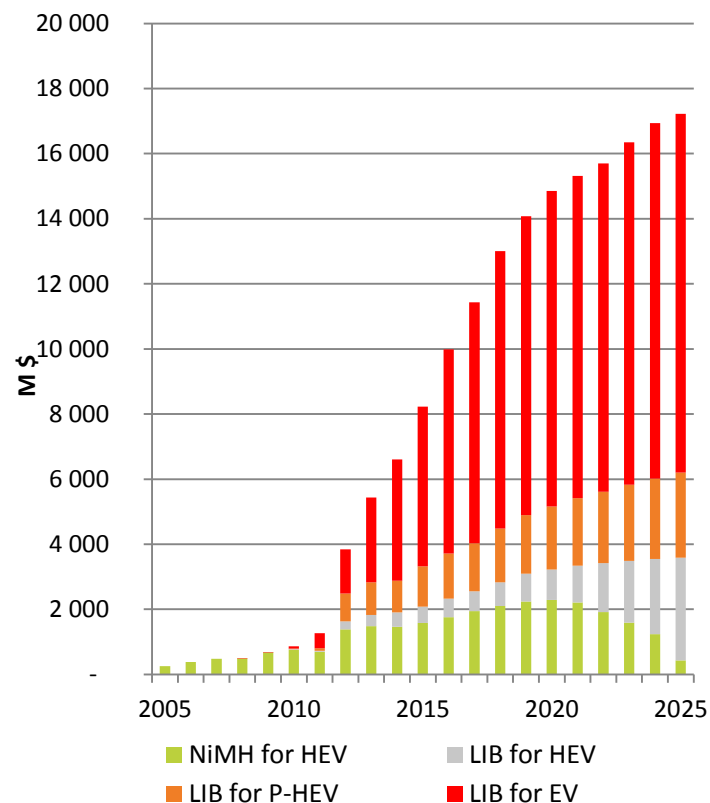
CAGR 2013-2020: +23%



Source: AVICENNE ENERGY Analyses 2013

Rechargeable battery market for  
Auto<sup>(1)</sup>, M\$ for x-EV 2000-2025

CAGR 2014-2020: +14%



(1) Pack level



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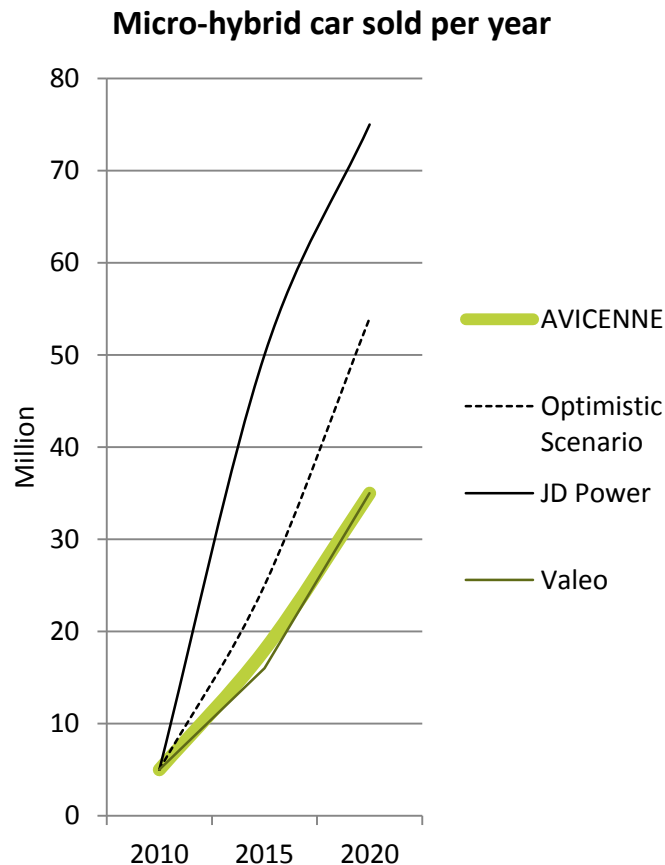
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# 35 MILLION MICRO-HYBRIDS CAR IN 2020

## 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

	Micro-hybrid	Full HEV
Battery	Advanced lead acid	NiMH or LIB
Cost (\$)	300	3000
Fuel saving	5%	20%
Million Vehicle sold per year in 2020	35	3.5





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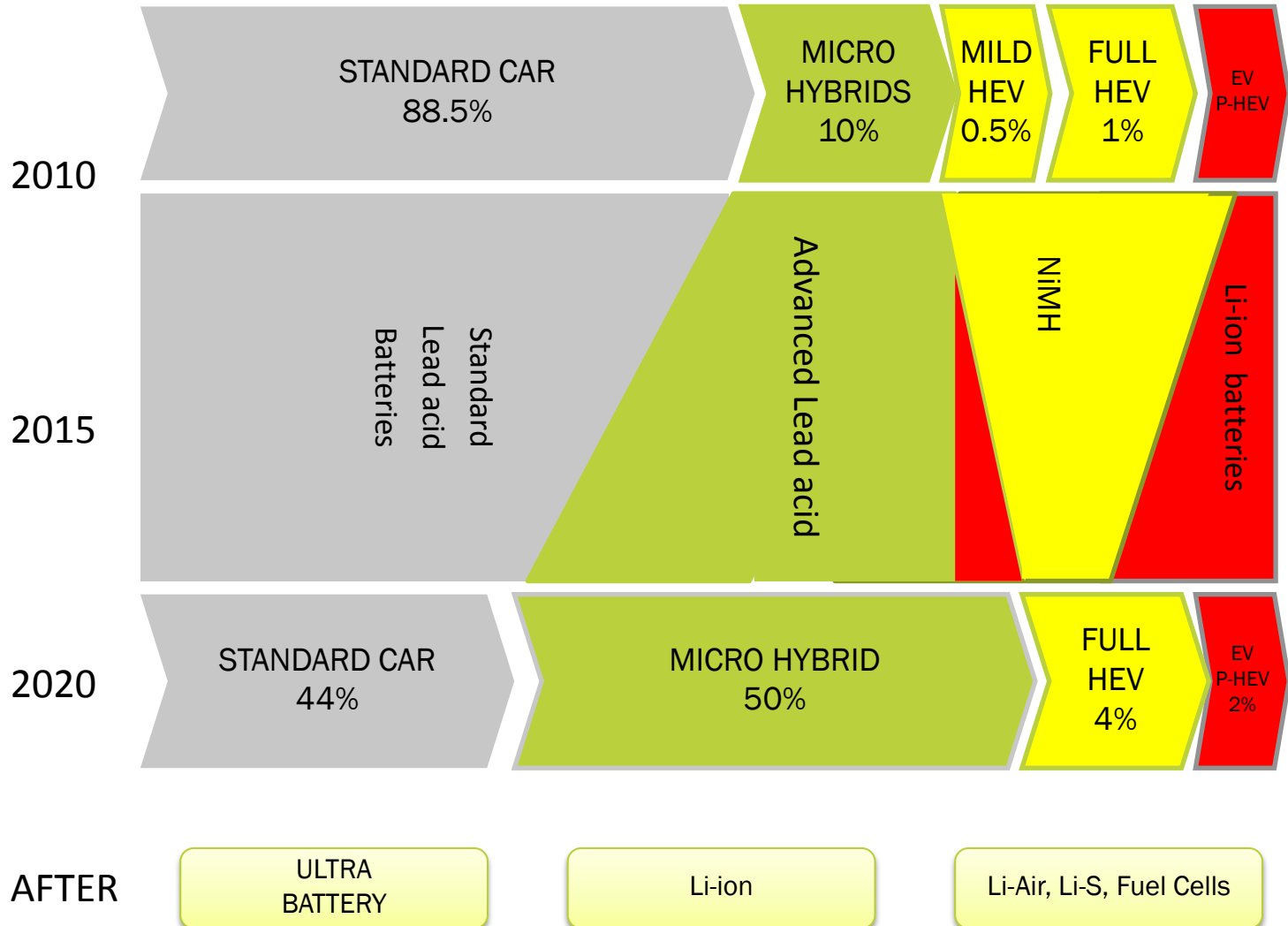
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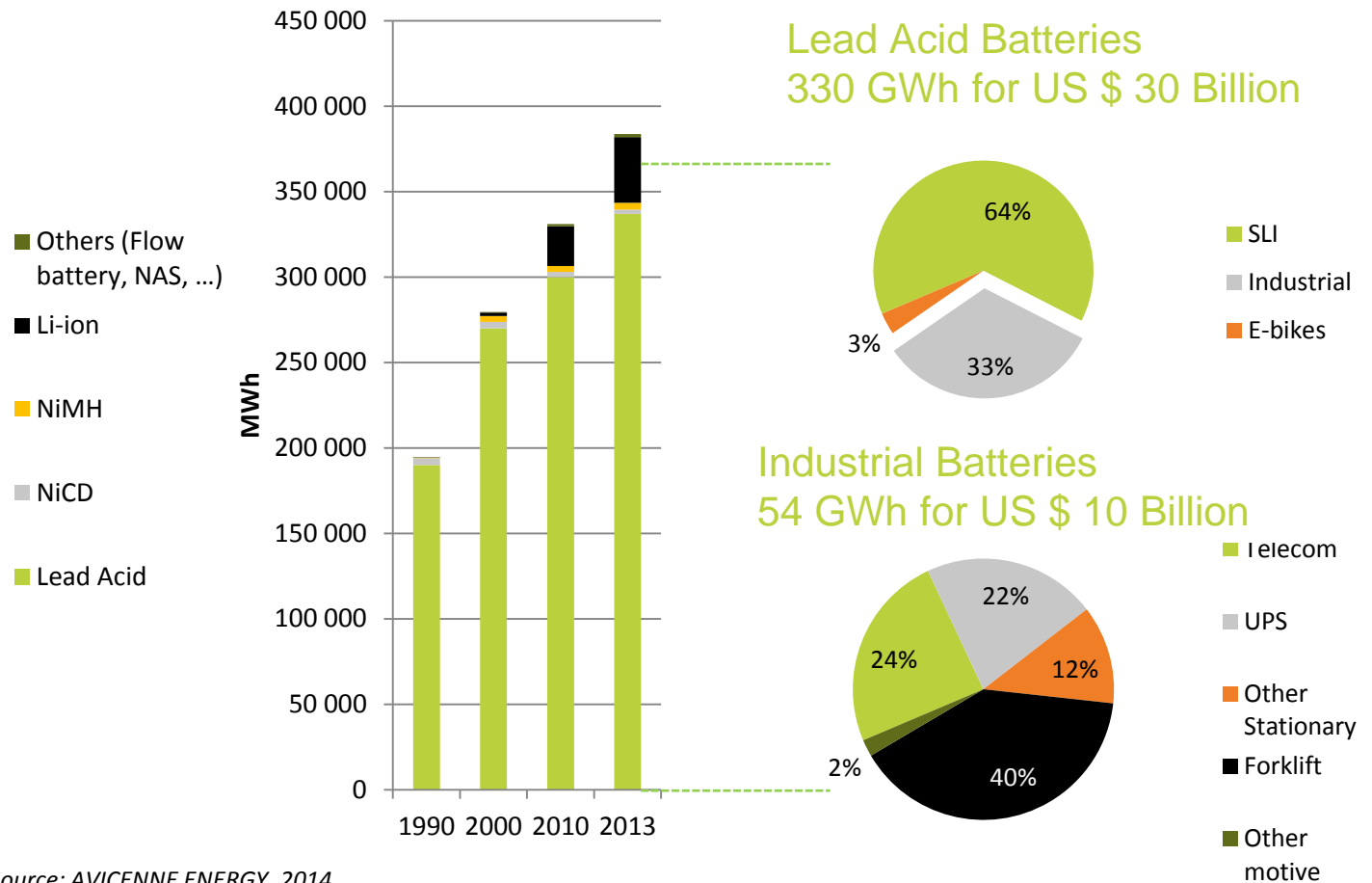
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# HEV, P-HEV AND EV REALITY OF THE MARKET WILL BOOST MICRO HYBRID AND ADVANCED LEAD ACID BATTERIES



# THE WORLDWIDE BATTERY MARKET 1990-2013

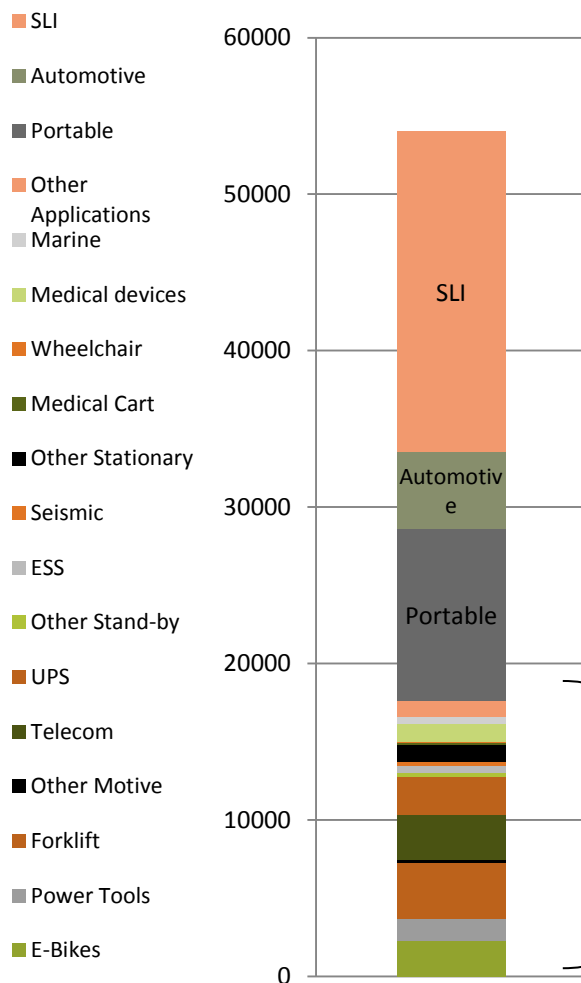
Lithium Ion Battery: Highest growth & major part of the investments  
Lead acid batteries: By far the most important market (90% market share)



Source: AVICENNE ENERGY, 2014

# BATTERY FOR OTHER APPLICATION US\$ 18 BILLION<sup>1</sup> MARKET

## Battery market in 2013 (M\$)

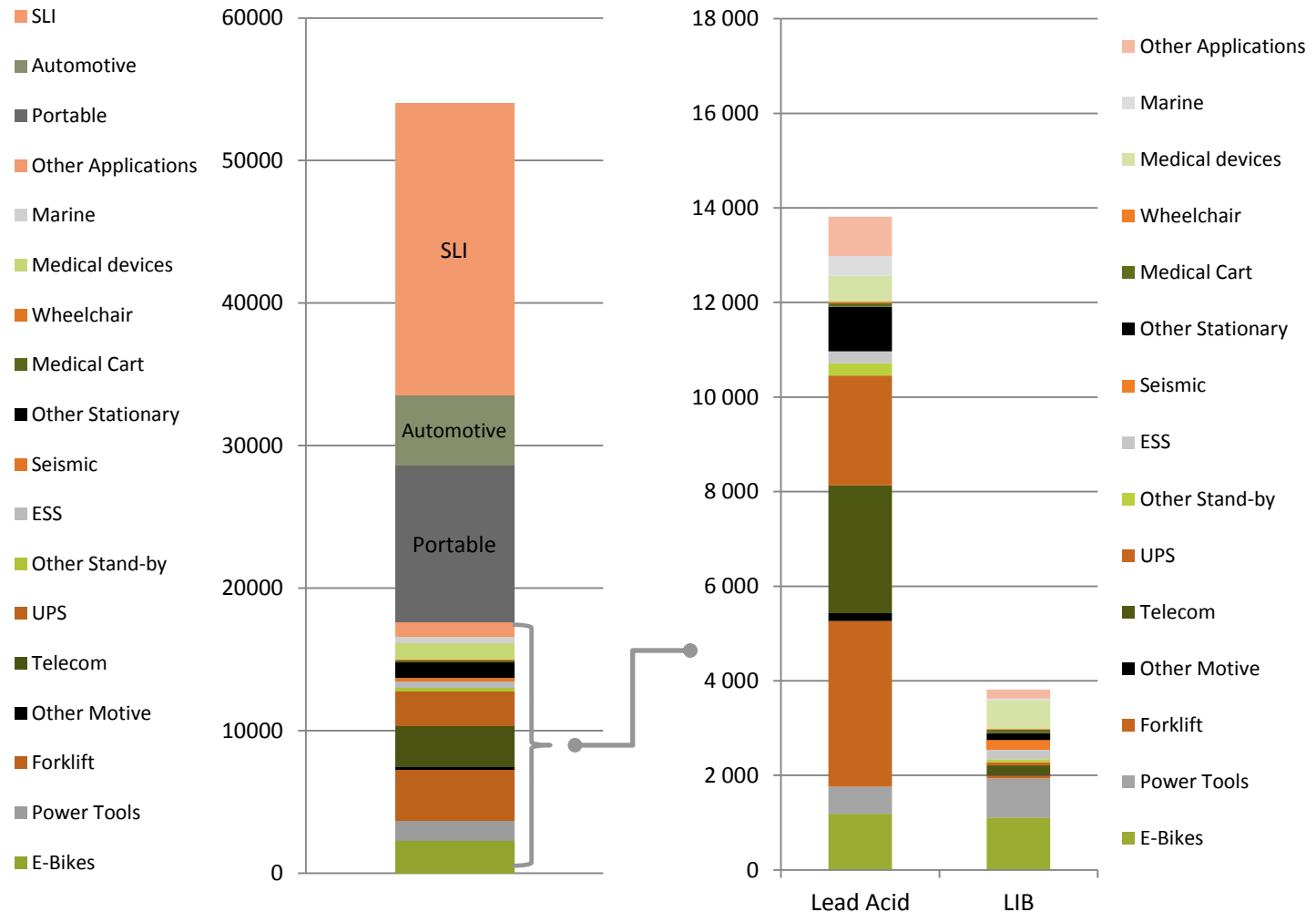


Battery Market			M\$
Power Tools			1400
E-bikes			2290
Industrial	Motive	Forklifts	3 570
		Others	180
		TOTAL MOTIVE	3 750
	Stationary	Telecom back-up	2 900
		UPS	2 400
		Misc. Standby	315
		ESS	450
		Seismic (1)	210
		Other Stationary	1090
		Total STATIONARY	7 370
		TOTAL INDUSTRIAL	
Medical Cart			150
Wheelchair			47
Medical Device (1)			1150
Marine			450
Others			1 000
TOTAL			17 600

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

# 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

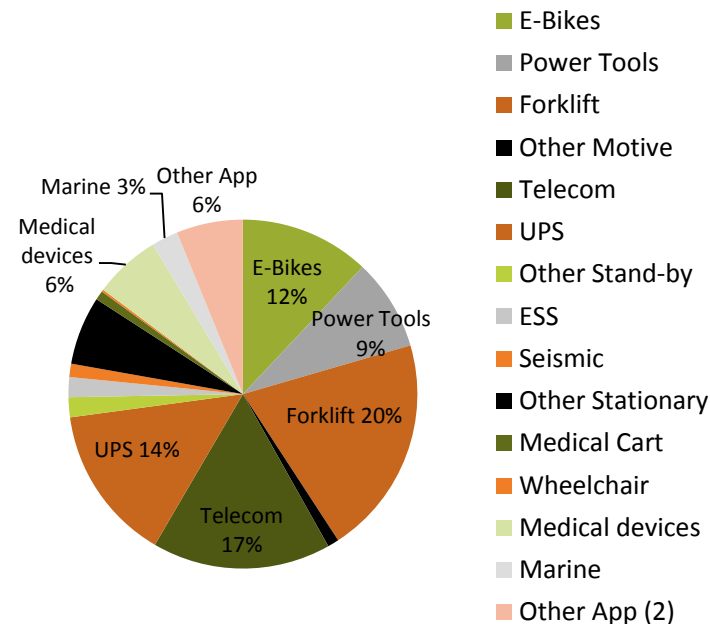
Source: AVICENNE ENERGY, 2014

# TOTAL POTENTIAL MARKET ANALYZED IN THE SURVEY (M\$, PACK LEVEL<sup>1</sup>)

## Application details

Battery Market			M\$
Power Tools			1400
E-bikes			2290
Industrial	Motive	Forklifts	3 570
		Others	180
		TOTAL MOTIVE	3 750
	Stationary	Telecom back-up	2 900
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TOTAL INDUSTRIAL		11 120	
Medical Cart			150
Wheelchair			47
Medical Device (1)			1150
Marine			450
Others			1 000
TOTAL			17 600

## 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,...



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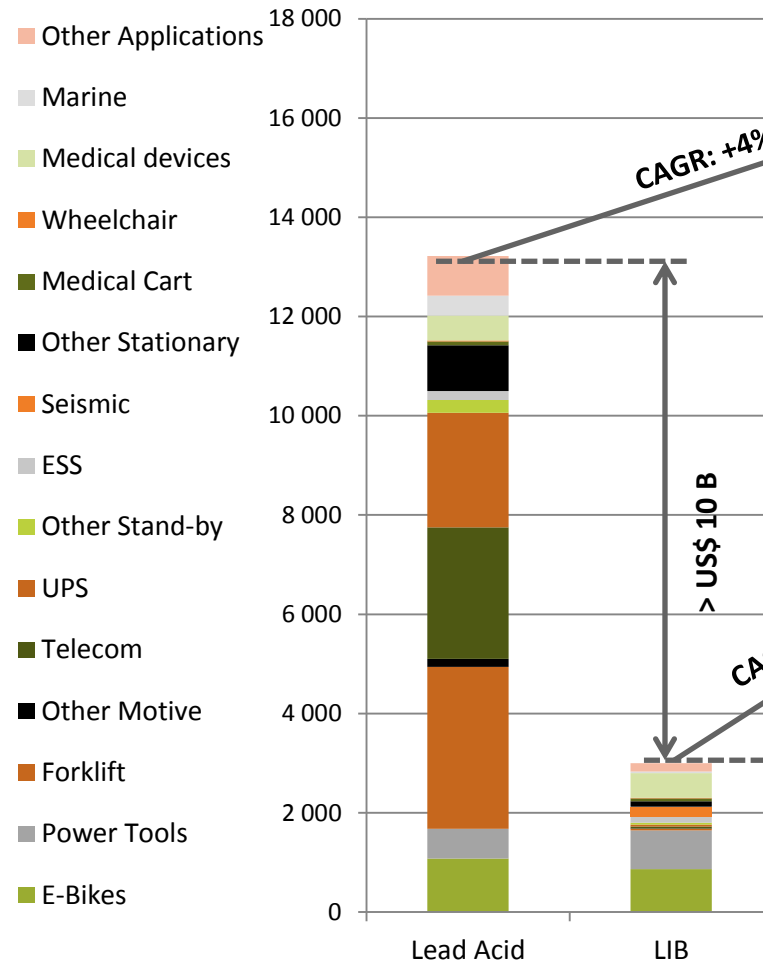
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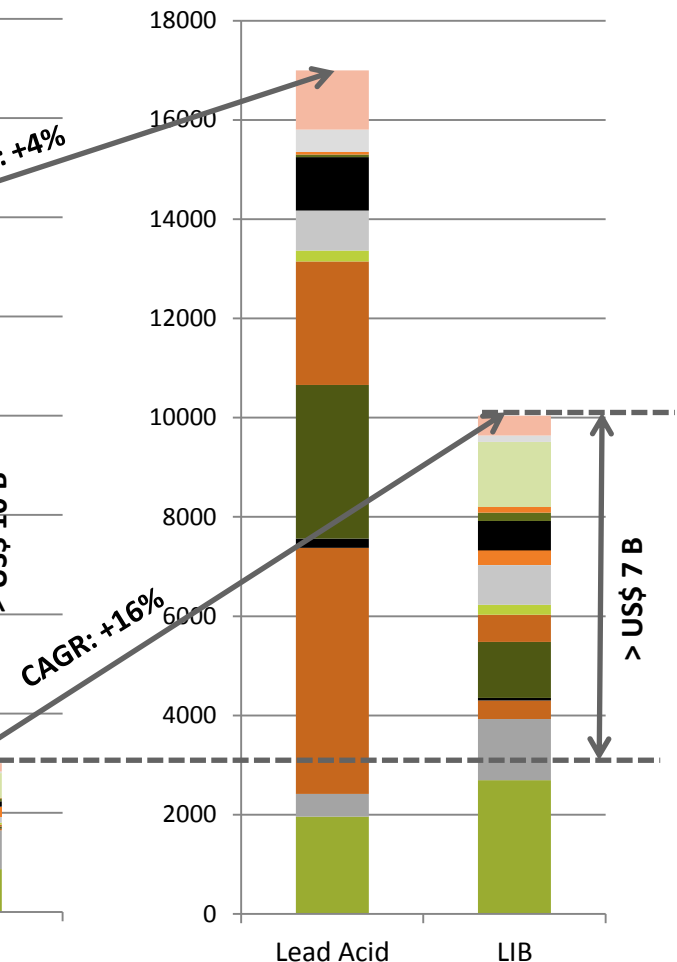
# "OTHER APPLICATIONS" 10 B\$ POTENTIAL MARKET<sup>1</sup>

Battery market in 2012 (M\$)



Source: AVICENNE ENERGY, 2013

Battery market in 2020 (M\$)

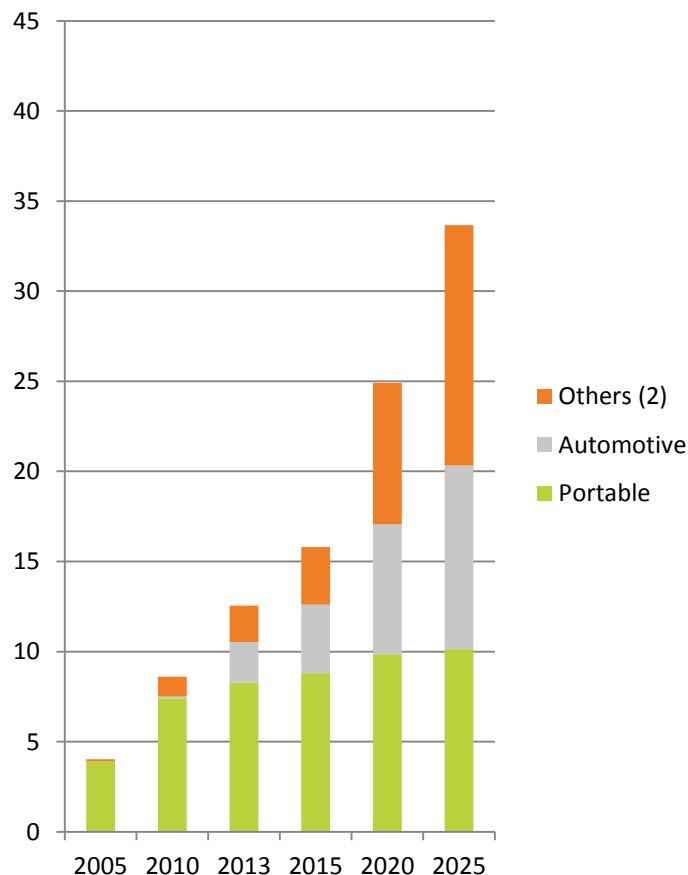


For Power tools, NiCd batteries are used rather than lead acid batteries  
1- Pack level

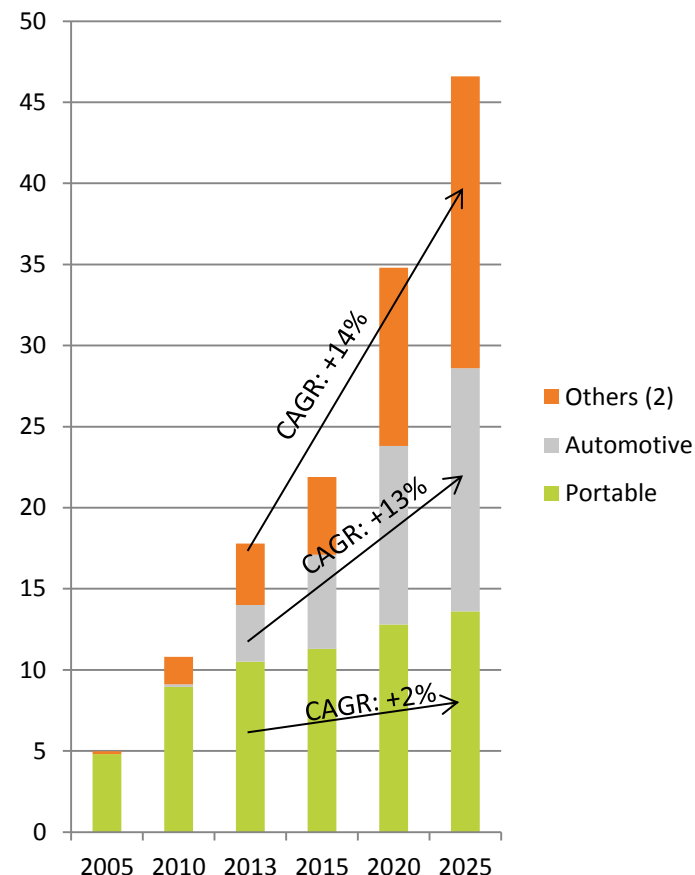
# LI-ION CELL & PACK MARKET DETAILS

2013 -2025 { Portable: 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<sup>1</sup> (B\$)



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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

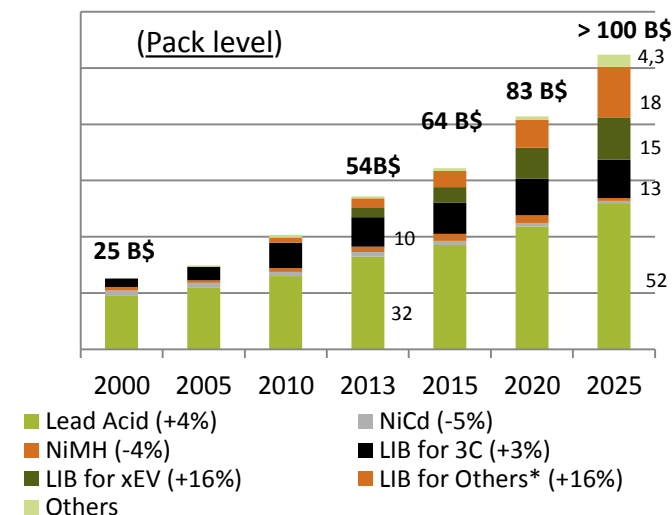
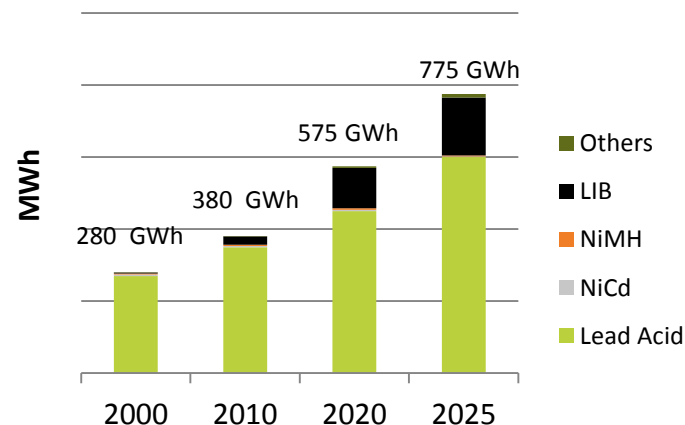
# TAKEAWAYS

## 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



(CAGR 2012-2025)

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



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# THANK YOU



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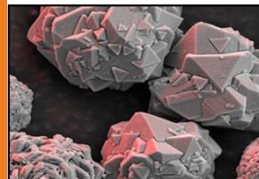
JANUARY 2015

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# AVICENNE PROFILE

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

Creation: 1992, by Ali MADANI

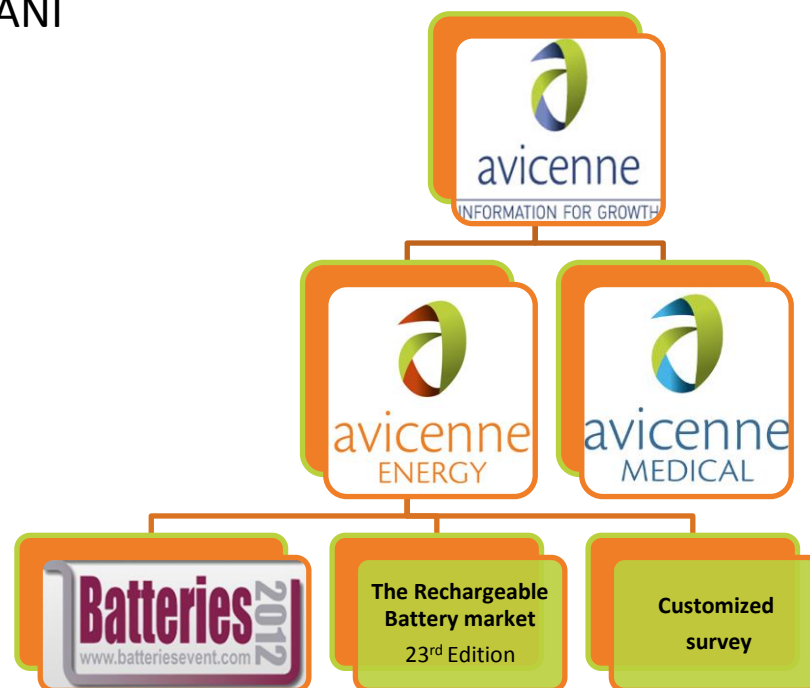
Headquarter: Paris

Liaison Office: Japan, USA

AVICENNE Energy Director:  
Christophe Pillot

5 consultants

- A Madani
- C Pillot
- JP Salvat
- X Zhang
- A Yassari





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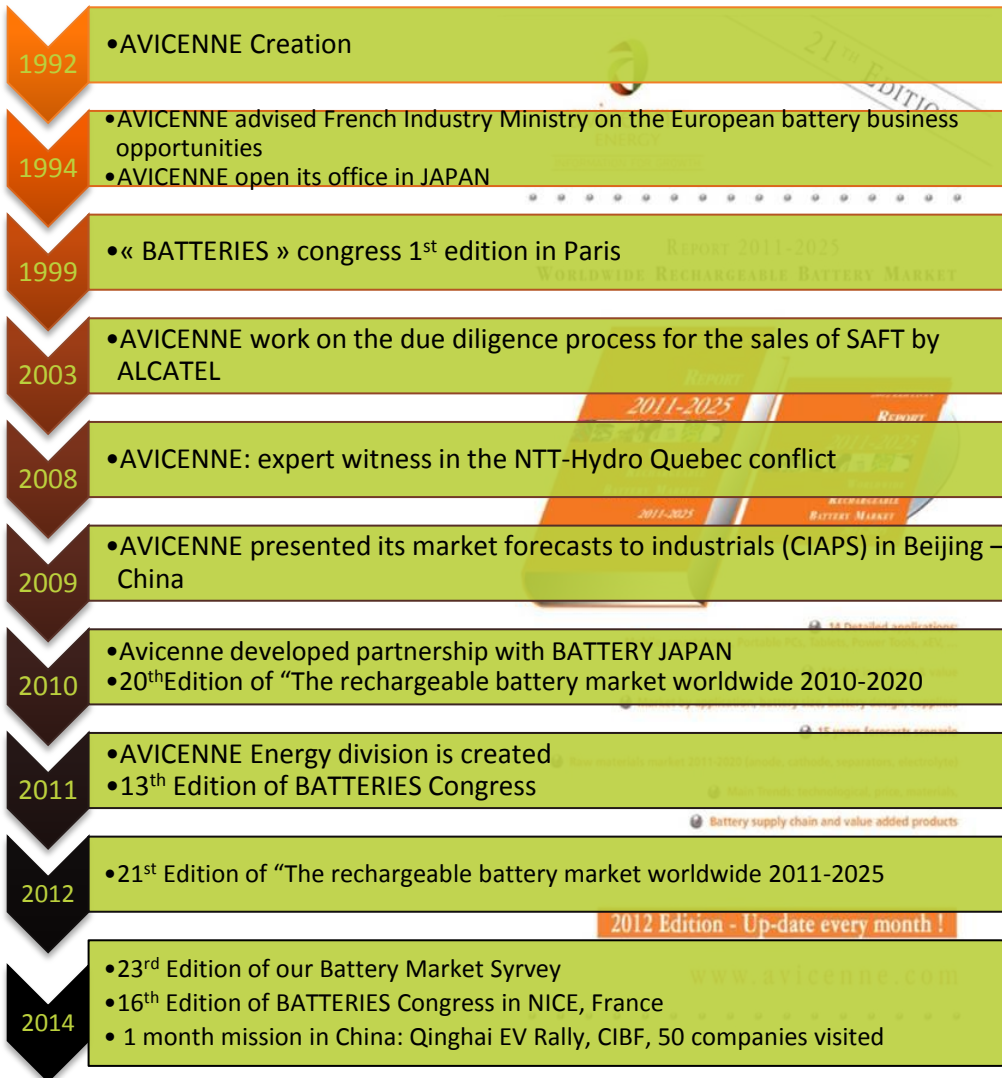
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# OUR BUSINESS STORY





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# OUR METHODOLOGY

Track valuable  
Information's



Strategic  
Analysis



Presentation of  
the results



Q&A with  
customers



Customer  
Evaluation

SUPPLY  
SIDE  
  
DEMAND  
SIDE

## INFORMATION COLLECTION

### Primary Research

- Executive Interviews
- Vendor Briefings
- Product Demos and Tours

### Secondary Research

- Company News & Financials
- Technology & Product Specs
- Government Data
- Economic, Demographic Data

- Consumer Surveys
- Business Leader Surveys

- Case Studies
- Reference Customers

## MARKET & STRATEGIC ANALYSIS

### Qualitative

- Business Models & Trends
- Technology Issues
- Policy & Regulatory Factors
- Competitive Landscape
- Profiles of Key Players

### Quantitative

- Company News & Financials
- Technology & Product Specs
- Government Data
- Economic, Demographic Data

### Strategic

- SWOT Analysis
- Gap Analysis
- Business Plan
- Value Proposition
- Due Diligence
- Merger & Acquisition



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# METHODOLOGY: EXTENSIVE FIELD RESEARCH TO RETRIEVE & CROSS CHECK INFORMATION

Top management  
contact network  
> 19 000 contacts

Conferences &  
Exhibitions



2nd Int'l Rechargeable Battery Expo  
**BATTERY JAPAN**



In Depth analysis  
Of applications



Cross Check  
Analysis





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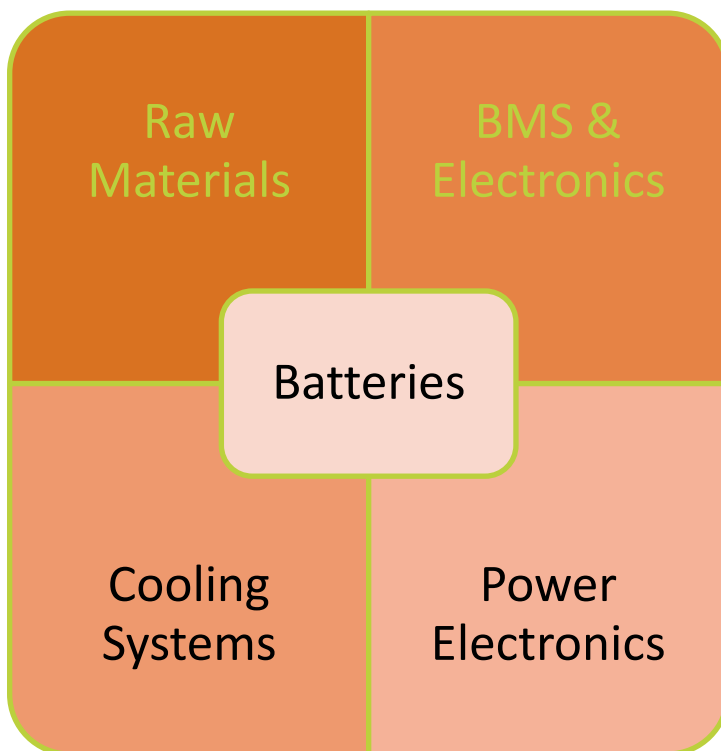
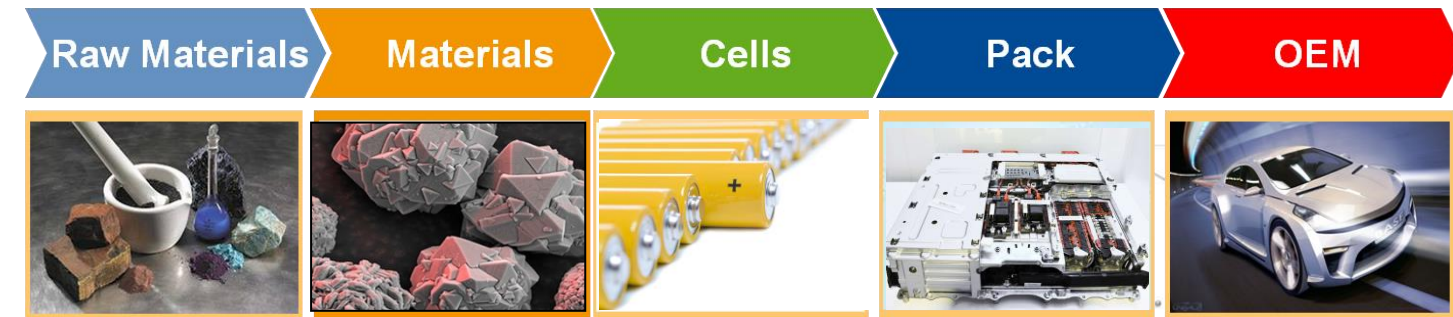
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# CUSTOMIZED & MULTICLIENT SURVEY FOR ALL THE VALUE CHAIN



REPORT 2011-2025 *Source : Photo from BASF*  
WORLDWIDE RECHARGEABLE BATTERY MARKET



- 14 Detailed applications: Mobile, smartphone, Portable PCs, Tablets, Power Tools, xEV, ...
- Market in volume & value
- Market by application, battery size, battery design, suppliers
- 15 years forecasts scenario
- Raw materials market 2011-2020 (anode, cathode, separators, electrolyte)
- Main Trends: technological, price, materials,
- Battery supply chain and value added products

2012 Edition - Up-date every month !

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# MORE THAN 200 REFERENCES WORLDWIDE

3M	DIALOG SEMICONDUCTOR	JOHNSON MATTHEY	SAKTI
A123	DOW CHEMICAL	KODAK	SAMSUNG SDI
AIR LIQUIDE	DOW CORNING	KRUGER	SANIK
AIR PRODUCT	DUPONT	LAZARD	SCHRODER VENTURE
AHLSTROM	DURACELL	LECLANCHÉ	SCOTENT ENTREPRISE
ALCATEL	EDF	LEGRAND	SEPCELL
AMPEREX (ATL)	ELECTRO ENERGY	LG CHEMICAL	SFPZ
APPLIED MATERIALS	ENER 1	LION CELLS	SHENZHEN HIGH POWER TECHNOLOGY
ARKEMA	ENERGIZER	LITTLE FUSE	SCHOTT AG
AROS SECURITIES	EOLITE	LILIPUCIAN	SKC
ARC	EPCOS OHG	LYNAS CORP	SQM
ASHLAND	ERAMET	MATSUSHITA	SVE - DASSAULT
ATL AMPEREX	ETC AB	MICROSOFT	SOLVAY
AT KEARNEY	FACOM	MTI MICRO FUEL CELLS	SONY
AUSTRIAN INSTITUTE OF TECHNOLOGY	FALCON BRIDGE	MOLTECH	STIBAT
AXEON	FAIRSHILD SEMICONDUCTOR	MOLYCORP	STORCK
BAIN	FAMEART	MOMENTIVE	STRATEGY ANALYSIS
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BAYER	FMC	MUNSTER UNIVERSITY	TODA KOGYO
BLACK & DECKER	FORTU POWER CELL	NANOCYL	TOTAL
BHP BILLITON	FRANCE TELECOM	NCCP – RUSSIA	TOTAL WIRELESS SOLUTION
BRAND LICENCING PARTNERS (BLP)	FREUDENBERG VLIESTOFFE SE & CO	NEC	TOYO
BOURNS	FRAUNHOFER INSTITUTE	NITECH	TOYOTA
BOSCH	FULTON INNOVATION	NKKPC	TREOFAN
BOOZ	GAIA	NORILSK NICKEL	TYCO
BRUCKNER	GIL IMPORT BATTERIES LTD.	NOVALED	UMICORE
BUHLER GMBH	GS MELCOTEC	NTK POWERDEX	UNIROSS
BYD	HC STARCK	OLIVER WYMAN	URALELEMENT
CABOT	HILTI	OMG INC	US NAVY
CALL2RECYCLE	HITACHI MAXELL	ORANGE	VARTA
CAP X	HOLLINGSWORTH & VOSE CIE	OSKR	VOLTRACK
CATELLA	HONEYWELL	PANASONIC	WACKER CHEMIE AG
CARBONE LORRAINE	HPL (HIGH POWER LITHIUM)	PHILIPS	WARBURGPINCUS
CARLYLE	HUTCHINSON	PHOTON	WILDCAT
CATELLA	ICC NEXERGY	PK & WISE	WORLD INDUSTRIAL INFORMATION CENTER
CATERPILLAR INC.	IER	PLEXTRONICS	
CDN COBALT	IGL EXPORT.	POWER GENIX	WR GRACE & CIE
CEA/LITEN	INTERNATIONAL COMPONENT CORP.	PRAYON	YASLAMEN
CELGARD	INTERNATIONAL RECTIFIER	PRISMARK	ZEBRA
CHEMETALL	INTEK	PSA	ZPOWER
CHEMISHE FABRIK BUDENHEIM	INTEL	RAYOVAC	
CIBA	INTERSIL	RECHARGE	
CIAPS CHINA	INCO	RENAULT	
COGEMA	ISRAEL CONSULTING	RHODIA	
CONOCO PHILIPS	ITRI	ROLAND BERGER	
CRU GROUP	ITS	ROSKILL INFORMATION SERVICES	
CSC CHALLENGE STRATEGY CHANGE	JBC	SAFT	
DELTA	JETRO	SAGENTIA	
DGA	JOHNSON CONTROLS	SAINT GOBAIN	

The Rechargeable  
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Main Trends  
2014-2025

32<sup>nd</sup> INTERNATIONAL  
BATTERY SEMINAR  
& EXHIBIT

March 9, 2015

#### CONTACT

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# 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"*
- ✎ BATTERIES 2014, FRANCE – (1999-2014)  
Owner, chairman & speaker  
*"The battery market 2013-2025"*
- ✎ INTERNATIONAL Li-ion BATTERY SUMMIT – Dec 2013, Shenzhen, China  
*"The Li-ion battery raw materials market 2012-2020"*
- ✎ AABC Europe, Mainz (2012, 2013, 2015)  
*"The Lithium ion raw material battery market 2010-2020"*
- ✎ 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"*
- ✎ Advanced Battery for Vehicles, IQPC, Frankfurt, 2009, 2010, 2012  
Chairman & speaker,  
*"The battery business 2009-2020"*
- ✎ EET-2008 European Ele-Drive, MOTOR SHOW GENEVA,  
International Advanced Mobility Forum – Geneva Motor Show  
(Professor Gaston Maggetto Award: C. Pillot as the best rated paper & presentation by EET-2008 Scientific Reviewing Committee)  
*"The HEV & EV market trends & main challenges"*
- ✎ China Industry Battery Fair 2006, 2010, 2014  
*"The Chinese battery Industry"*
- ✎ ...





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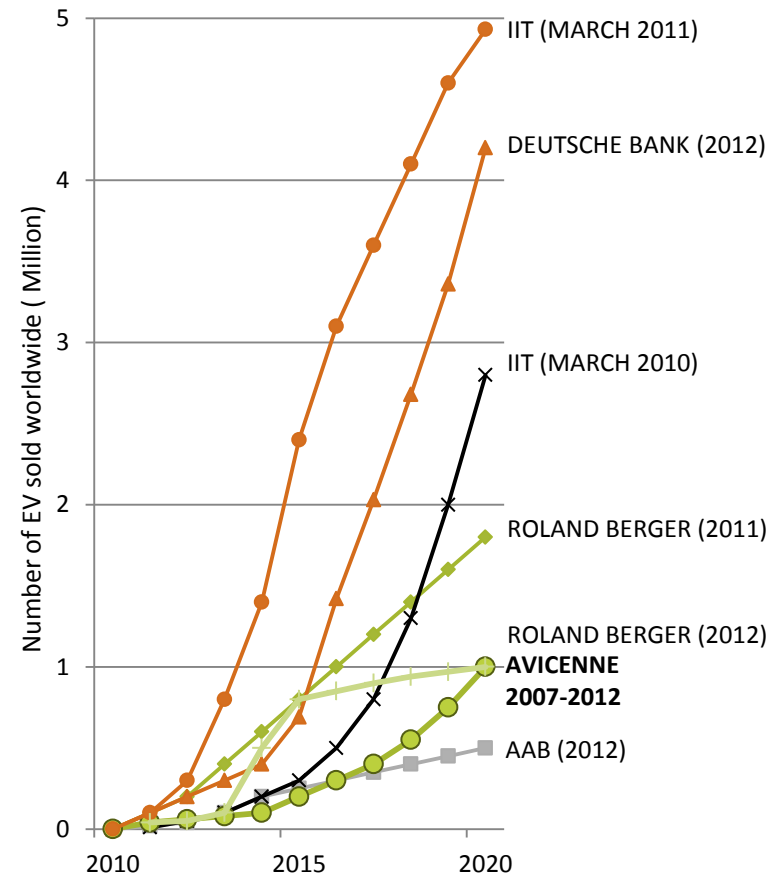
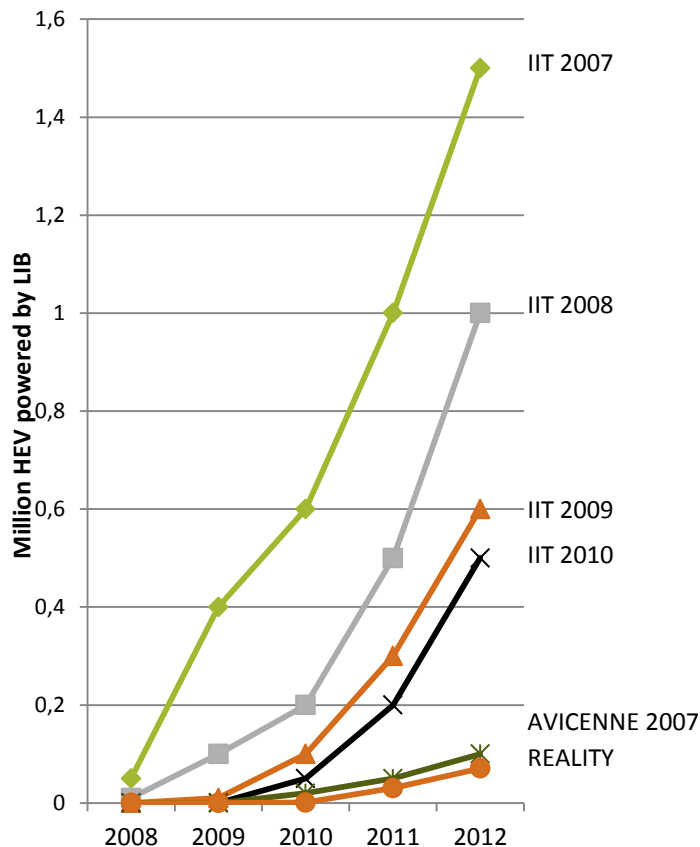
March 9, 2015

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# AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

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



Source : International Battery Conference, Fort Lauderdale  
2007, 2008, 2009, 2010 & 2011

HEV powered by Lithium ion battery  
forecasts from 2008 to 2012

# BATTERIES 2015

[www.batteriesevent.com](http://www.batteriesevent.com)



- 🌀 3 days congress in France (Paris, Nice, Cannes)
- 🌀 17<sup>th</sup> Edition (first edition in 1999)
- 🌀 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

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