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BATTERIES 2013

October 14 -16, 2013

Nice, FRANCE

CONTACT

Christophe PILLOT
c.pillot@avicenne.com
+33(0)1 4778 4600

The worldwide battery market 2012-2025

Christophe PILLOT

Director, AVICENNE ENERGY

Presentation Outline

- The rechargeable battery market in 2012/2013
- The Li-ion battery value chain
- Li-ion battery material market
- Forecasts & conclusions



The International Energy & Power Supply Conference and Exhibition



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maîtriser le risque |
pour un développement durable |



THE CARBON NANOTUBE SPECIALIST



SERMA TECHNOLOGIES

Shmuel De-Leon
Energy Ltd



asking more from chem



umicore
Rechargeable
Battery Materials



CONTACT

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



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

BATTERIES 2013: 80 SPEAKERS

14 th October		15 th October		16 th October	
Keynotes AVICENNE ENERGY REAL LI TORU AMAZUTSUMI GTAI US DOE ATL BASF TIAX		R&D KC MOLLER - FRAUNHOFER ICT I. BELHAROUAK - ARGONNE SHMUEL DE-LEON BRUNO SCROSATI – Elettrochimica ed Energia C. MASQUELIER - LRCS D. AURBACH – BAR ILAN UNIV R. YAZAMI – NANYANG UNIV		PORTABLE CONTOUR TEXAS INSTRUMENTS INTEL ST ERICSSON	AUTO NATUREO PSA RENAULT SGC
		R&D BIO-LOGIC CEA – LITEN INP ZBT	Safety ATL CELGARD EUROBAT ETTEPLAN	AUTO FORD BOSCH US DOE ICC NEXERGY	
Materials UMICORE TODA KOGYO QING DAO TINCI SILATRONIX DREAMWEAVER JSR MICRO ZEON FMC	ESS ROLAND BERGER EDF 24M SAFT IECR EASY LI GTAI ENBW VERTRIEB	Micro Hyb R. BRODD POWERGENIX ALTAIRNANO A123	Safety LITHIUM BALANCE CADEX INTERTEK BATTERY MAN FRAUNHOFER ISE	MFG. BUHLER PEC SOVEMA MEGTEC KROENERT NETZSCH ENTEGRIS	R&D AKASOL IFP CNRS ZSW
		Micro Hyb MAGNA ALABC MAXWELL	Safety SERMA INERIS RECHARGE		





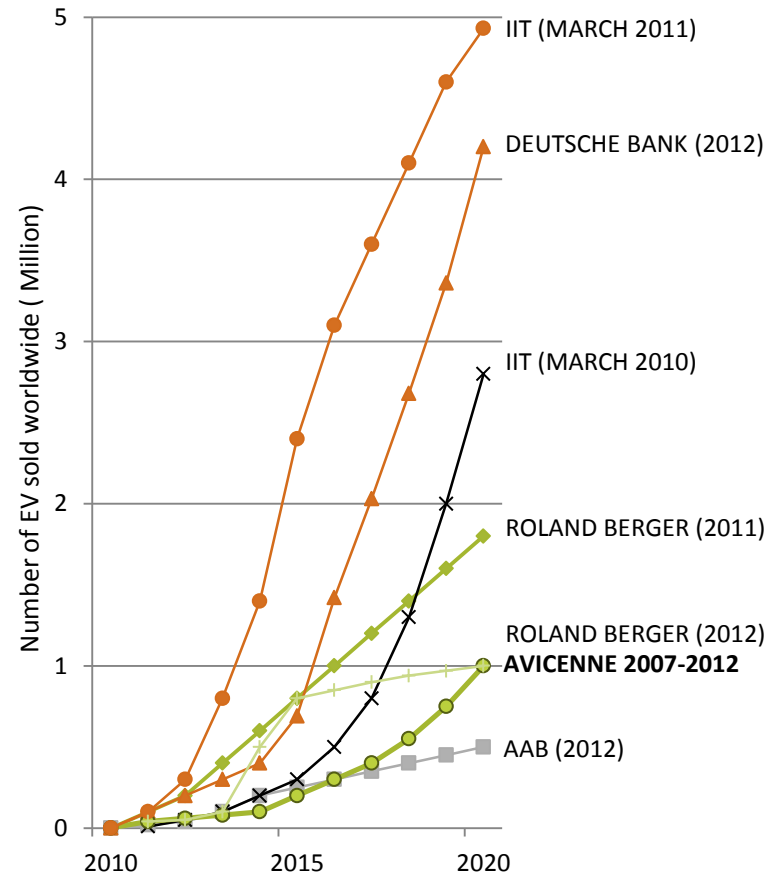
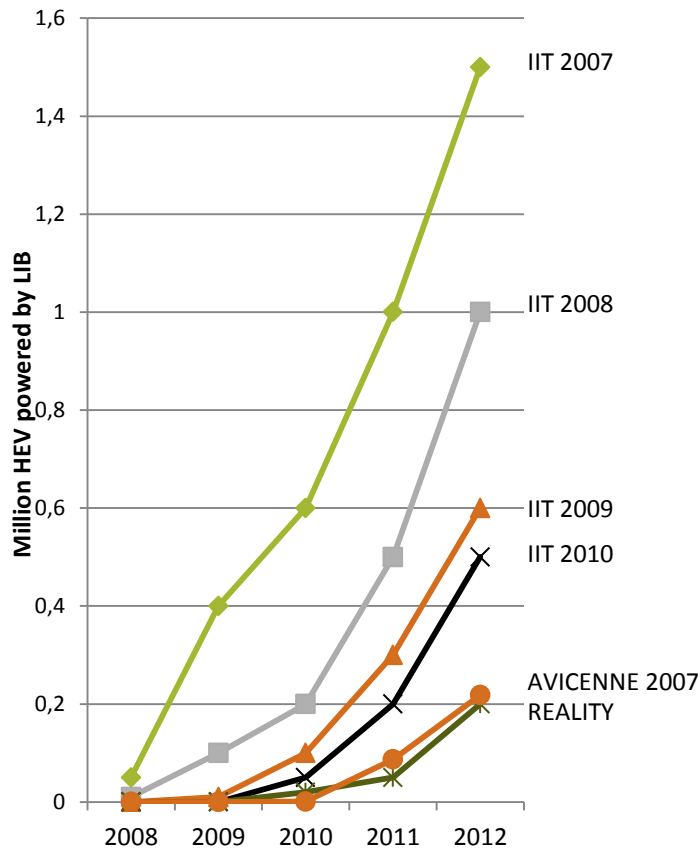
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AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

HEV powered by Lithium ion battery forecasts from 2008 to 2012

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



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

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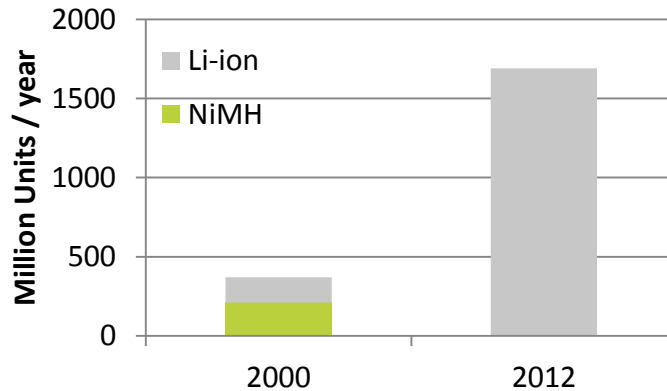


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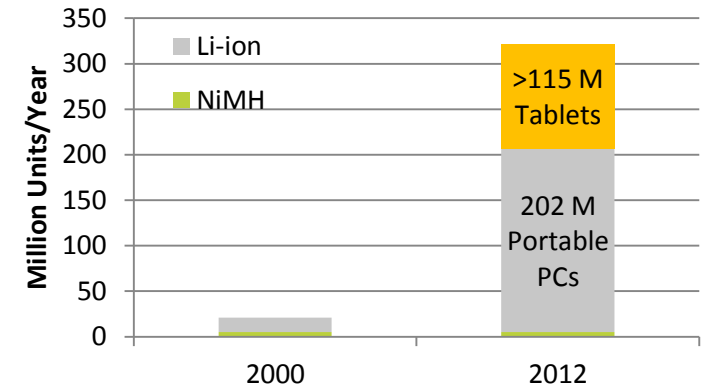
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+ 33 1 47 78 46 00
c.pillot@avicenne.com

THE BATTERY MARKET IS REALLY DYNAMIC

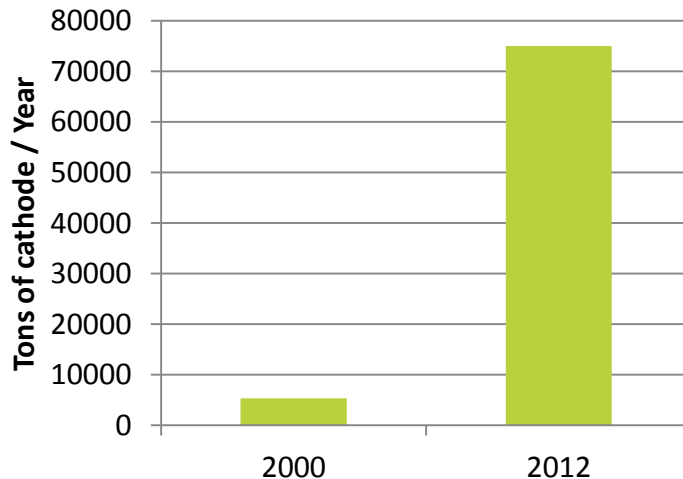
Cellular Phones sold per Year (Million)



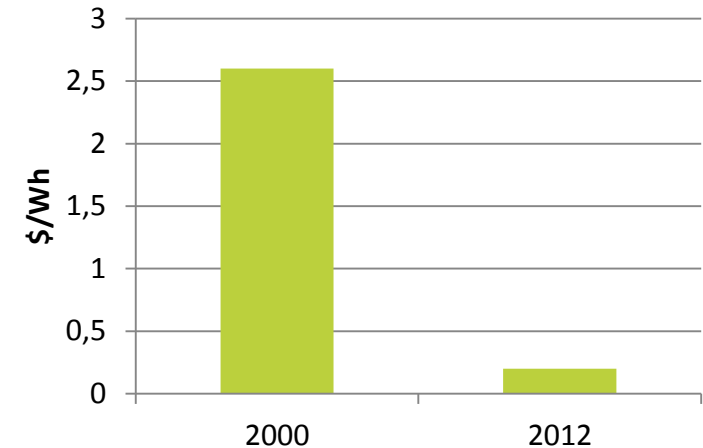
Portable PC sold per Year (Million)



Tons of Li-ion Cathode per year



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



Source: AVICENNE ENERGY Analyses 2013

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c.pillot@avicenne.com



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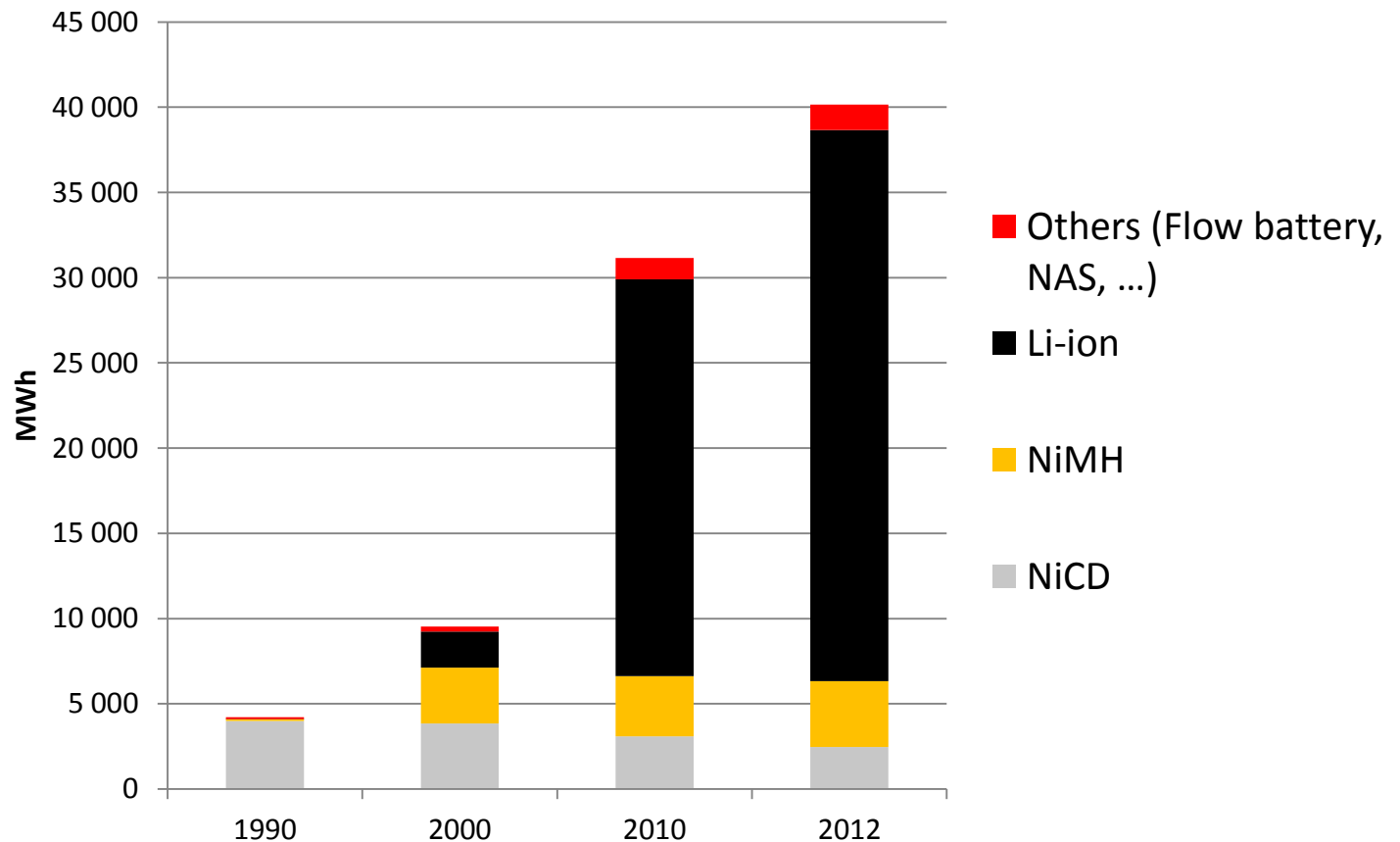


CONTACT

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

THE WORLDWIDE BATTERY MARKET 1990-2012

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



Source: AVICENNE ENERGY, 2013



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THE WORLDWIDE BATTERY MARKET 1990-2012

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

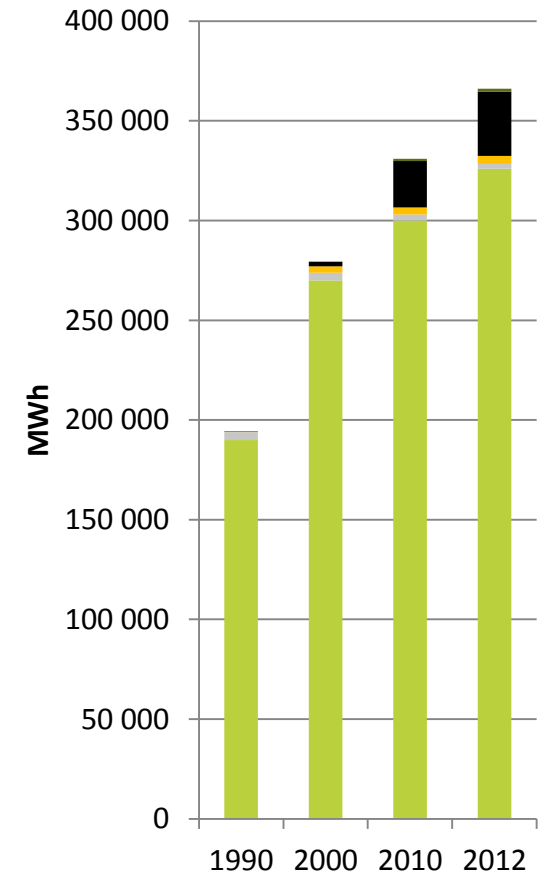
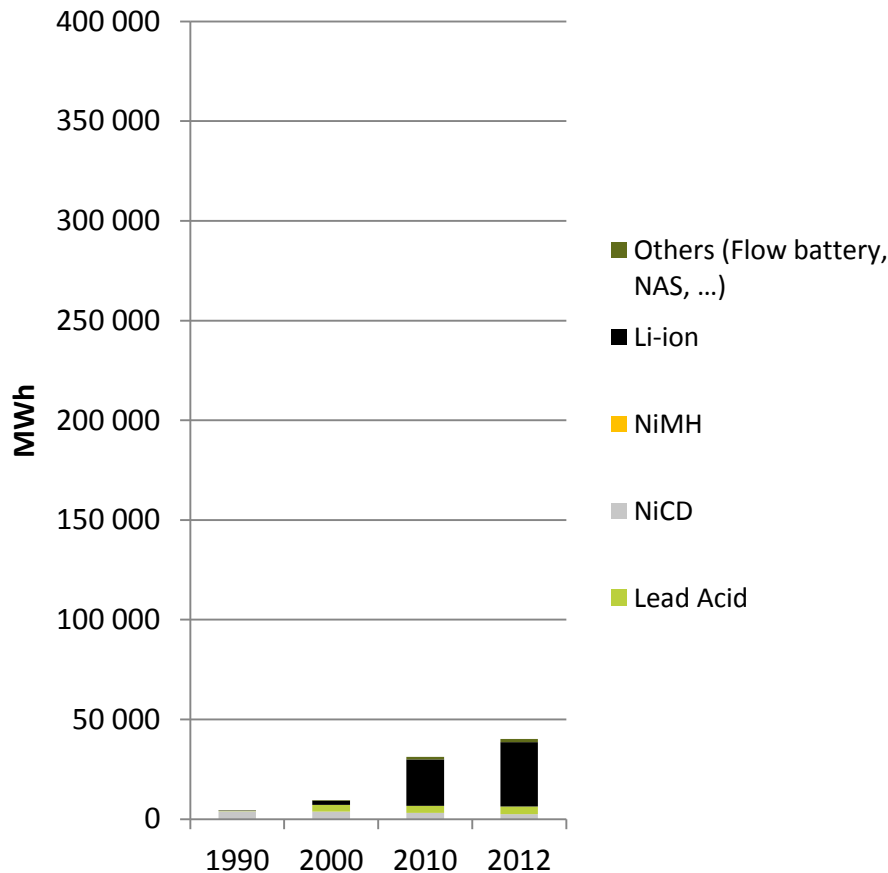
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c.pillot@avicenne.com



Source: AVICENNE ENERGY, 2013



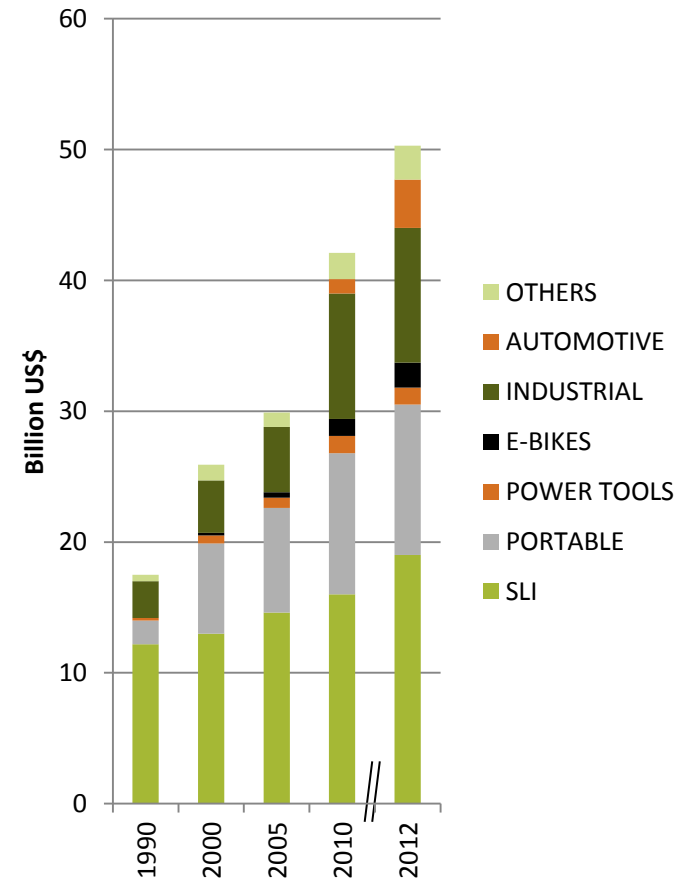
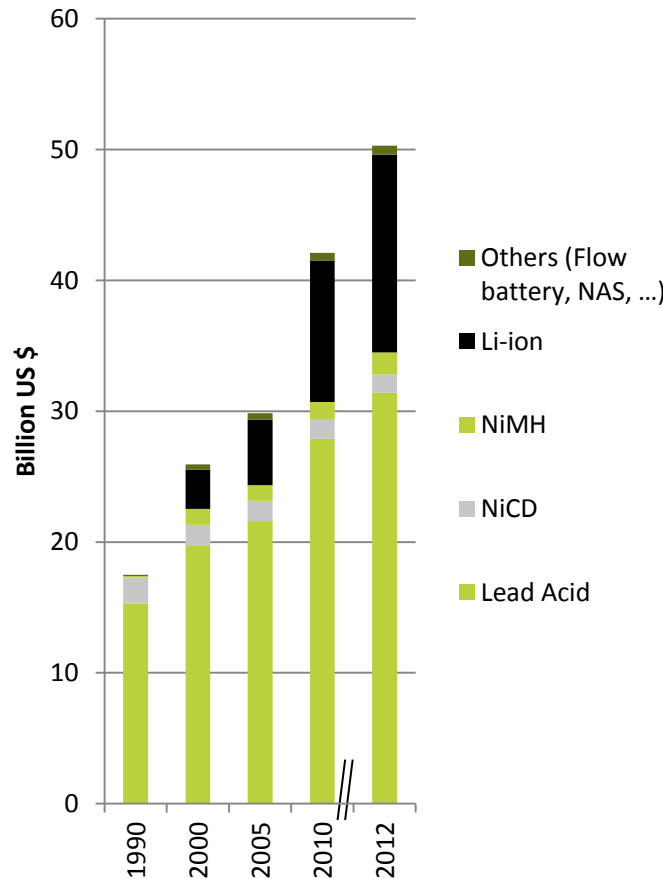
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THE WORLDWIDE BATTERY MARKET 1990-2012

50 BILLION US\$ in 2012¹

5% AVERAGE GROWTH PER YEAR (1990-2012)



Source: AVICENNE ENERGY Analyses 2013

1- Pack level

The worldwide Battery
market 2012-2025

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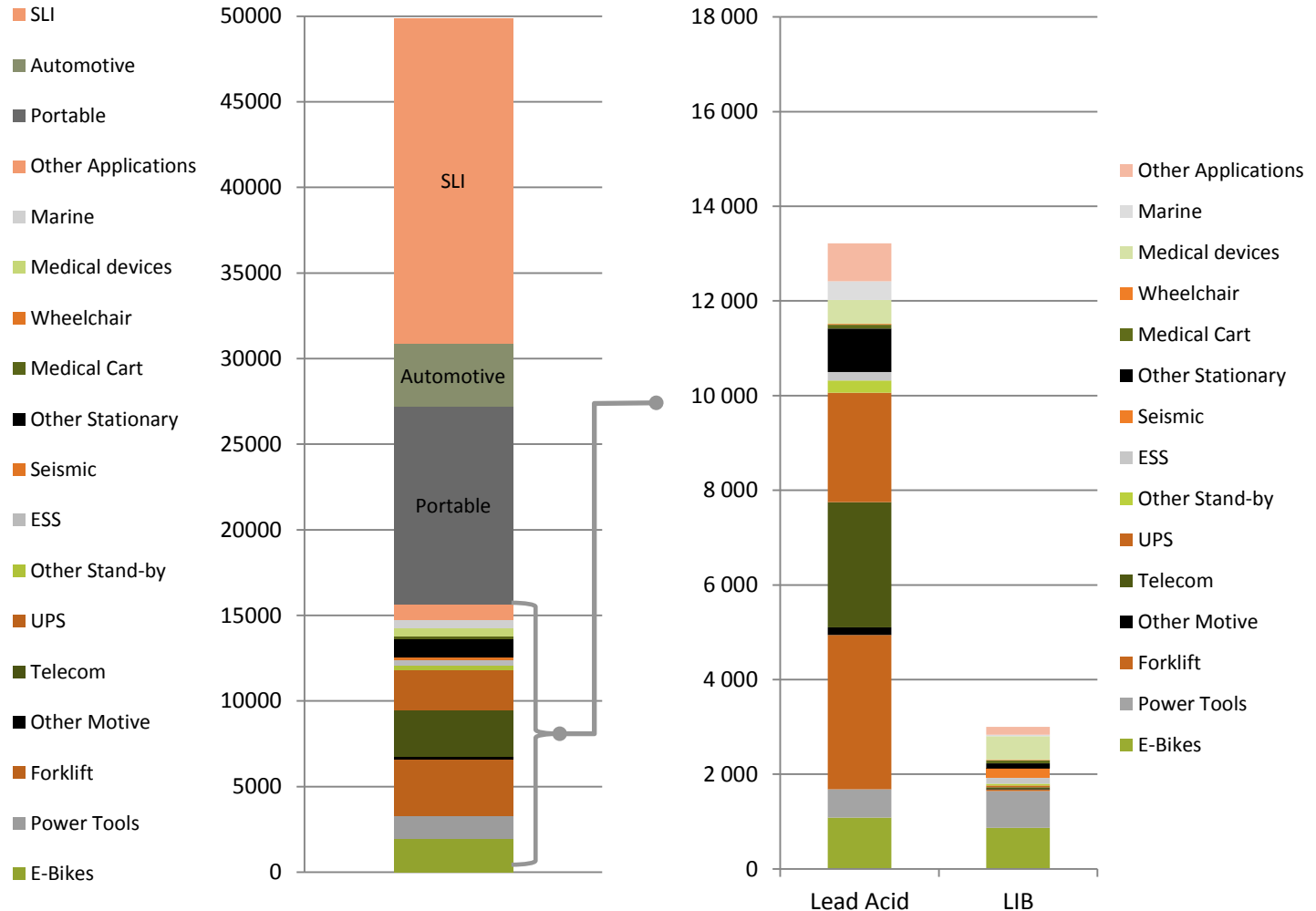


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THE WORLDWIDE BATTERY MARKET IN 2012: US \$ 50 BILLION

Battery market in 2012 (M\$)



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

Source: AVICENNE ENERGY, 2013

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LI-ION IN 2012

MAIN APPLICATIONS: CELLULAR, NOTEBOOK

4 450 M cells – 32 000 MWh
10 500 M\$

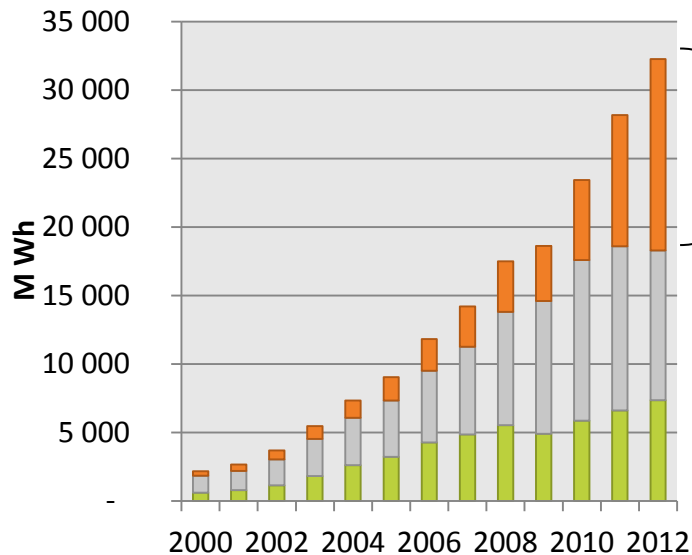
CAGR 2002/2012
+25 % per year in Volume
+14% per year in value

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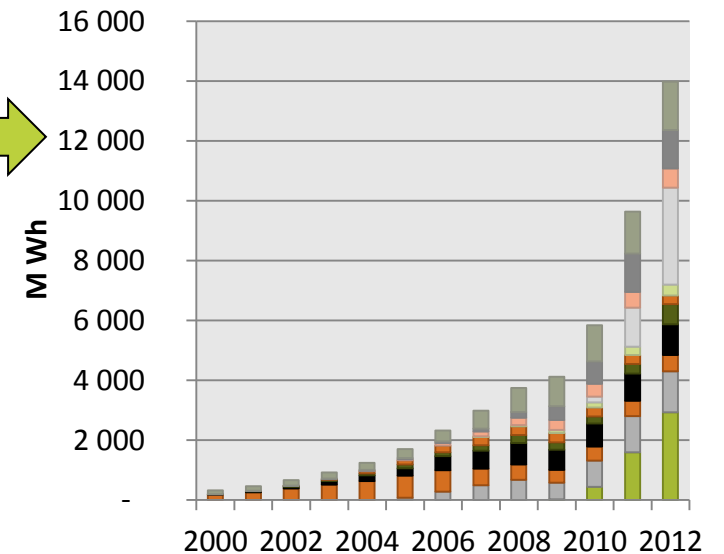


Li-ion Battery sales,
MWh, Worldwide, 2000-2012



Cellular Phones Portable PCs Others

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



Tablets Digital Camera Toys E-bikes Power Tools Auto Video Games Others Camcorders MP3 Household devices

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LI-ION IN 2012

MAIN APPLICATIONS: CELLULAR, NOTEBOOK

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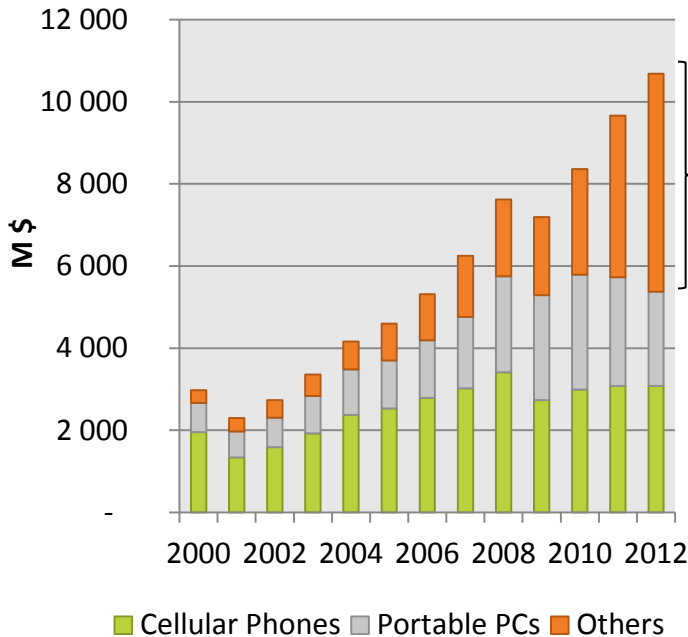
10 700 M\$ (cell level)

CAGR 2002/2012

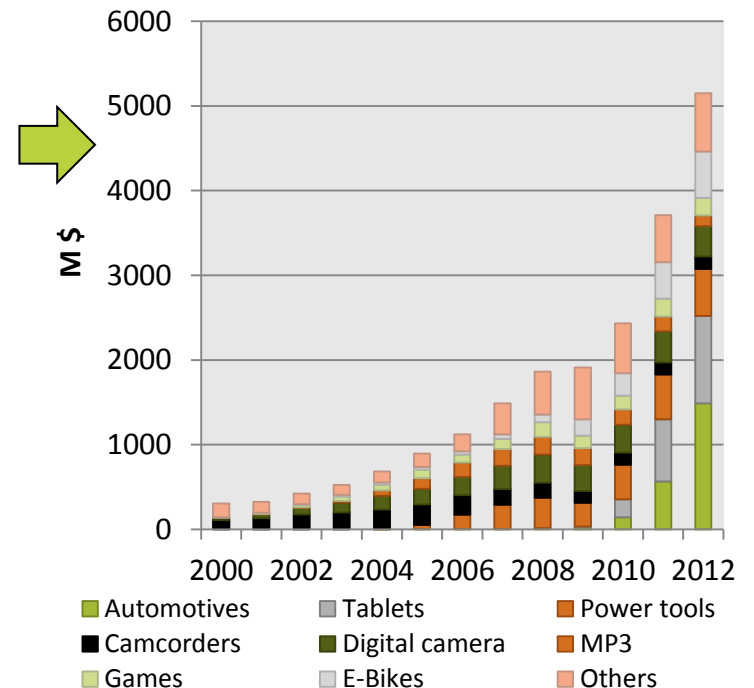
+25 % per year in Volume

+14% per year in value

Li-ion Battery sales,
M\$, Worldwide, 2000-2012



Li-ion Battery sales,
M\$, Worldwide, 2000-2012



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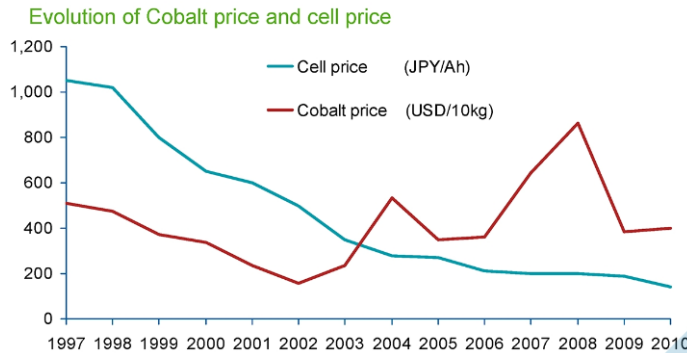


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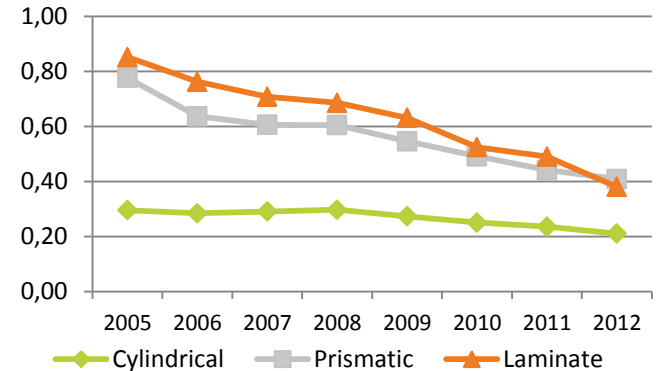
BATTERY PRICE IS DECREASING DRASTICALLY

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



Source: UMICORE, march 2011

Average LIB cell price (\$/Wh)

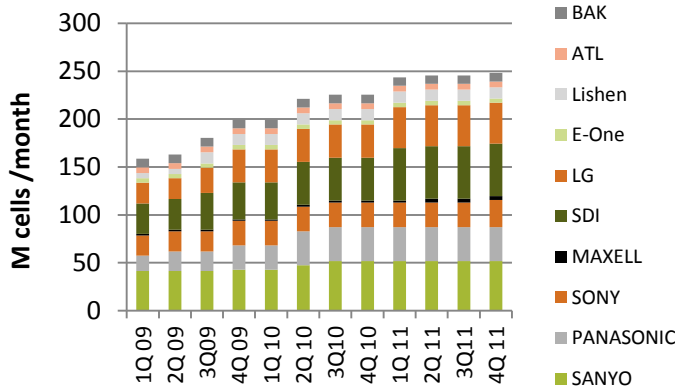


Note- Q4 2012: Cylindrical: 0,18 \$/Wh ; Laminates: 0,34 \$/Wh

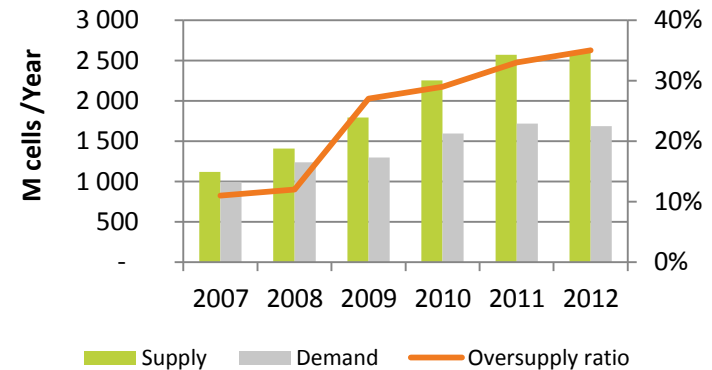
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Production capacity 2009/2011:
from 150 to 250 M cells/month



18650 oversupply ratio is
increasing



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



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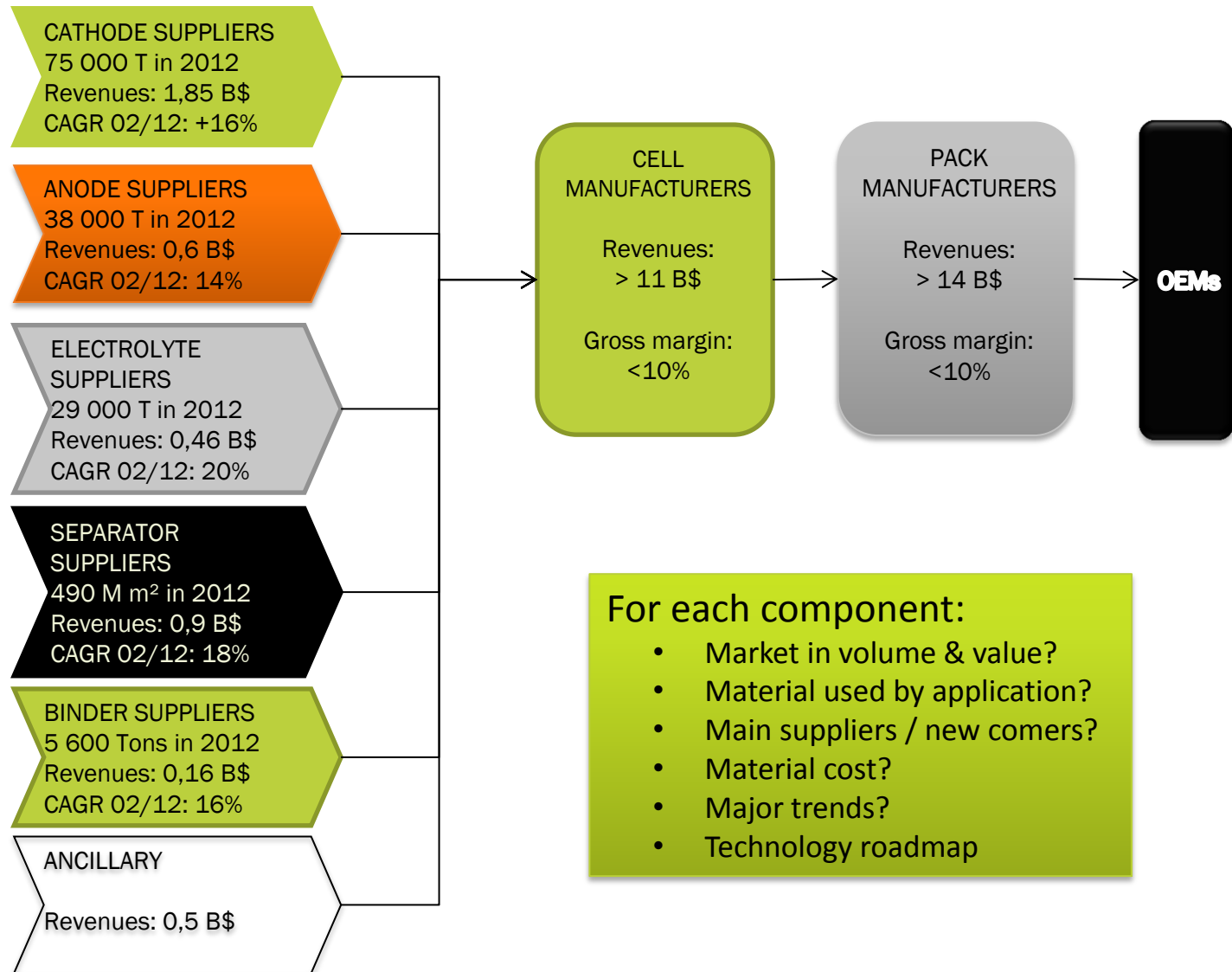
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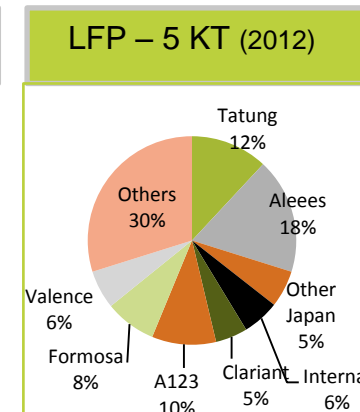
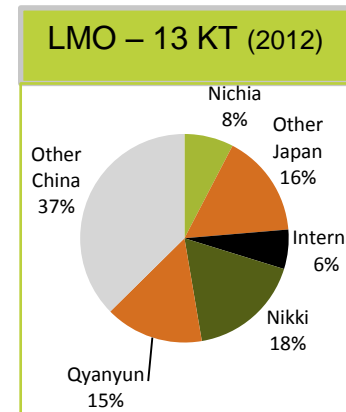
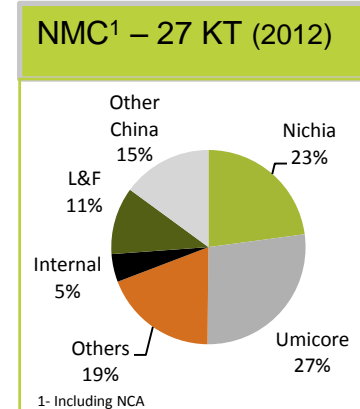
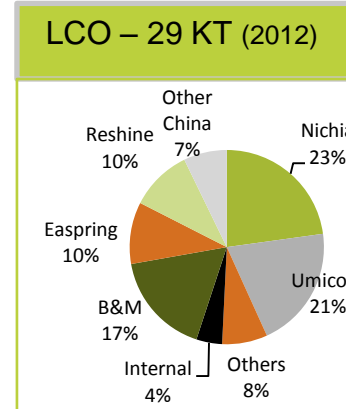
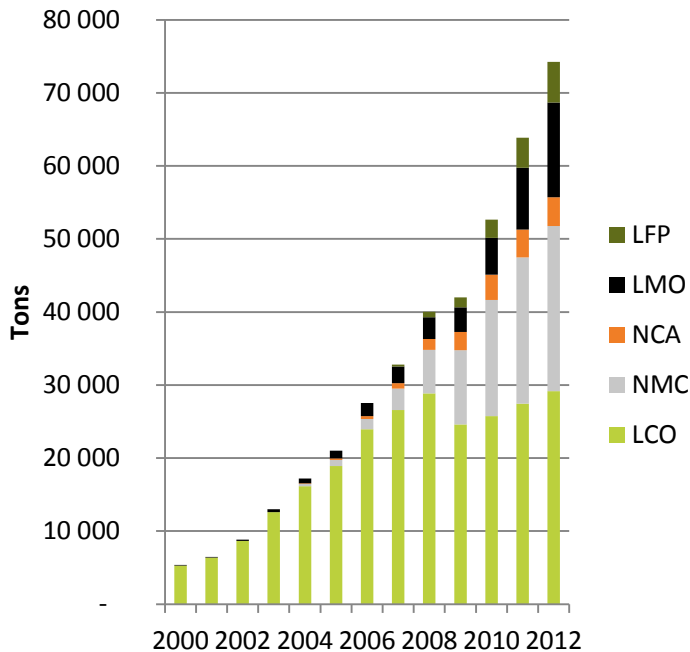
Christophe PILLOT
+ 33 1 47 78 46 00
c.pillot@avicenne.com

LI-ION VALUE CHAIN



CATHODE ACTIVE MATERIALS NEEDS BY CHEMISTRY

Cathode active materials for LIB in Tons, 2000-2012



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LEADERS:



NEW ENTRANTS ON THE FIELD:



(...)

CONTACT

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



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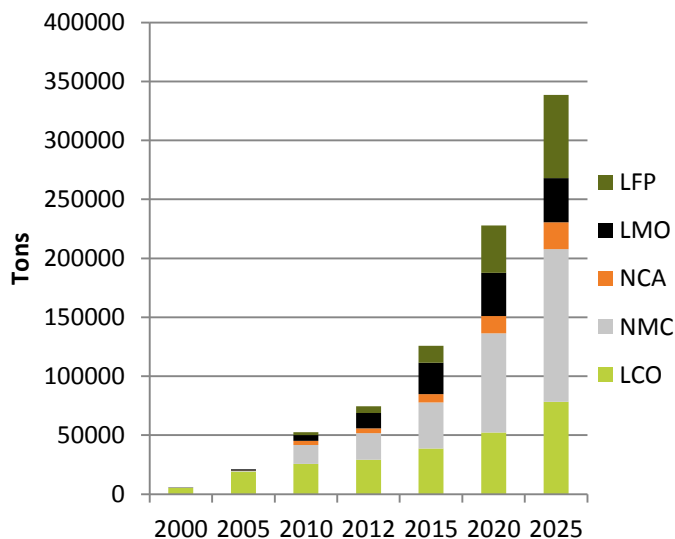


CONTACT

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

CATHODE ACTIVE MATERIAL FORECASTS 2000-2025

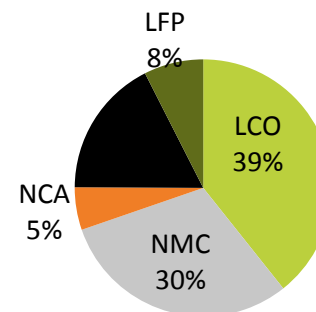
Cathode active materials 2000-2025 - Tons



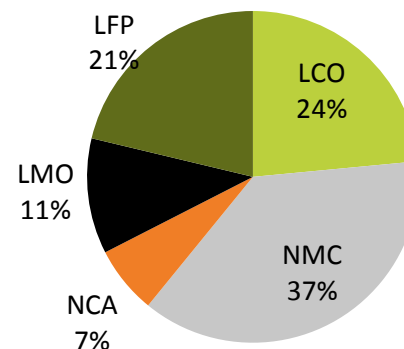
ASSUMPTIONS:

- Portable devices:
2010-2025: +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

Cathode active materials in 2012: 75 000 Tons



Cathode active materials in 2025: > 330 000 Tons



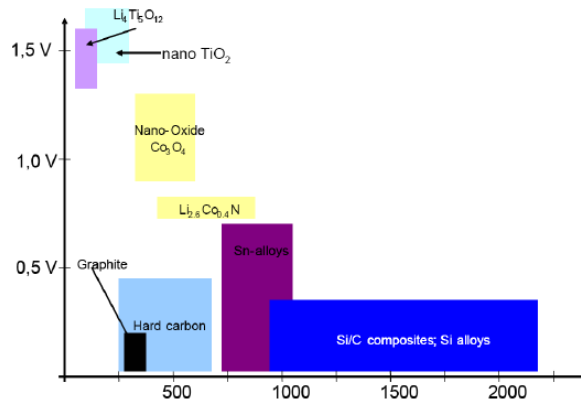


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ANODE ACTIVE MATERIALS 38 000 TONS IN 2012

LIB Anode Materials



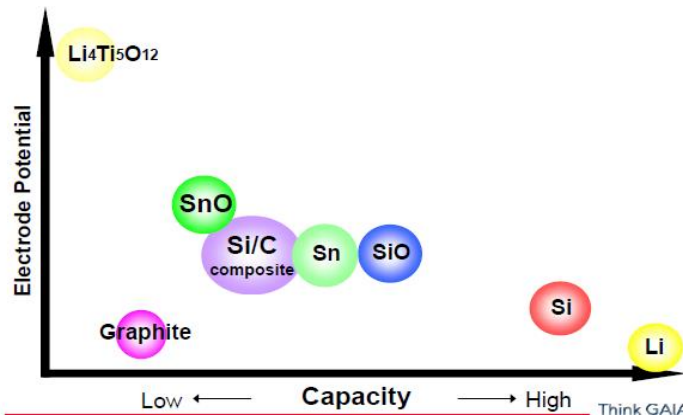
Source: A. Jossen, IRES 2007



Source: Hitachi Chemical

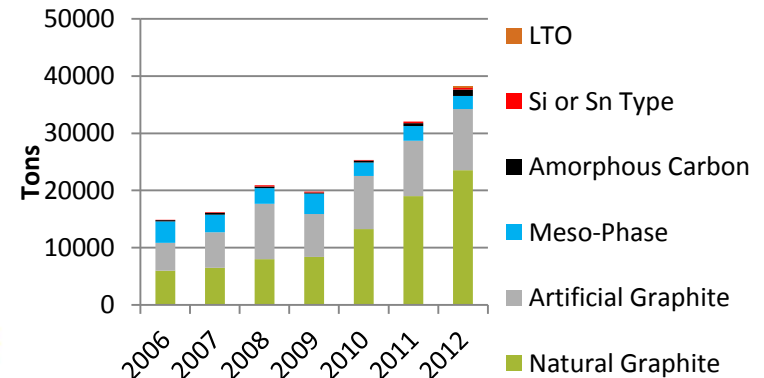
The worldwide Battery market 2012-2025

LIB Anode Materials



Source: Sanyo, March 2011

LIB Anode market, (Tons)



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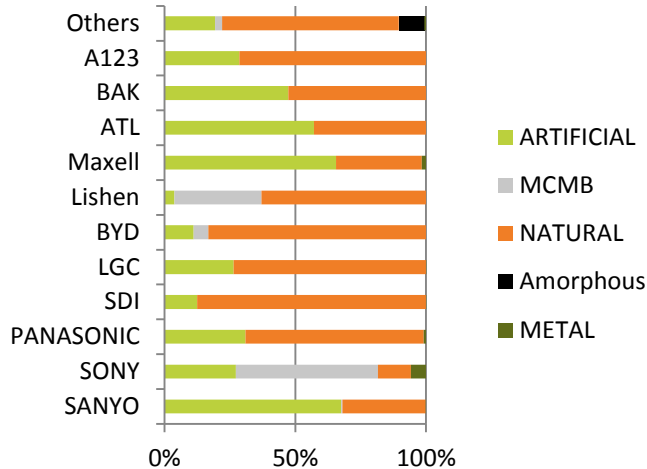


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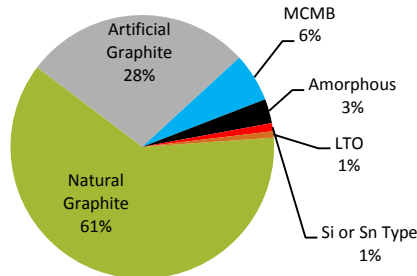
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ANODE FOR LIB IN 2012

Natural graphite become a commodity



Carbon for LIB anodes by type (2012)



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

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LEADERS:



HITACHI

Nippon Carbon

NEW ENTRANTS ON THE FIELD:



(...)

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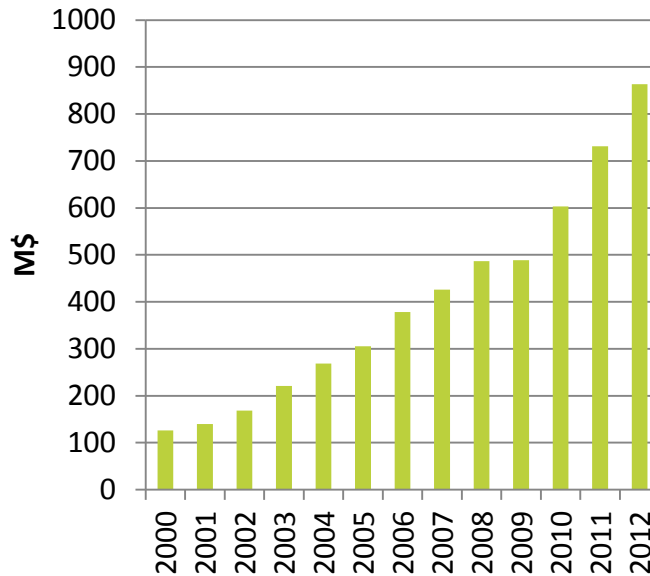


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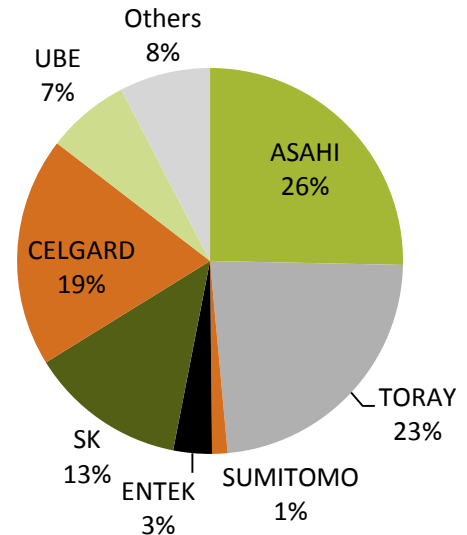
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LIB SEPARATOR MARKET 2012

LIB separator market, M\$,
CAGR 2000/2012: +18%



LIB Separator supplier, market share in 2012



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

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LEADERS:

AsahiKASEI



UBE



TORAY

NEW ENTRANTS ON THE FIELD:



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

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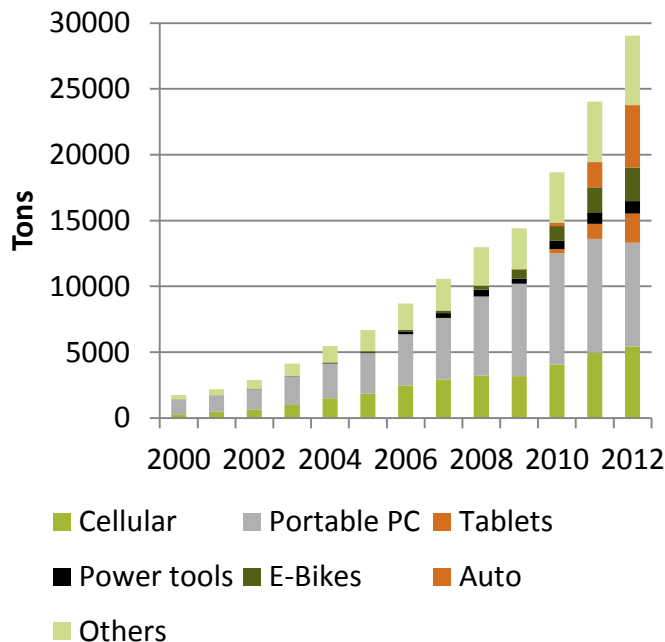


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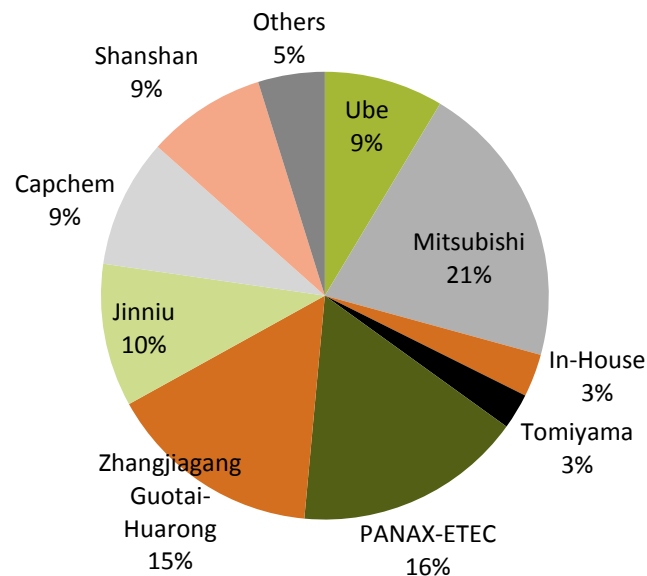
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ELECTROLYTE SUPPLIERS/CUSTOMERS 29 000 TONS IN 2012

LIB electrolyte market, Tons,
CAGR 2000/2012: +20%



LIB electrolyte supplier, market
share in 2012



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

LEADERS:



Zhangjiagang
Guotai-Huang



JINNIU



SHANSHANTECH



新宙邦
CAPCHEM

NEW ENTRANTS ON THE FIELD:



LG Chem



The Chemical Company



UBE
UBE INDUSTRIES LTD.





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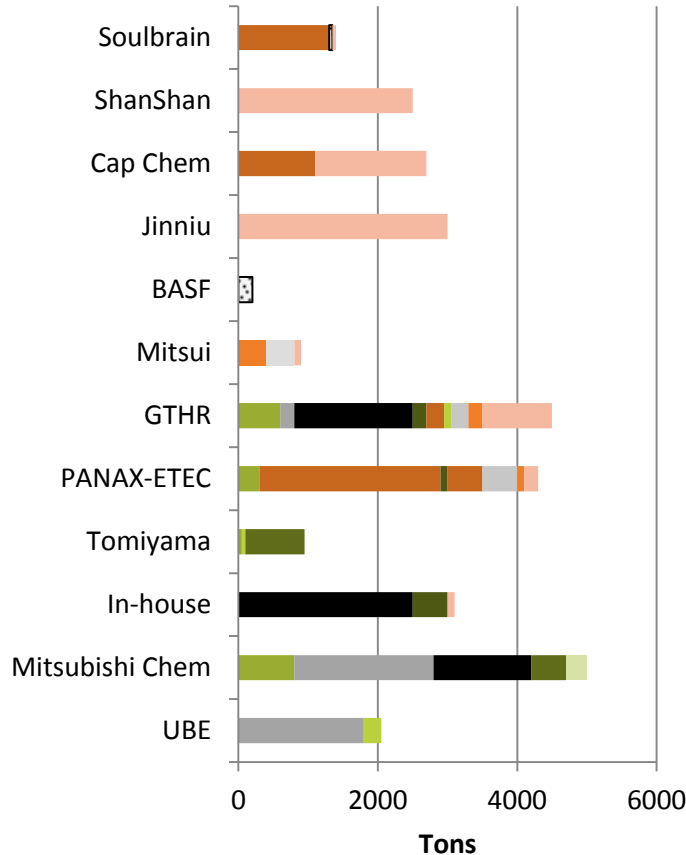


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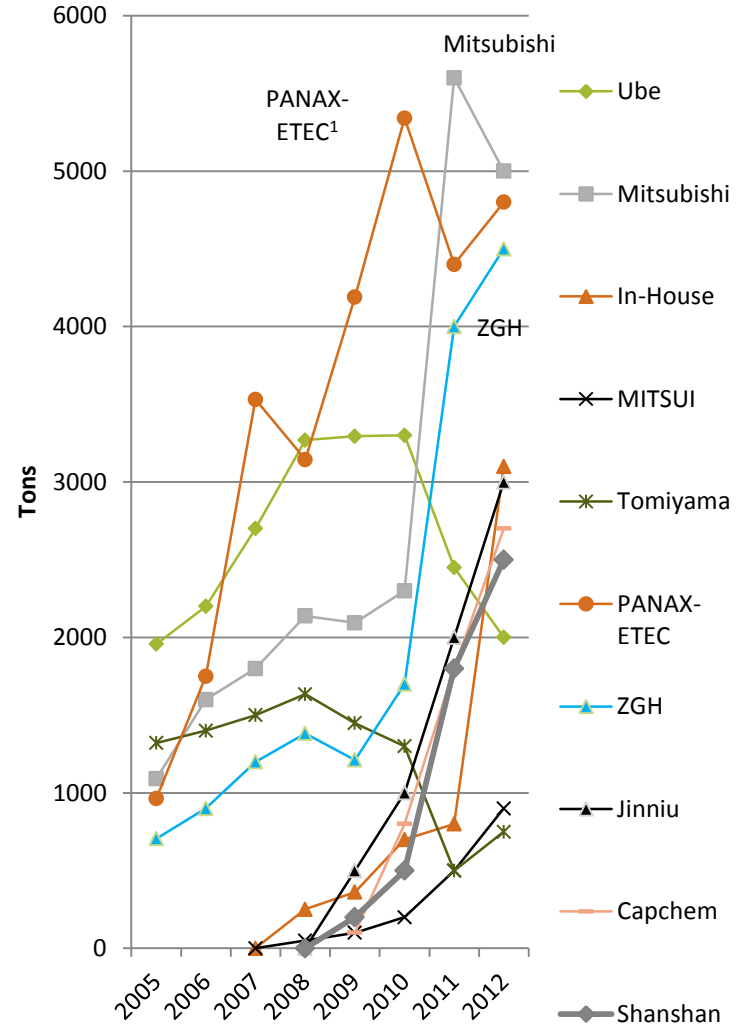
LIB ELECTROLYTE MARKET 2012

Electrolyte Battery makers & suppliers relation in 2012



- | | | |
|-------------|---------------|---------------|
| ■ Panasonic | ■ SDI | ■ LG Chem |
| ■ BYD | ■ Lishen | ■ Maxell |
| ■ ATL | ■ BAK | ■ A123 |
| ■ AESC | ■ YUASA (LEJ) | ■ Yuasa (BEC) |
| ■ TOSHIBA | ■ Others | |

Electrolyte maker sales 2005-2012



Note: ¹ former Samsung Chiel



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TIME TO MARKET FOR NEW MATERIALS IN LIB INDUSTRY



	2000	2005	2010	2015	2020	2025	2030
CATHODE	LCO		LMO LFP NMC/NCA	LiNiMnO ₂ High voltage	5v spinel LiNiPO ₄ , 5v LiCoPO ₄ , 5v LiMnPO ₄ , 4v	Sulfur	Air
ANODE	Graphite Hard Carbon		Soft Carbon Li ₄ Ti ₅ O ₁₂		C/Alloy Composite Non Si Alloys	Li Metal Si Alloys	
ELECTROLYTE	LiPF ₆ + Org. solvents		LiPF ₆ free electrolyte	Gel-polymer electrolyte	5v electrolyte		
SEPARATORS	Polyolefin		Polyolefin+ ceramic coating	Cellulose Non-woven		Polymer membrane	Solid Electrolyte

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BATTERY MARKET FORECASTS 2011-2025

Applications covered

- ☞ Portable PCs, net-book
- ☞ Cellular Phones, Smartphones
- ☞ Tablets
- ☞ Camcorders
- ☞ Cordless Tools, Gardening tools
- ☞ Digital Camera
- ☞ Games, MP3
- ☞ Cordless Phones
- ☞ Shavers, Toothbrush,
- ☞ RC Cars
- ☞ E-bikes
- ☞ Security lighting
- ☞ Vehicles: HEV, P-HEV, EV
- ☞ Energy Storage (Grid, residential)
- ☞ UPS
- ☞ Telecom
- ☞ Forklift, automatic handling equipment
- ☞ Medical
- ☞ Others...

Parameters analysis

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

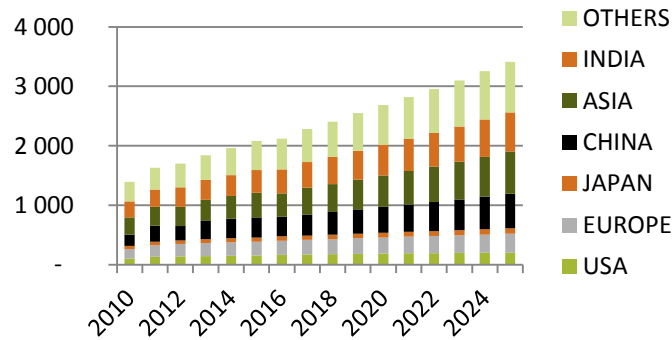


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PORTABLE ELECTRONIC DEVICES FORECASTS 2010-2025

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



Cellular Phones market Drivers

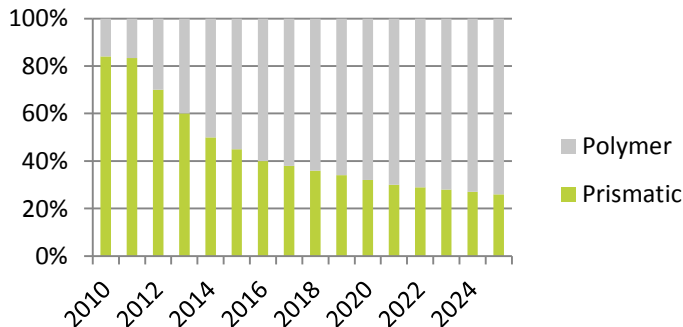
- Emergent market
- Renewal ratio increase
- Smartphone penetration increase



The worldwide Battery
market 2012-2025

LIB cells demand 2010-2025

Polymer penetration: 30% -> 75%



LIB cells for cellular phones
trends

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

Source: AVICENNE ENERGY Analyses

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October 14-16, 2013
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CONTACT

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



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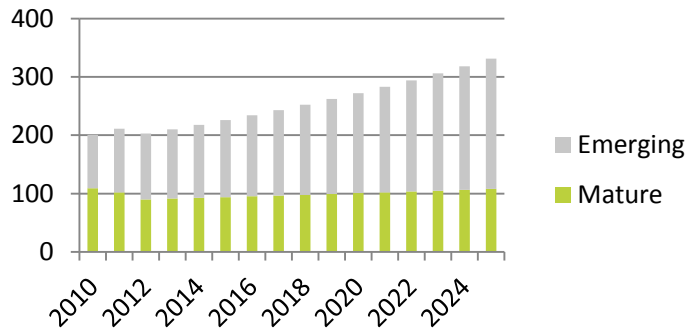


CONTACT

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

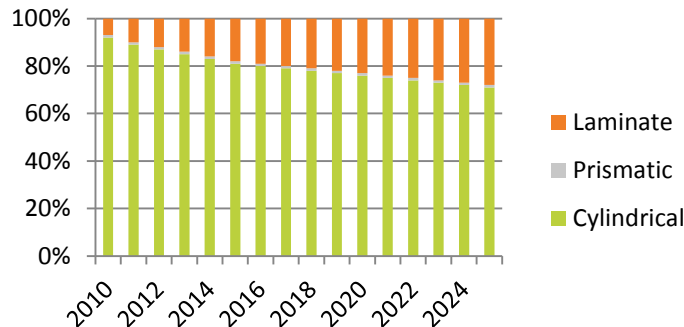
PORTABLE ELECTRONIC DEVICES FORECASTS 2012-2025

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



Source: IDC, Gartner, AVICENNE Energy

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



Source: AVICENNE ENERGY Analyses

Portable PCs market trends

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

(1) Samsung & AVICENNE (2) Intel

LIB cells for portable 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

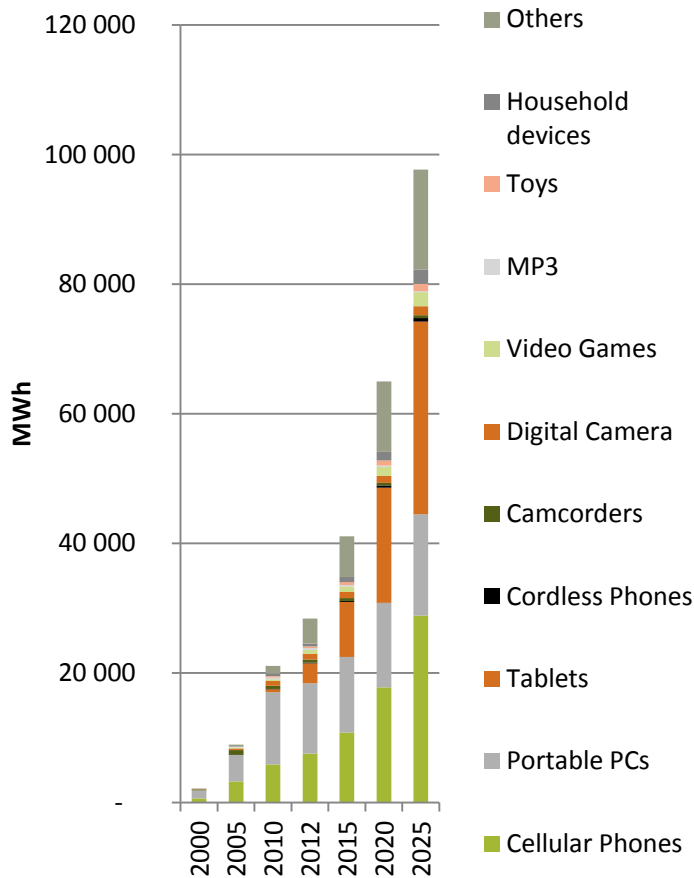


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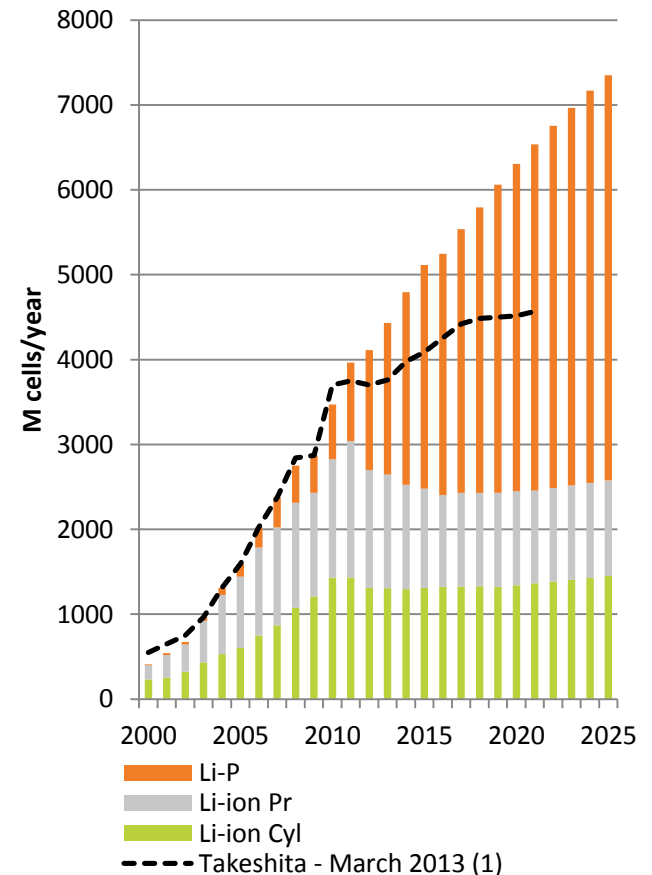
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2025 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

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



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



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CONTACT

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

Source: AVICENNE ENERGY Analyses

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



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HEV FORECASTS 2012-2025

HEV MARKET: 2,5 Million units in 2015 – 5 M in 2020 – 7M in 2025

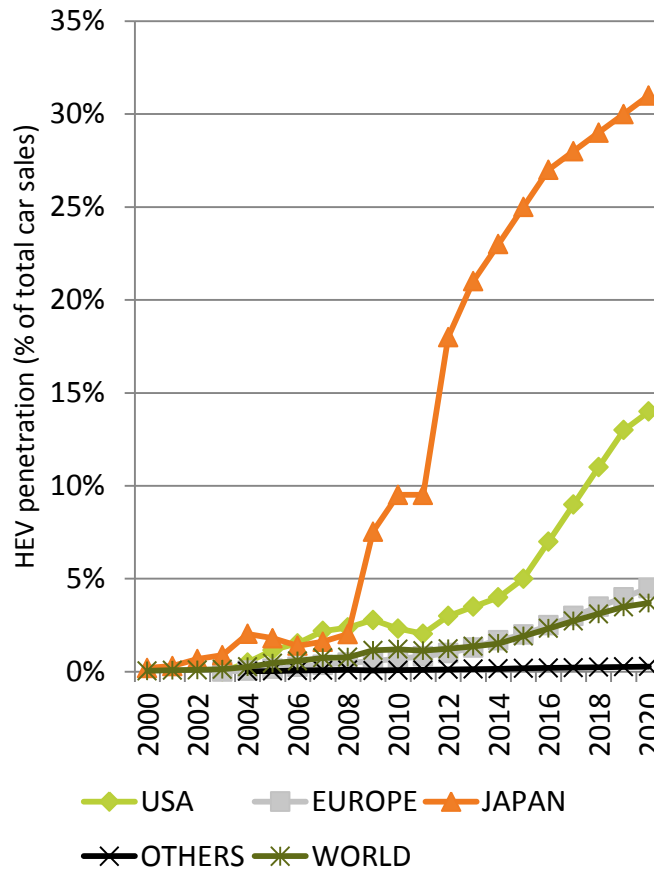
The worldwide Battery
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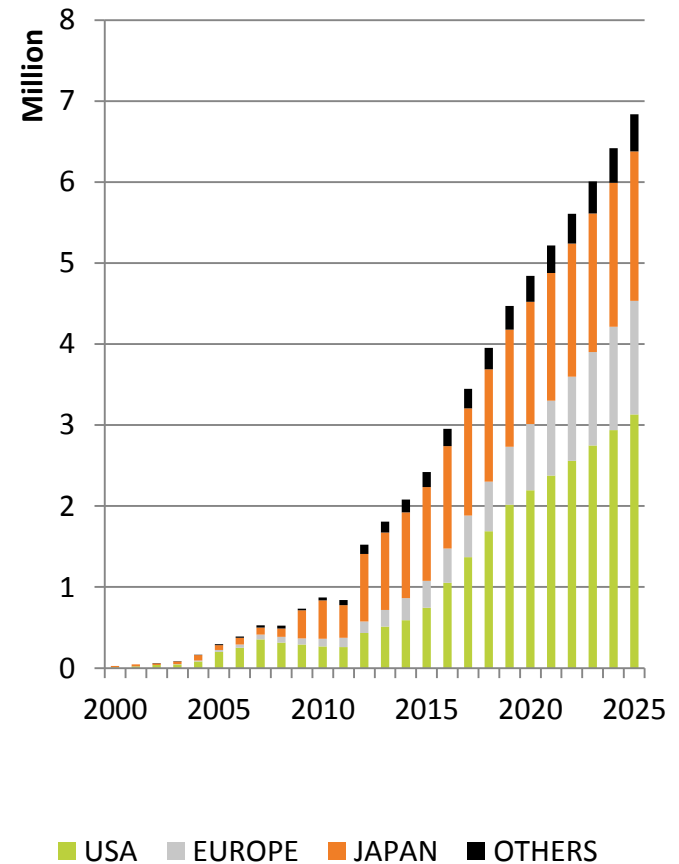


CONTACT

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



Micro hybrid not included



LI-ION BATTERY DEVELOPMENTS FOR HEV, P-HEV & EV

LIB >>> NiMH but
SAFETY & COST ISSUES

	PRIUS III NiMH	PRIUS x - Li-ion
Volts	201.6	201.6
Cells	168 (28*6)	56
Capacity	6.5 Ah	3.8 Ah
Energy	1310 Wh	766 Wh
Weight	38 kg	25 kg
T°C Range	+	+
Cyclability	+	++
Safety		
Cost		

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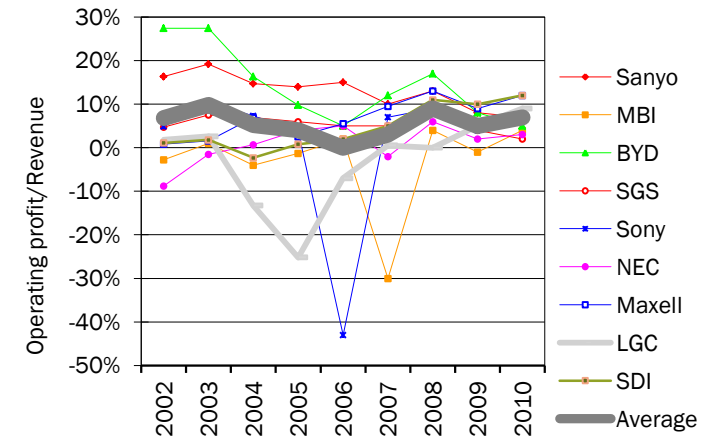


CONTACT

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



Recall slash battery profit





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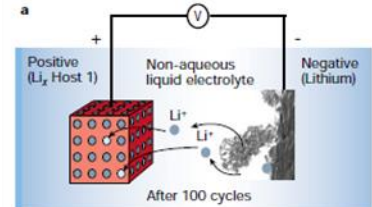
SAFETY ISSUES

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

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.



The worldwide Battery market 2012-2025

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CONTACT

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

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	YES	?	?

BMS

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

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

Packaging

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

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

Thermal

- Thermal management improve both the safety and the life time

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

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.

The worldwide Battery market 2012-2025

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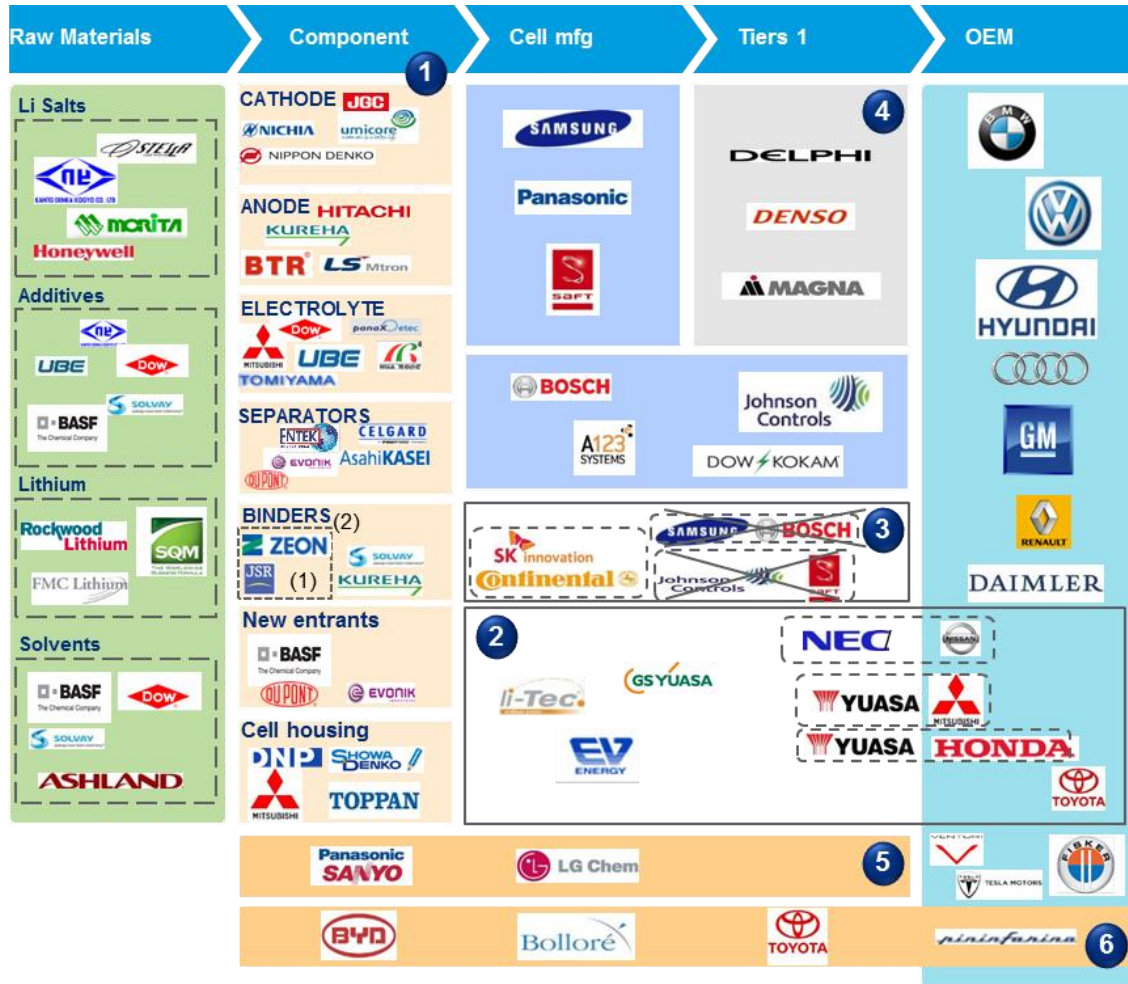
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+ 33 1 47 78 46 00
c.pillot@avicenne.com



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LIB FOR AUTOMOTIVE VALUE CHAIN



Comments

- 1 The largest share of the value (40%) comes from cell components
- 2 Cell manufacturers & OEM alliance may be the winning model but comes with high risk if the wrong cell manufacturer is selected
- 3 Tiers 1- cell manufacturers alliance: most of them disappear (eg. Saft-Johnson Controls, Bosch-Samsung, Enerdel-Delphi...)
- 4 Tiers 1- OEM alliance on Battery are not successful
- 5 Panasonic and LG Chem, cell manufacturers develop raw -material in-house and make the pack integration for OEM
- 6 On a different scale, Toyota, BYD or BOLLORÉ are fully integrate

The worldwide Battery market 2012-2025

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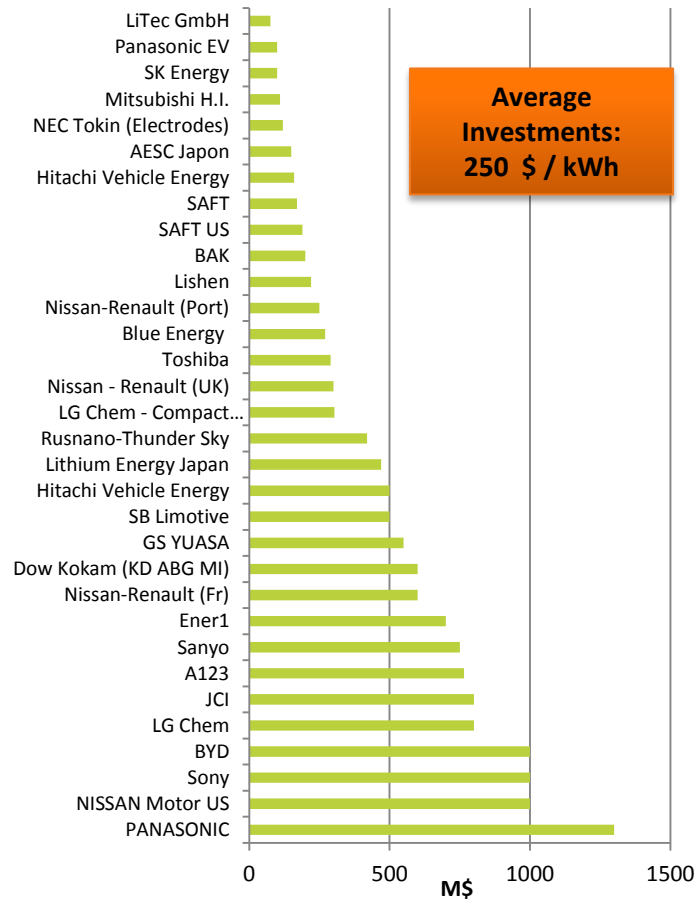
CONTACT

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

LIB MANUFACTURING INVESTMENTS 2009-2015

10-12 B\$ WORLDWIDE
>50 GWh in 2015

Total Investment (M\$) made for LIB manufacturing



The worldwide Battery
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CONTACT

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



A123 Michigan Plant - Photo courtesy of A123 Systems



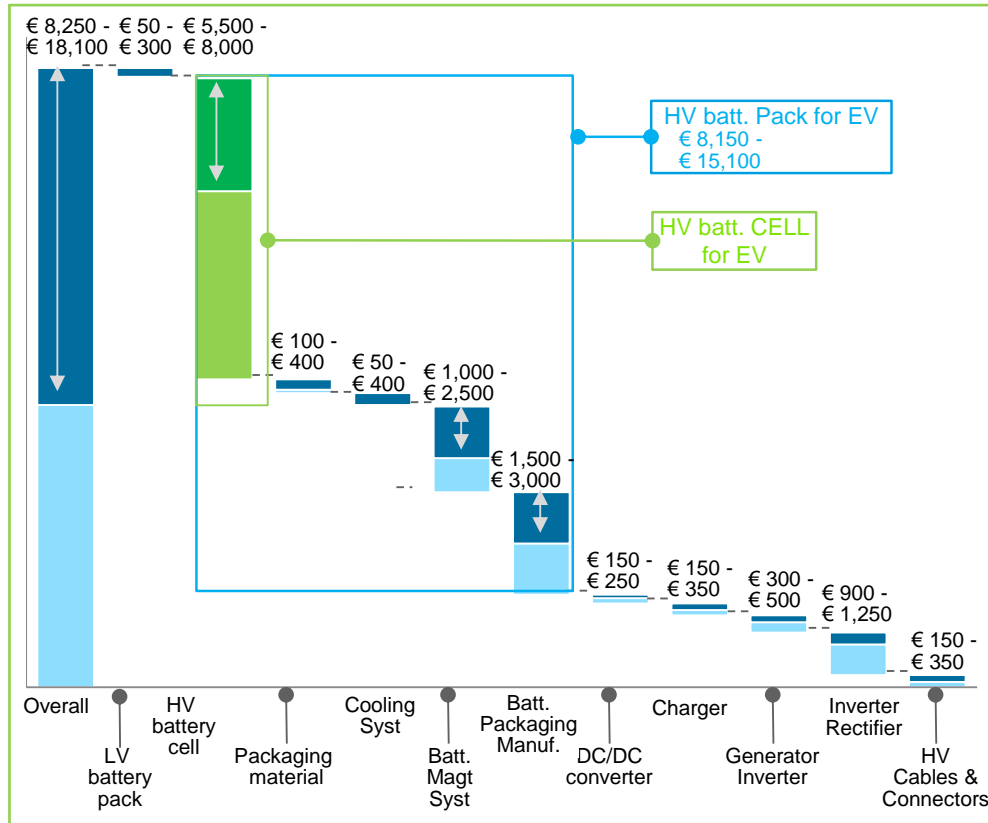
Liotech Plant, Novosibirsk – 1,5 GWh production capacity



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BATTERY & POWER ELEC. COST IN EV



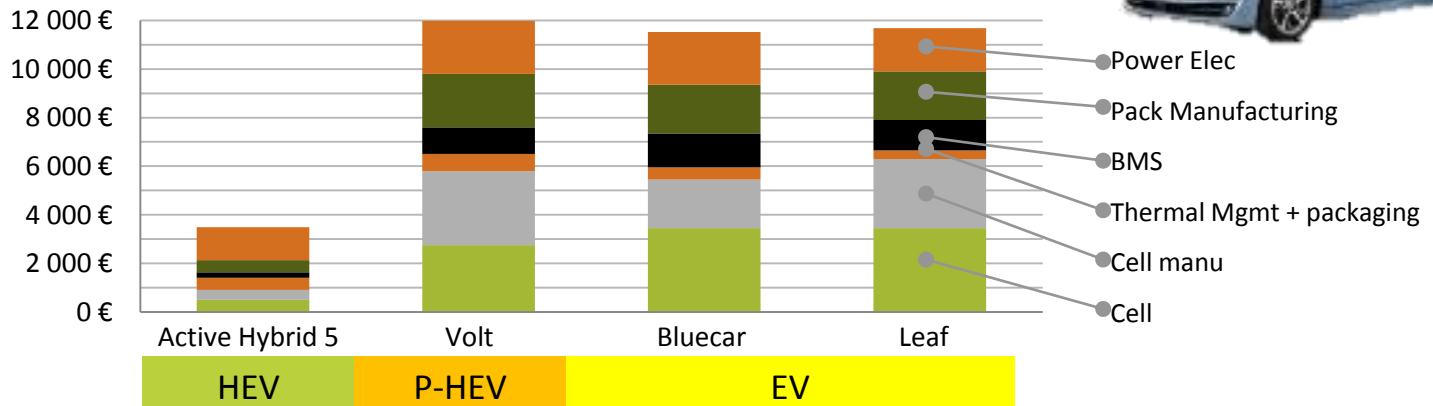
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CONTACT

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





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LIB CELL BILL OF MATERIALS

The worldwide Battery market 2012-2025

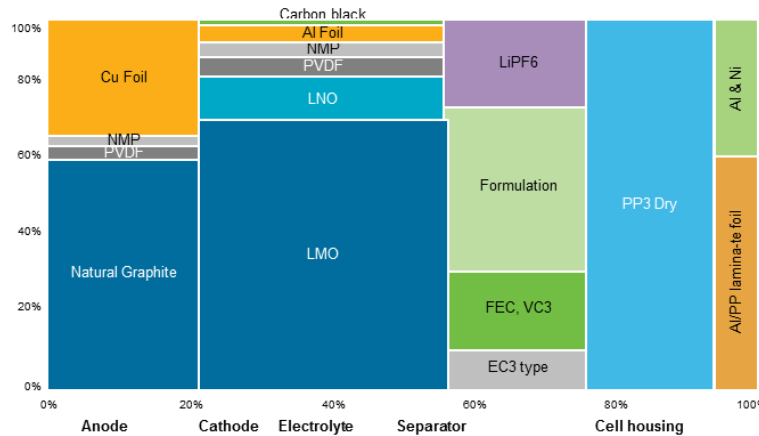
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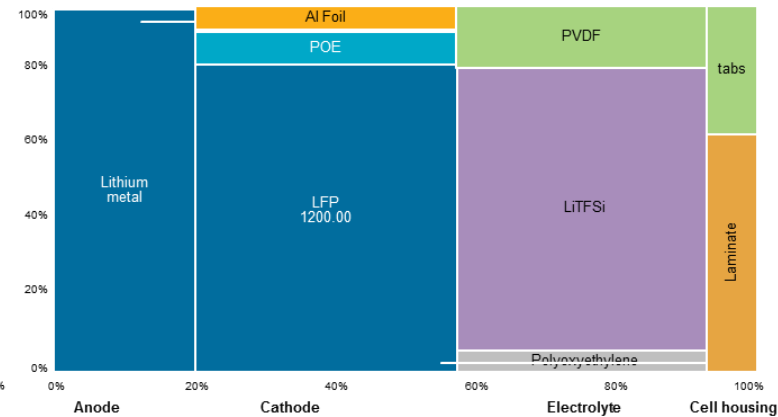
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Christophe PILLOT
+ 33 1 47 78 46 00
c.pillot@avicenne.com

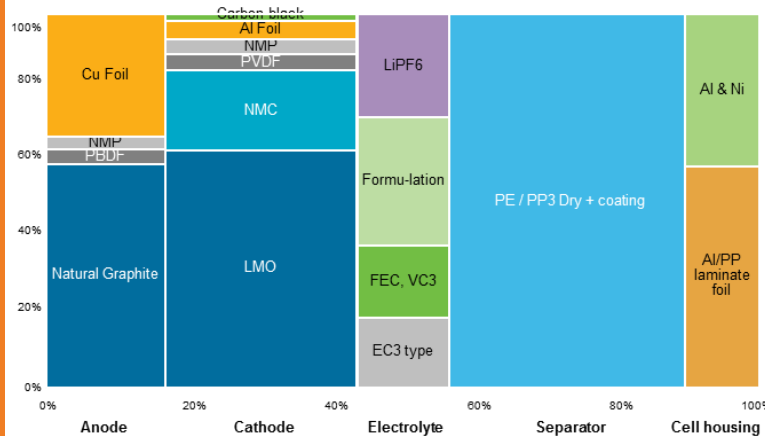
NISSAN LEAF



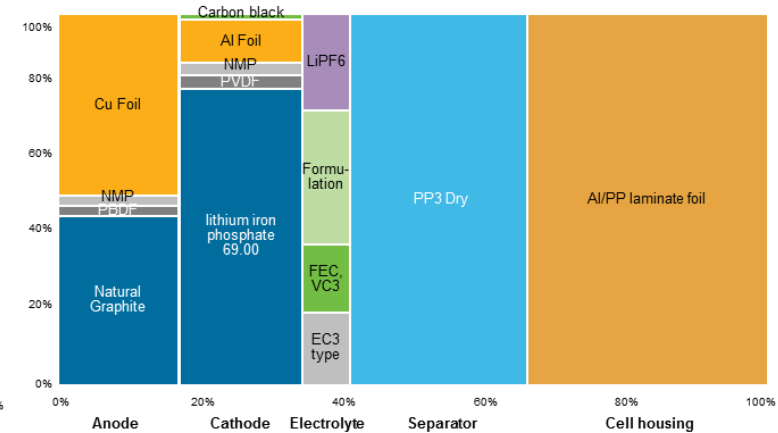
BOLLORE BLUE CAR



GM VOLT



BMW ACTIVE HYBRID 5





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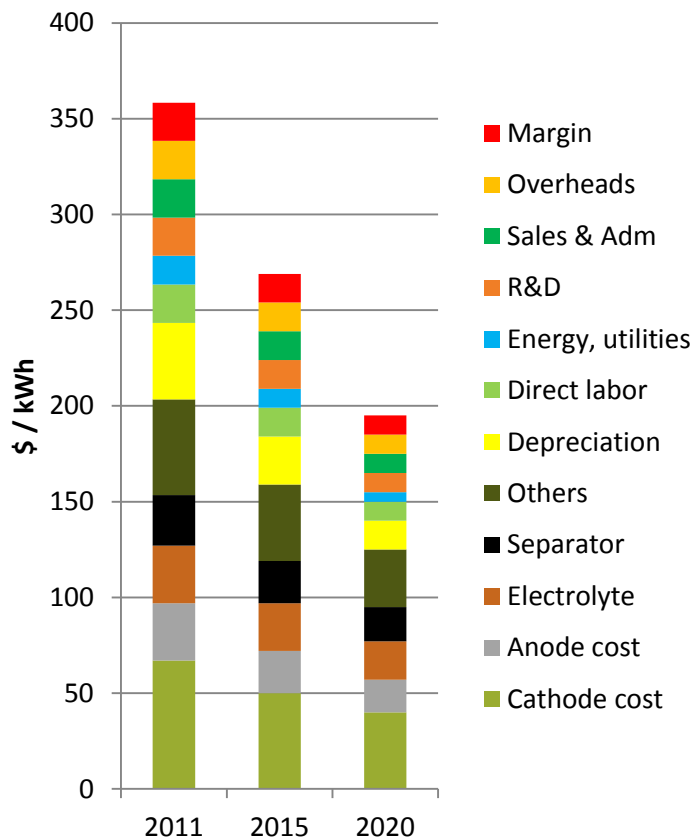


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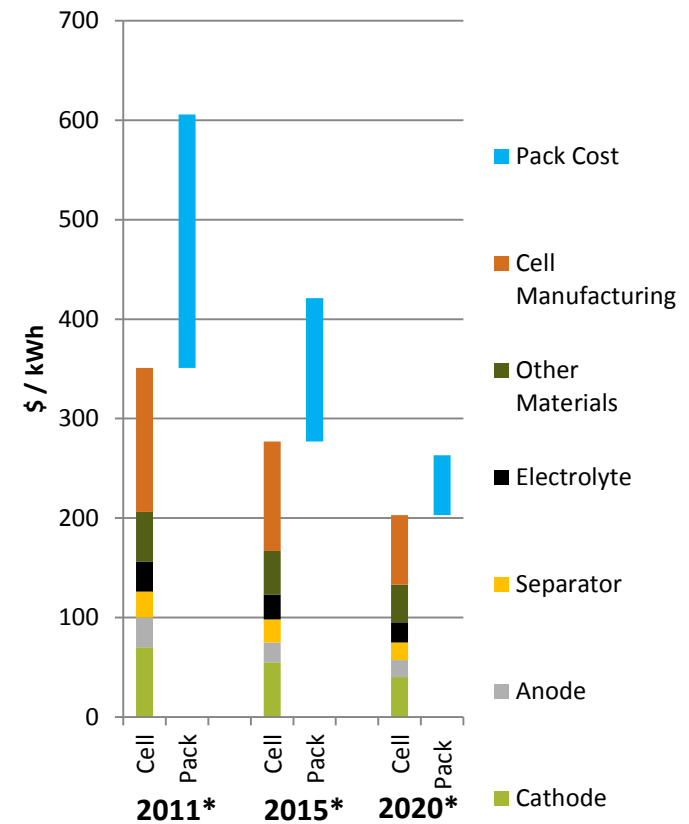
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+ 33 1 47 78 46 00
c.pillot@avicenne.com

LI-ION BATTERY COST 2011-2020

LIB cell average cost
(EV design ; NMC cathode)



LI-ION BATTERY PACK COST
FOR EV



* For Production > 100 000 packs/year

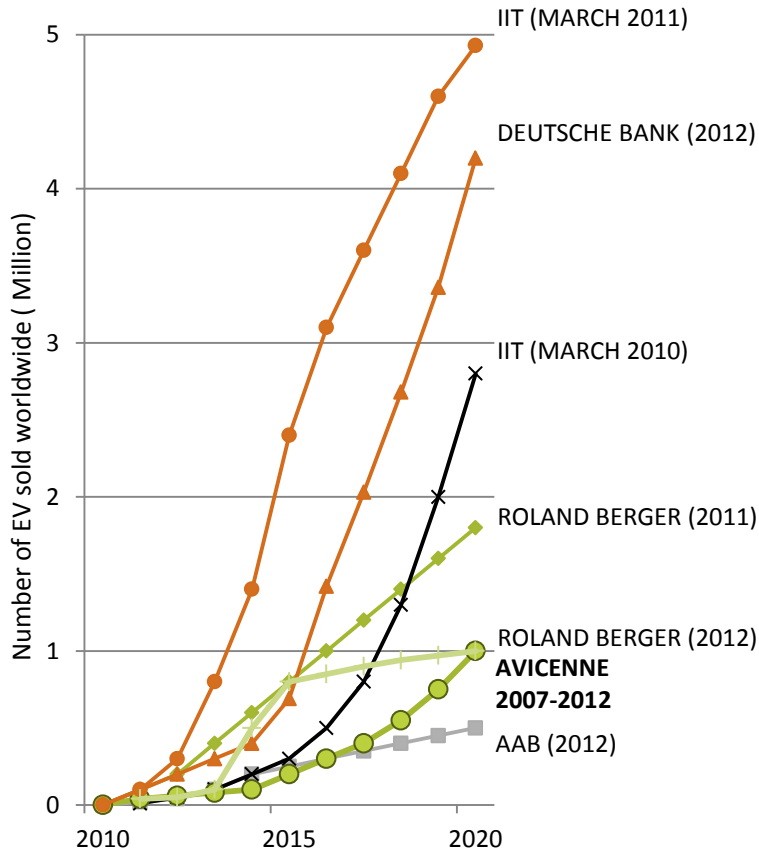


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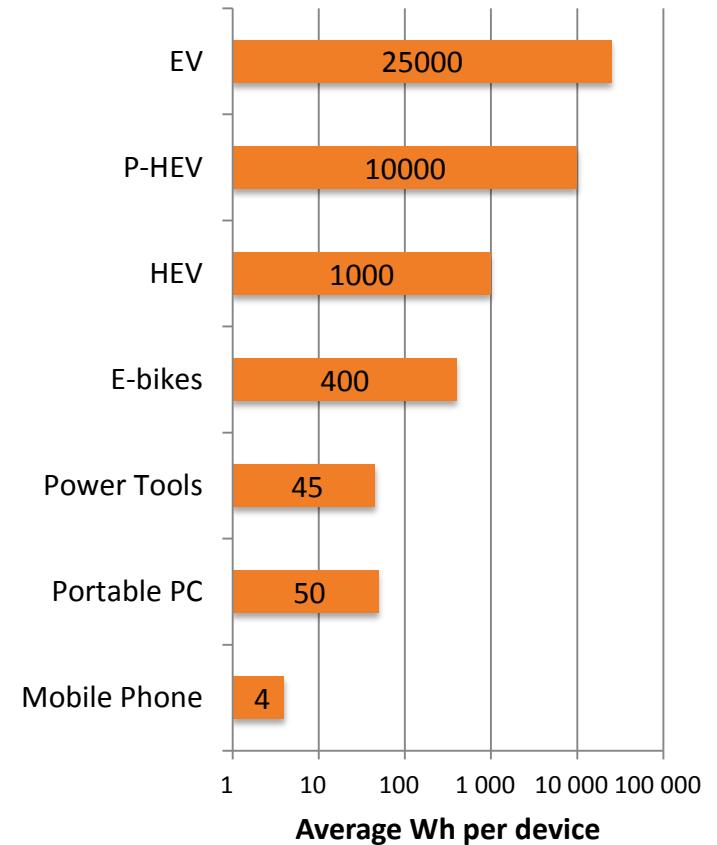
EV FORECASTS 2011-2020

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



The worldwide Battery
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CONTACT

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



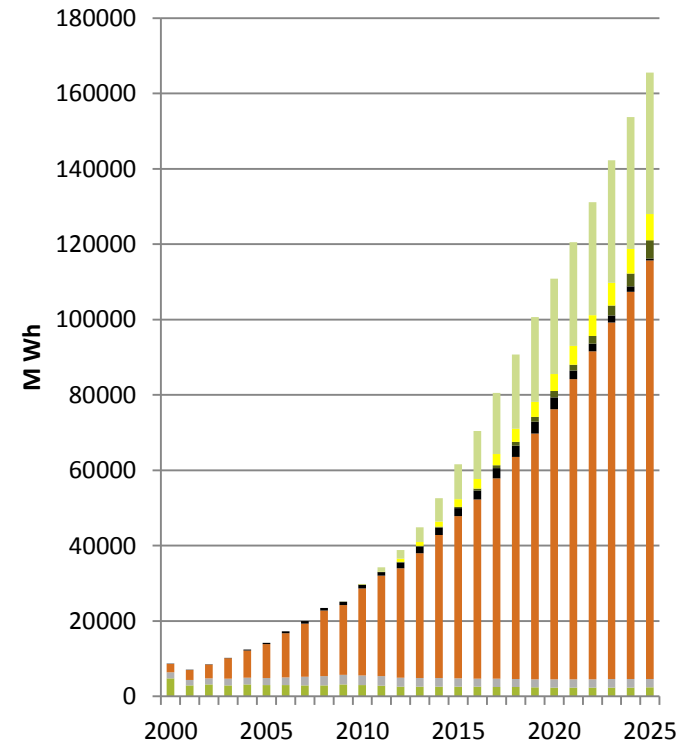
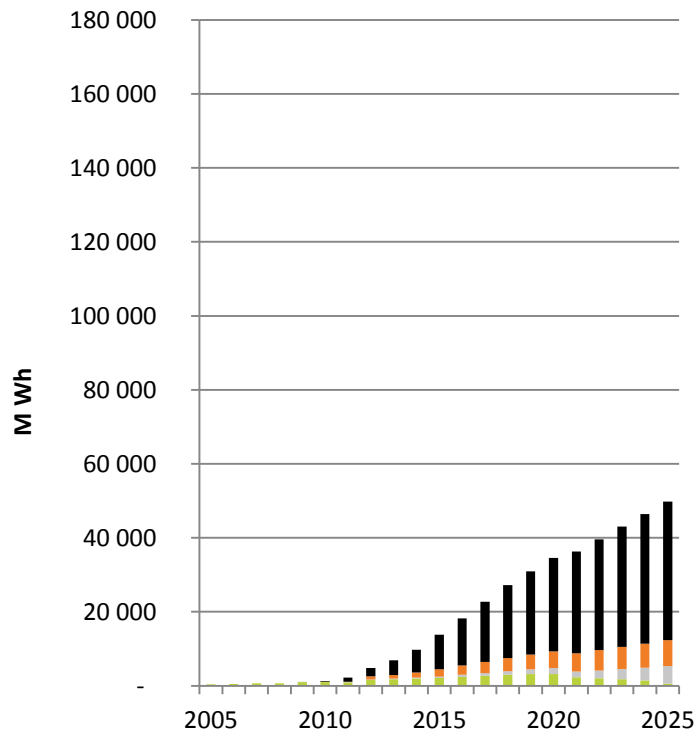
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TOTAL BATTERY DEMAND 2025 FORECASTS

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

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



■ NiMH for HEV ■ LIB for HEV
■ LIB for P-HEV ■ LIB for EV

■ NiCd ■ NiMH except Auto ■ LIB except Auto
■ NiMH for HEV ■ LIB for HEV ■ LIB for P-HEV
■ LIB for EV

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CONTACT

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

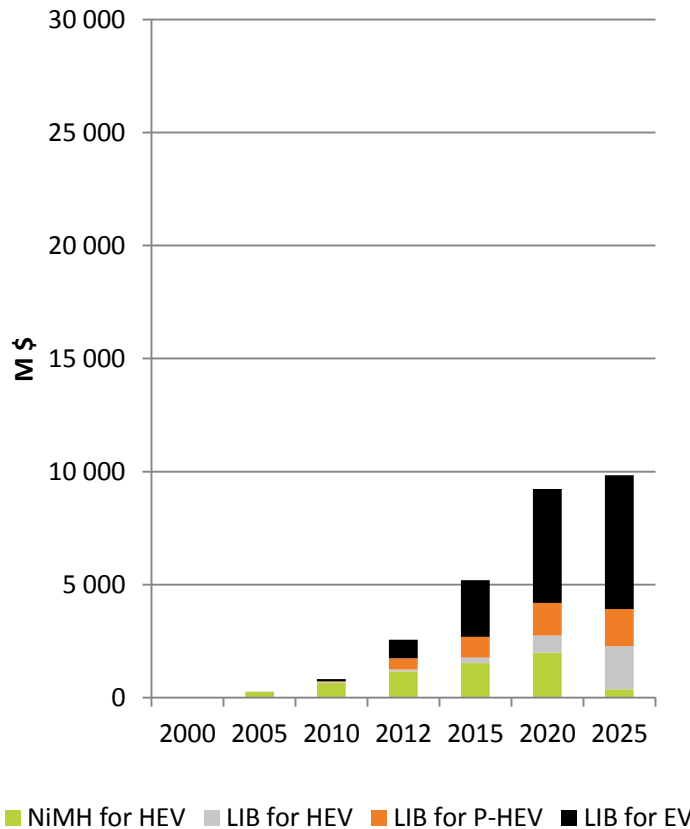


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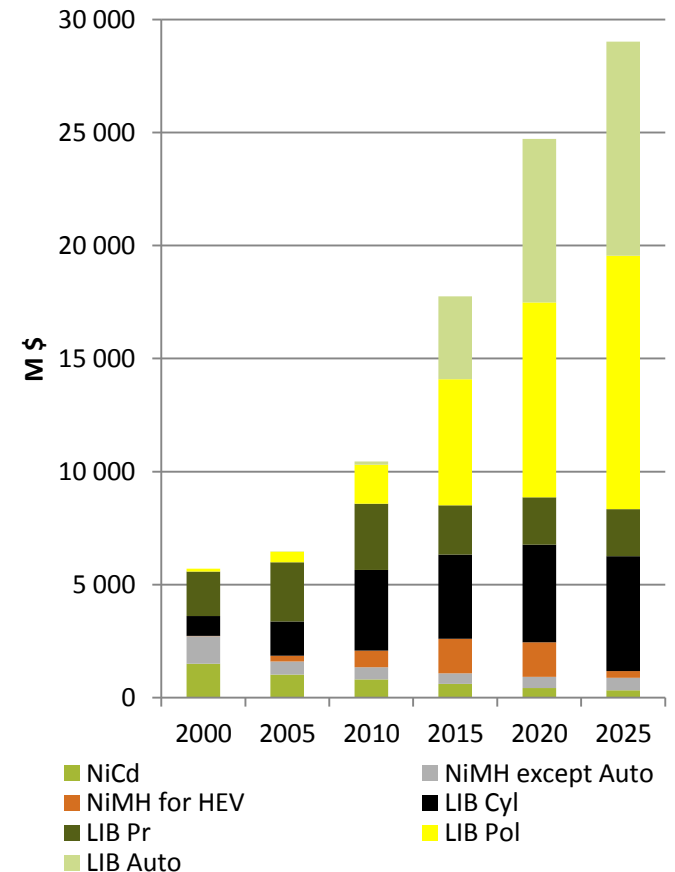
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RECHARGEABLE BATTERY MARKET 2000 – 2025

Rechargeable battery market,
M\$ for x-EV 2000-2025 (cell level)



Rechargeable battery market,
M\$, 2000-2025 (cell level)



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CONTACT

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

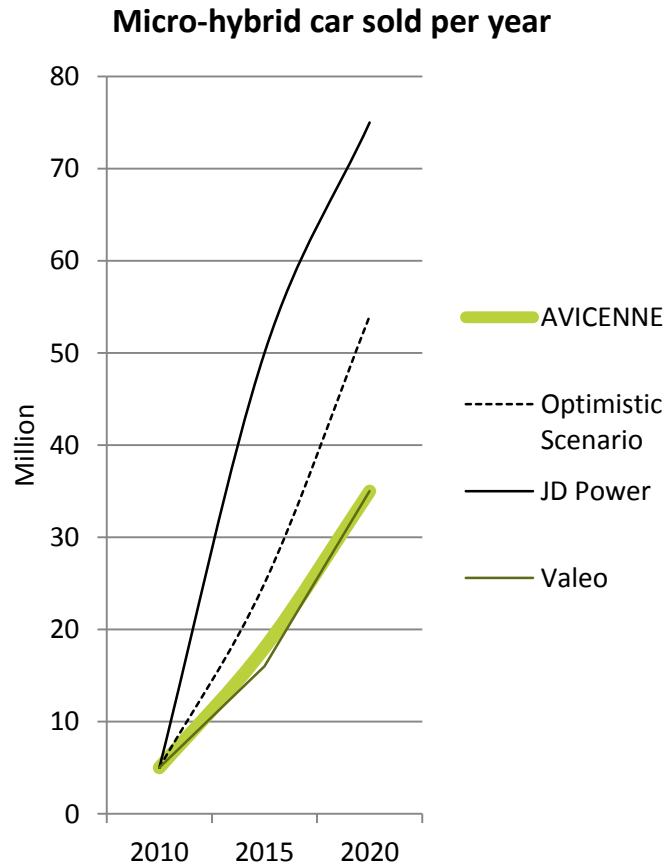


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35 MILLION MICRO-HYBRIDS CAR IN 2020

Micro-hybrids car market 2010-2020



Micro-hybrid batteries

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

Advantages of micro-hybrid compare to HEV

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

	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

The worldwide Battery market 2012-2025

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CONTACT

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



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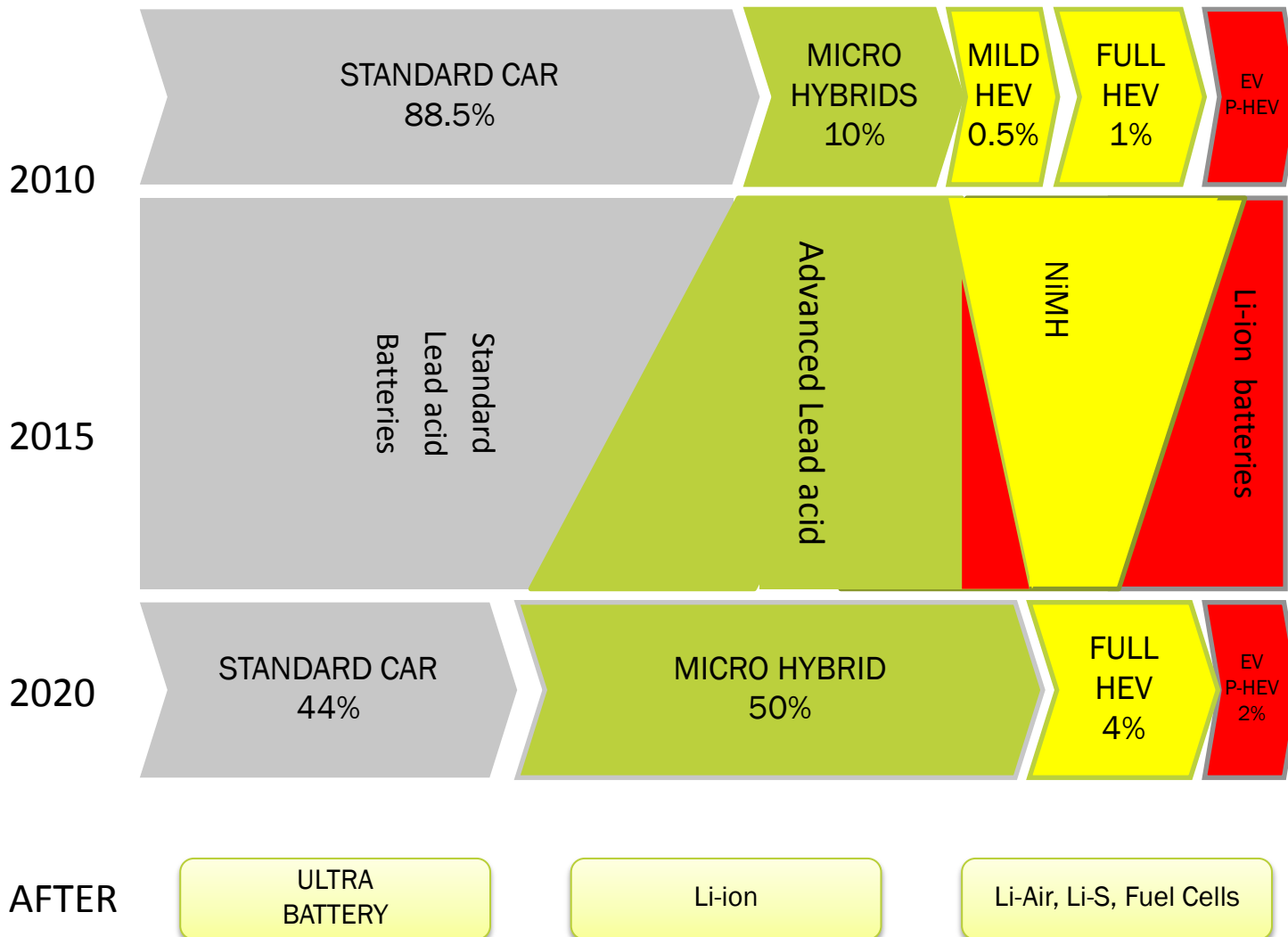
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HEV, P-HEV AND EV REALITY OF THE MARKET WILL BOOST MICRO HYBRID AND ADVANCED LEAD ACID BATTERIES



CONTACT

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



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CONTACT

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

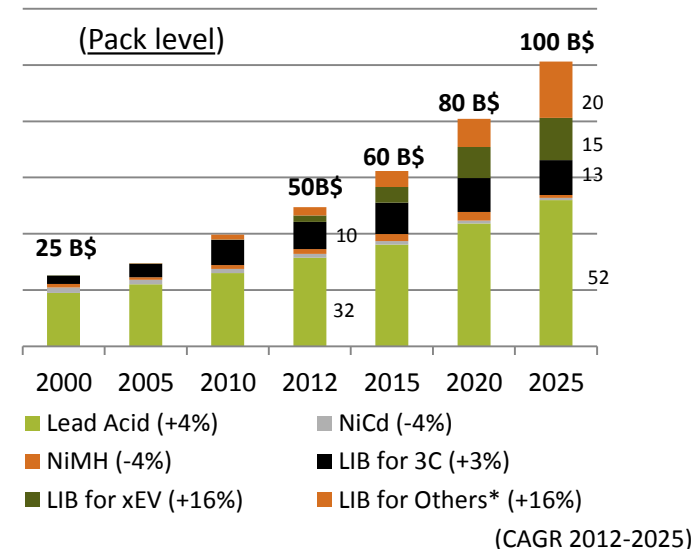
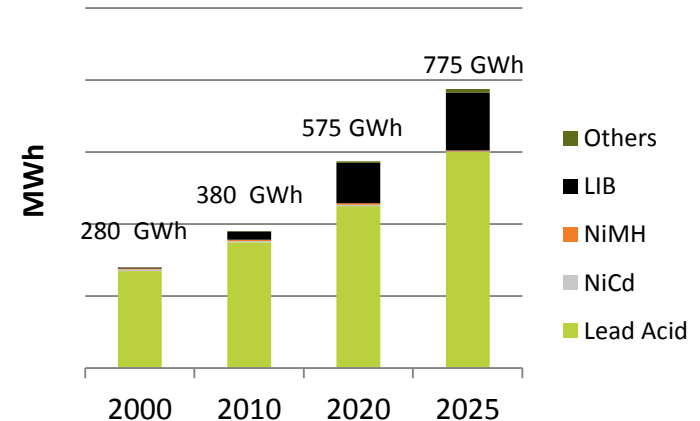
TAKEAWAYS

Battery Market 2010-2025

CAGR = +10%

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

RECHARGEABLE BATTERY MARKET WORLDWIDE 2000-2025



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

CONTACT

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

THANK YOU



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

