



avicenne
ENERGY

INFORMATION FOR GROWTH

www.avicenne.com



March 20th, 2017

CONTACT

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

The Rechargeable Battery Market and Main Trends 2016-2025

Christophe PILLOT

Director, AVICENNE ENERGY

Presentation Outline

- The rechargeable battery market in 2016
- The Li-ion battery value chain
- Li-ion battery material market
- Forecasts & conclusions

AGENDA

- The market in 2016 by technology, applications & battery suppliers
- Li-ion components market & value chain
 - Raw materials market
 - Supplier / customer relationship
 - Raw material cost
 - New entrants strategy
 - Raw material road map 2000-2030
- xEV market in 2016
- xEV forecasts up to 2025
- Industrial, stationary & ESS applications 2016-2025
- Rechargeable battery market forecasts up to 2025

The rechargeable battery
market 2016-2025

International
Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

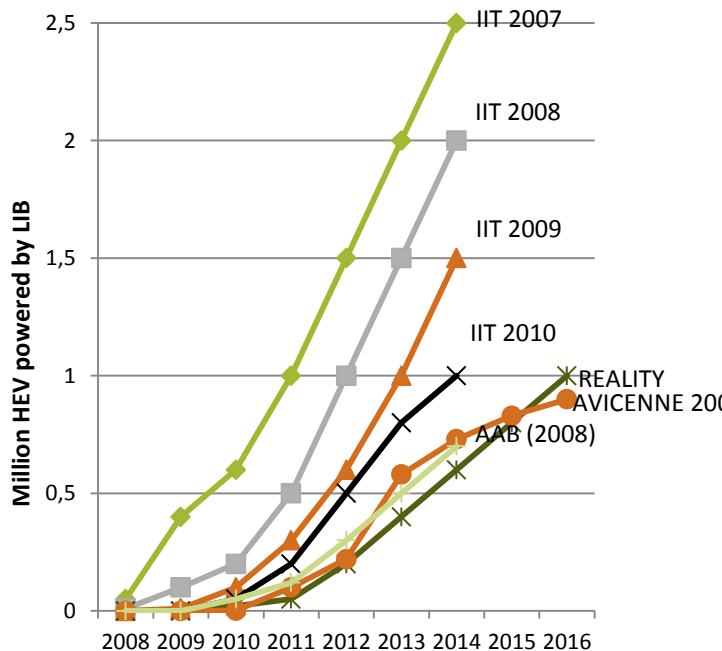
March 20th, 2017
Fort Lauderdale, FL, USA

CONTACT

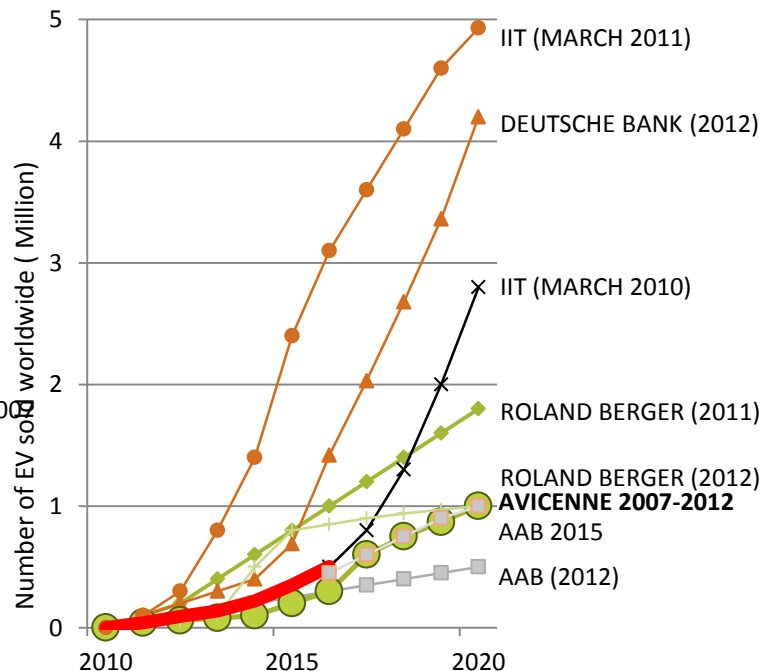
Christophe PILLOT
+ 33 1 47 78 46 00
c.pillot@avicenne.com

AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

HEV powered by Lithium ion battery
forecasts from 2008 to 2016



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



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

The rechargeable battery market 2016-2025

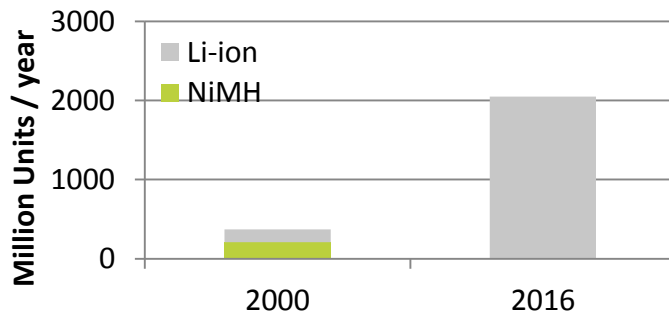
Your contacts
International Battery Seminar & Exhibit
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

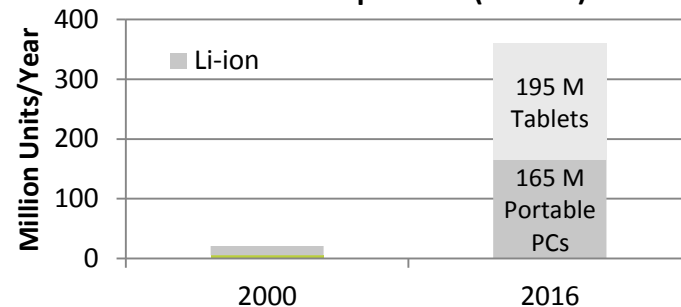
CONTACT
 Christophe PILLOT
 + 33 1 47 78 46 00
c.pillot@avicenne.com

THE BATTERY MARKET IS REALLY DYNAMIC

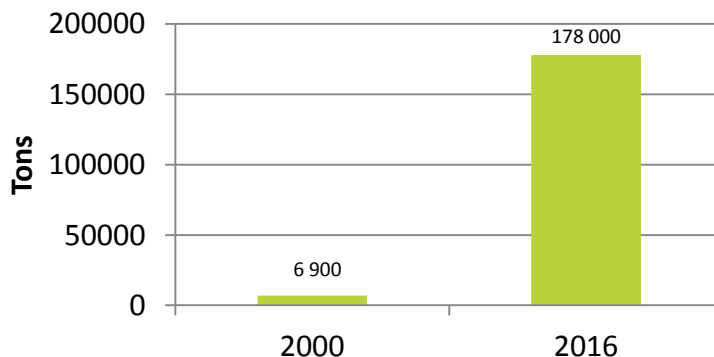
Cellular Phones sold per Year (Million)



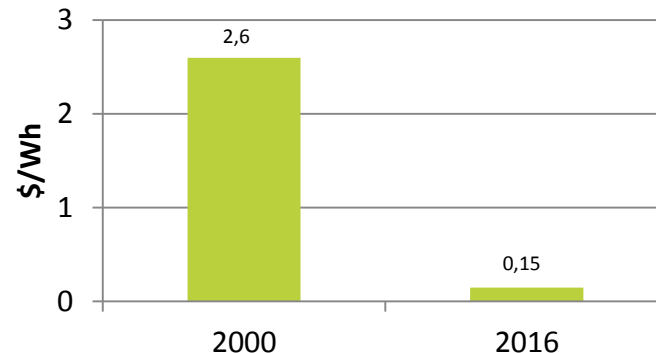
Portable PC sold per Year (Million)



Tons of cathode active materials



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



The rechargeable battery market 2016-2025



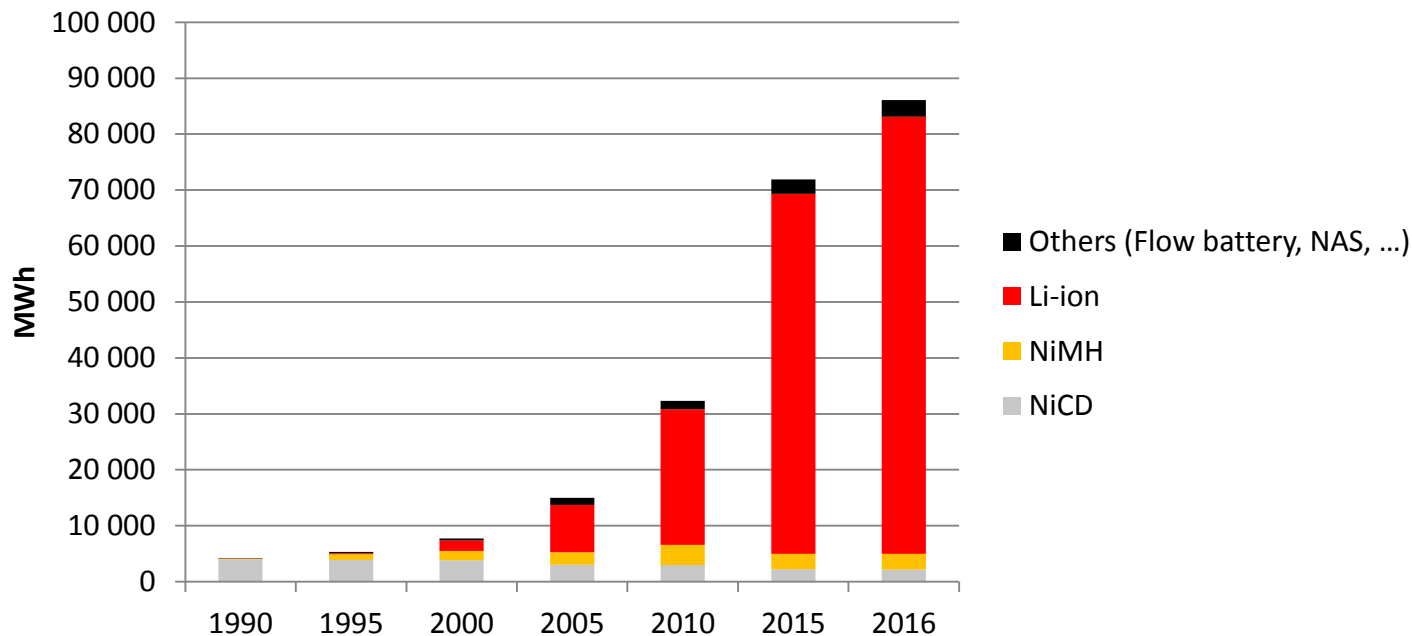
March 20th, 2017
 Fort Lauderdale, FL, USA

CONTACT

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

THE WORLDWIDE BATTERY MARKET 1990-2016

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



The rechargeable battery
market 2016-2025

International
Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

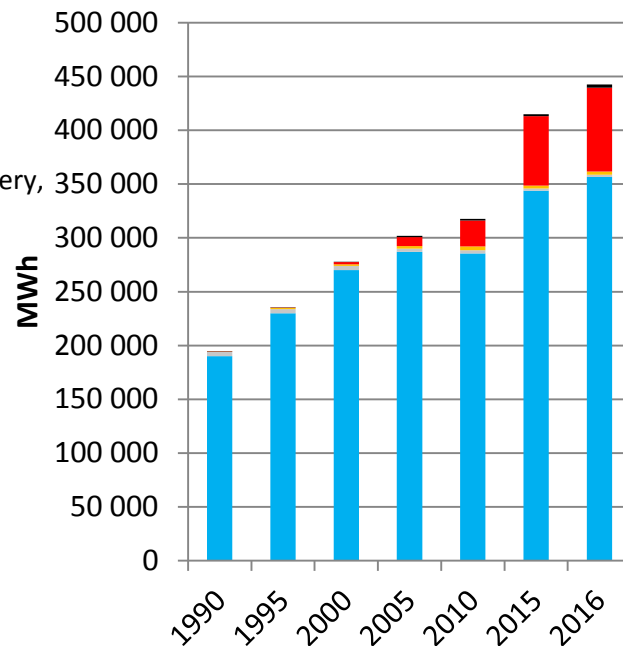
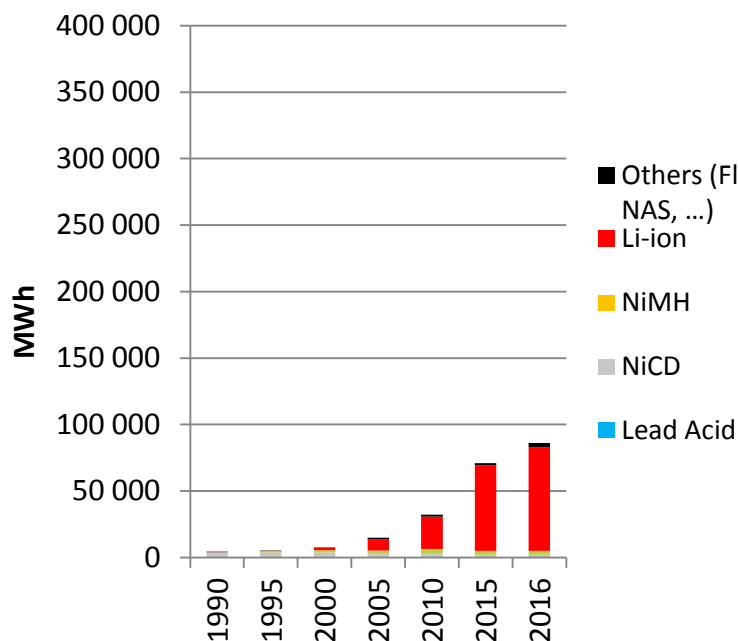
March 20th, 2017
Fort Lauderdale, FL, USA

CONTACT

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

THE WORLDWIDE BATTERY MARKET 1990-2016

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



The rechargeable battery market 2016-2025



March 20th, 2017
 Fort Lauderdale, FL, USA

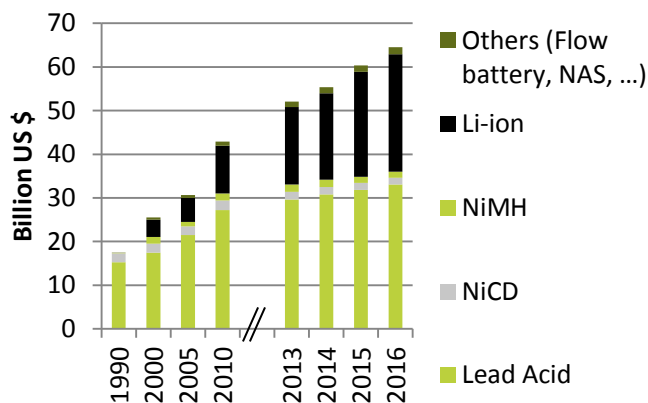
CONTACT

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

THE WORLDWIDE BATTERY MARKET 1990-2016

65 BILLION US\$ in 2016 – Pack level¹

5% AVERAGE GROWTH PER YEAR (2000-2016)



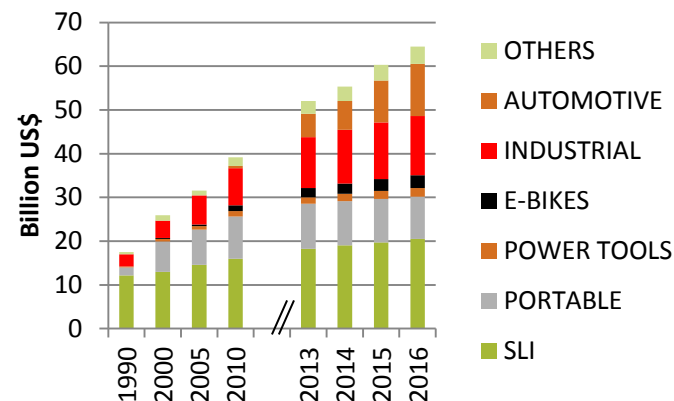
SLI: Start light and ignition batteries for cars, truck, moto, boat etc...

PORTABLE: consumer electronics (cellular, portable PCs, tablets, Camera, ...), data collection & handy terminals,

POWER Tools: power tools but also gardening tools

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

Source: AVICENNE ENERGY, 2017



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

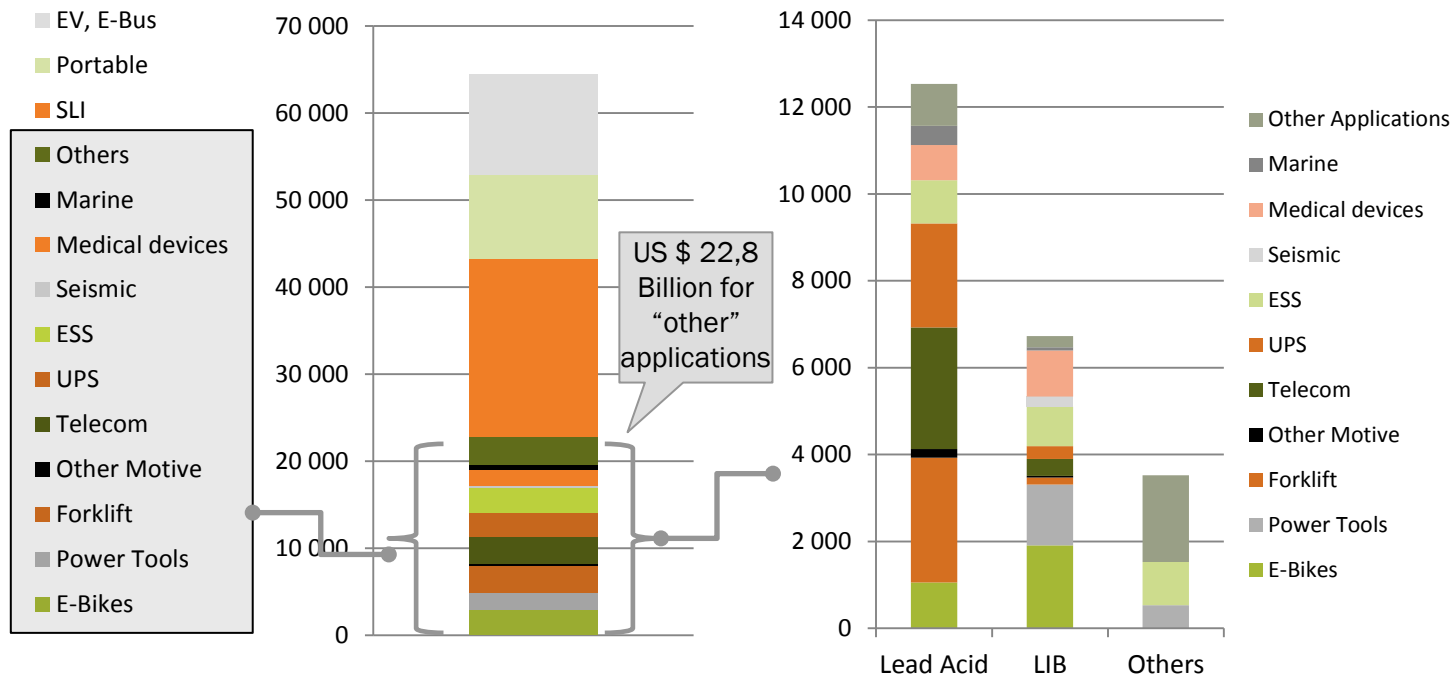
The rechargeable battery market 2016-2025

Two dates
International Battery
 SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & INDUSTRIAL APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

THE WORLDWIDE BATTERY MARKET IN 2016: US \$ 65 BILLION



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

Source: AVICENNE ENERGY, 2017

The rechargeable battery market 2016-2025

The ultimate
International Battery SEMINAR & EXHIBIT
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

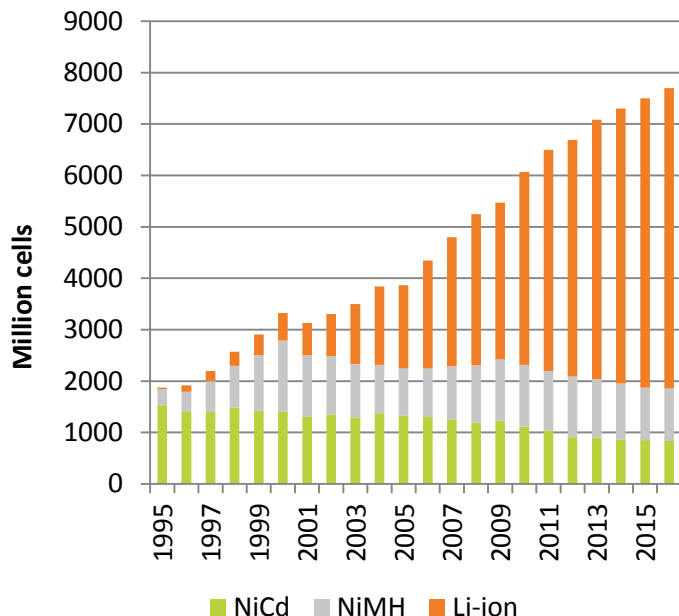
March 20th, 2017
 Fort Lauderdale, FL, USA

CONTACT

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

WORLDWIDE BATTERY SALES BY CHEMISTRY, UNITS, 1995-2015

The worldwide rechargeable battery market, Million cells, 1995-2016



Source: AVICENNE ENERGY, 2017

Which cell are we talking about?



Front Edge Technology, Inc



GS Yuasa International / Lithium Energy Japan

The rechargeable battery market 2016-2025

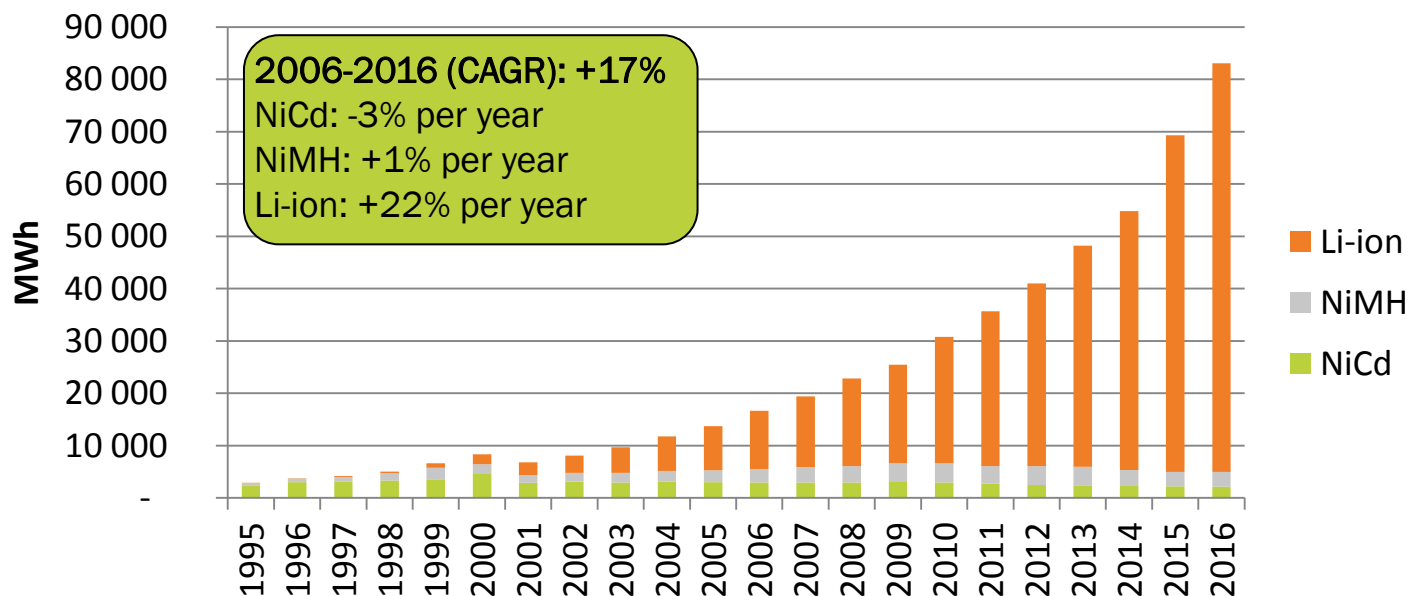


March 20th, 2017
 Fort Lauderdale, FL, USA

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

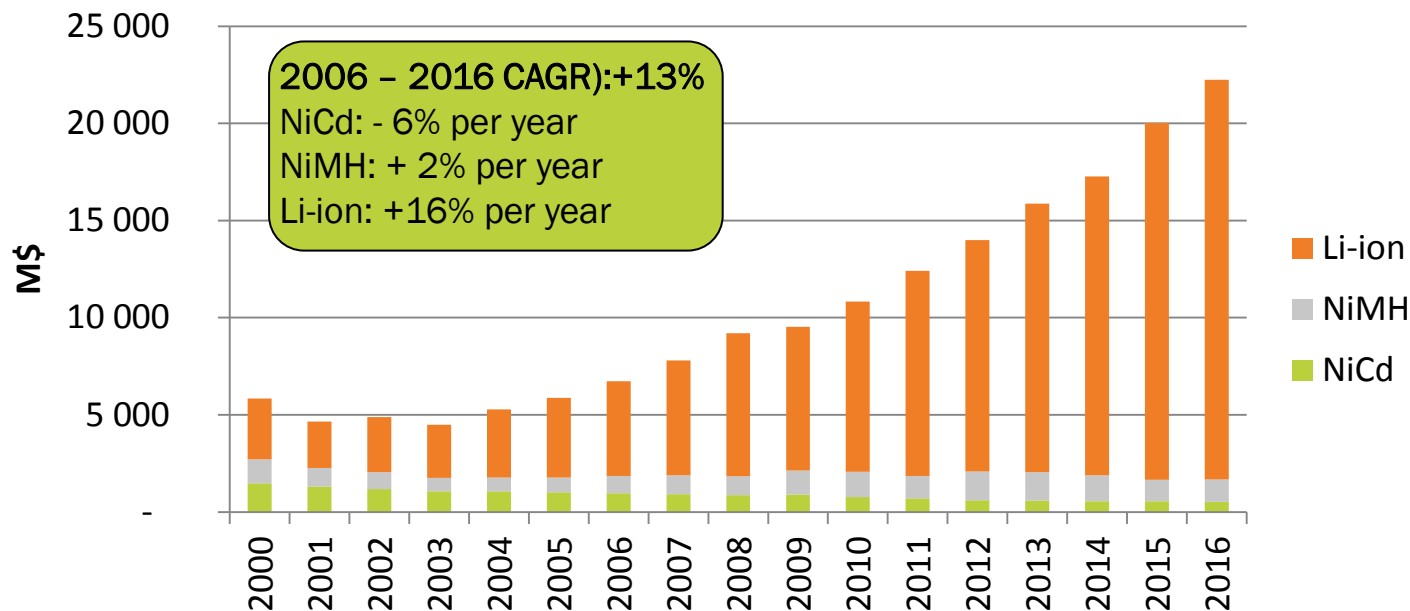
WORLDWIDE BATTERY SALES BY CHEMISTRY, MWh, 1995-2016

The worldwide rechargeable battery market, in volume, MWh, 1995-2016



WORLDWIDE BATTERY SALES BY CHEMISTRY, M\$, 1995-2016

The worldwide rechargeable battery market, in value, M\$, 1995-2016 (1)



(1) Cell level

Source: AVICENNE ENERGY, 2017

The rechargeable battery
market 2016-2025

THE SEMINAR
**International
Battery SEMINAR & EXHIBIT**
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & INDUSTRIAL APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

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

EACH BATTERY TECHNOLOGY HAS ITS SPECIFIC ABSOLUTE ADVANTAGES

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

Source: AVICENNE ENERGY, 2017

The rechargeable battery
market 2016-2025

International
Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

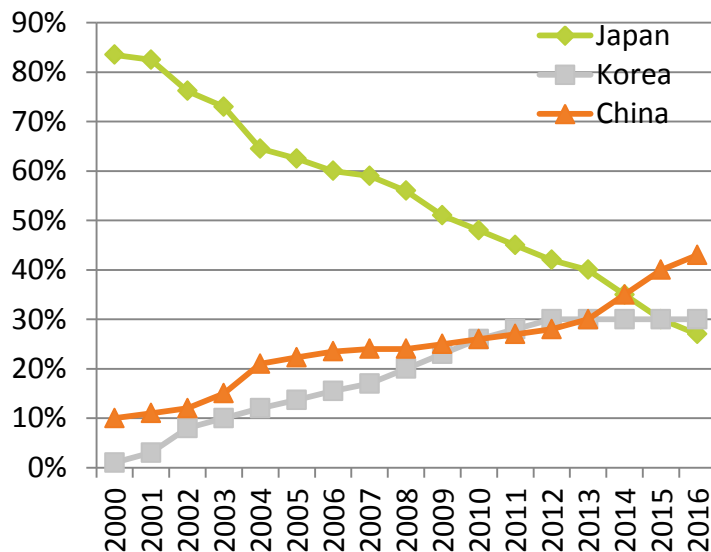
CONTACT

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

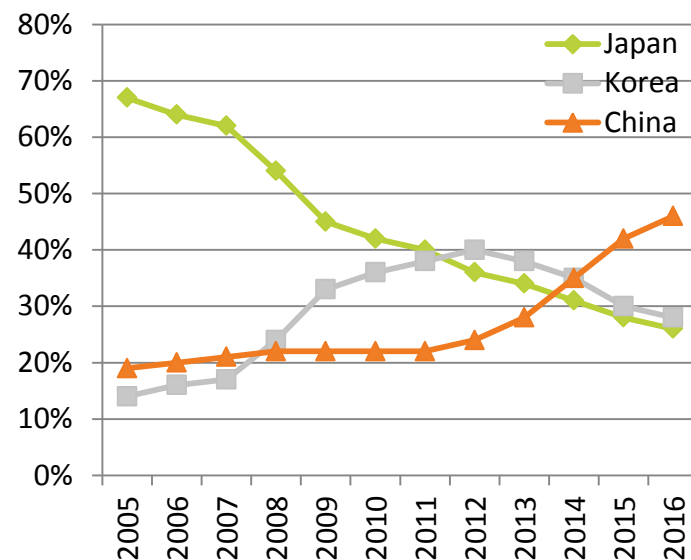
JAPANESE, CHINESE & KOREAN MARKET SHARE

Japanese market share (value) decreasing: from 84 % of the market in 2000 to < 30% in 2016

Battery⁽¹⁾ market by country



LIB market by country

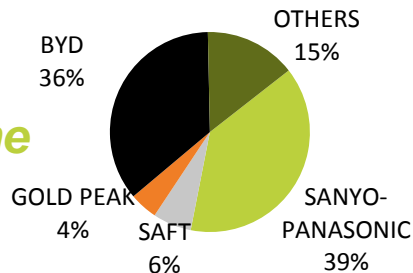


(1) Excluding lead acid batteries
Source: AVICENNE ENERGY, 2017

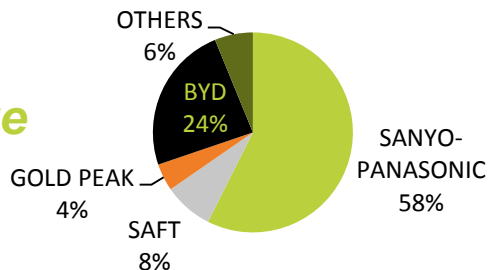
NICD BATTERY: MARKET SHARE IN 2016 IN VOLUME WORLDWIDE

The worldwide NiCd battery market Company market share in 2016 in volume – 830 M cells

In volume



In value



SANYO-PANASONIC is leading

Companies	Million cells
SANYO-PANASONIC	320
SAFT	50
GOLD PEAK	40
BYD	300
OTHERS	120
TOTAL	830



Fumio Ohtsubo
 (Panasonic) &
 Seiichiro Sano
 (Sanyo)
 January 8th,
 2012

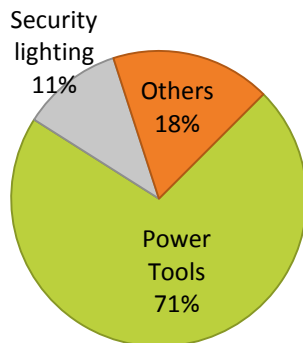
NICD IN 2016

MAIN APPLICATION: POWER TOOLS

830 M cells – 2250 MWh

526 M\$¹

**NiCd by application worldwide, %
in value, 2015**



Note:

¹ Portable applications, power tools and emergency lighting only:
industrial application as well as energy storage are excluded

Source: AVICENNE ENERGY, 2017

CAGR 2006/2016

-3% per year in volume

-6% per year in value

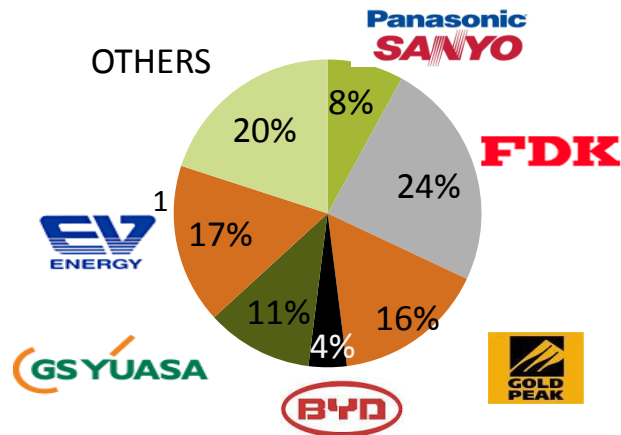
- 🔧 All the applications are decreasing
- 🔧 Competition with NiMH & Li-ion
- 🔧 New application (?)
 - 🔧 Energy storage



ABB Inc., Fairbanks, Alaska, 27 MW/15 minutes

NIMH BATTERY: MARKET SHARE IN 2016 WORLDWIDE

The worldwide NiMH battery market Company market share in 2016 in volume – 1020 M cells



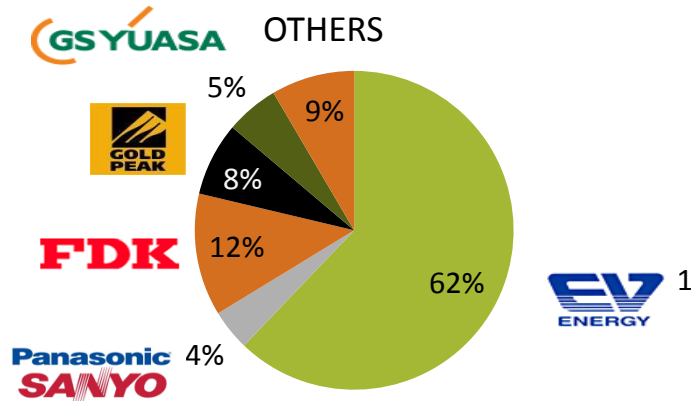
Note:

¹ PEVE: Primearth EV Energy (PEVE) The company was known as Panasonic EV Energy Co until 2 June 2010. The company was formed in 1996 as a joint venture between Toyota and Panasonic, with Panasonic holding 60% of the capital. Panasonic sold 40.5% of the company to Toyota. PEVE is the supplier of the NiMH battery packs for Toyota's hybrids, as well as for Honda (Civic hybrid and first generation Insight) hybrids. The company also provides the NiMH prismatic battery modules for the General Motors

² Japan's Sanyo Electric Co sold part of its battery operations to FDK Corp a Fujitsu Ltd unit, for 6.4 billion yen (\$70 million) to satisfy antitrust regulators ahead of its planned takeover by Panasonic Corp at the end of 2009.

Source: AVICENNE ENERGY, 2016

The worldwide NiMH battery market Company market share in 2016 in value – 1150 M\$



Note: Market in value at the cell level – 1,45 B\$ at the pack level

NIMH IN 2016

MAIN APPLICATION: HYBRID VEHICLES

1 020 M cells – 2 700 MWh

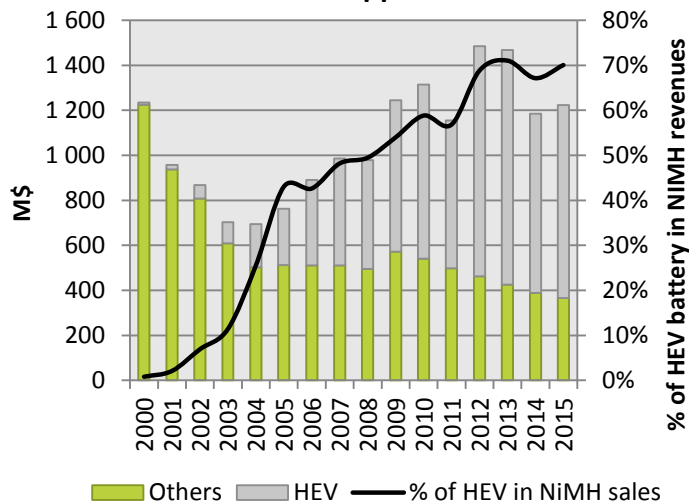
1.15 B\$(¹)

CAGR 2006/2016

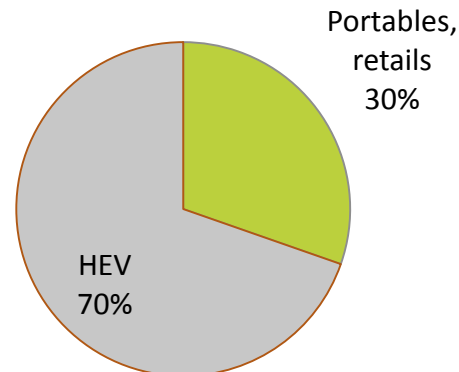
+2% per year in Volume

+2% per year in value

**NiMH battery market worldwide in value
% for HEV application**



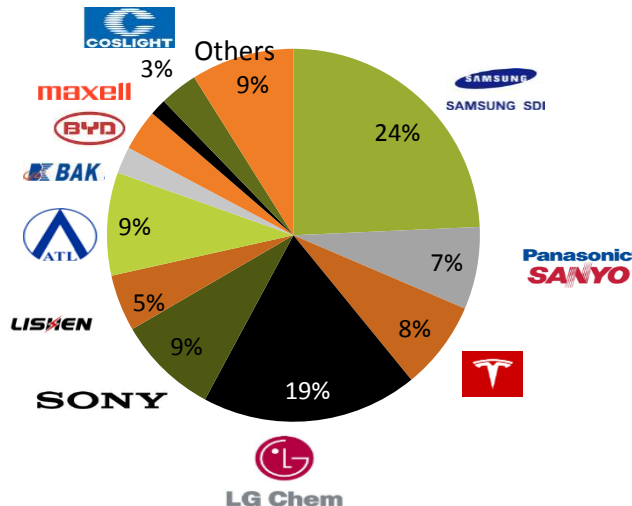
**NiMH battery by applications,
worldwide, % in value, 2016**



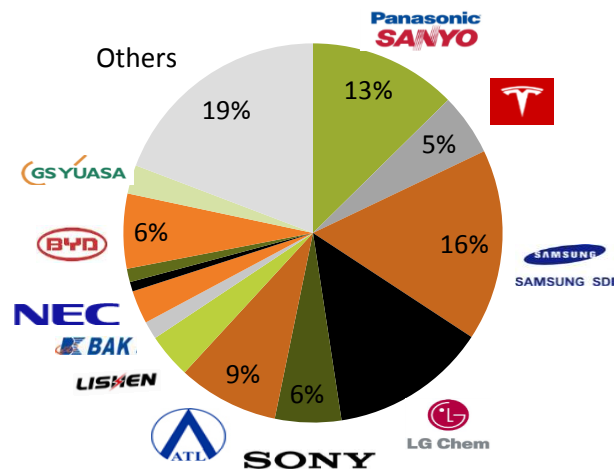
(1) Cell based market – 1,45 B\$ at the pack level
 Source: AVICENNE ENERGY, 2016

LI-ION BATTERY: MARKET SHARE IN 2015/2016 WORLDWIDE

The worldwide Li-ion battery market
 Company market share in 2016 in volume
 (small cells only) 5675 M cells



The worldwide Li-ion battery market
 Company market share in 2015 in value⁽¹⁾
 – 18,4 B\$ (Estimated at B\$ 20,6 in 2016)



Others for Small cells: Chinese suppliers like First new Energy, Zhuoneng, Tenpower, DLG... For Auto market: CALB, Microvast, Guoxuan, Optimum Nano, Wanxiang, and many others

(1) Cell level. LIB battery pack market: > 20 B\$ in 2015 and 24,4 B\$ estimated for 2016

Source: AVICENNE ENERGY Analyses 2016

The rechargeable battery market 2016-2025

The date:
International Battery
 SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

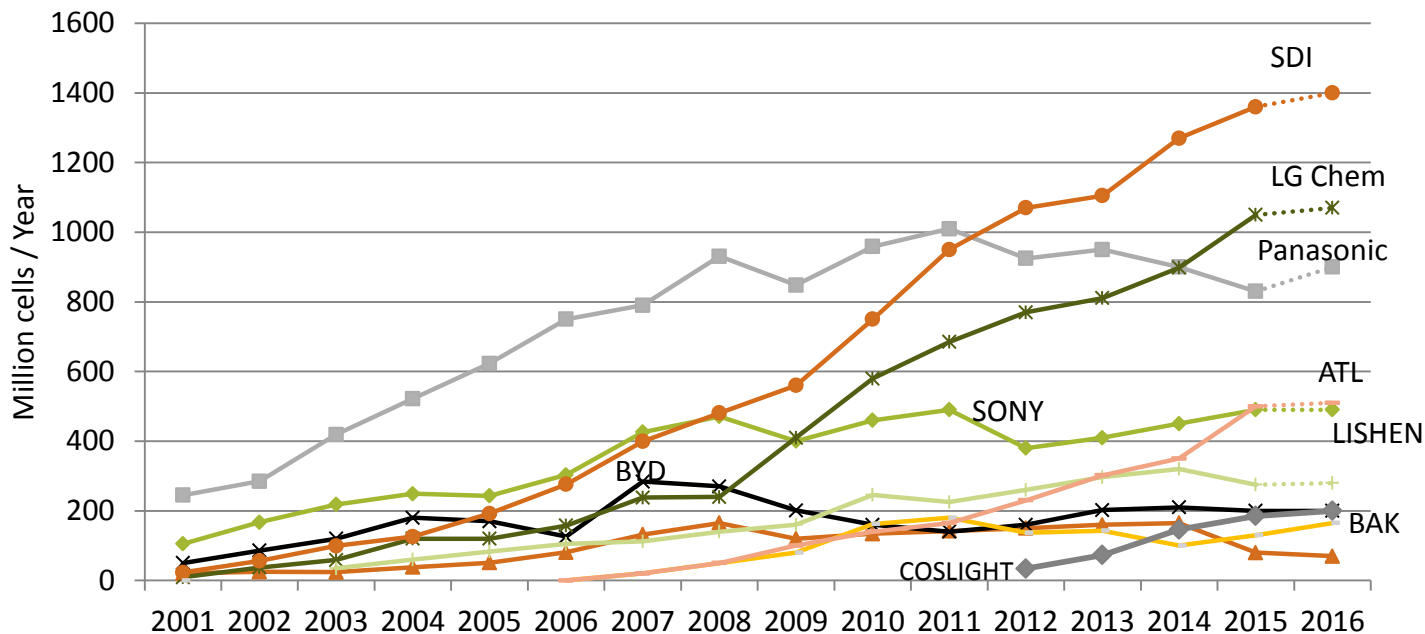
March 20th, 2017
 Fort Lauderdale, FL, USA

CONTACT

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

MAJOR LI-ION MANUFACTURERS YEARLY PRODUCTION 2001-2016

Samsung SDI & LG Chem are growing very fast



Panasonic acquired Sanyo in Dec 2009

Source: AVICENNE ENERGY Analyses 2016

The rechargeable battery market 2016-2025

The Battery
 International
 Battery SEMINAR & EXHIBIT
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

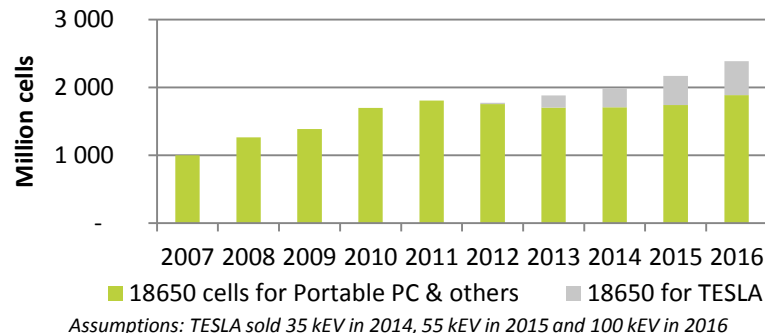
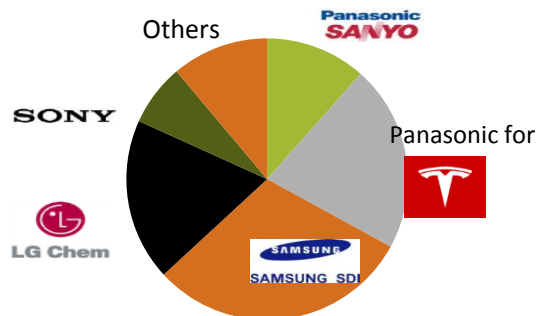
CONTACT
 Christophe PILLOT
 + 33 1 47 78 46 00
c.pillot@avicenne.com

CYLINDRICAL LI-ION BATTERY (SMALL CELLS)

In 2016, TESLA demand represent more than 20% of the Cylindrical cells demand

Cylindrical LIB market Company market share in 2016 in volume: 2330 Million cells (+6%)

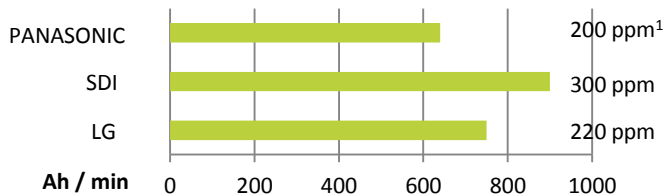
SANYO-PANASONIC, SDI & LG will share the market



Key success factor

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

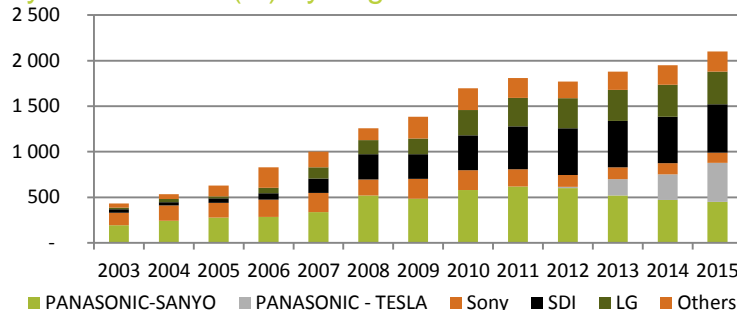
Production Speed: 18650 – 2,8Ah cells



Note: ¹ ppm: piece per minutes

Source: Interviews with LG, SAMSUNG, SANYO-PANASONIC, AVICENNE Energy Analyses 2016

Cylindrical cells (M) by mfg.



The rechargeable battery market 2016-2025

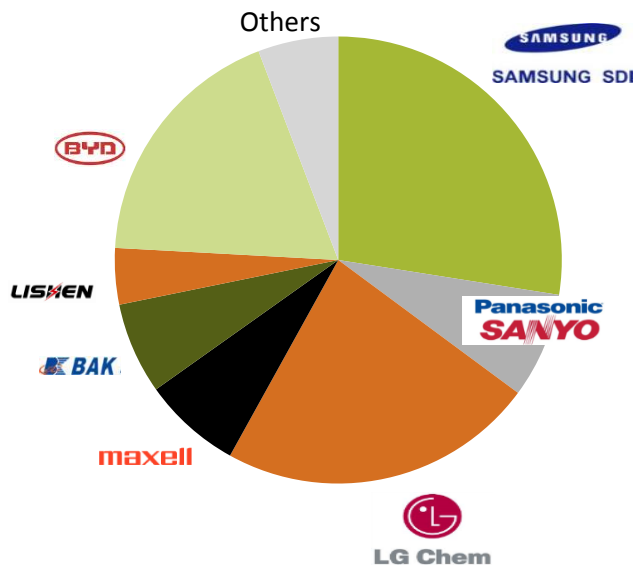
The seminar
International Battery SEMINAR & EXHIBIT
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

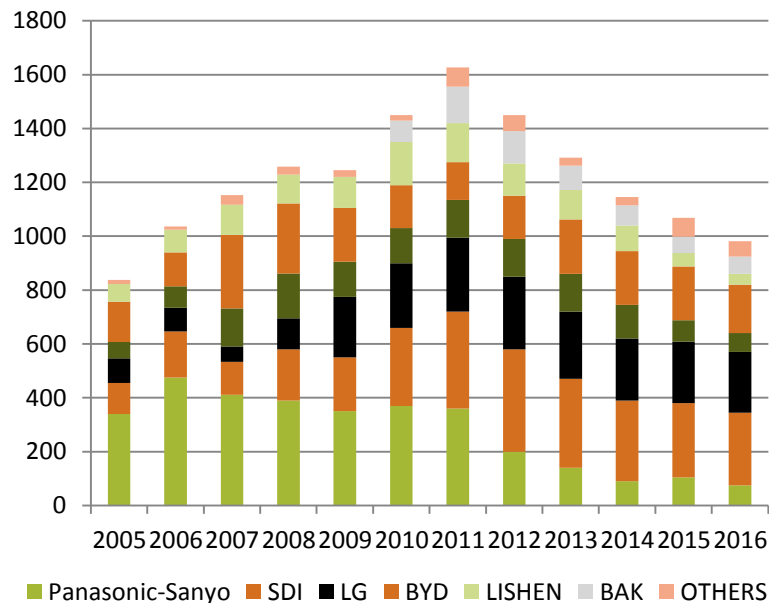
CONTACT
 Christophe PILLOT
 + 33 1 47 78 46 00
c.pillot@avicenne.com

PRISMATIC LI-ION BATTERY (SMALL CELLS)

Prismatic LIB market Company
 market share in 2016 in volume:
 980 Million cells (-8%)



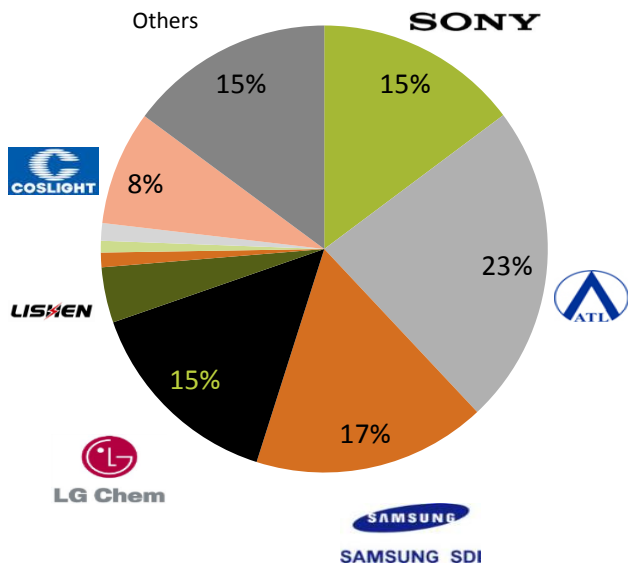
Prismatic cells (M) by Mfg. :
 SAMSUNG is leading



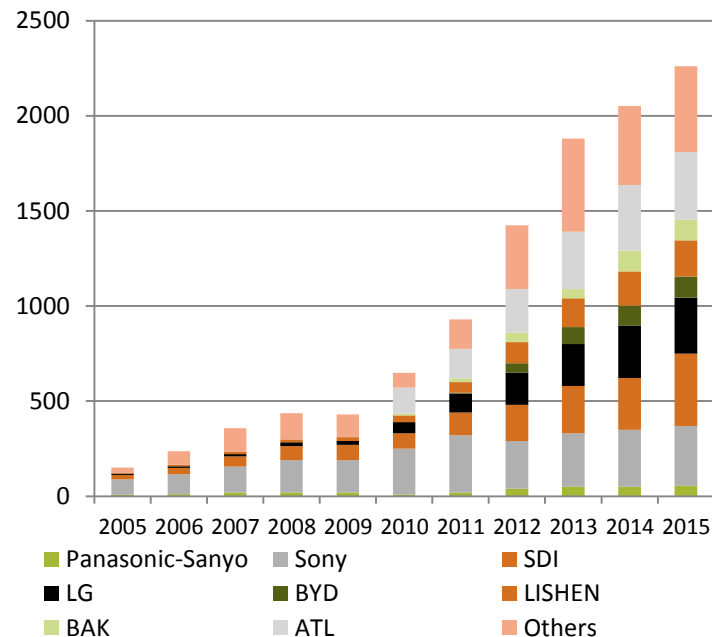
Source: AVICENNE ENERGY Analyses 2016

LI-LAMINATE BATTERY (SMALL CELLS)

Laminate battery market Company
 market share in 2016 in volume:
 2 350 Million cells (+7%)



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



LI-ION IN 2016 - MAIN APPLICATIONS

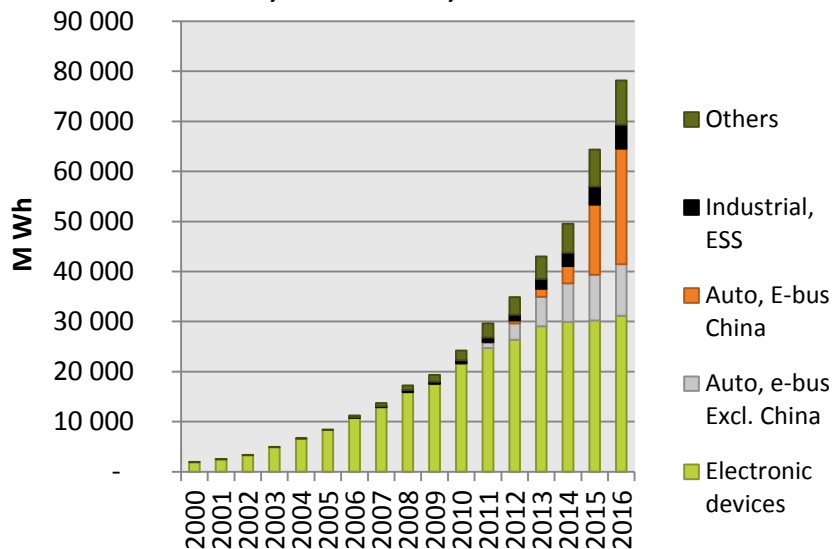
+78 000 MWh - 20 600 M\$ (1)

5 675 M small cells

CAGR 2006/2016

+22 % per year in Volume

Li-ion Battery sales, MWh, Worldwide, 2000-2015

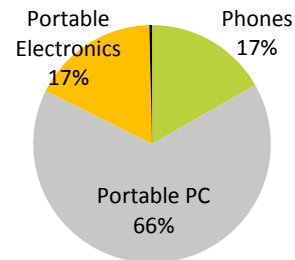


(1) Cell level

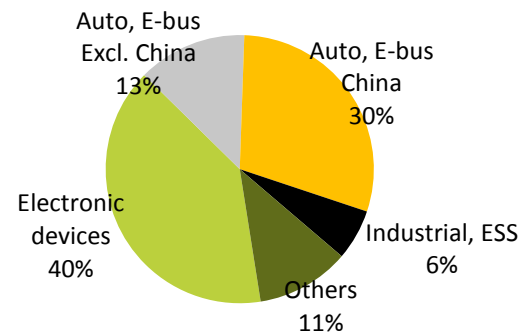
Others: medical devices, power tools, gardening tools, e-bikes...

Source: AVICENNE Energy 2016

2000: < 2GWh



2016: 78 GWh



The rechargeable battery
market 2016-2025



March 20th, 2017
Fort Lauderdale, FL, USA

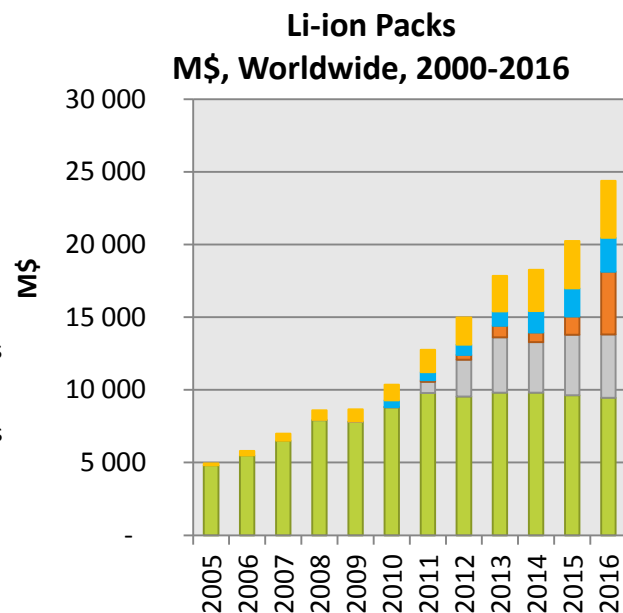
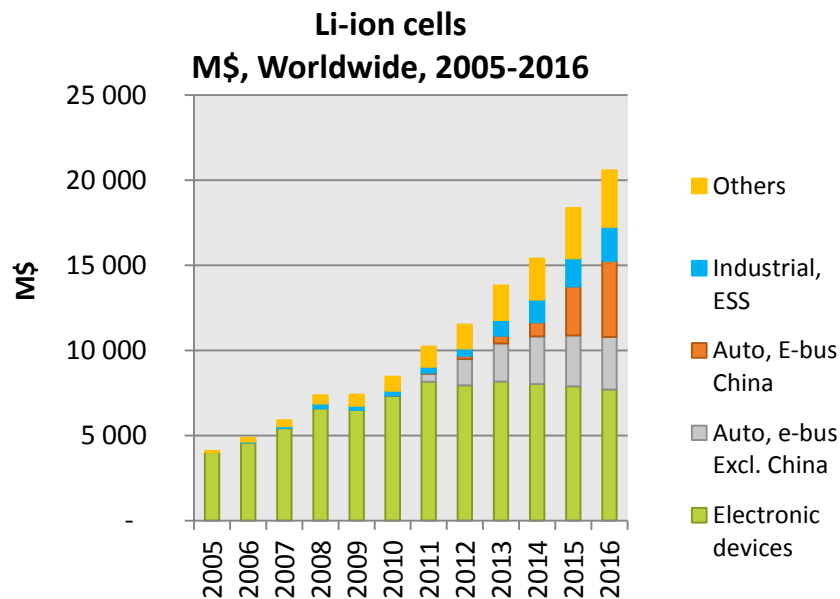
CONTACT

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

LI-ION IN 2016 - MAIN APPLICATIONS

+78 000 MWh - 20 600 M\$ (1)
5 675 M small cells

CAGR 2006/2016
+22 % per year in Volume
Cell: +15,5% per year in value
Pack: +16% per year in value



Others: medical devices, power tools, gardening tools, e-bikes...

Source: AVICENNE Energy 2016

The rechargeable battery market 2016-2025

Your company
International Battery
 SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

CELLULAR PHONES MARKET

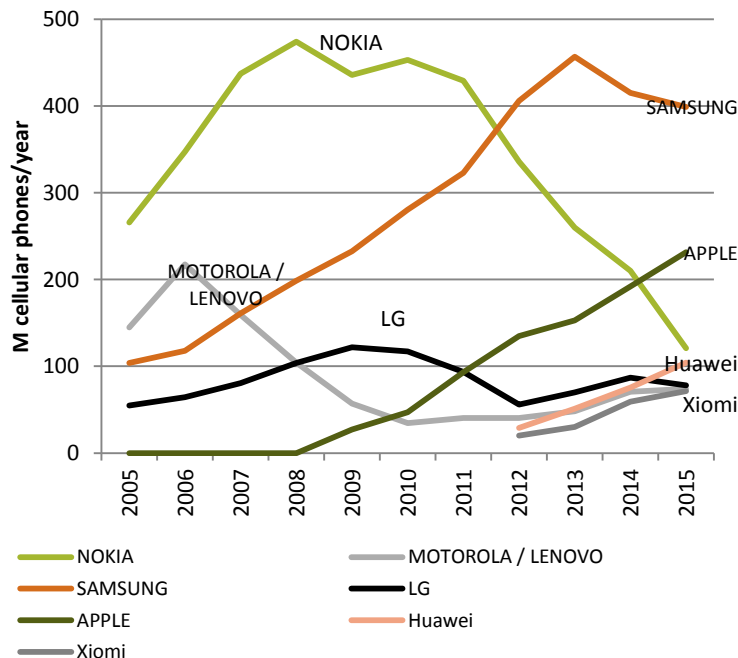
> 2 000 M LIB CELLS IN 2015



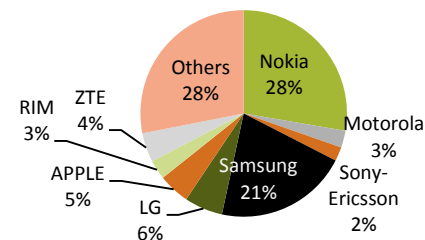
LIB cell format
(Volume) 2015

+2000 M cell phones sold in 2015 (+4% CAGR)

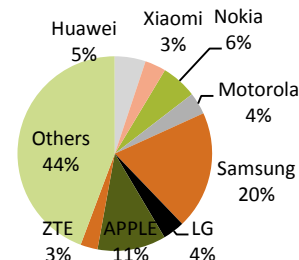
Samsung Galaxy & I-phone change the game



2012
1630 M Phones



2015
> 2000 M Phones



Source: AVICENNE Energy 2016

The rechargeable battery market 2016-2025

Your database
International Battery SEMINAR & EXHIBIT
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

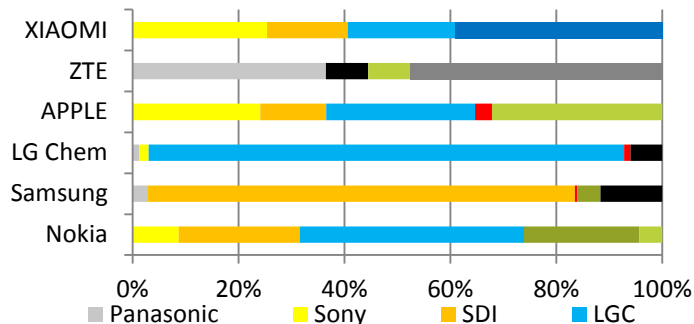
March 20th, 2017
 Fort Lauderdale, FL, USA

CONTACT

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

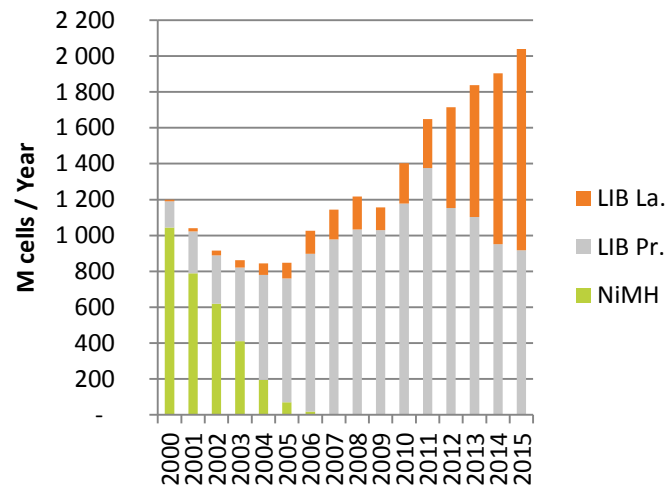
CELLULAR PHONES/LIB SUPPLIERS RELATIONSHIPS

2015 Cellular Phone makers / battery suppliers relation

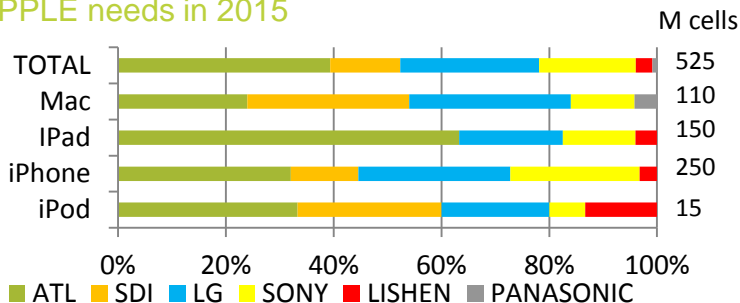


Smartphones / ie laminate LIB increasing

Battery market for cellular phones worldwide, 2000-2015, in Volume (M cells)



APPLE needs in 2015

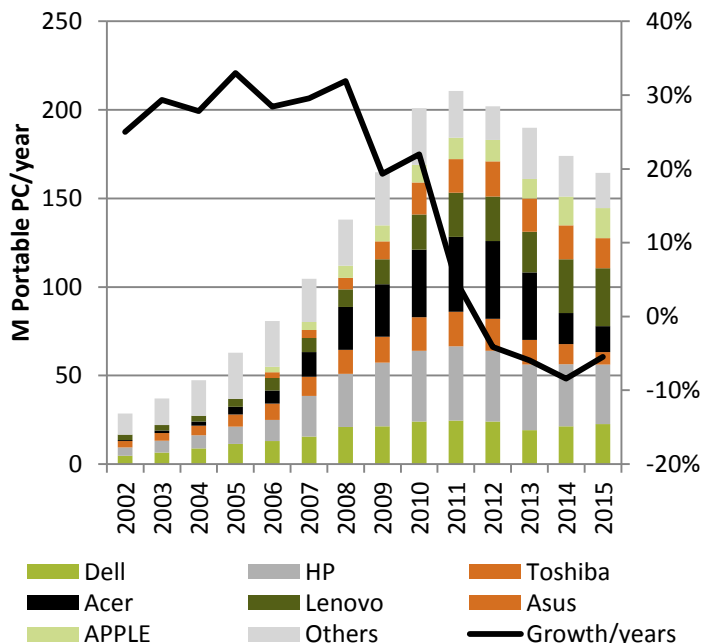


Source: AVICENNE Energy 2016

PORTABLE PC MARKET

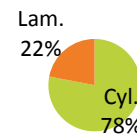
960 M LIB CELLS IN 2015

165 M portable PCs sold - 2014/2015: -5%



Note: Excluding Tablets & convertible or hybrid portable PC + tablets

Source: AVICENNE Energy 2016

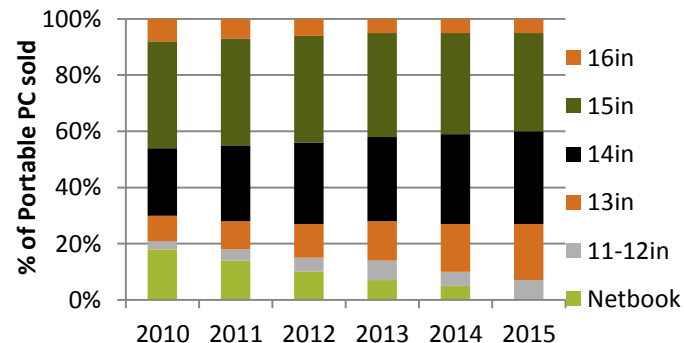


LIB cell format
(Volume) 2015

Market outlook 2015

- 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



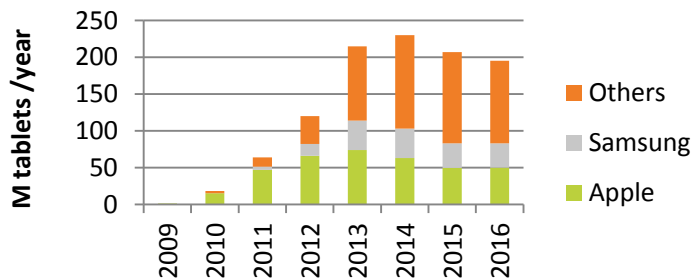
TABLET MARKET

> 500 M CELLS IN 2015

Lam.
100%

LIB cell format
(Volume) 2015

Tablets sold (Million) - Apple leadership



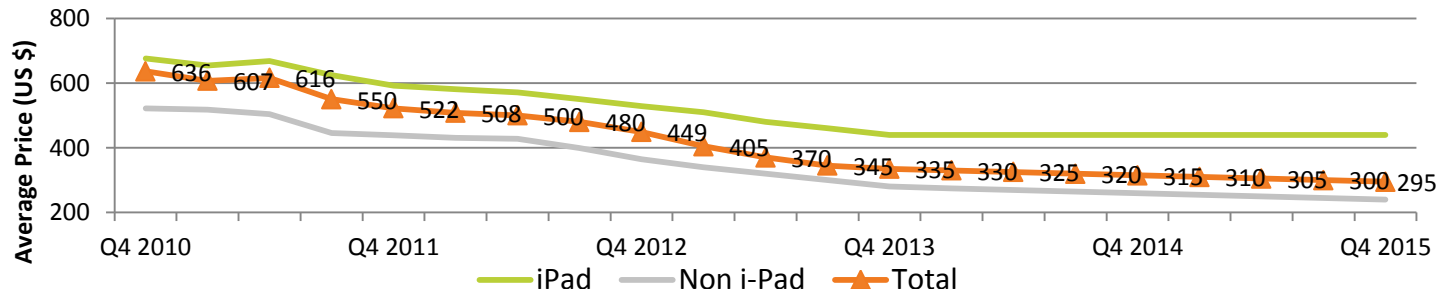
Source: Gartner, IDC, Display search

Others 2015: Asus 8 M, Lenovo 11 M, Amazon 5,2 M...

Market Outlook 2015

- Decrease in 2015 (-10%), and 2016 (-6%)
- Market driven by
 - mature market (77%)
 - consumer market (90%)
- Apple (27%), Samsung (17%), Asus (5%), Acer, Lenovo, Amazon are the key competitors
- Increasing part of convertible (Tablets+PC): 16,6 M in 2015 (8 % of the market)

ASP tablets drop From \$636 in Q4 2010 to < 300 \$ in Q4 2015



Source: AVICENNE Energy 2016

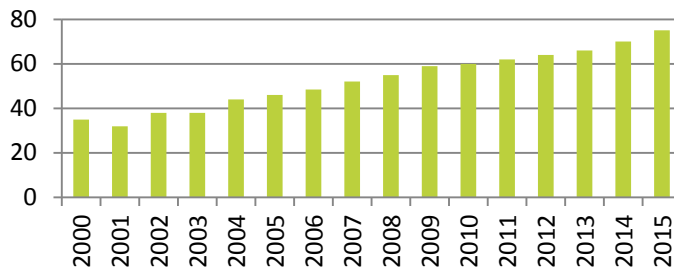
POWER TOOL MARKET LIB DEMAND IS GROWING

Cyl.;
100%

LIB cell format
(Volume) 2015

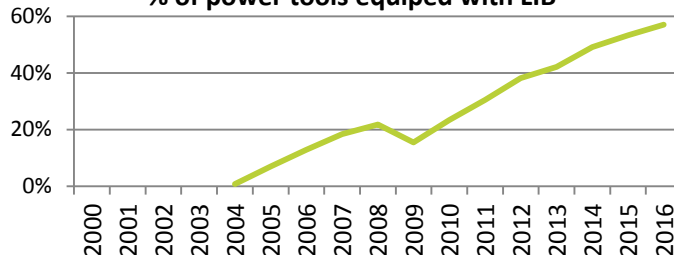
Power tools market is growing

Power Tools (Million/year)



LIB penetration in power tools

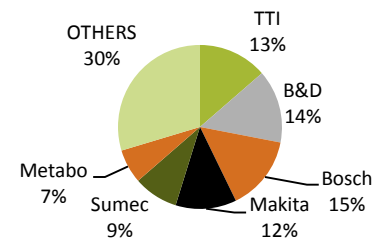
% of power tools equipped with LIB



Source: AVICENNE Energy 2016

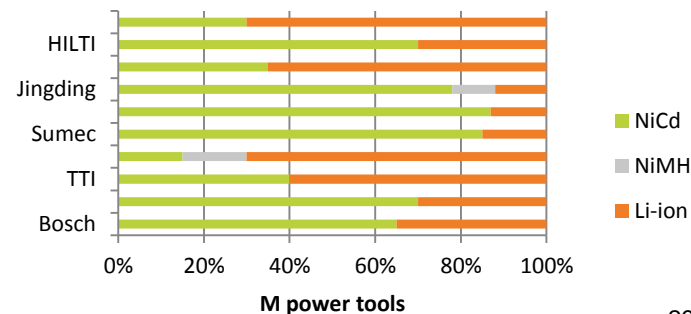
Power tools suppliers

Power tools maker market share (2015)



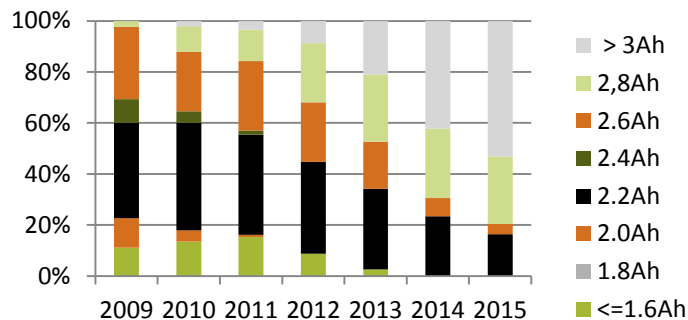
Others: Jingding (3.6 M), Panasonic (0.5 M), Hitachi (2.4 M), Hilti (2M)...

Power tools maker battery choice



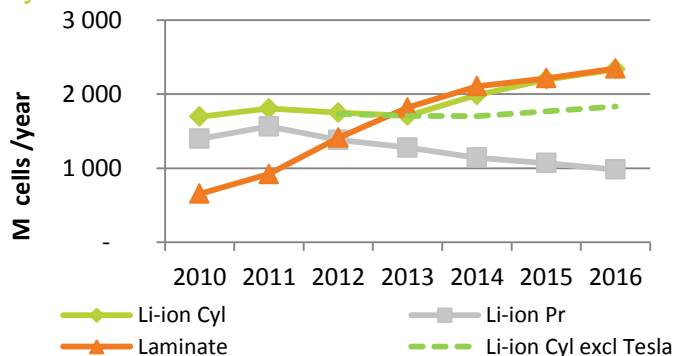
LIB BATTERY SHORT TERM TRENDS

18650 battery capacity*



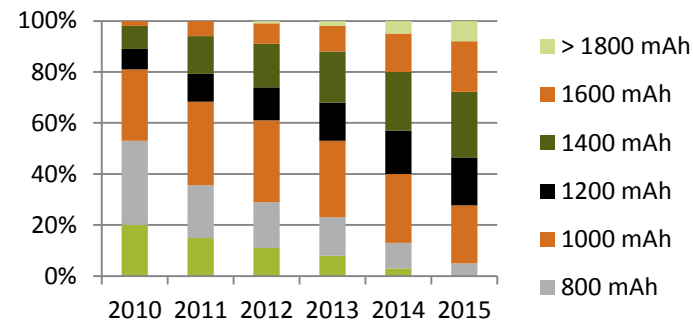
*1C rate or laptop type 18650 cells

Cylindrical/Prismatic/Laminates

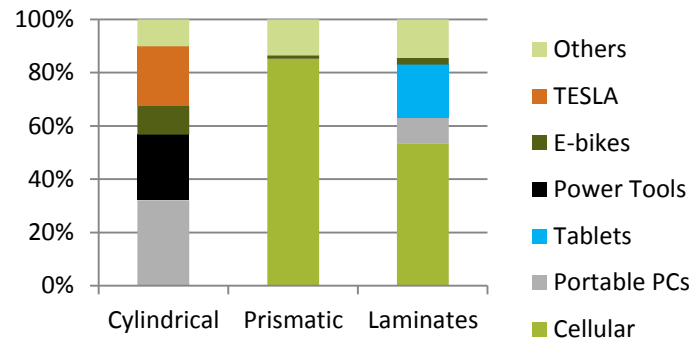


Li-ion cylindrical: "Tesla impact": 180 M cells in 2013, 300M in 2014, 430 M in 2015 and 600 M cells in 2016 (Avicenne Assumptions)

Cellular phones battery capacity

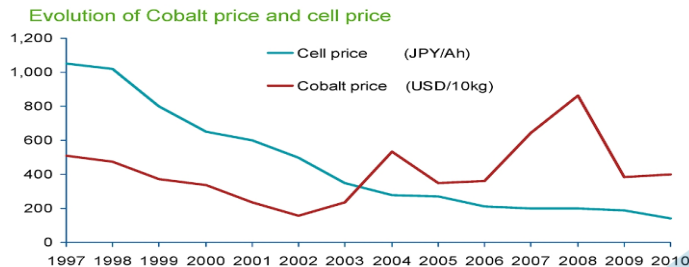


Cylindrical/Prismatic/Laminates in 2016



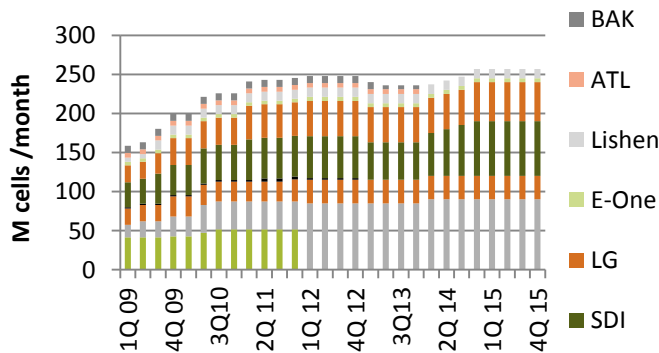
BATTERY PRICE IS DECREASING

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



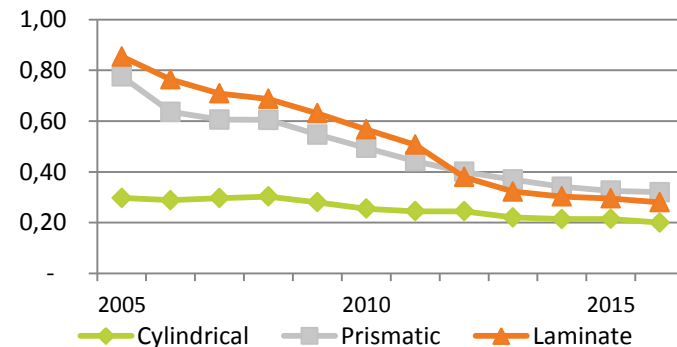
Source: UMICORE, march 2011

Cylindrical Production capacity 09/11: from 150 to 250 M cells/month

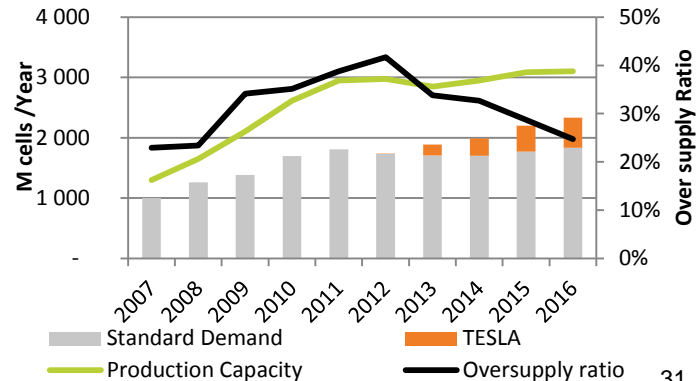


Source: AVICENNE Energy 2016

Average LIB cell price (\$/Wh)



18650 oversupply ratio is decreasing thanks to TESLA

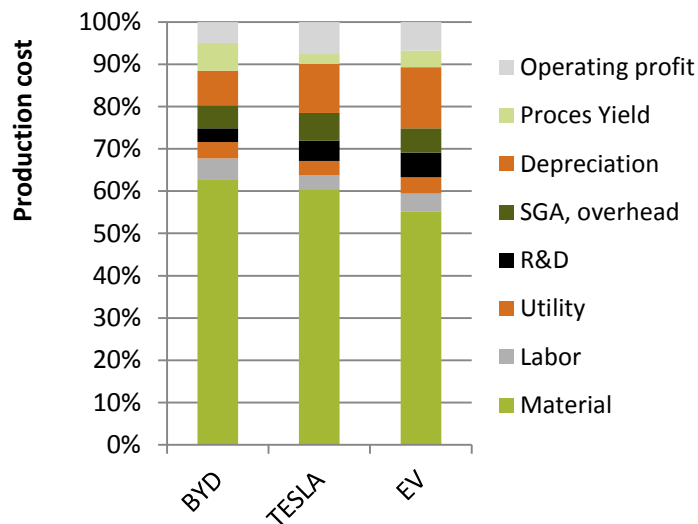


LIB: THE BIGGEST PART OF THE COST IS RAW MATERIALS

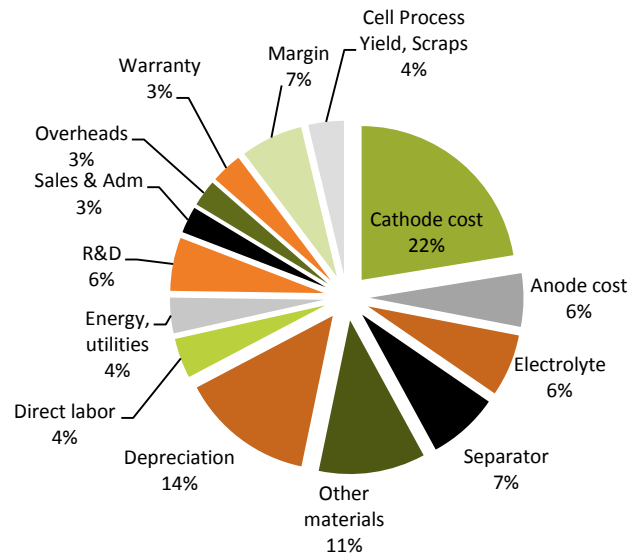
RAW MATERIALS ACCOUNT FOR 50 TO 70% OF LIB CELLS BUSINESS

RAW MATERIAL COST IMPACT DRASTICALLY ON THE BATTERY MAKERS PROFIT

**LIB Cost structure for TESLA & 40 Ah EV
pouch cell NMC**

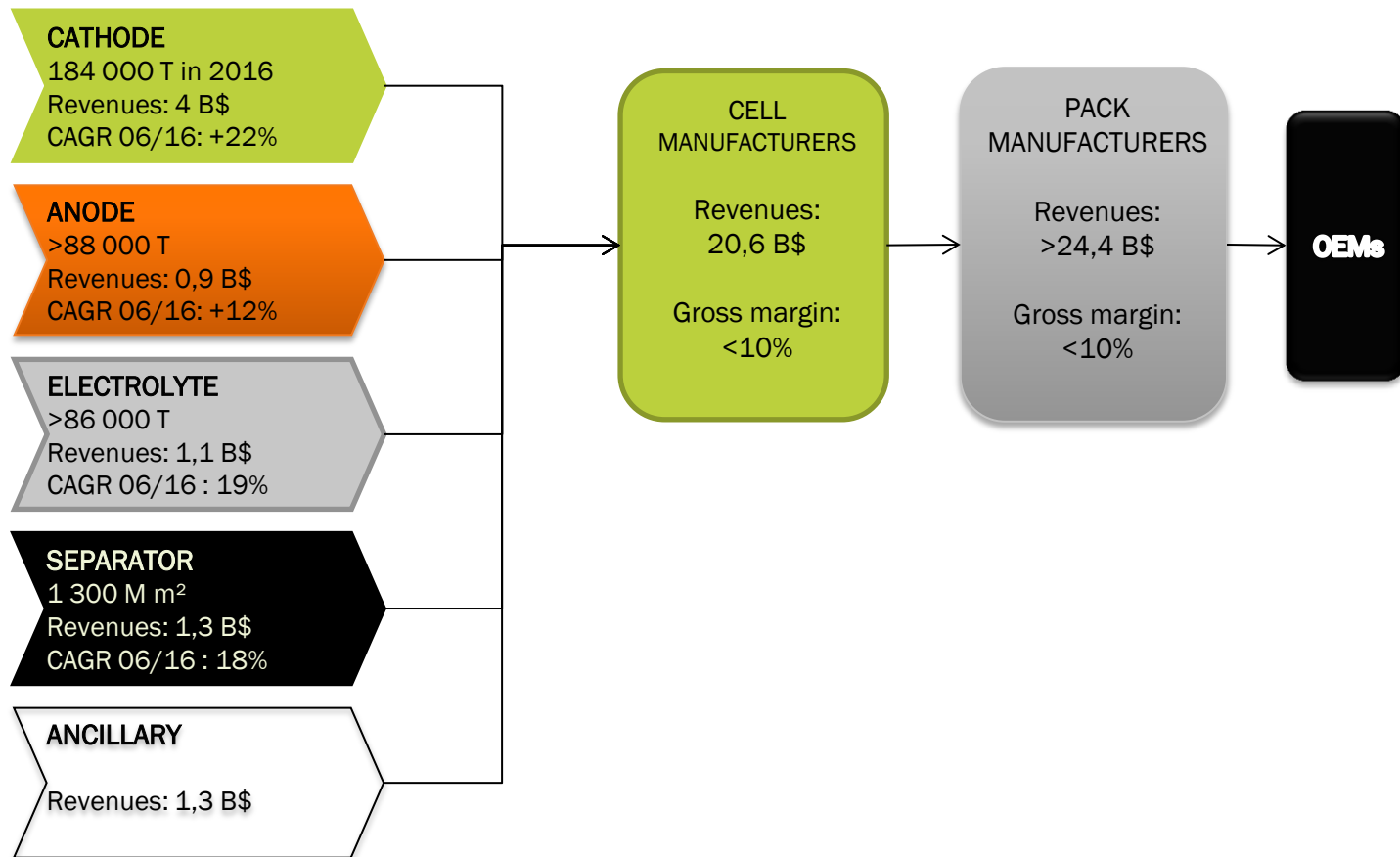


Average cost structure of Li-ion cell in 2016



Note: Average mix of cylindrical, prismatic & laminate cells
Sources: AVICENNE ENERGY 2017

LI-ION VALUE CHAIN – MARKET DEMAND

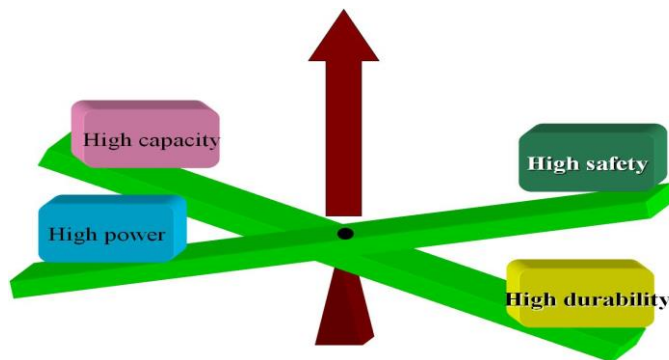


LIB CATHODE MATERIAL

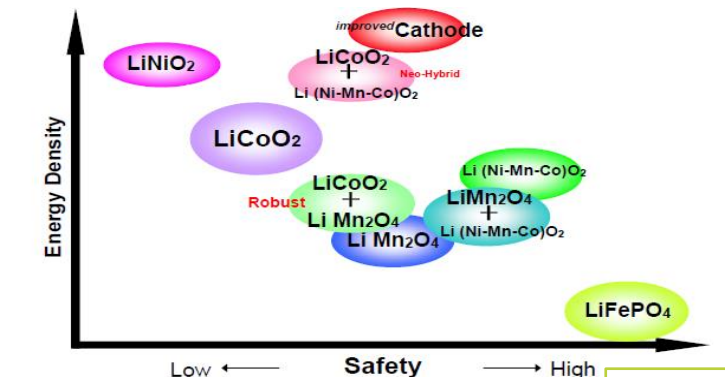
⌚ Cathode raw materials market

- ⌚ LiCoO₂ (LCO)
- ⌚ LiMn₂O₄ (LMO)
- ⌚ LiMPO₄⁽¹⁾ (LFP)
- ⌚ Li[NixMnyCoz]O₂ - NMC
- ⌚ Li[NixCoyAlz]O₂ - NCA

(1) M= Fe or Mn

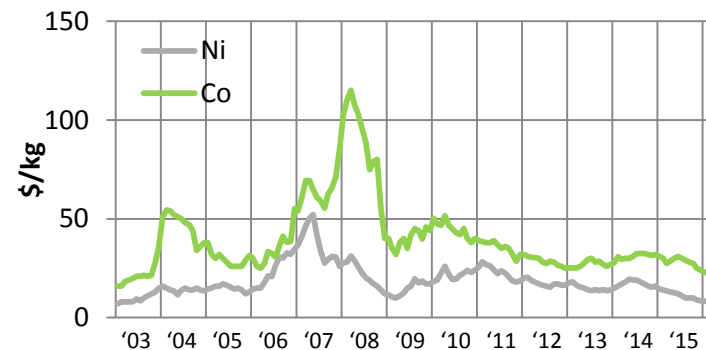


Source: Mitsubishi, Batteries 2012 – Nice



Source: SANYO, March 2011

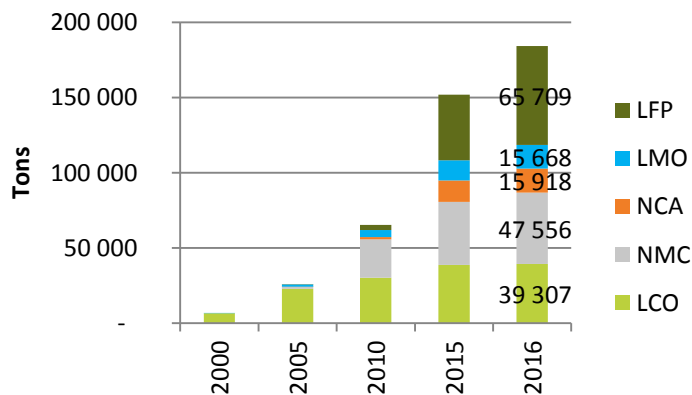
Ni & Co price 2003-2015



Source: LME

CATHODE ACTIVE MATERIALS NEEDS

Cathode active materials for LIB in Tons, 2000-2016 (Demand)



LEADERS:



NEW ENTRANTS ON THE FIELD:

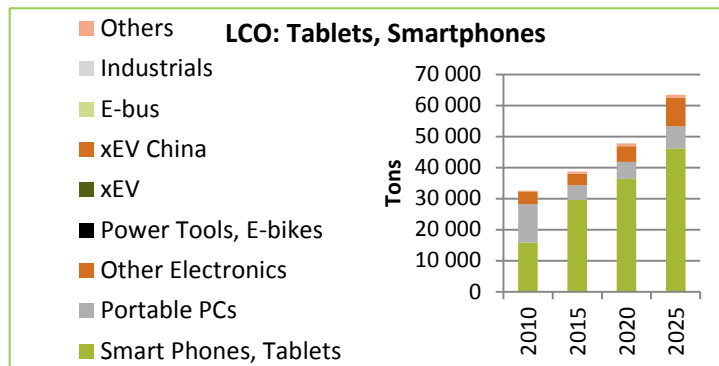


Rationales

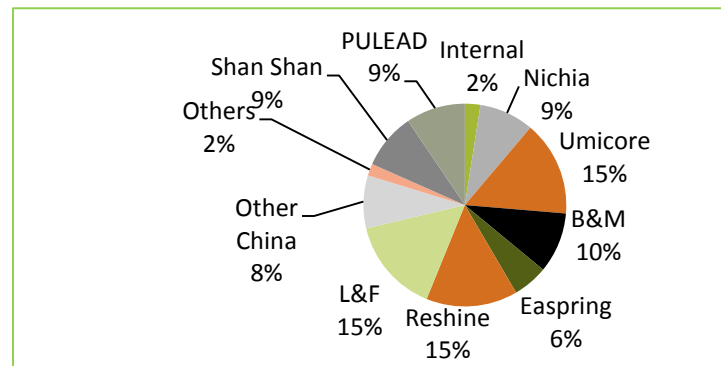
- 🔋 In 2016, LCO is used in pouch cells for electronic devices: smartphones, tablets, ultra thin portable PCs
- 🔋 NMC is used in other electronic devices & xEV
- 🔋 NCA is used by 18650 Panasonic cells in Tesla cars and as a blend with LMO in other xEV
- 🔋 LMO is mostly used as a blend with NMC in xEV
- 🔋 LFP is used in xEV, e-buses in China and for industrial applications

LCO DEMAND: CAGR 2015-2025:+5%

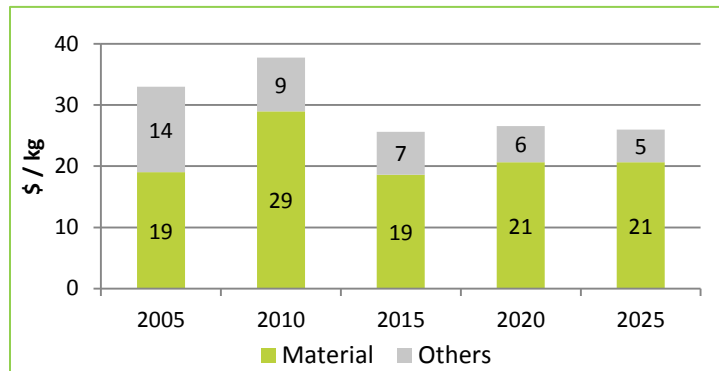
LCO demand details



LCO Offer in 2015



LCO Price forecasts



Assumption: 2016-2025 : Co price stable @ 28\$/kg – Lithium carbonate stable @ 10 \$/kg

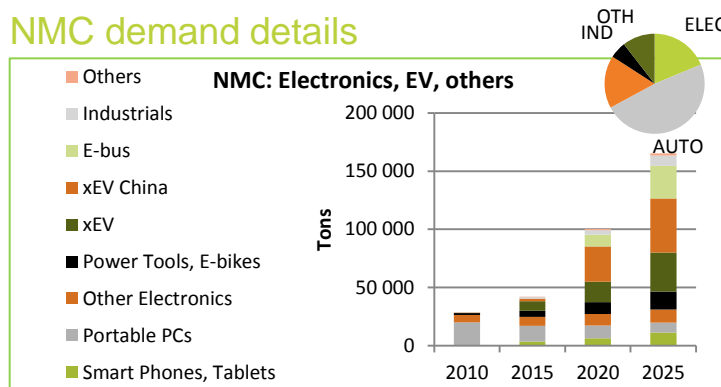
LCO summary of outlook

Demand:

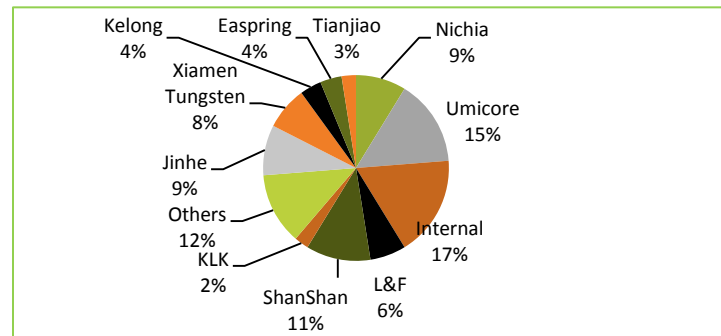
- LCO was used in most of the pouch cell lithium ion batteries for electronic devices like smartphones & tablets.
- Most OEM (Samsung, Apple, etc..) confirm that LCO will be the first choice for the future.
- Then, for portable PCs, penetration of LCO will increase thanks to thinner high end portable PC using pouch cells.
- LCO will not be used in large format cells where NMC is preferred.
- Price: if the metal price are stable from 2016 to 2025, small cost decrease thanks to scale economy.
- Suppliers: Umicore, L&F, and main Chinese (Pulead, ShanShan, Reshine) will keep the lead. Not sure that Nichia will stay at the top.

NMC DEMAND: CAGR 2015-2025: +15%

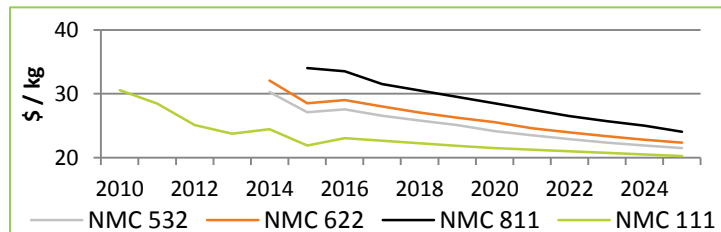
NMC demand details



NMC Offer in 2015

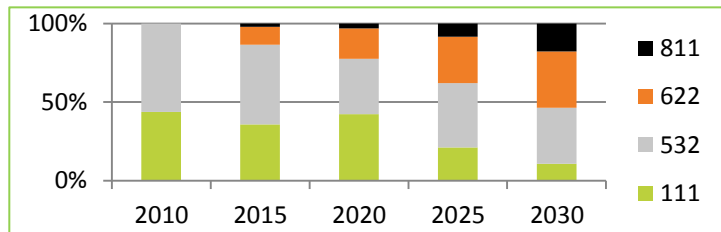


NMC Price forecasts



Assumption: 2016-2025 : Co price stable @ 28\$/kg – Lithium carbonate stable @ 10\$/kg – Ni stable @ 12\$/kg

NMC evolution

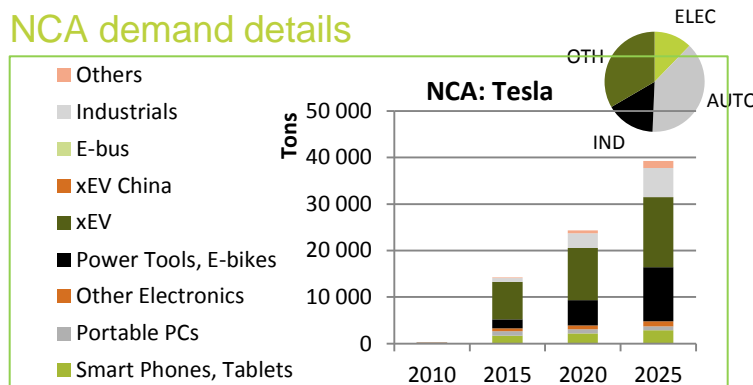


NMC summary of outlook

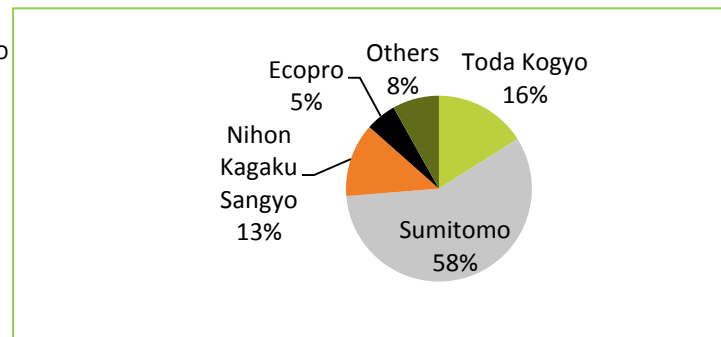
Demand: Except xEV in China, **NMC** is driven by xEV: **Nissan** will switch from NCA-LMO to NMC for example. Then, **Toyota, Mitsubishi, Honda** all choose NMC. From 2012 to 2016 the clear trend was to switch from LMO-NMC 75/25 to LMO-NMC 25/75. **LG, Panasonic and Samsung** agreed that NMC will be the 1st choice for xEV first in Japan, US and Europe, and then, in 2020 in China. **Price** will decrease thanks to process manufacturing improvement. **Suppliers:** Umicore, L&F, and main Chinese (ShanShan) will keep the lead. LG and Samsung will outsource more (Internal part will decrease). As new entrant, BASF try to be on this market since 2011. There market share may increase.

NCA DEMAND: CAGR 2015-2025: +11%

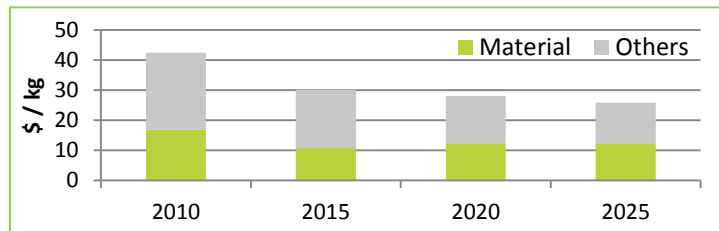
NCA demand details



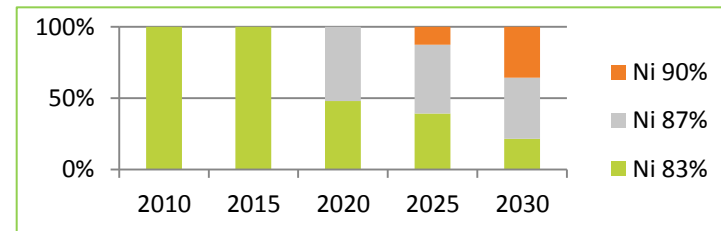
NCA Offer in 2015



NCA Price forecasts



NCA evolution



Assumption: 2016-2025 : Co price stable @ 28\$/kg – Lithium carbonate stable @ 10\$/kg – Ni stable @ 12\$/kg

NCA summary of outlook

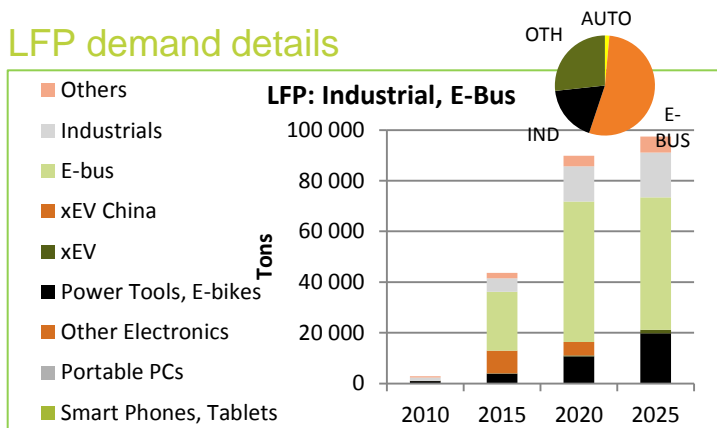
Demand: NCA are also used in electronic devices, in prismatic and cylindrical cells. Main NCA users in electronic devices are [Panasonic](#), [Sony](#) and [Samsung](#). They will keep using NCA but LCO will stay the first choice. [Panasonic](#) and [Samsung](#) confirm that they supply more and more power tools mfg with NCA (from 15% in 2015 to 25% in 2025). Other NCA usage is of course for the [TESLA](#). We do not think [TESLA](#) will switch for another technology in the next years.

Price decrease thanks to better mfg. process

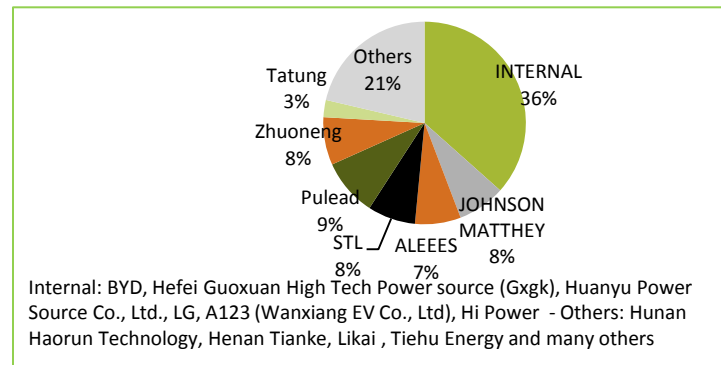
Supplier: Sumitomo will keep the lead thanks to Panasonic / Tesla. Toda Kogyo market share will probably increase thanks to BASF partnership.

LFP DEMAND: CAGR 2015-2025:+8%

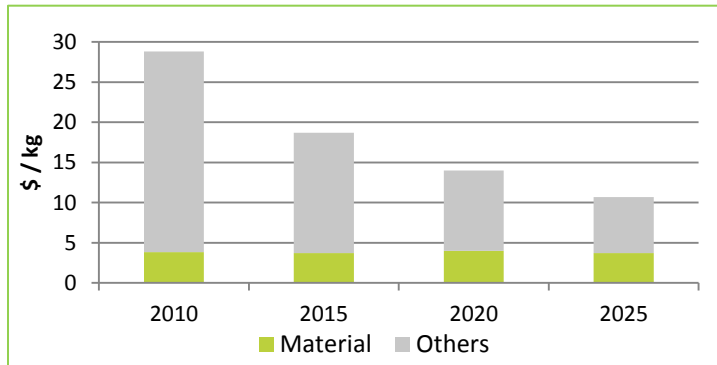
LFP demand details



LFP Offer in 2015



LFP Price forecasts



LFP summary of outlook

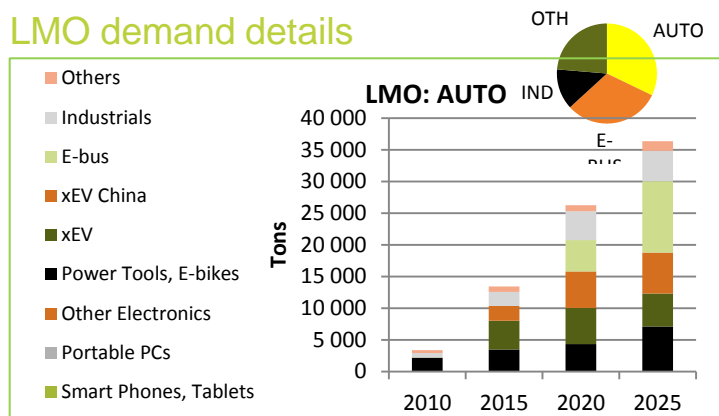
LFP demand is driven by xEV, E-Bus in China, e-bikes and Stationary application. Chinese industrial agreed that E-bikes, e-bus and stationary app will use LFP for the next 10 years. The cost and the life time are the main criteria and Energy density is not so important. Then, Chinese xEV mfg. (BYD, Kandi, Zotye, Baic, Chery...) told us that they will switch from LFP to NMC.

Price: Process manufacturing cost will decrease. Pulead forecast price @ 11-12\$/kg in 2025.

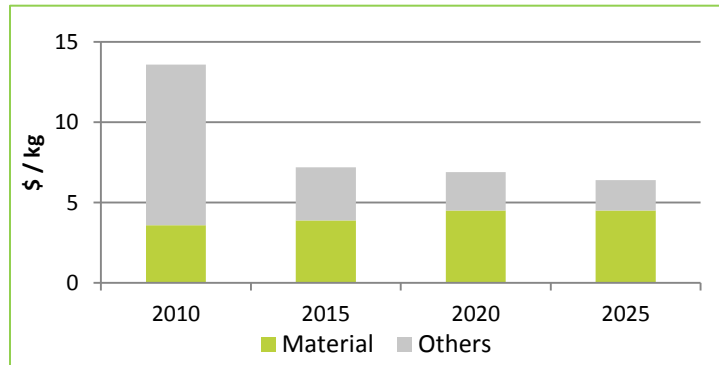
Suppliers: Pulead will probably increase market share thanks to new contract with BYD and others Chinese battery mfg.

LMO DEMAND: CAGR 2015-2025: +10%

LMO demand details

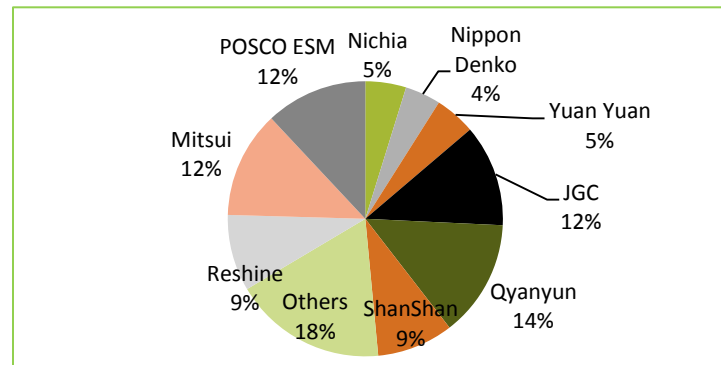


LMO Price forecasts



Assumption: Lithium carbonate price 2016 – 2025 stable @ 10 \$/kg

LMO Offer in 2015



LMO summary of outlook

Demand: LMO is almost never the first choice for Lithium ion cathode. But, LMO is low cost and bring stability to the cathode. LMO is used in power tools and will be used, blended with NMC. So, for the future, LMO demand will be mostly driven by NMC/LMO blended cathode used in EV worldwide, EV in China to replace LFP (2020) and later E-bus in China (2025).

Price: LMO price decreased a lot from 2010 to 2015. We think we almost achieve the lowest possible level.

Suppliers: Most of the supply will stay in China (ShanShan, Qyanyun, ...).

The rechargeable battery market 2016-2025

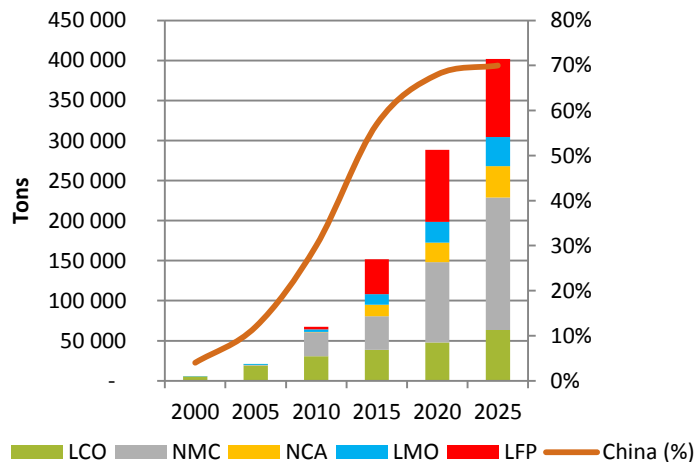
Your contacts
International Battery SEMINAR & EXHIBIT
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & INDUSTRIAL APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

CATHODE ACTIVE MATERIAL FORECASTS 2000-2025

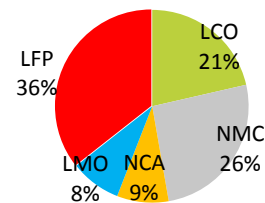
Cathode active materials
2000-2025 - Tons



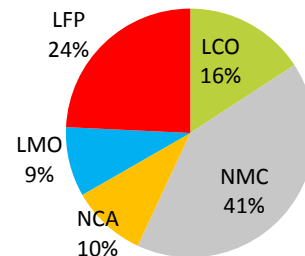
ASSUMPTIONS:

- Portable devices:
2015-2025: +6% 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 + 0,5 M in China in 2020, 0,6 M in 2025 + 1M in China, 100% LIB
- EV: 0,6 M EV/year in 2020 + 1M in China, 1M/year + 1,5 M in China in 2025, 100% LIB
- Industrial & stationary: 2015-2025: +16% per year

Cathode active materials in 2016
> 180 000 Tons



Cathode active materials in 2025
400 000 Tons

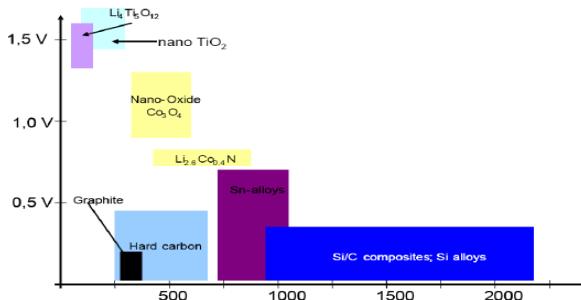


Assumption: Tesla keep NCA chemistry and have a relative success
 (200 000 EV sold per year in 2025 – TESLA forecast 500 000)

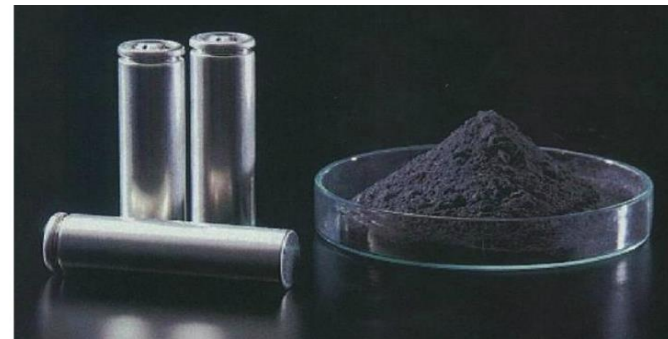
ANODE ACTIVE MATERIALS

> 88 000 TONS IN 2016

LIB Anode Materials

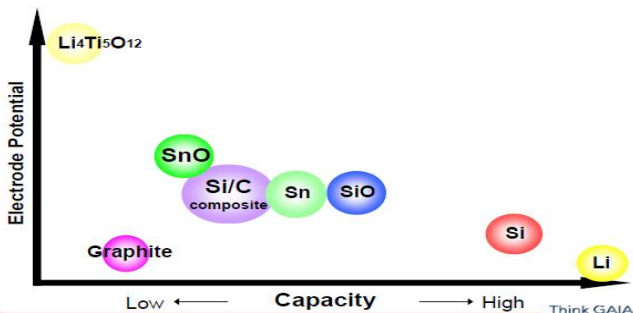


Source: A. Jossen, IRES 2007



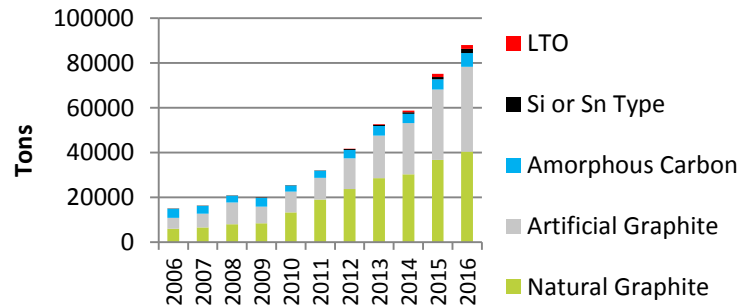
Source: Hitachi Chemical

LIB Anode Materials



Source: Sanyo, March 2013

LIB Anode market, (Tons)



Sources: AVICENNE ENERGY 2016 42

The rechargeable battery market 2016-2025

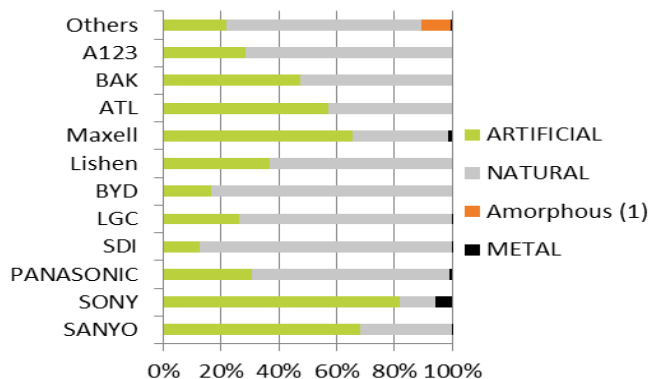
Your contacts
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

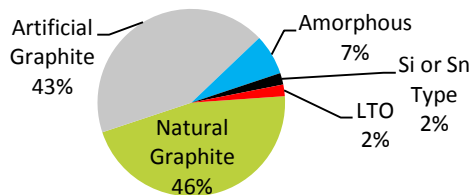
CONTACT
 Christophe PILLOT
 + 33 1 47 78 46 00
c.pillot@avicenne.com

ANODE FOR LIB IN 2016

Natural graphite become a commodity



Carbon for LIB anodes by type (2016)



	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 2015->2020	25 -> 20 \$/kg	20->15 \$/kg	7-13-> 6-10 \$/kg
SUPPLIERS	KUREHA	HITACHI	HITACHI BTR...

LEADERS:



 Nippon Carbon

HITACHI

NEW ENTRANTS ON THE FIELD:



(...)

Sources: AVICENNE ENERGY 2017



avicenne
ENERGY

INFORMATION FOR GROWTH
www.avicenne.com

The rechargeable battery
market 2016-2025

International
Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & INDUSTRIAL APPLICATIONS

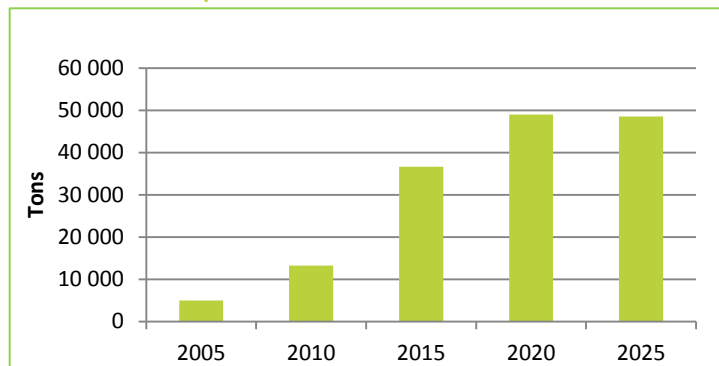
March 20th, 2017
Fort Lauderdale, FL, USA

CONTACT

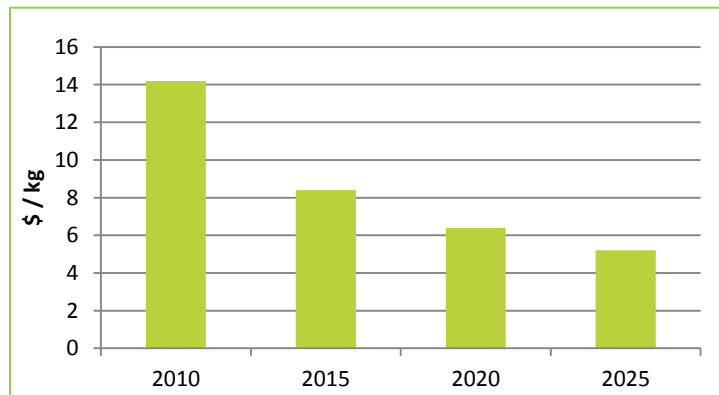
Christophe PILLOT
+ 33 1 47 78 46 00
c.pillot@avicenne.com

NATURAL GRAPHITE: CAGR 2015-2025: +3%

Natural Graphite demand details

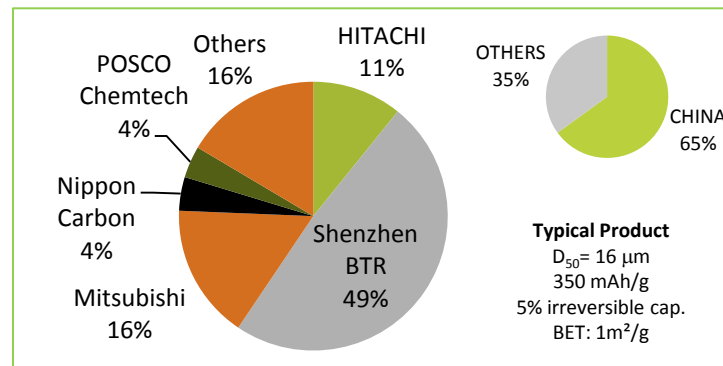


NG Price forecasts



Sources: AVICENNE ENERGY 2017

NG Offer in 2016



NG summary of outlook

Demand: small growth because new app. Need artificial Gr. This demand may change if the price decrease is more important for NG compare to AG. **Price:** The price will decrease fast because the supply is huge. Already over supply in China (Capacity: BTR 30 000 Tons, Zichen: 10 000 Tons, Shinzom: 10 000 Tons, Sinuo: 8 000 Tons, Qingdao: 8 000 Tons, Jianxi Zhentuo: 7000 Tons, Kimwan: 5 000 Tons...). Then, a lot of new projects in China and Canada: Focus Graphite > 40000 Tons/year (2020*), Northern Graphite > 20 000 Tons/year (after 2018*) Syrah Resources Ltd. > 80 000 Tons (2020*)

Suppliers: BTR and new Chinese (Zichen thanks to ATL, - Shinzom thanks to BYD, CATL – Sinuo etc...). New entrant like Focus Graphite, Northern Graphite, or Syrah Resources Ltd. May change the market share in the future

* Subject to financing

The rechargeable battery
market 2016-2025

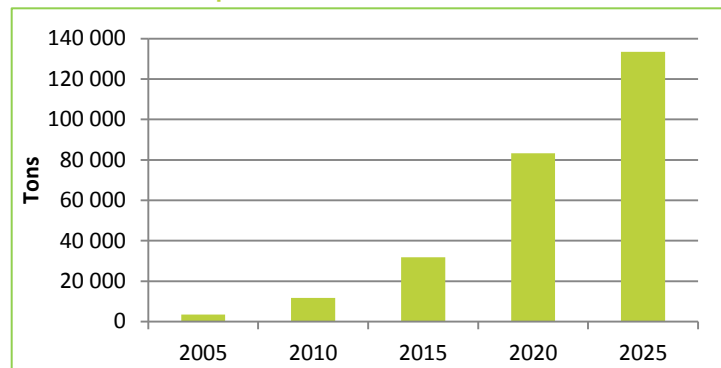
International
Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

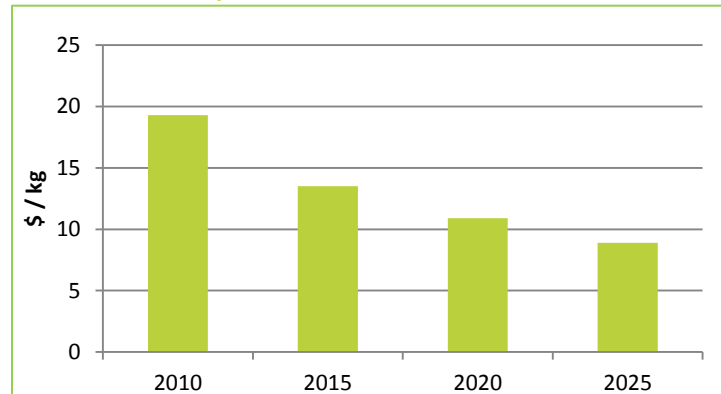
CONTACT
Christophe PILLOT
+ 33 1 47 78 46 00
c.pillot@avicenne.com

ARTIFICIAL GR.:CAGR 2015-2025: +15%

Artificial Graphite demand details

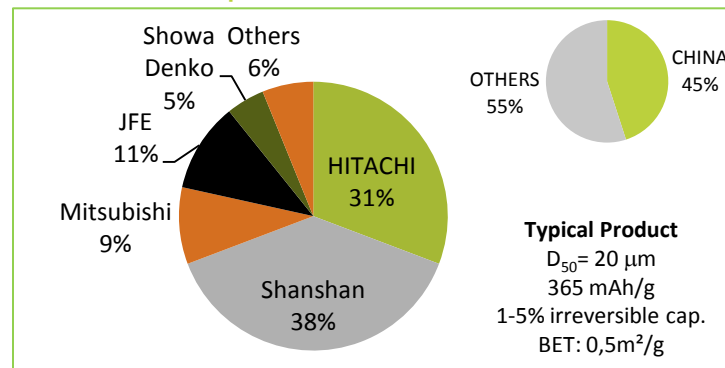


Artificial Graphite Price forecasts



Sources: AVICENNE ENERGY 2017

Artificial Graphite Offer in 2016



Artificial Graphite summary of outlook

Demand: The demand will increase fast thanks to xEV market. Long life time requirement involve high level of purity and high consistency, difficult to achieve with Natural Graphite.

Price will decrease fast thanks to better process efficiency, new process

Supply: Thanks to the best quality, Hitachi will keep the lead but Chinese main suppliers market share will increase (ShanShan mostly).

Production Capacity: Hitachi: 15 000 Tons, ShanShan: 15 000 Tons project in Lingang Park (Shanghai) to add 20 000 Tons/year, Mitsubishi: 7 000 Tons, JFE: 7000 Tons, Showa Denko: 3000 Tons

The rechargeable battery
market 2016-2025

Our clients
**International
Battery SEMINAR & EXHIBIT**
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

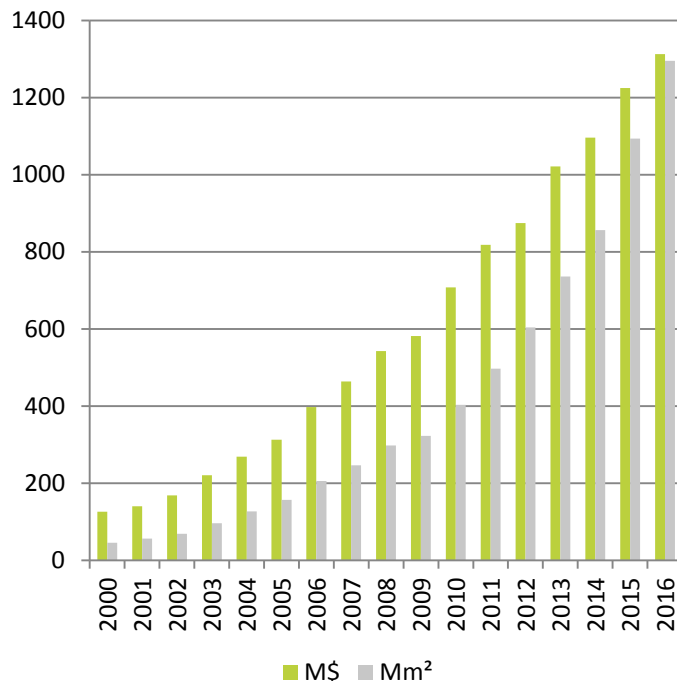
March 20th, 2017
Fort Lauderdale, FL, USA

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

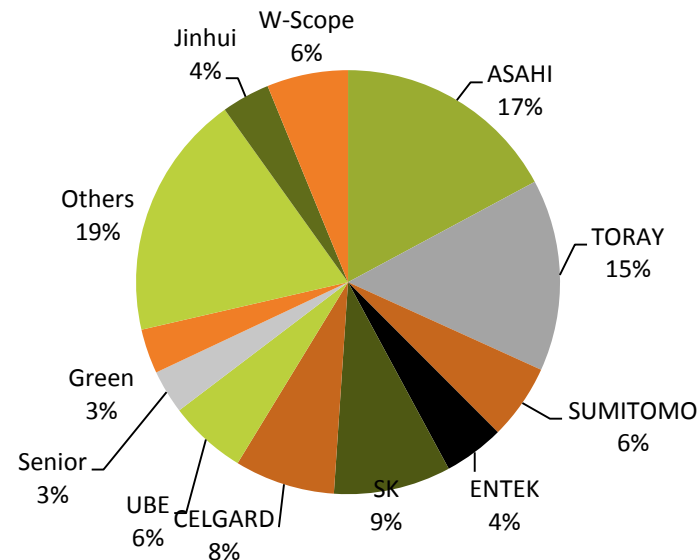
LIB SEPARATOR MARKET 2016

In February 2015, ASAHI announced that they will acquire all Polypore shares in the Energy Storage segment: Asahi Kasei to pay around \$2.2billion to purchase Polypore's battery separator business

LIB separator market, M\$ - CAGR 2006/2016: +13%



Supplier, market share in 2016



Others: Shanghai Energy, Newmi, JGP, TDK, In house (BYD), Mingzhu, Tianfeng, Yiteng, BNE...

Sources: AVICENNE ENERGY 2017

The rechargeable battery market 2016-2025

Your company
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

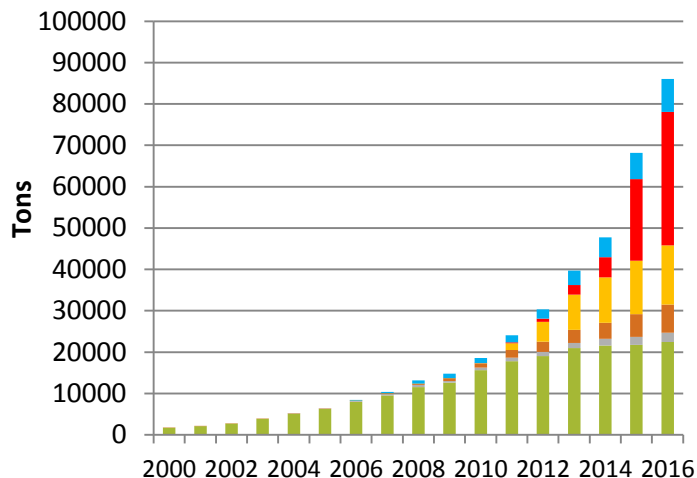
March 20th, 2017
 Fort Lauderdale, FL, USA

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

ELECTROLYTE SUPPLIERS/CUSTOMERS

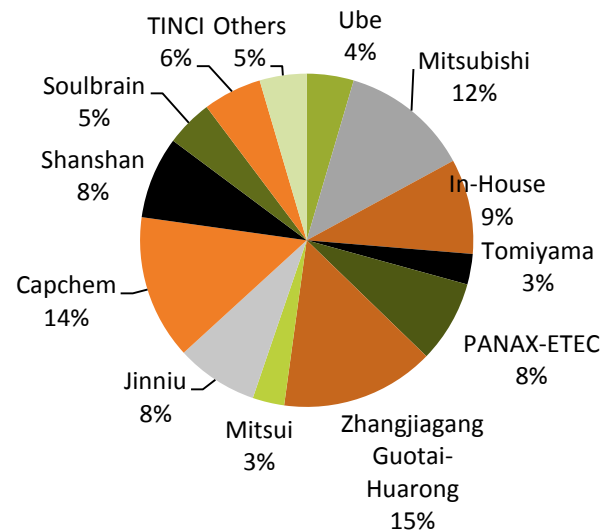
> 86 000 TONS IN 2016

LIB electrolyte market, Tons,
 CAGR 2006/2016: +26%



■ Portables electronics ■ Power Tools
 ■ E-bikes ■ Automotive (12v, HEV, PHEV, EV)
 ■ Auto & E-Bus China ■ Industrial

LIB electrolyte supplier, market share in 2016



Sources: AVICENNE ENERGY 2017

Note: (1) GTHR: Zhangjiagang Guotai-Huarong

The rechargeable battery
market 2016-2025

The seminar
**International
Battery** SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & INDUSTRIAL APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

CONTACT

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

BATTERY MARKET FORECASTS 2016-2025

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,
- 🔋 2016 -2025 Forecasts
- 🔋 OEM strategies and positions
- 🔋 Main drivers & limiters

The rechargeable battery market 2016-2025

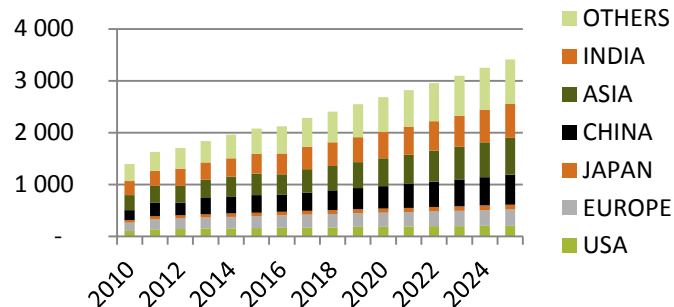
Your contacts
International Battery Seminar & Exhibit
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

PORTABLE ELECTRONIC DEVICES FORECASTS 2010-2025

Cellular phones demand (M Units)
 CAGR 2010-2025: +4%



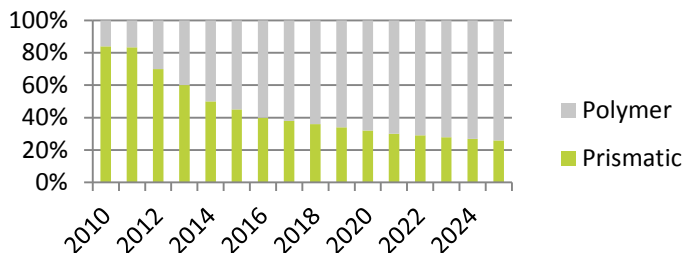
Cellular Phones market Drivers

- Emergent market
- Renewal ratio increase
- Smartphone penetration increase



LIB cells demand 2010-2025

Polymer penetration: 20% -> 75%

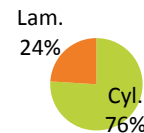


LIB cells for cellular phones trends

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

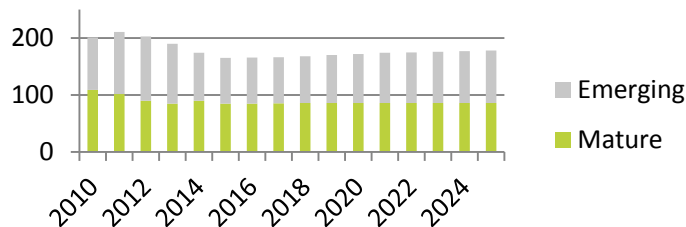
Source: AVICENNE ENERGY Analyses

PORTABLE ELECTRONIC DEVICES FORECASTS 2010-2025



Portable PCs demand (M Units)

2016-2025 – Almost stable

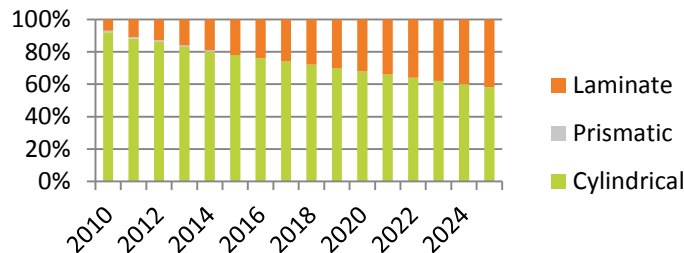


Excluding Tablets and convertibles (Tablets + PC)

Source: IDC, Gartner, AVICENNE Energy

LIB cells demand 2014-2025

Polymer penetration: 20% -> 40%



Source: AVICENNE ENERGY Analyses

Portable PCs market trends

- 🔗 Mature market stable or decreasing
- 🔗 Growth driven by Emerging market
- 🔗 Ultrabook is increasing
- 🔗 ASP decreasing (<499\$ Portable PCs increase from 25% in 2010 to 40% in 2015)

LIB cells for portable PCs trends

- 🔗 Thinner cells
- 🔗 Pouch cells penetration increasing from 7% in 2010 to 40% in 2025
- 🔗 > 2800 mAh for Premium/corporate
- 🔗 2.2 Ah for consumer, emerging market

The rechargeable battery market 2016-2025

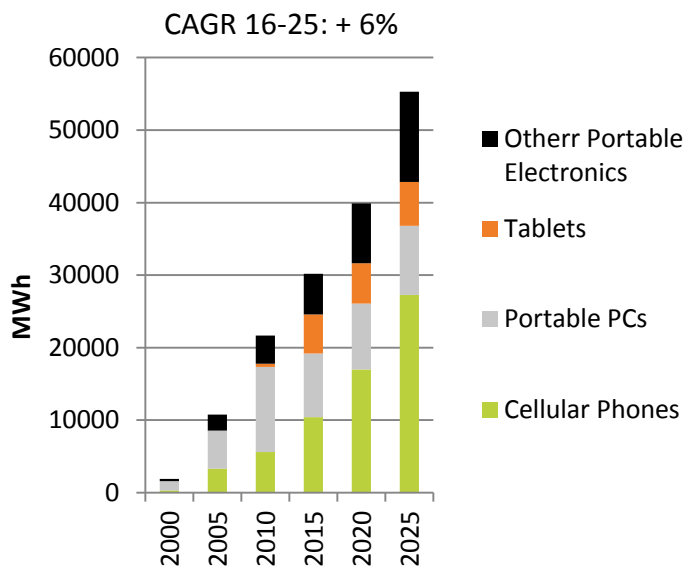
14th edition
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

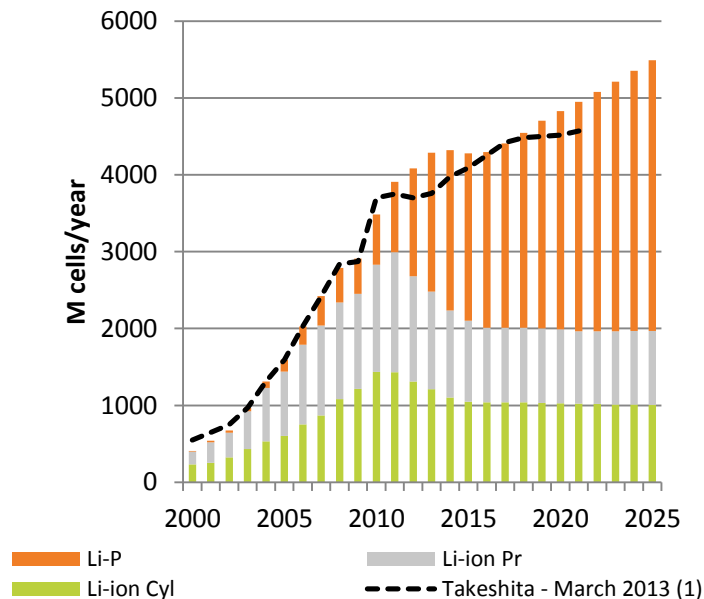
2025 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

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



Source: AVICENNE ENERGY Analyses

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



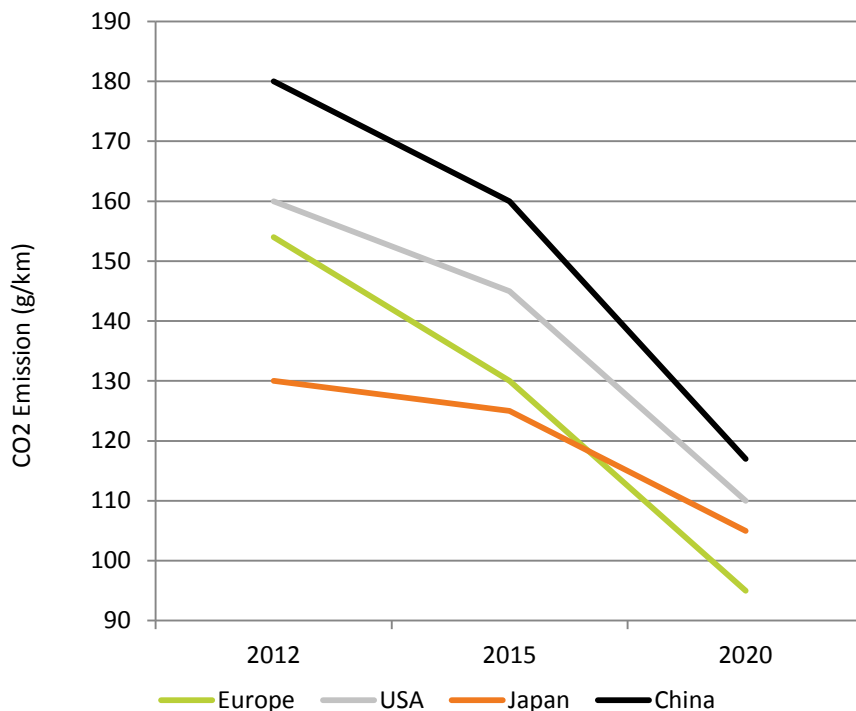
(1) Source: Takeshita, Battery Japan 2013 BJ-3 conference Slide p 4

X-EV MARKET

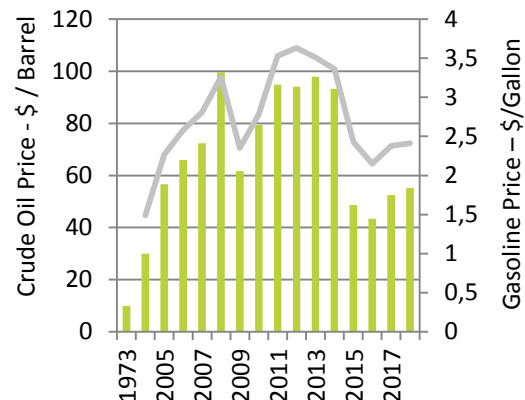
- Why x-EV ?
- Definition & segmentation
- X-EV worldwide in 2015
 - By country
 - By car makers
 - By battery chemistry
- X-EV forecasts
 - AVICENNE ENERGY & other analyst forecasts
 - Battery chemistry forecasts
 - Battery cost forecasts
- X-EV battery forecasts

WHY X-EV ?

MAJOR DRIVER: CO₂ regulation worldwide: From 2013 to 2014 Oil price decrease but HEV sales increase by 5%, P-HEV by 30% and EV by 60%

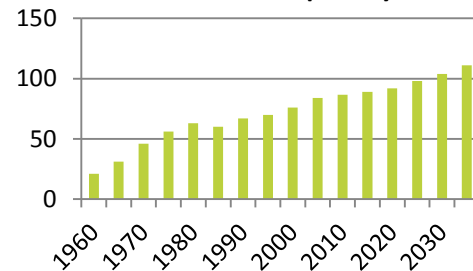


Price of the WTI¹ barrel of oil, US \$



Source: <http://www.eia.doe.gov/emeu/steo/pub/contents.html>

Petroleum consumption worldwide
 Million barrel per day



Source: Energy Information Administration, US Government

Note

¹ WTI: West Texas Intermediate

The rechargeable battery market 2016-2025

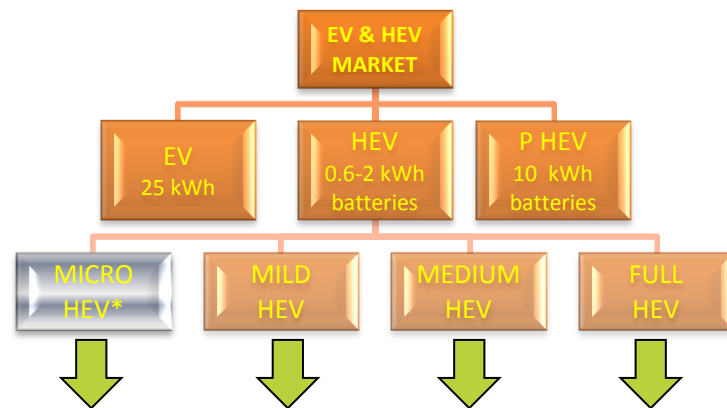
Your contacts
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

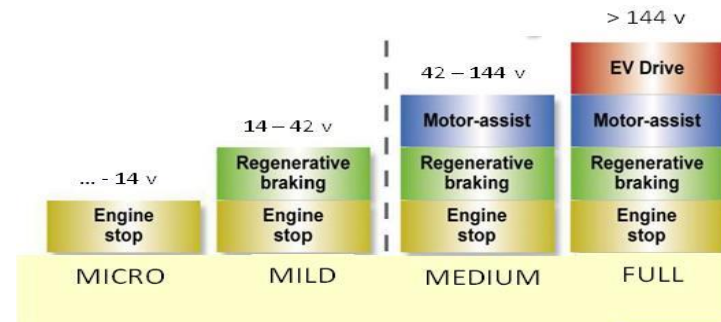
CONTACT
 Christophe PILLOT
 + 33 1 47 78 46 00
c.pillot@avicenne.com

HEV, P-HEV & EV

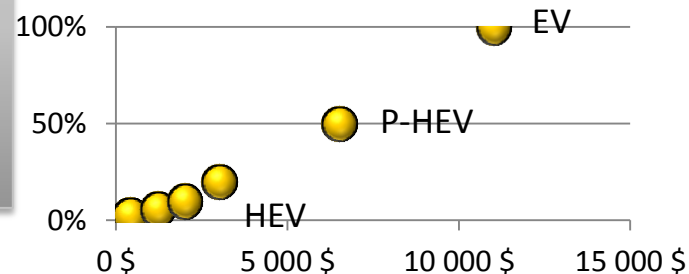
DEFINITION & SEGMENTATION



CITROEN C2, C3 BMW 3Series Fiat 500 Hyundai i10 Hyundai i30 Kia Smart for2 Toyota Yaris Toyota Auris VW Passat	GM Saturn Vue GM AURA GM MALIBU HONDA ACCORD	HONDA CIVIC INSIGHT MERCEDES S400	TOYOTA PRIUS TOYOTA CAMRY FORD ESCAPE FORD FUSION MILAN GM YUKON GM TAHOE NISSAN ALTIMA
---	---	---	--



Fuel saving Vs. Cost

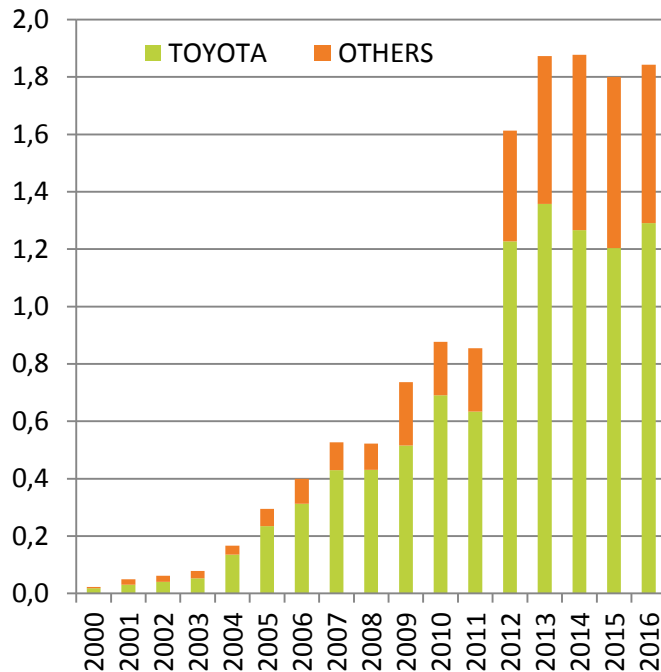


Note: Micro HEV are not in the HEV statistics & HEV forecast

HEV WORLDWIDE IN 2016

1,8 M HEV

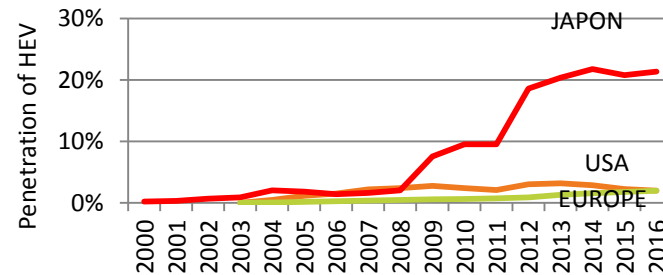
HEV sold per year, M units, worldwide, 2000 - 2016



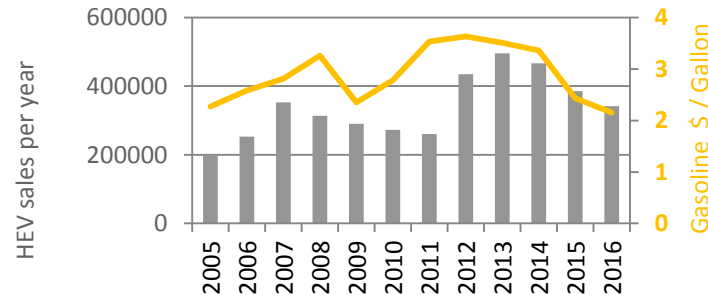
Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY
Micro hybrid not included

Growth 2014-2015: +2%
 From 1,8 M to 1,84 M HEV

Penetration of hybrids in the global sales, 2000-2016

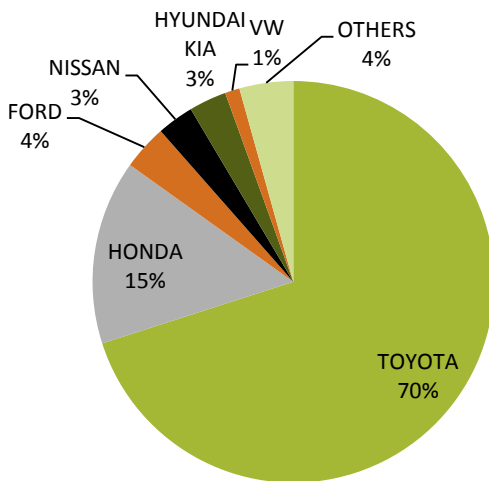


Gazoline price impact on HEV market in the US



HEV WORLDWIDE IN 2016 BY CAR SUPPLIER

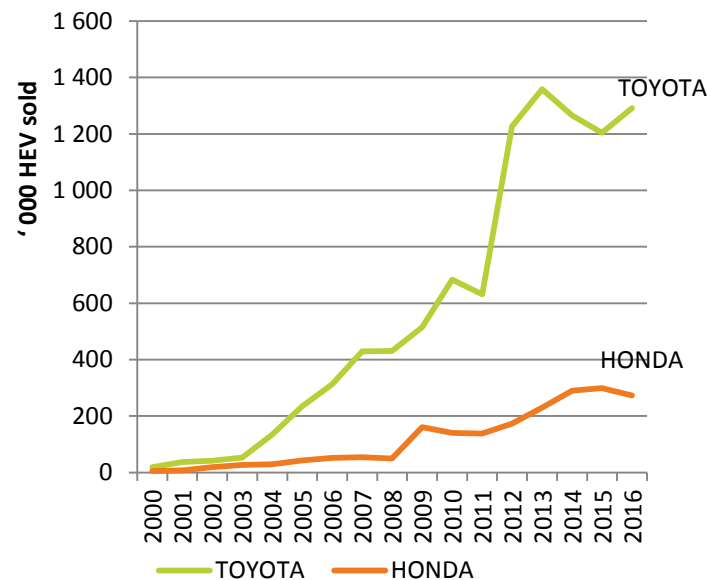
Total HEV Vehicles
1,8 Million HEV in 2016



Others: GM, Porsche, Mercedes, Mazda, Audi, Subaru etc...

Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY
 Micro hybrid not included

HEV sold per year, M units per car manufacturers, 2000-2016



The rechargeable battery
market 2016-2025

14th edition
**International
Battery** SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & INDUSTRIAL APPLICATIONS

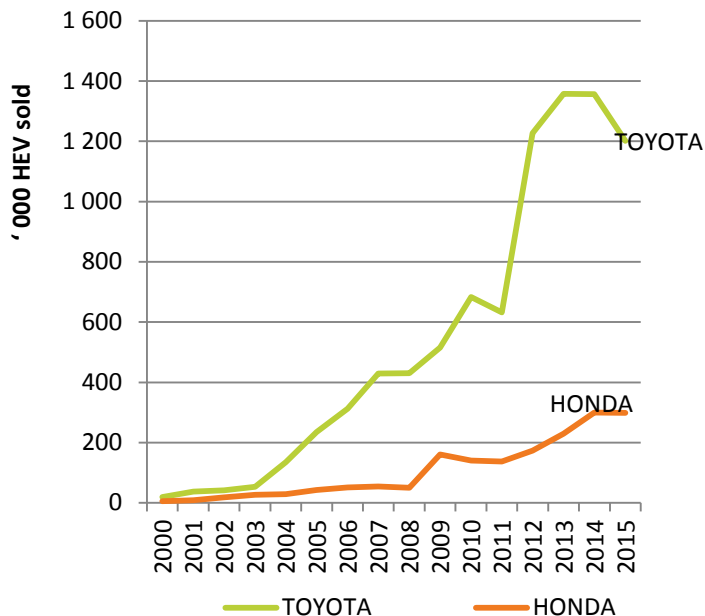
March 20th, 2017
 Fort Lauderdale, FL, USA

CONTACT

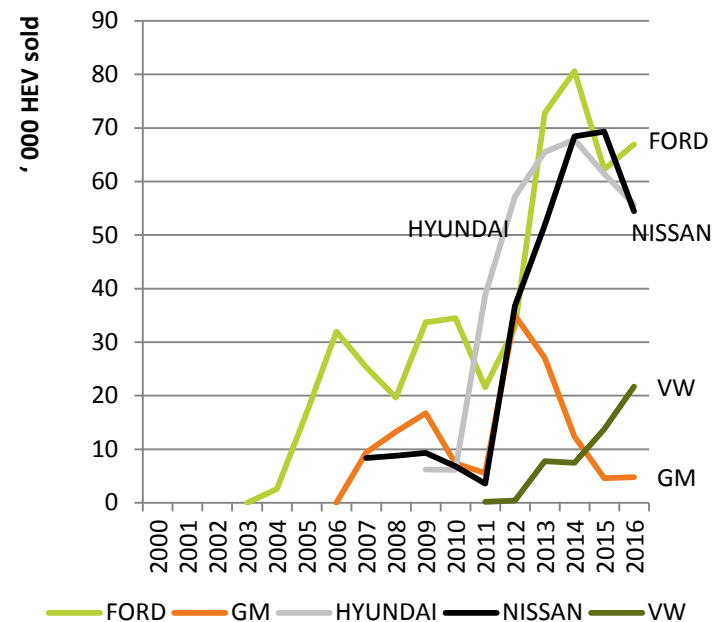
Christophe PILLOT
 + 33 1 47 78 46 00
c.pillot@avicenne.com

HEV WORLDWIDE IN 2016 BY CAR SUPPLIER

TOP 2: TOYOTA, HONDA



OTHERS: FORD, VW, HYUNDAI, ...



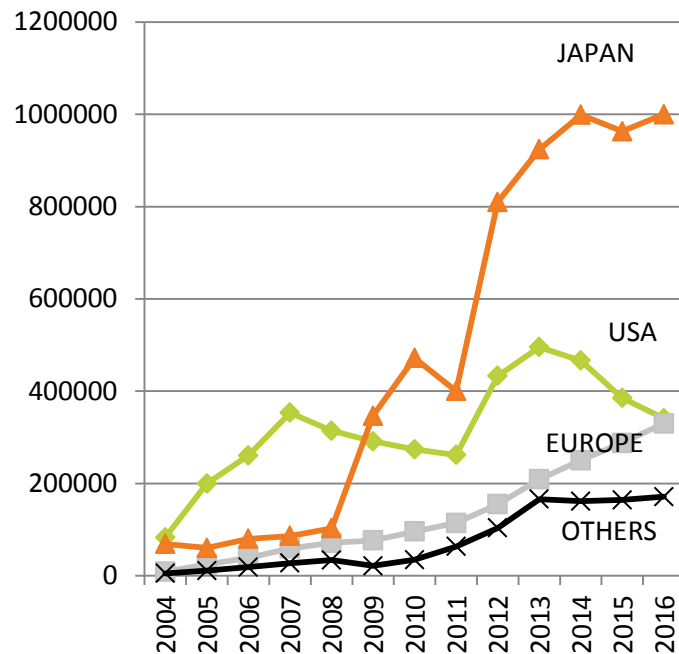
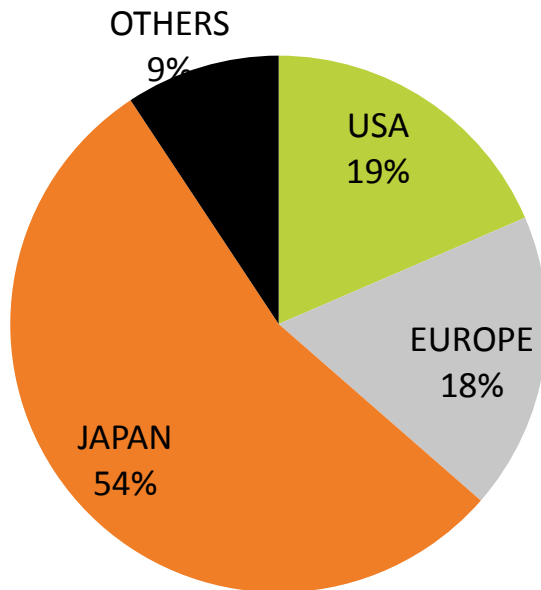
Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY

Micro hybrid not included

HEV WORLDWIDE IN 2016 BY COUNTRY

Total HEV Vehicles
 1,84 M in 2016

HEV sold per year, M units per
 country, 2004-2016



The rechargeable battery
market 2016-2025



March 20th, 2017
Fort Lauderdale, FL, USA

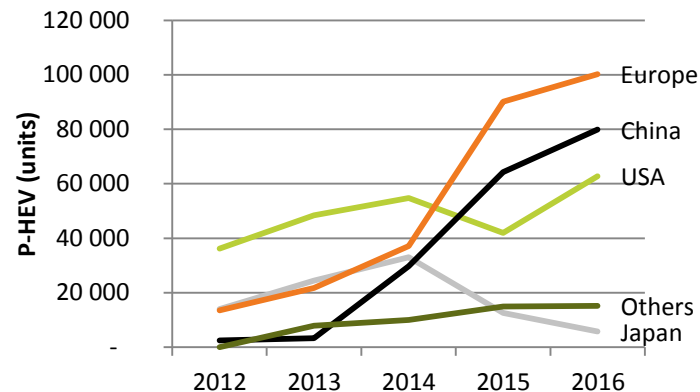
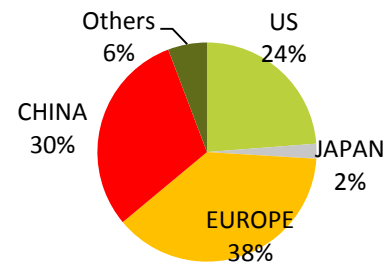
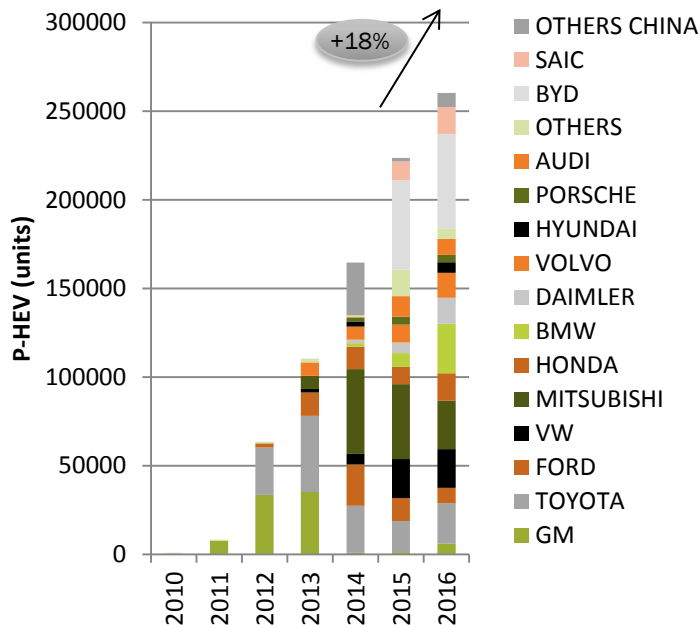
CONTACT

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

PHEV SOLD WORLDWIDE

World excl. China growth +14%
Chinese Growth + 26%

China is leading the P-HEV
market thanks to high incentives



Source: AVICENNE ENERGY Analysis, 2017

The rechargeable battery
market 2016-2025



March 20th, 2017
Fort Lauderdale, FL, USA

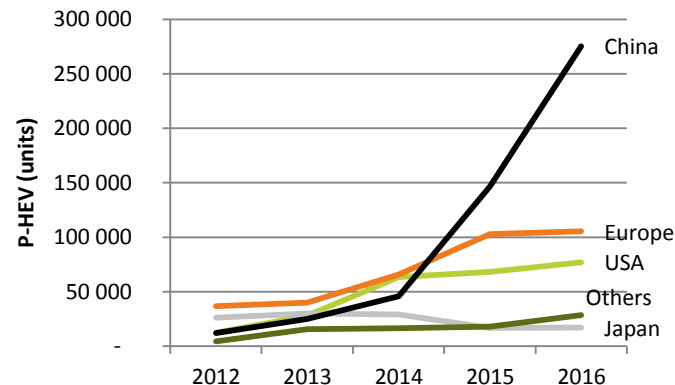
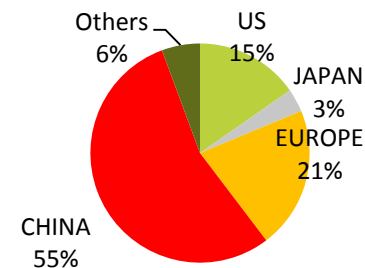
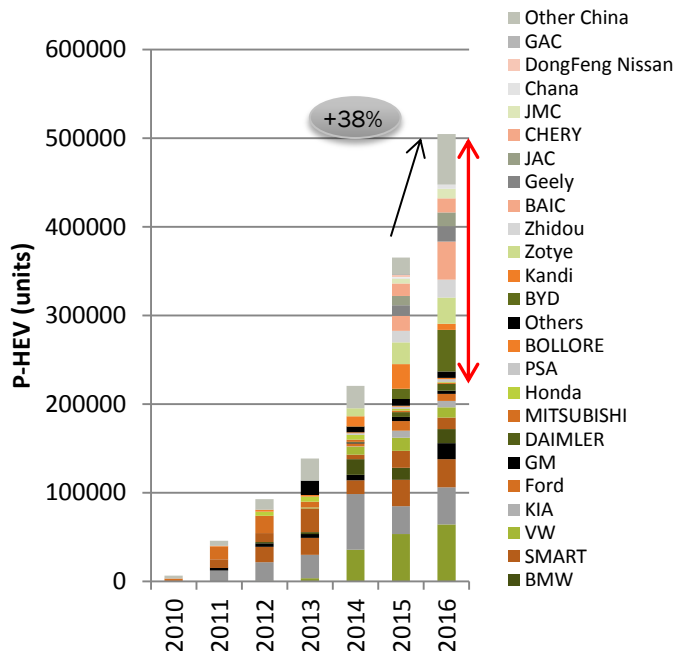
CONTACT

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

EV SOLD WORLDWIDE

World excl. China growth +15%
Chinese Growth + 68%

China is leading the EV market
thanks to high incentives



Source: AVICENNE ENERGY Analysis, 2017

The rechargeable battery
market 2016-2025

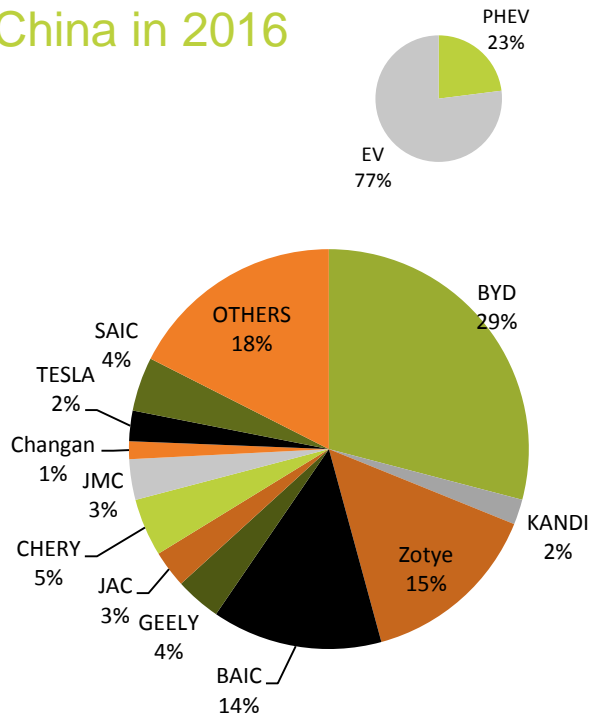
Our clients
**International
Battery** SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

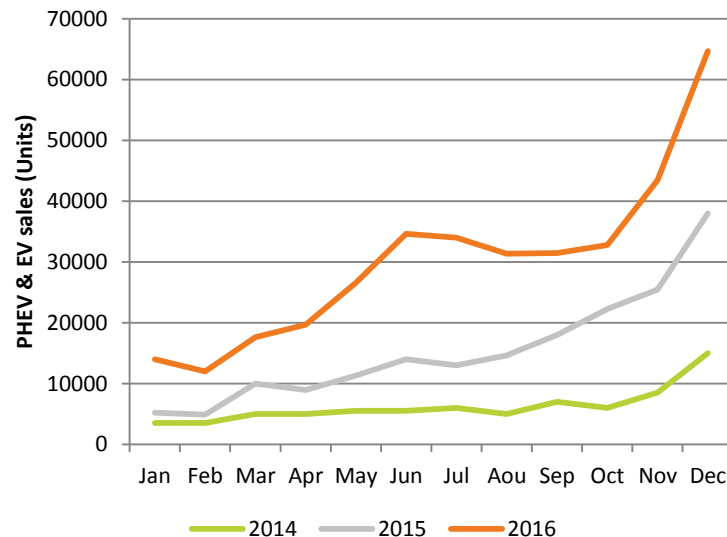
CONTACT
 Christophe PILLOT
 + 33 1 47 78 46 00
c.pillot@avicenne.com

NEV* DEVELOPMENT IN CHINA

362 100 PHEV & EV sold in
China in 2016



PHEV & EV evolution

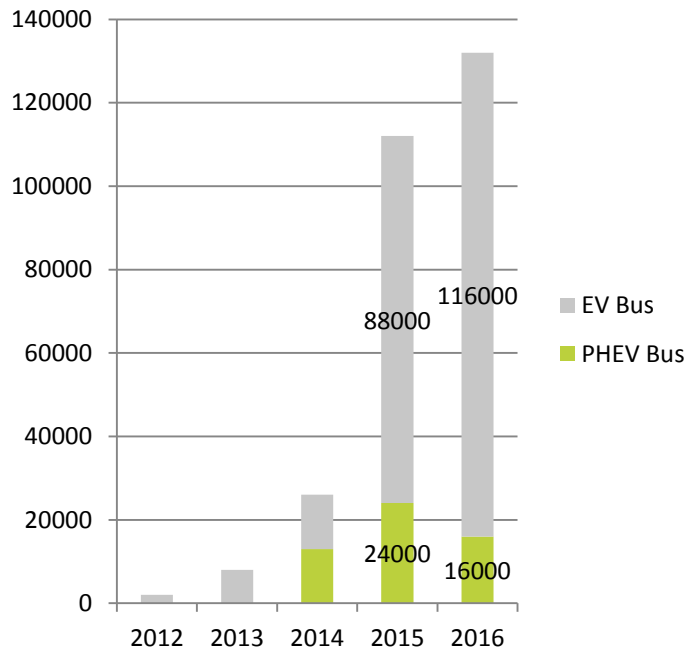


*NEV=PHEV+EV (New Energy Vehicles)


XEV BUSES MARKET IN CHINA

xEV buses market in China:

132 000 xEV Buses sold in 2016



Rationales

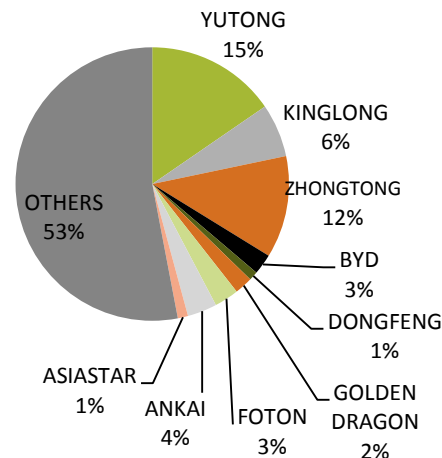
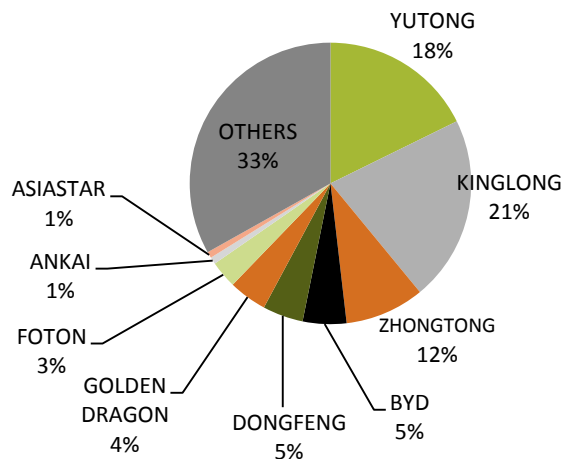
-  The Chinese government is working on addressing environmental issues. Central and local governments are engaged in subsidy policies to promote EV/PHV/FCV as new energy vehicles. The amount of subsidy for EV/FCV with low environmental impact is set high. As the subsidy policy is announced to be carried out until 2020, it is predicted that this market will be on an expansion trend centering on EV. However, due to the occurrence of the case of receiving subsidies illegally in 2015, the government has begun to strictly control the production of new energy vehicles after 2016.

XEV BUSES MARKET IN CHINA

xEV buses market in China:

132 000 xEV Buses sold in 2016

112 000 xEV Buses sold in 2015



- ❶ The new energy bus market in China is mainly made up of EV with a large amount of subsidy from the government, and there are many cases where older makers also produce PHV.
- ❷ As a result of the illegal receipt of subsidy occurred in 2015, publication of the company name and administrative guidance (penalty) from the government were carried out. Consequently, several makers including King Long have significantly reduced their market share in 2016, and old makers such as Yutong and Zhong Tong are expanding their market shares.

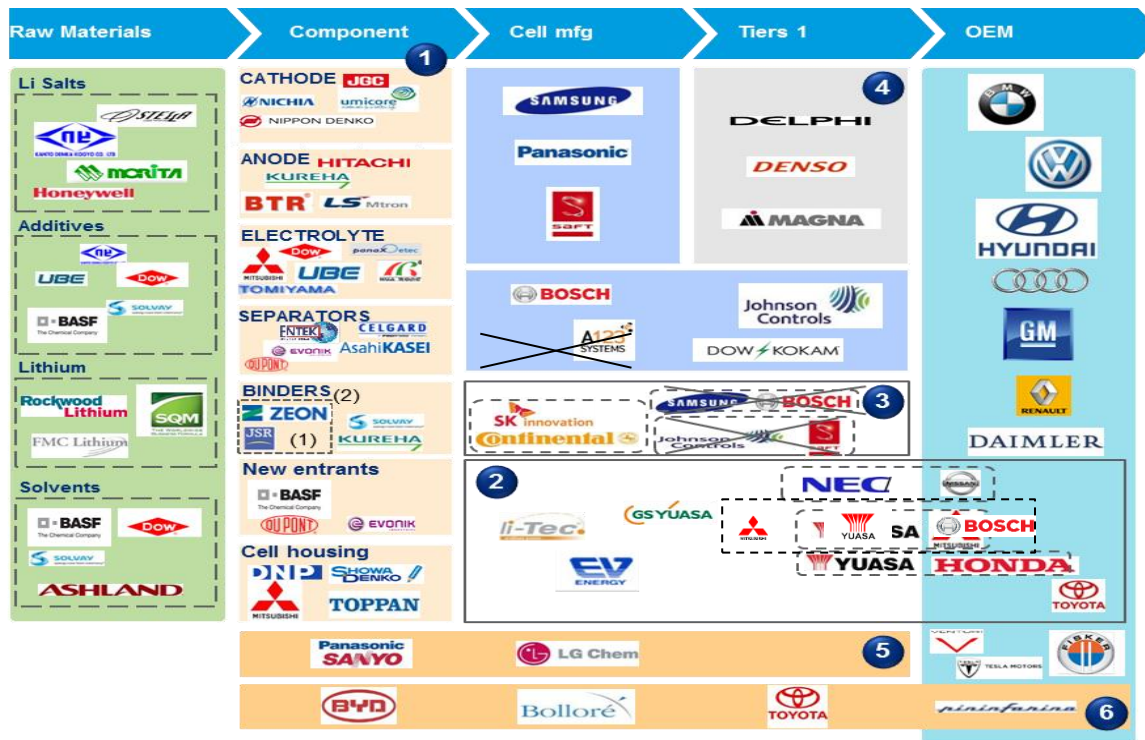
The rechargeable battery
market 2016-2025

International
Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

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

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 BOLLORE are fully integrate

The rechargeable battery market 2016-2025



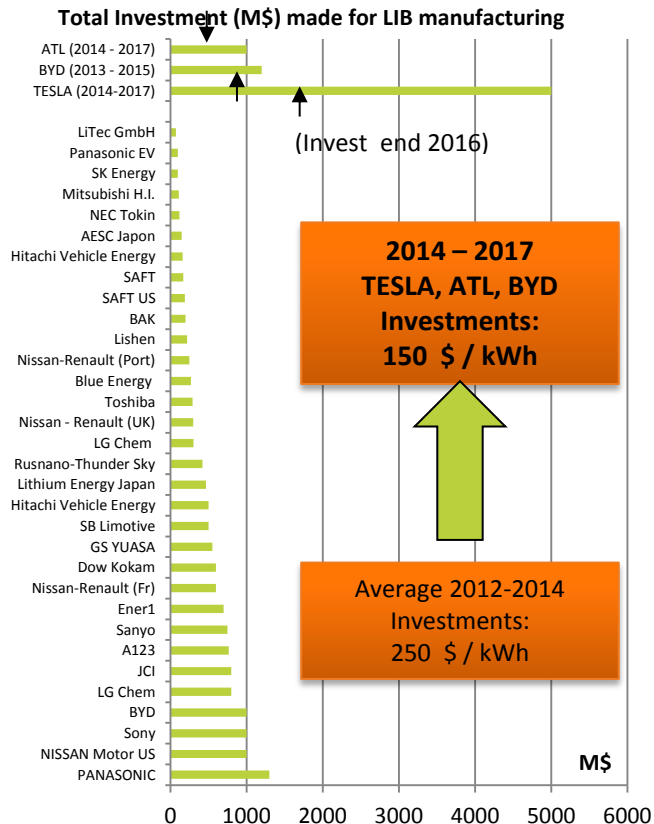
March 20th, 2017
 Fort Lauderdale, FL, USA

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

LIB MANUFACTURING INVESTMENTS 2009-2015

10-12 B\$ WORLDWIDE (>50 GWh invest from 2011 to 2014)

> 7 B\$ invested from 2014 to 2017 by TESLA (5), BYD (1,2), ATL (1)



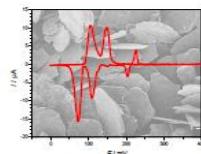
TESLA Plant, Nevada, Feb 2015



TESLA GIGA FACTORY, Dec 2016

Source: AVICENNE ENERGY Analyses 2017

TIME TO MARKET FOR NEW MATERIALS IN LIB INDUSTRY



1970ies



1980ies



1991



2004

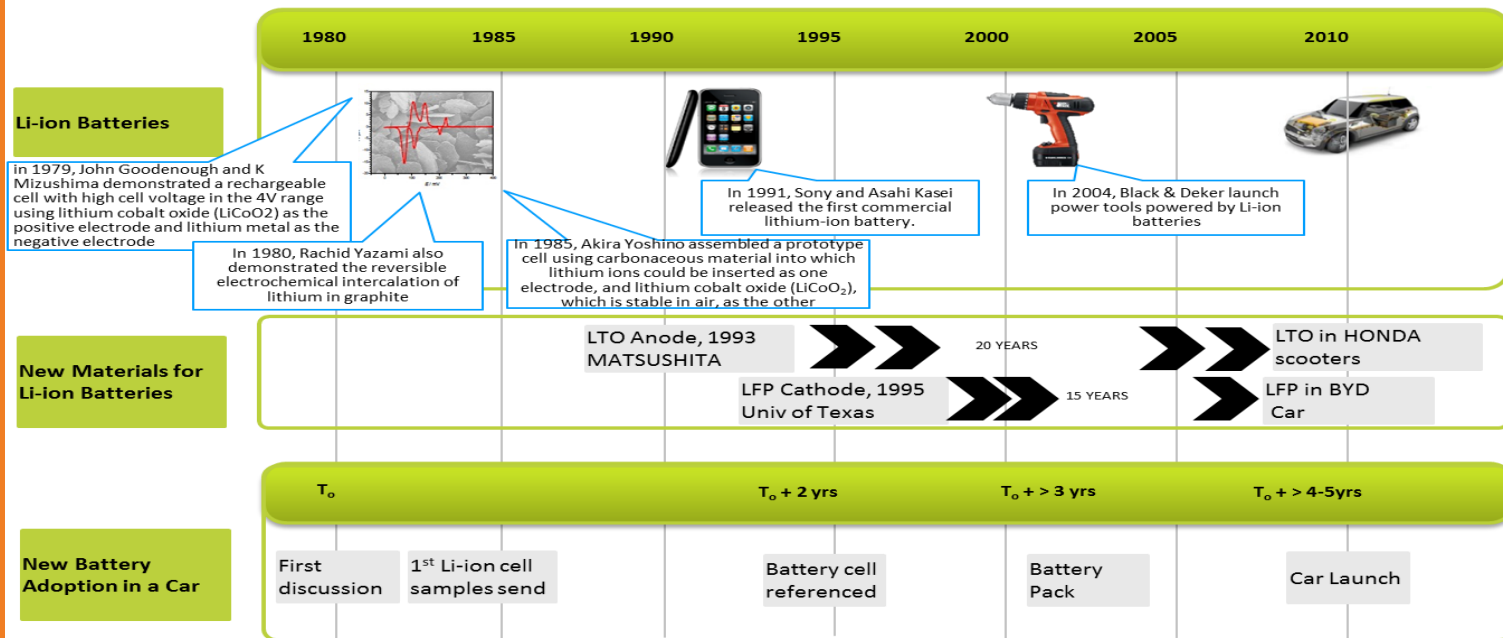


2010

- ⌚ The research and development in this industry is very long and time consuming.
- ⌚ Time to market to commercialize a new material is long. Remember that the first Li-ion battery was launched by Sony in 1991 with LCO cathode, graphite, LiPF_6 electrolyte & polyolefin membrane. It was 20 years ago.
- ⌚ LTO was invented by Matsushita in 1993 (22 years ago)
- ⌚ Lithium iron phosphate was invented in 1995 (20 years ago).
- ⌚ So, it takes between 10 & 20 years to commercialize a new material in the battery industry.

BATTERY TECHNOLOGY ROADMAP

Batteries take a long time to develop; to reach the automotive market, another 4 to 5 years are needed



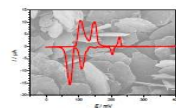
The rechargeable battery market 2016-2025

Two dates
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

TIME TO MARKET FOR NEW MATERIALS



1970ies



1980ies



1991



2004



2010

	2000	2005	2010	2015	2020	2025	2030
CATHODE	LCO		NMC/NCA LMO LFP	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

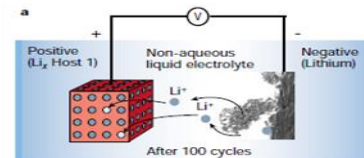
Source: AVICENNE ENERGY 2016

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. 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")
In 2006, SONY had to recall millions of portable PCs for total costs of 400 million USD, more than there profit-to-date



Automotive

With new cathode chemistry, most of the automotive today on the markets experienced safety concerns: (1) BYD Taxi in China with a lithium iron phosphate cathode (2) GM Volt in the US with a LG Chemical battery using LMO cathodes (as a result of a crashed tested Chevrolet Volt caught three weeks after the testing !) (3) PRIUS P-HEV in the US (converted from HEV Prius by a local engineering company without any authorisation by Toyota)



Aircraft

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.

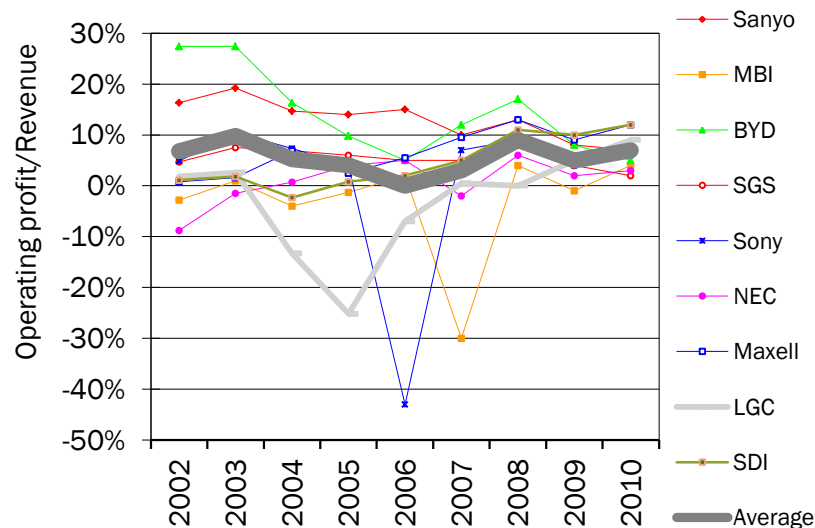


LIB BUSINESS

RECALLS SLASH BATTERY PROFIT

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

RECALL SLASH BATTERY PROFIT



Source: AVICENNE ENERGY 2016

The rechargeable battery
market 2016-2025

Our clients
**International
Battery SEMINAR & EXHIBIT**
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

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	?	?

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

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

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

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.

Source: AVICENNE ENERGY 2016

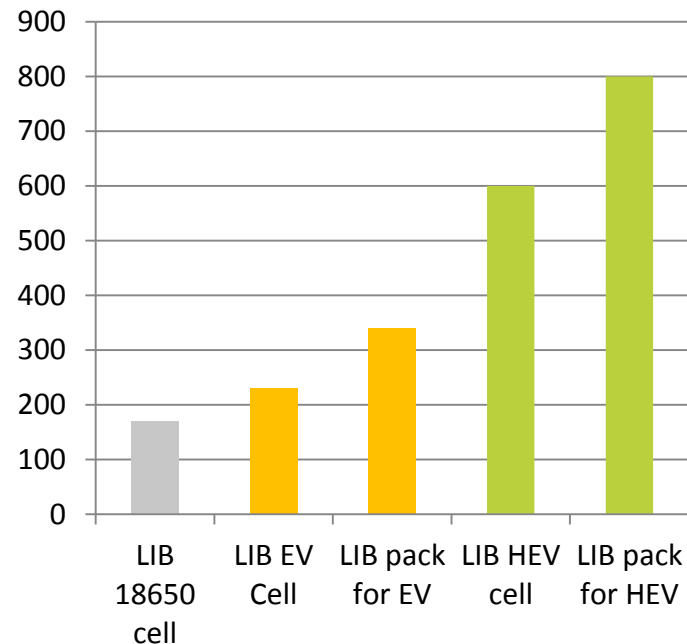
LIB BATTERY COST

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
- ...

Source: AVICENNE ENERGY 2016

Battery price in 2016 \$/kWh



The rechargeable battery market 2016-2025

Two days
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

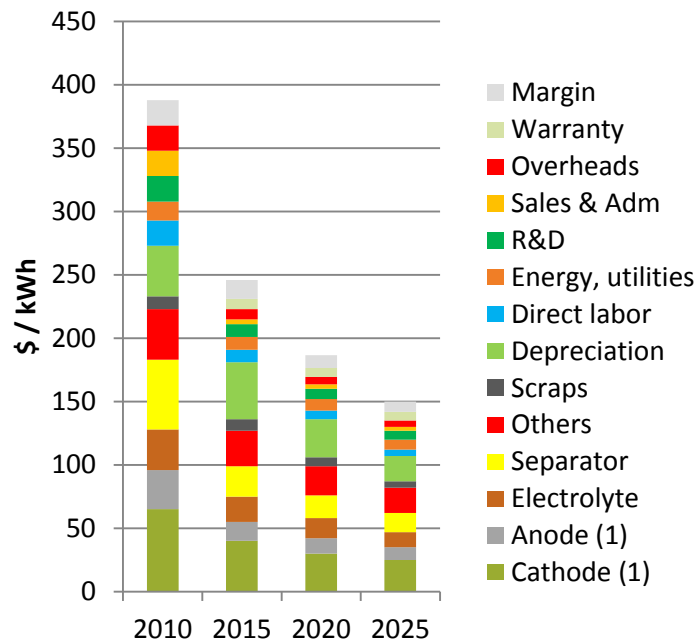
March 20th, 2017
 Fort Lauderdale, FL, USA

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

LI-ION BATTERY COST

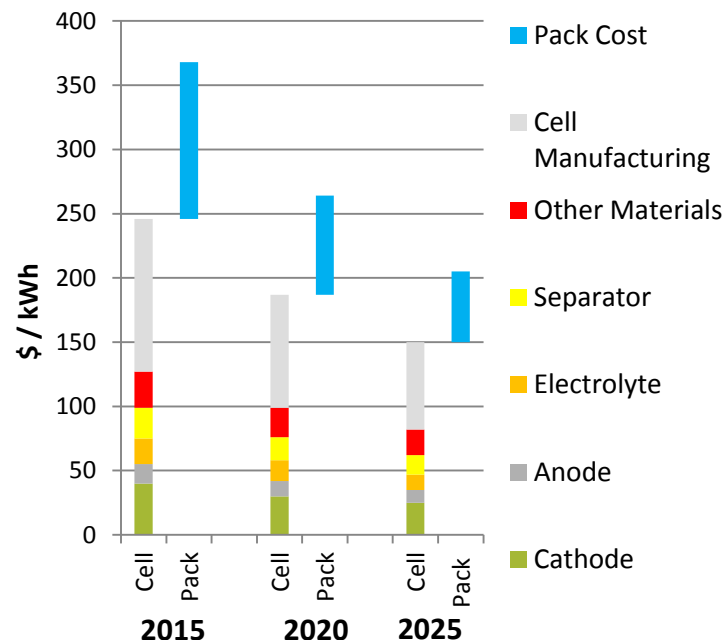
2015-2025

LIB cell average cost (40 Ah pouch)
(EV design ; NMC cathode)



(1) Active materials only
 Source: AVICENNE ENERGY 2016

LI-ION BATTERY PACK COST FOR EV



* For Production > 100 000 packs/year

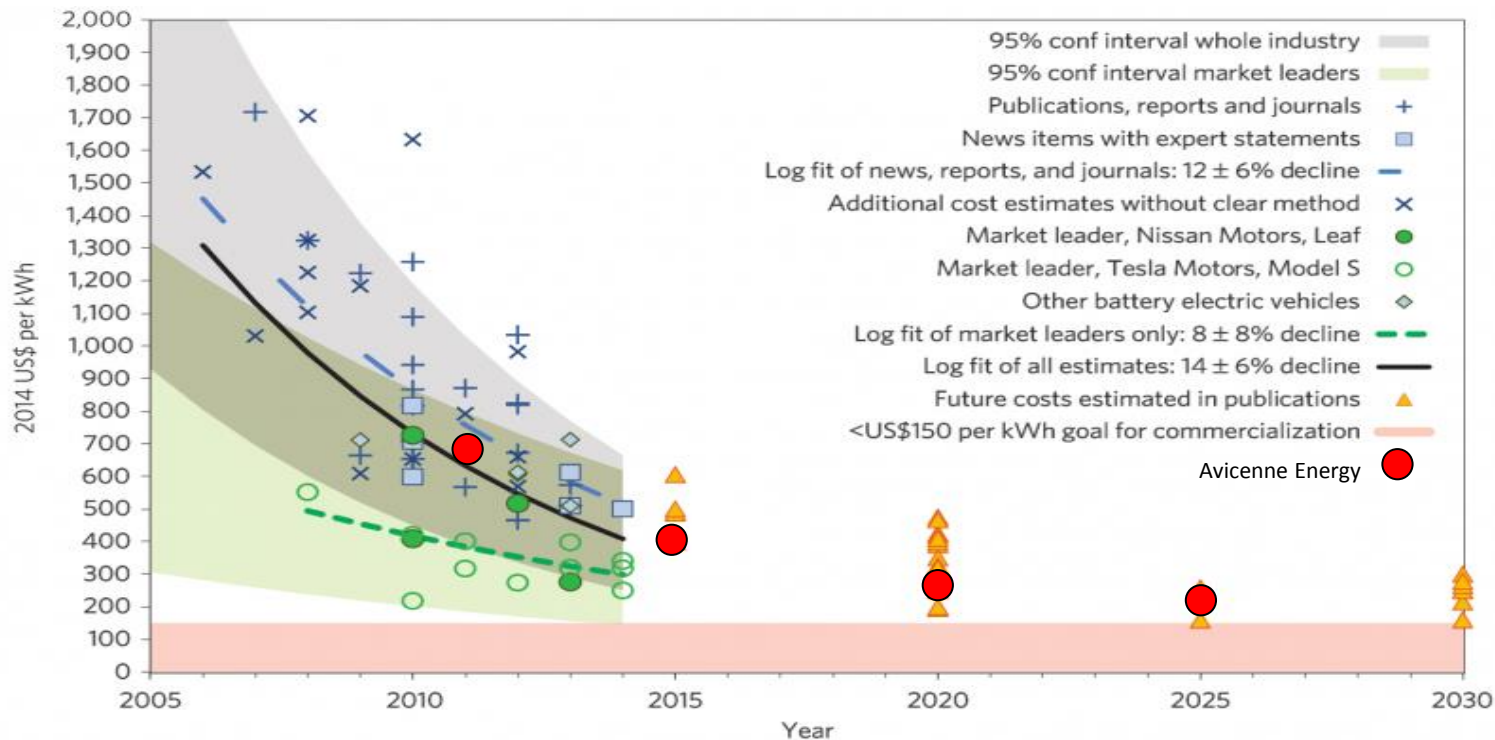
The rechargeable battery market 2016-2025

The battery
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

LIB PRICE FORECASTS



Source: *Rapidly falling costs of battery packs for electric vehicles*, Nature Climate Change, March 2015

The rechargeable battery
market 2016-2025

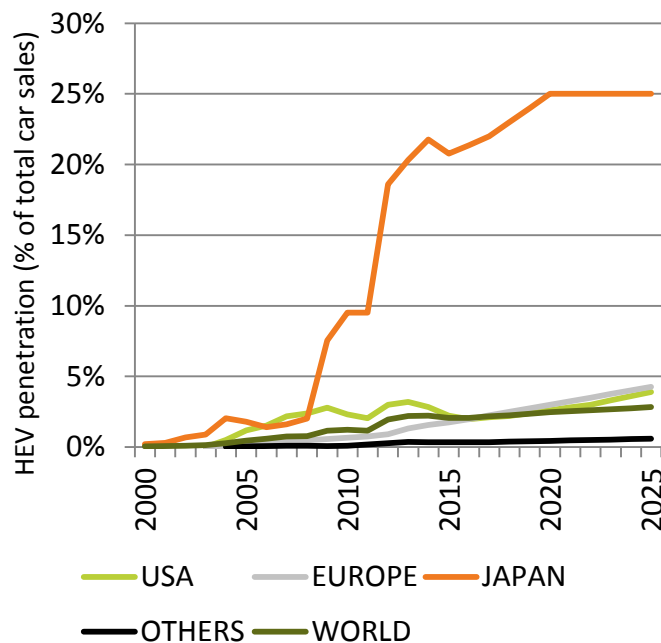
International
Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

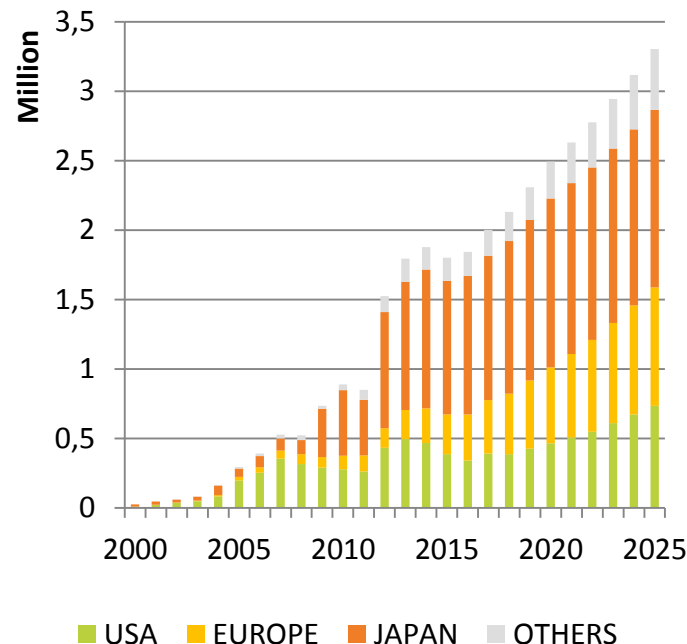
CONTACT
Christophe PILLOT
+ 33 1 47 78 46 00
c.pillot@avicenne.com

HEV FORECASTS 2000-2020

HEV MARKET: <2 M units in 2016 – 2,5 M in 2020 – 3,3 M in 2025



Micro hybrid not included



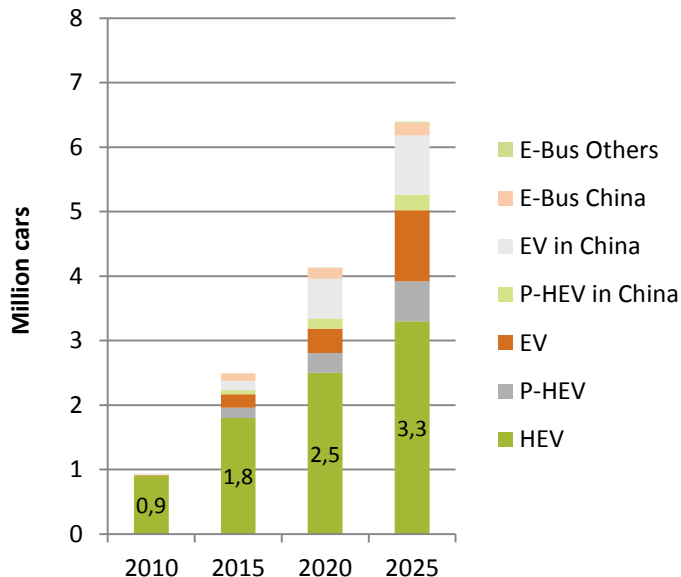
Source: AVICENNE ENERGY Analyses 2016

EV, P-HEV, EV 2025 FORECASTS

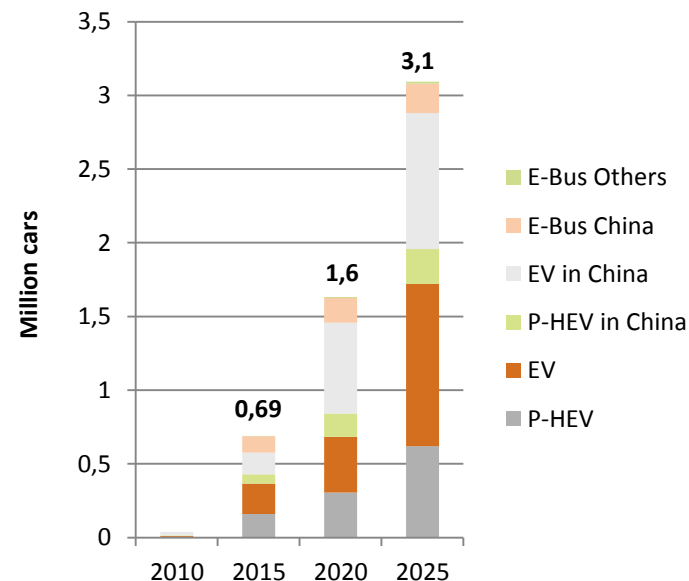
Thanks to very high incentives, China change the game

2016 forecasts: HEV, P-HEV & EV market forecasts up to 2025

HEV, PHEV, EV & E-Bus



PHEV, EV & E-Bus



The rechargeable battery
market 2016-2025

Our partner
**International
Battery** SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

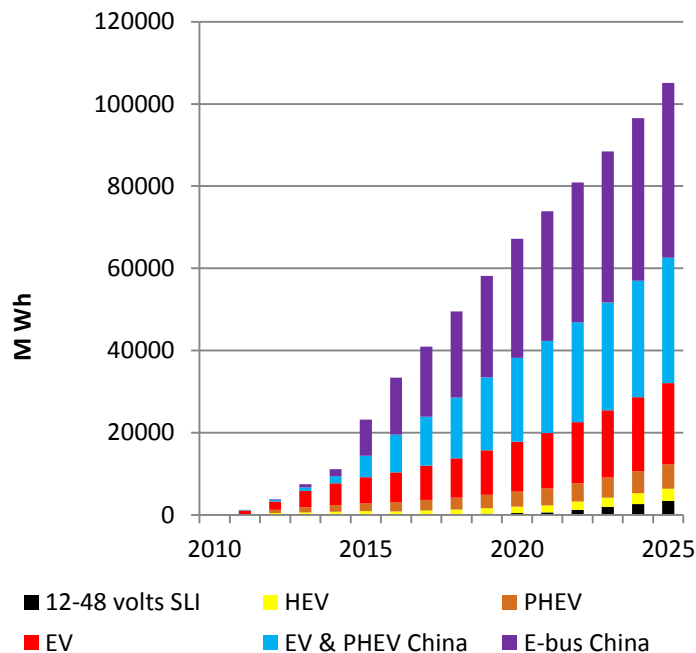
CONTACT

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

TOTAL BATTERY DEMAND 2025 FORECASTS

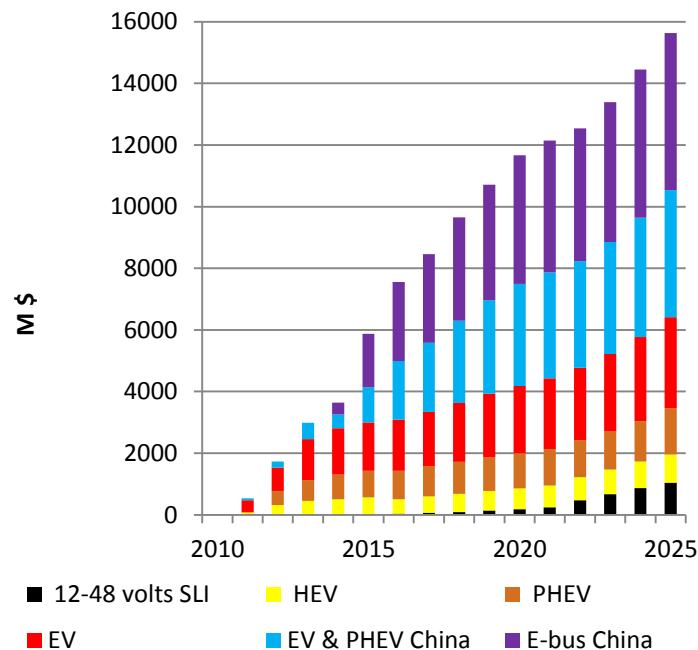
Li-ion for EV, HEV & P-HEV Battery
needs (MWh)

CAGR 2016-2025: +14%



Li-ion for EV, HEV & P-HEV Battery
needs (M\$)

CAGR 2016-2025: +8%



The rechargeable battery
market 2016-2025

International
Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

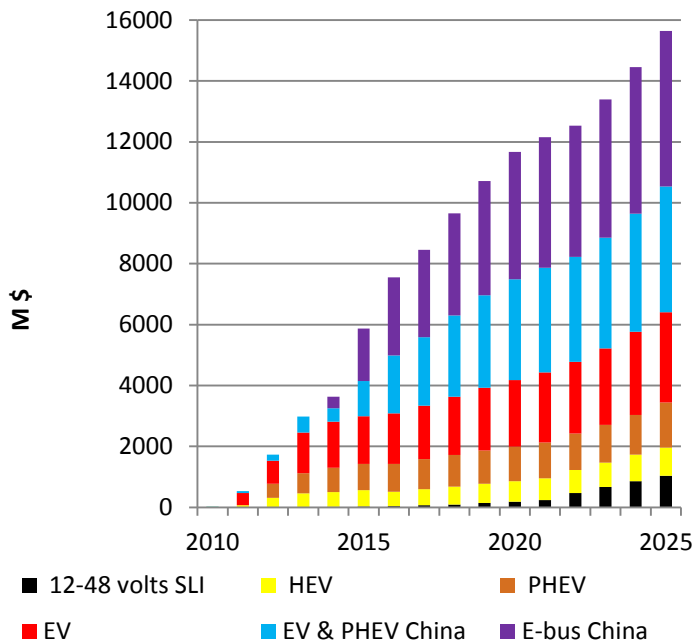
March 20th, 2017
Fort Lauderdale, FL, USA

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

X-EV BATTERY MARKET 2000 – 2025 IN M\$

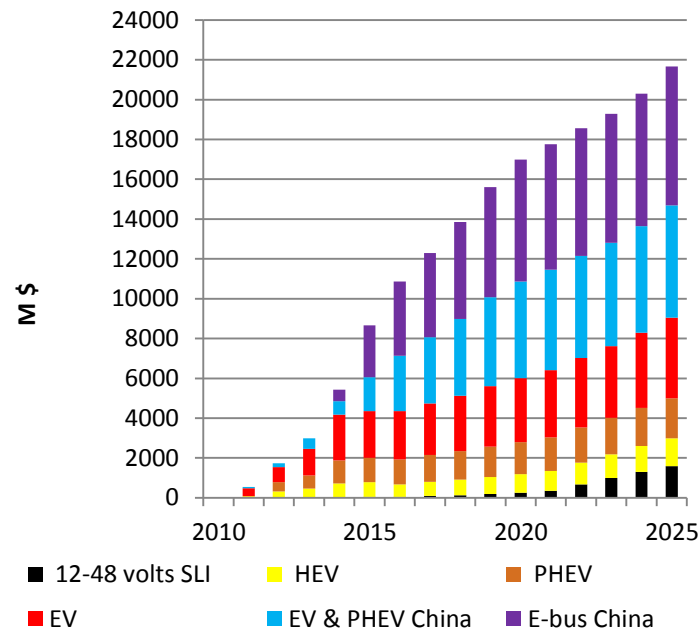
Cell Level

CAGR 2016-2025: +8%



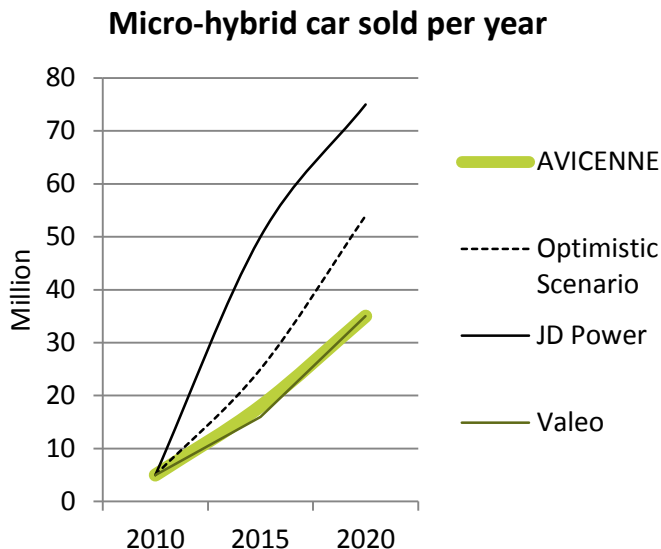
Pack Level

CAGR 2015-2025: +8%



35 MILLION MICRO-HYBRIDS CAR IN 2020

Micro-hybrids car market 2010-2020

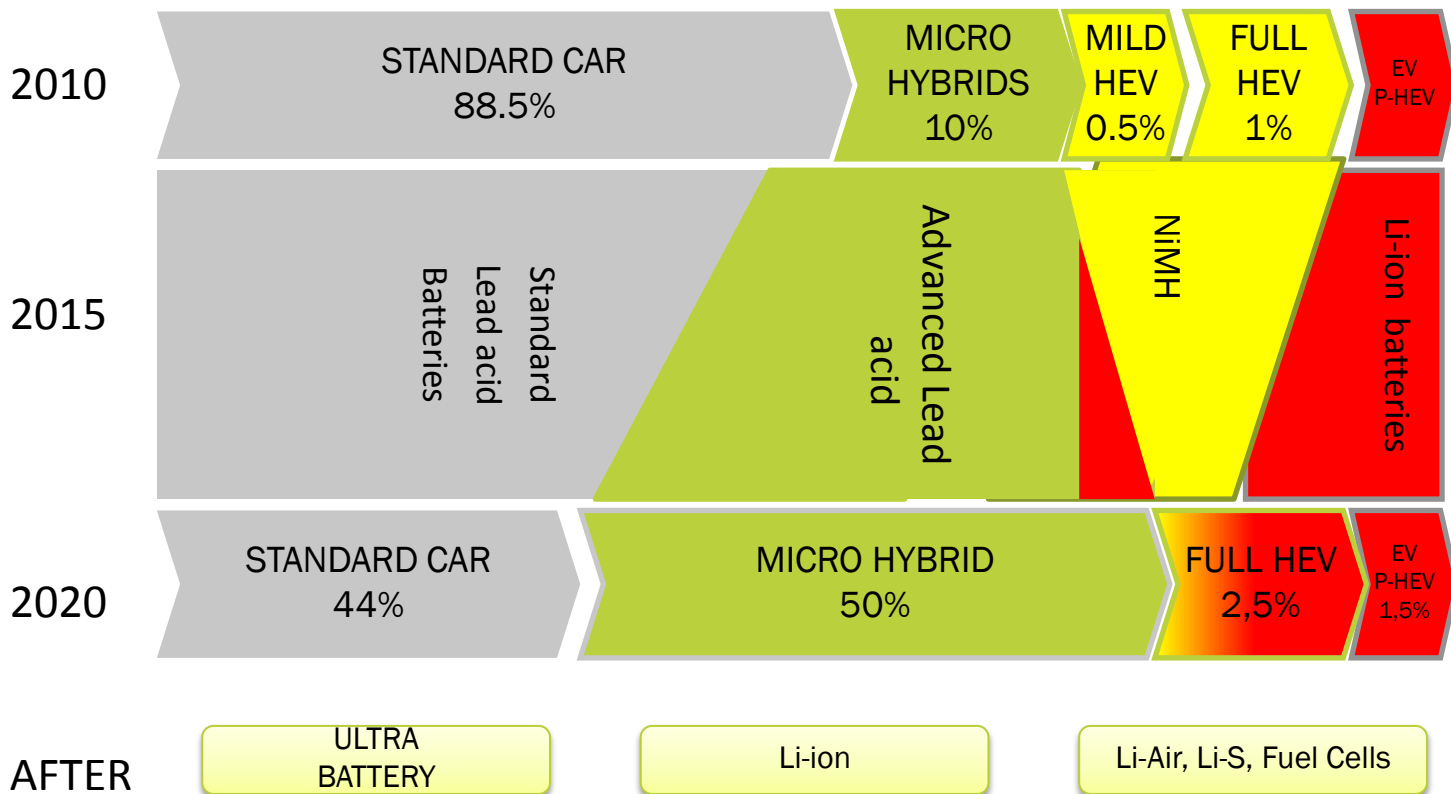


Advantages of micro-hybrid compare to HEV

- ⌚ 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	2,5

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



The rechargeable battery market 2016-2025



March 20th, 2017
 Fort Lauderdale, FL, USA

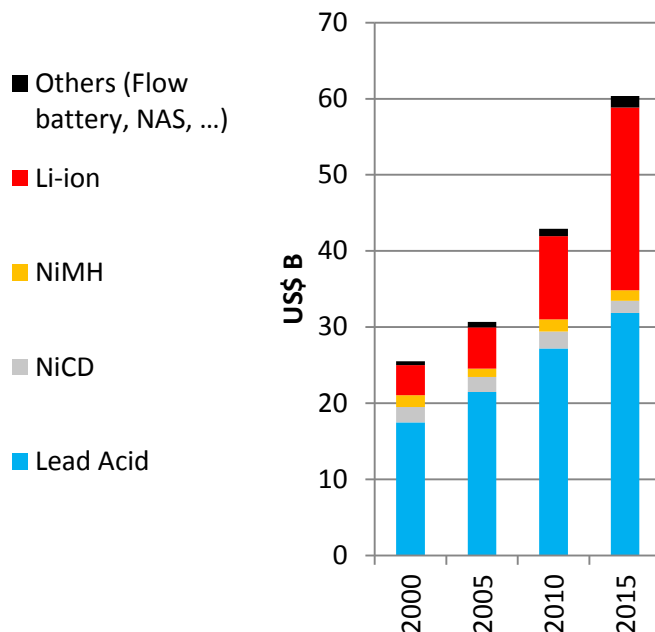
CONTACT

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

THE WORLDWIDE BATTERY MARKET 1990-2015

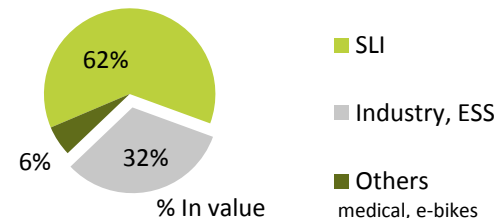
Lithium Ion Battery: Highest growth & major part of the investments

Lead acid batteries: The most important market (90% market share)

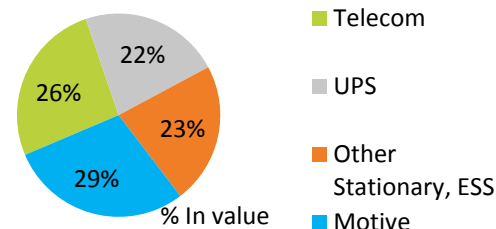


Source: AVICENNE ENERGY, 2016

Lead Acid Batteries 2016
 +360 GWh for > US \$ 33 Billion



Industrial Batteries
 55 GWh for US \$ 11 Billion



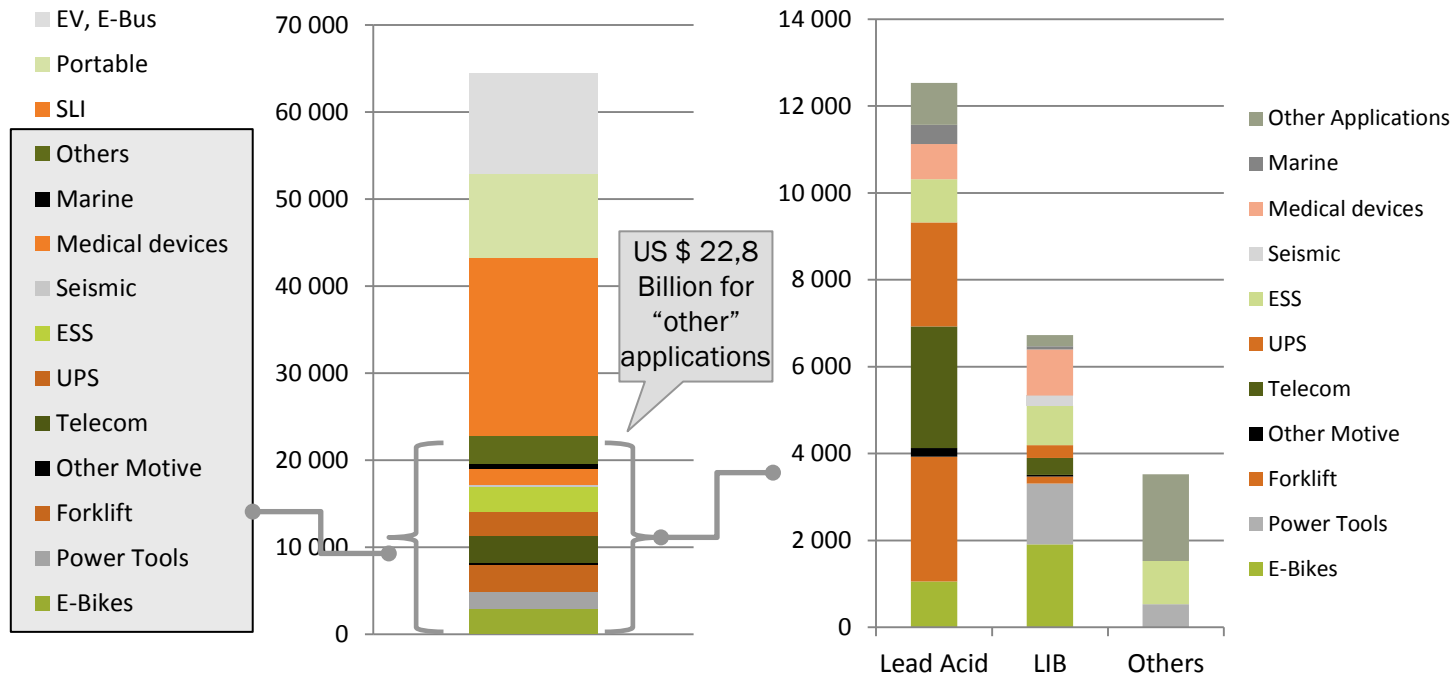
The rechargeable battery market 2016-2025

Two dates
International Battery
 SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & INDUSTRIAL APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

THE WORLDWIDE BATTERY MARKET IN 2016: US \$ 65 BILLION



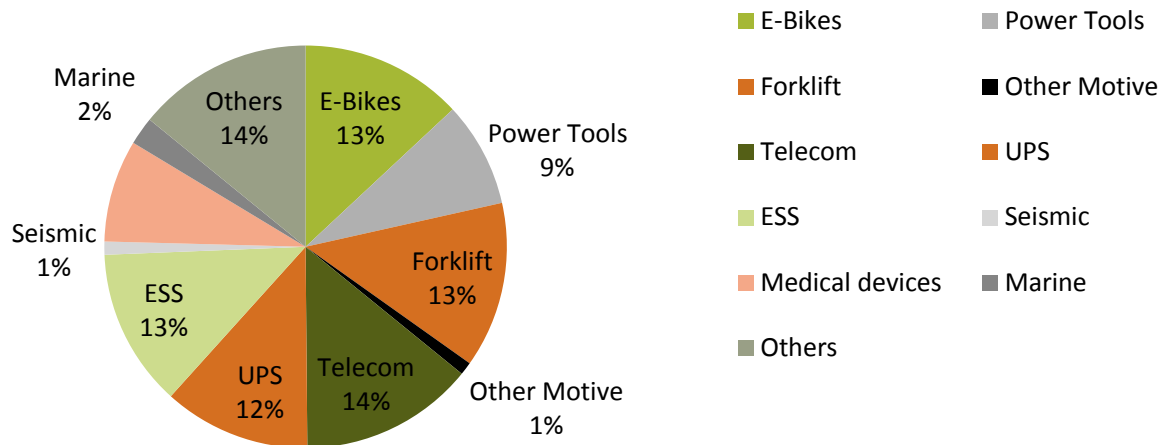
1- Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC DC converters, invertors...) not included

Source: AVICENNE ENERGY, 2017

TOTAL POTENTIAL MARKET (M\$, PACK LEVEL¹)

Application details

US\$ 22,8 Billion in 2016 (1)



Source: AVICENNE ENERGY 2016



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,...

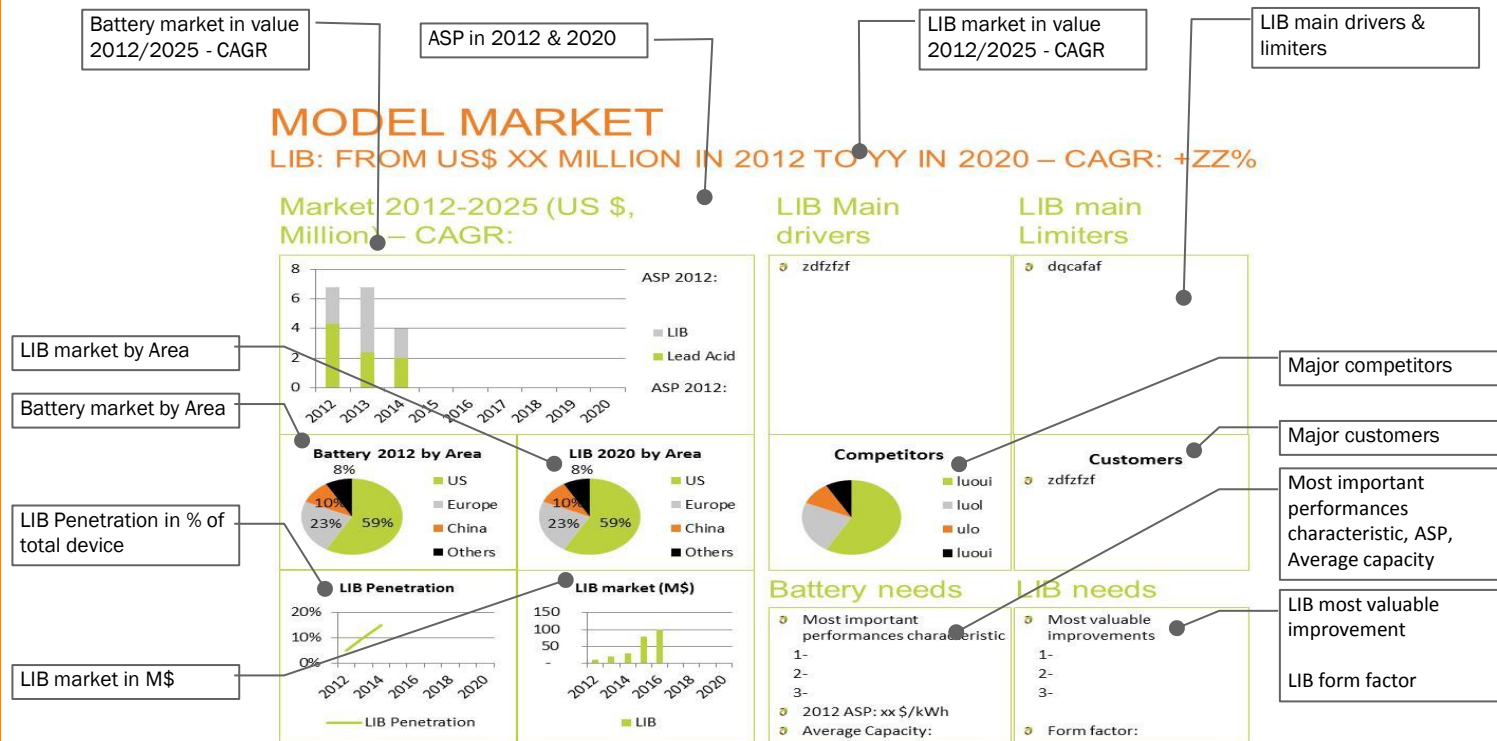
The rechargeable battery market 2016-2025

Your chance
International Battery Seminar & Exhibit
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

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

MARKET SEGMENT SYNTHESIS TEMPLATE



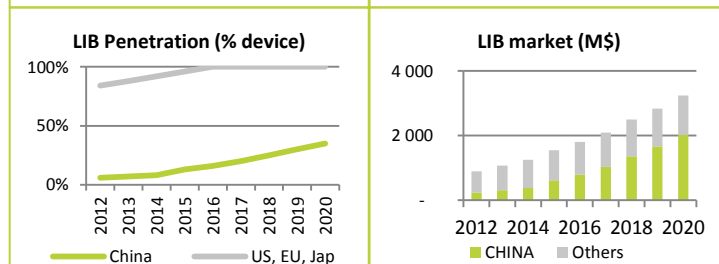
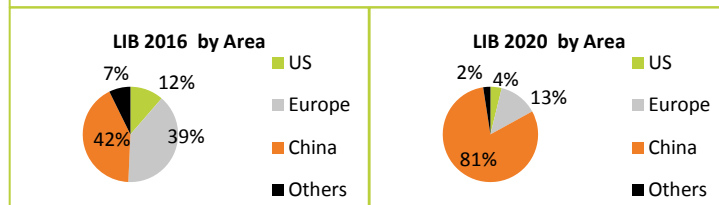
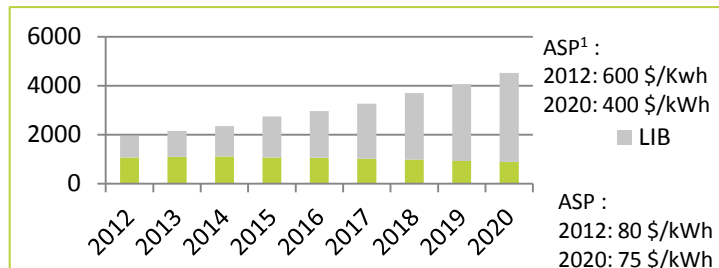
Source: AVICENNE ENERGY Analyses

1- E-BIKES

LIB: FROM US\$ 1,8 BILLION IN 2016 TO 3,2 IN 2020¹ – CAGR: +16%



Market 2016-2020 (US \$, Million) – CAGR: 11%



Main drivers

- 🔗 E-bike in China: Banning of gasoline powered motorcycles in china boost e-bikes: "Necessary"
- 🔗 In US, Europe and Japan, "Green image", sport, leisure, transportation: "Environment & Health"
- 🔗 LIB penetration in China from 6 to 14%

Competitors

- 🔗 BMZ (Germany)
- 🔗 AXEON² (UK)
- 🔗 HITECH (Taiwan)
- 🔗 Phyllion (China)

Main Limiters

- 🔗 In Japan, US and Europe, E-bikes are already equipped by Li-ion
- 🔗 In China the only parameter to choose a battery is the cost
- 🔗 Chinese E-bike ASP: 320 \$/kWh: very difficult to penetrate this market

Customers

- 🔗 Bosch, + > 500 e-bike mfg.
- 🔗 Panasonic
- 🔗 Bion-X
- 🔗 TranX-Z

Battery needs

- 🔗 Performances characteristic
 - 1- Cycle life
 - 2- Energy density
 - 3- Low cost
- 🔗 Average Capacity: 300 Wh

LIB needs

- 🔗 Most valuable improvements
 - 1- Price decrease
 - 2- Cycle life
 - 3- Fast charge
- 🔗 Form factor: from cylindrical to Laminate
- 🔗 No standardization

The rechargeable battery
market 2016-2025

International
Battery SEMINAR & EXHIBIT

March 20th, 2017
Fort Lauderdale, FL, USA

CONTACT

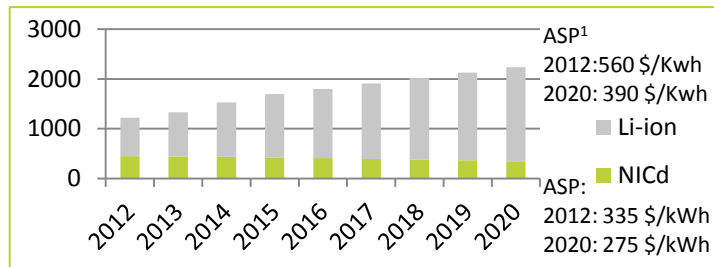
Christophe PILLOT
+ 33 1 47 78 46 00
c.pillot@avicenne.com

2- POWER TOOLS

LIB: FROM US\$ 1,4 BILLION IN 2016 TO 1,9 B IN 2020¹ – CAGR:+8%



Market 2016-2020 (US \$, Million) – CAGR:+5%



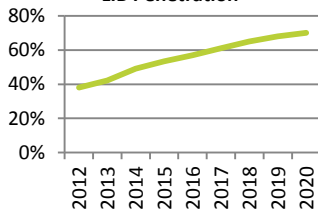
Battery 2013 by Area

- >75% of the power tools are made in China
- But, battery pack could be made on the end-user area (Ex: Bosch – Axeon Poland)

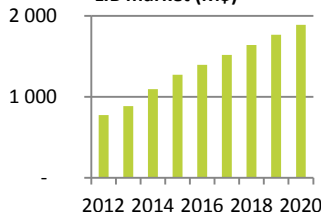
LIB 2020 by Area

- Power tools will be made in China
- Local demand in Europe, US, next to the end user to increase flexibility & Just in Time mfg.

LIB Penetration



LIB market (M\$)



LIB Main drivers

- Higher voltage
- NiCd substitution
- NiCd regulation
- Cordless power tools & gardening tools market increase (+4% per year)
- Higher energy density, less weight

LIB main Limiters

- LIB average sales price
- Reliability
- High rate discharge
- Fast charge
- Life time

Competitors

- Cell/Pack Mfg.: TOP3: Samsung, Panasonic, Sony (> 75%)
- Pack makers: AXEON (Bosch),

Customers

- Bosch
- B&D
- TTI
- Makita
- Jingding
- Hilti
- ...

Battery needs

- Important characteristic:
 - Higher power & capacity
 - Fast recharge
- 2012 ASP NiCd: 350 \$/kWh
- 2012 ASP LIB: 550 \$/kWh
- Average Capacity: 60 Wh

LIB needs

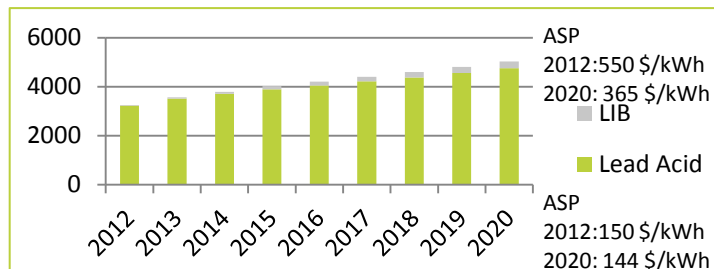
- Most valuable improvements
 - Price decrease
 - Fast charge
 - High rate discharge
- Form factor: Cylindrical
- No standardization

3- MOTIVE INDUSTRIAL: FORKLIFTS²

LIB: FROM US\$ 160 MILLION IN 2016 TO 275 IN 2020¹ – CAGR: 15%



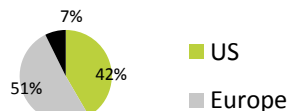
Market 2016-2020 (US \$, Million) – CAGR:7%



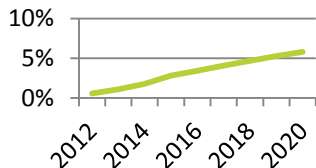
Battery 2012 by Area

Europe – largest producer of motive power batteries – has higher percentage of electric vs. gas trucks (75%) than in N. America (64%) – China: High % of Gas/propane trucks (> 80%)

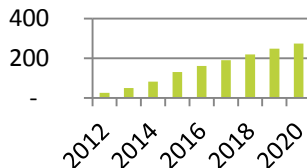
LIB 2020 by Area



LIB Penetration



LIB market (M\$)



Main drivers

- Where economies are healthy, they reflect strong motive power production
- Europe & US got high E-forklift ratio compare to Asia
- LIB higher life time (* 3 to 5)
- Multiple shift operation where battery change is required (time consuming)

Competitors

- Lead Acid & LIB: Ensysis (35%), Exide (10%), East Penn (10%), Hoppecke (10%), Crown (10%)
- LIB systems: BMZ, Lithium Balance, ...

Main Limiters

- Low penetration of E-forklift in Asia
- High LIB capital price (x 5 compare to lead acid)
- Safety concerns
- in two of the lift truck types, sit-down rider and high reach, the counterbalance for the lift truck is supplied mainly by a lead acid battery

Customers

For lead acid, After market represent 60% of the market: lot of different customers (industrials)
For LIB, OEM Forklift: TOYOTA, Kion, Jungheinrich, NACCO, Crown, Mitsubishi Caterpillar

Battery needs

- important characteristic
 - 1-high charge/discharge rates and capacity
 - 2-high life time, range,
- Average Capacity: 22 kWh

LIB needs

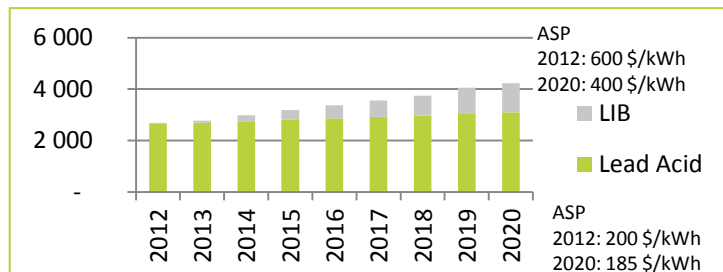
- Most valuable improvements
 - 1- Price
 - 2- Convince customers on "total cost of ownership"
- Form factor: large format prismatic – size standardization

4- STATIONARY: TELECOM MARKET

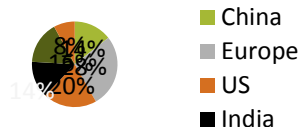
LIB: FROM US\$ 0,5 BILLION IN 2016 TO 1,1 IN 2020¹ – CAGR > 20%



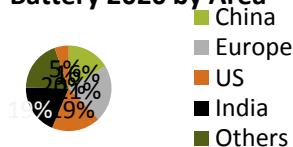
Market 2016-2020 (US \$, Million) – CAGR: +7%



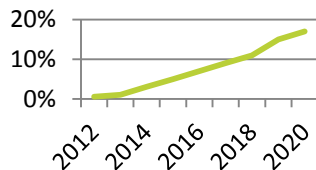
Battery 2012 by Area



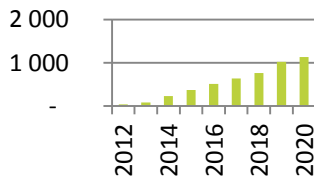
Battery 2020 by Area



LIB Penetration



LIB market (M\$)



Main drivers

- LIB developed for new equipment
- Increased Bandwidth requirements
- Wireless Market driving growth
- Strong Network Growth in China, India, E. Europe & S. America
- 2G-> 3G-> 4G ... need new equipment's
- LIB: **Specially in Hot climate**

main Limiters

- Lead Acid Vs. Li-ion...
- Lead Acid capital cost 5 times cheaper
- Total cost of ownership could be compare with Lead acid

Competitors

- Lead Acid & LIB: Energys (35%), Exide (10%), and local suppliers in each countries
- LIB systems: "large companies": SAFT, others?

Customers

- Not so many customers; big telecom carriers in each countries

Battery needs

- Most important performances characteristic
 - Hot T°C performances
 - Customized for the new Equipment network
- Average Capacity: 5-10 kWh modules (100 Ah)

LIB needs

- Most valuable improvements
 - Capital costs
 - Safety Proof
 - Reliability
- Customized battery developed for new equipment

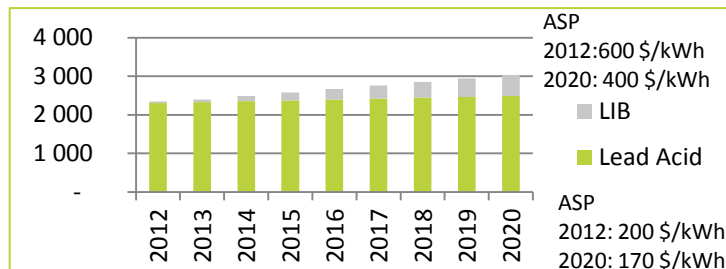
5- STATIONARY: UPS MARKET

LIB: FROM US\$ 0,27 BILLION IN 2016 TO 0,55 IN 2020¹ – CAGR: 19%

Market 2013-2020 (US \$, Million) – CAGR: +4%

Main drivers

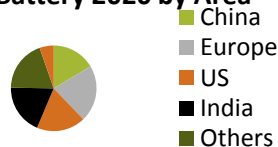
main Limiters



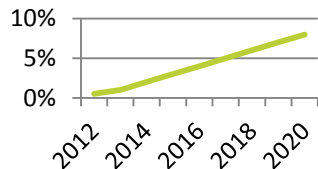
Battery 2012 by Area



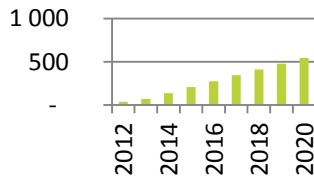
Battery 2020 by Area



LIB Penetration



LIB market (M\$)



- UPS Drivers:
- New Data Storage Centers
 - Mobile Society
- LIB drivers:
- Less volume, less place
 - > Life time
 - LIB is more needed where data are sensitive
 - Li-ion battery could also help to save electricity during peak time

- Safety could be an important issue here

Competitors

- Lead Acid & LIB: Energys (35%), Exide (10%), and local suppliers in each countries
- LIB systems: local companies providing > services

Customers

- Few leaders/many products: Emerson/Liebert, Schneider/APC, Eaton Powerware, Gamatronic, Riello

Battery needs

- Most important performances characteristic
 - Back-up at high current
 - weight, volume
 - life time
- Average Capacity: 3-5 kWh modules

LIB needs

- Most valuable improvements
 - Convince on Safety
 - Capital Cost
 - Reliability
- Form factor: Cylindrical
- New development for new equipment

Note: UPS: Uninterruptible Power Supply
 APC: American Power Conversion

ESS SEGMENTATION

Services provided by Energy Storage System (ESS)

On grid services

Regulation

- Reconcile momentary differences caused by fluctuations in generation and/ or loads
 - Frequency regulation
 - Voltage support
 - Load following/ ramping support
 - Power quality

Arbitrage

- Store energy when the price of electricity is low and releases it on the grid when prices are high

Back-up and reserves

- Provide emergency power when utility power is not available
 - UPS (Uninterruptible power supply)
 - Power continuity
 - Reserves to face loss of one generator

Black start

- Provide an active reserve of power and energy to (re)start power generator

Investment deferral

- Enable deferral of utility investments by using relatively small amounts of storage
 - Congestion relief
 - Avoid infrastructure investment

Grid independent power supply

- Provide electricity power supply in an area not connected to the grid e.g.
 - Rural community
 - Based stations powered by Solar energy

Off grid services

The rechargeable battery
market 2016-2025



March 20th, 2017
Fort Lauderdale, FL, USA

ESS SEGMENTATION

Stationary Energy Storage - Potential segmentation

		Regulation ¹	Arbitrage			Black start	Back-up			Invest. deferral	Grid independent power supply
			Hourly/daily peak	Weekly peaks	Seasonal peak		UPS	Power continuity	Reserves		
Generation	Conventional & regular RE	1 ✓	4 ✓	✓	7 ✓	8 ✓			9 ✓		10 ✓
	PV integration	2 ✓	5 ✓	✓	✓						✓
	Wind integration	3 ✓	6 ✓	✓	✓						✓
Transmission & Distribution		11 ✓							12 ✓	✓	
End-users	Residential	13 ✓	14 ✓	✓				✓			19 ✓
	Commercial	✓	15 ✓	✓		16 ✓	17 ✓	18 ✓			
	Industrial	✓	✓	✓		✓	✓	✓			20 ✓

Existing markets # Emerging markets

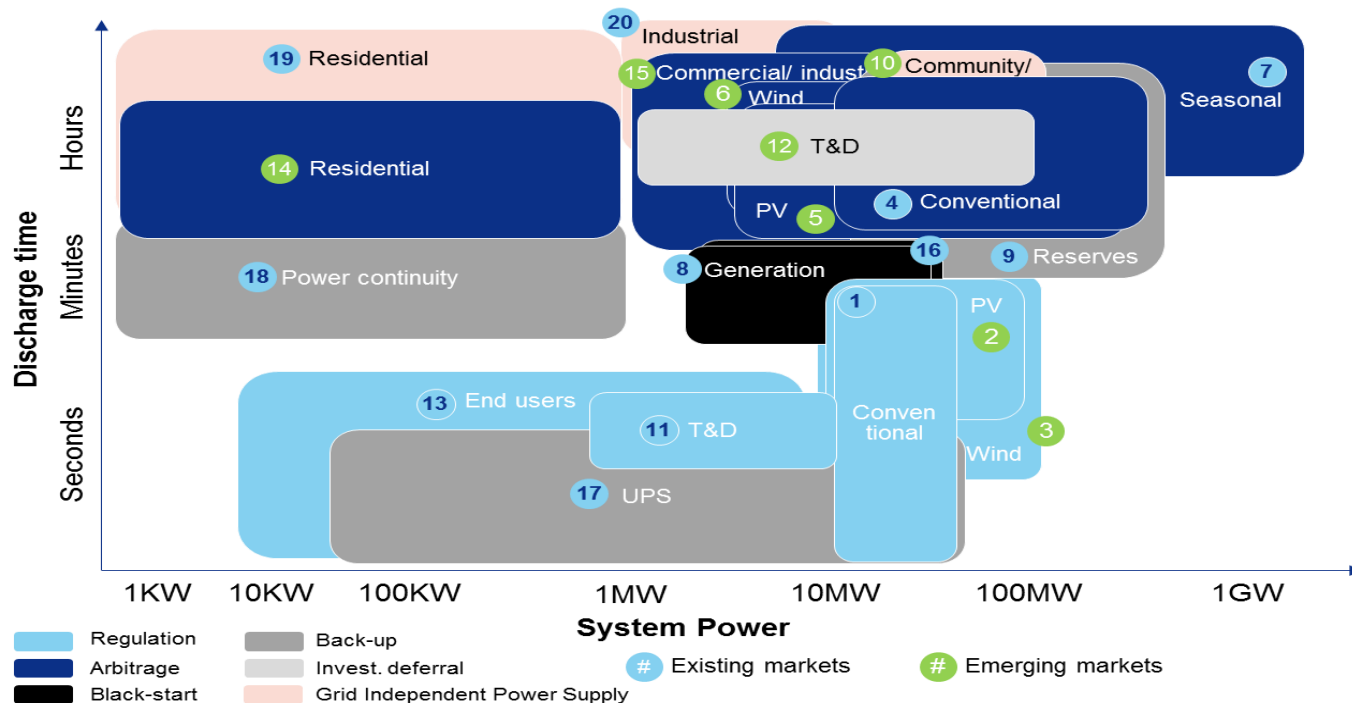
CONTACT

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

ESS REQUIREMENTS

On structuring parameters: discharge time and average power, segments highlight different patterns

Segment requirement: Powers and Discharge time



The rechargeable battery market 2016-2025

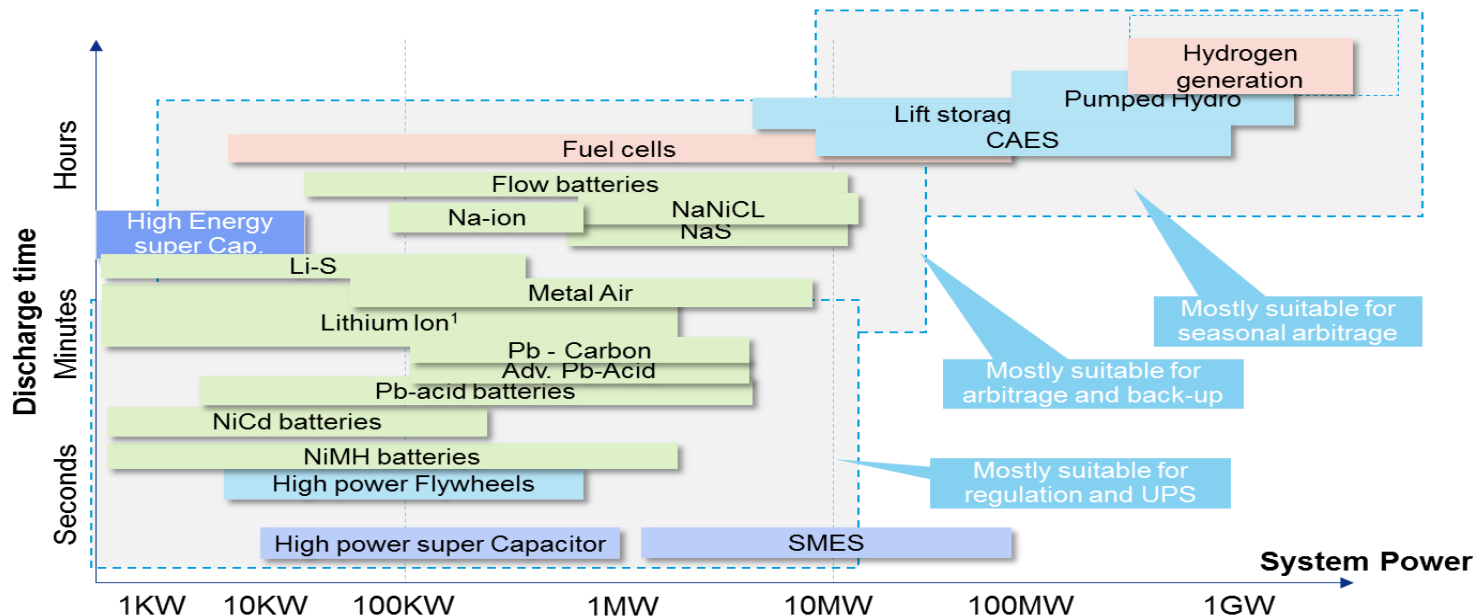
The rechargeable battery market 2016-2025
 International Battery Seminar & Exhibit
 ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

ENERGY STORAGE SOLUTIONS

Mapped on discharge time and power, technologies will appear suitable for certain segments only

System power and discharge time of energy storage technologies



Source: AVICENNE Energy, 2016

The rechargeable battery
market 2016-2025

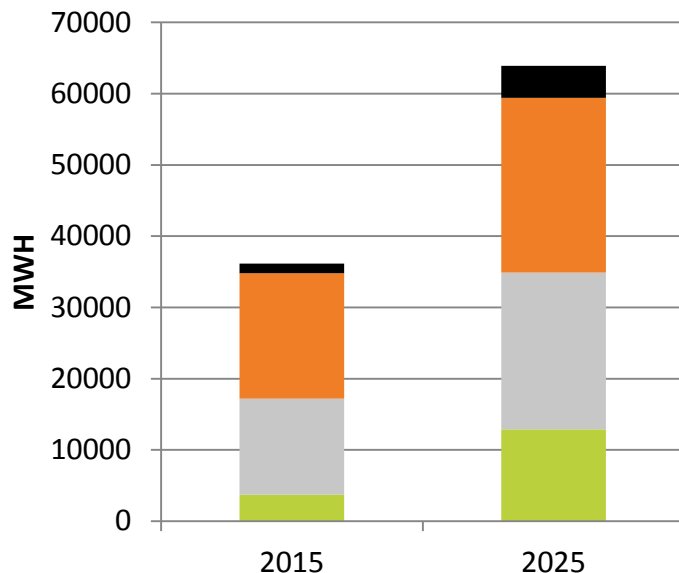
THE MARKET
**International
Battery** SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & INDUSTRIAL APPLICATIONS

March 20th, 2017
Fort Lauderdale, FL, USA

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

ESS MARKET & FORECASTS

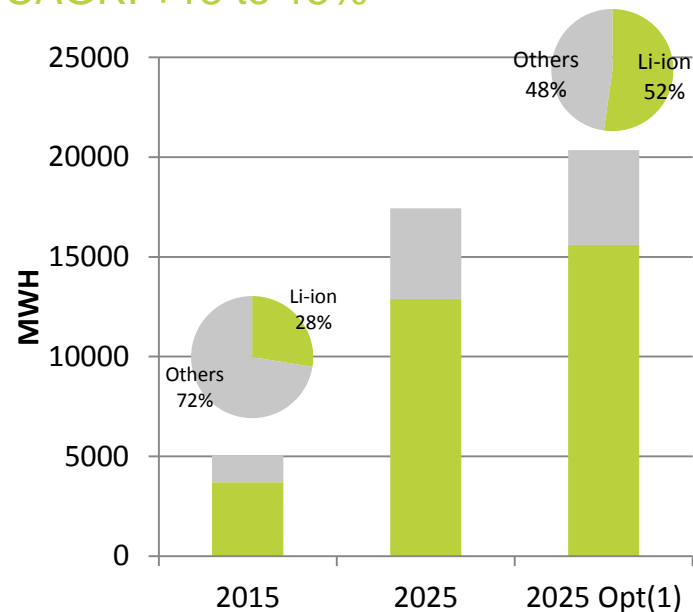
From 36 GWh to 65 GWh in 2025
CAGR: +6%



- Generation and T&D segments (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12)
- UPS (18)
- Power continuity, Telecom (17)
- ESS End Users (13, 14, 15, 16, 19, 20)

Source: AVICENNE Energy, 2016

ESS excl Telecom & UPS
CAGR: +13 to 15%



- Generation and T&D segments (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12)
- ESS End Users (13, 14, 15, 16, 19, 20)

(1) If LIB cost is < 150\$/kWh, the market could be much more important

The rechargeable battery market 2016-2025

Your chance
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

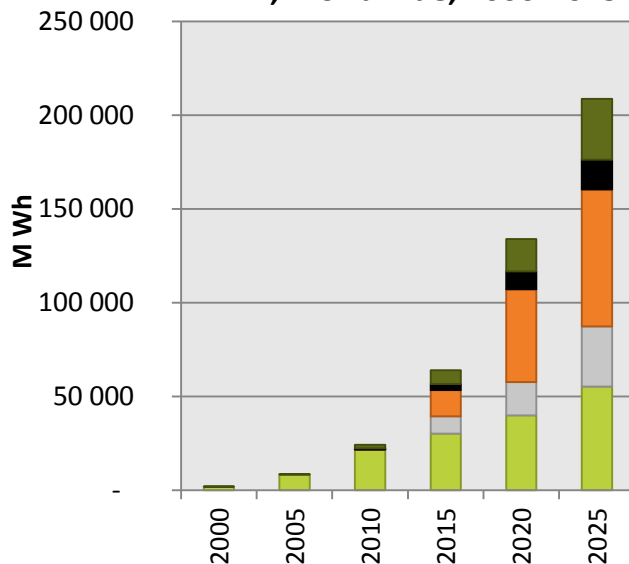
CONTACT
 Christophe PILLOT
 + 33 1 47 78 46 00
 c.pillot@avicenne.com

LI-ION BATTERY MARKET FORECASTS

From 78 GWh in 2016 to
210 GWh

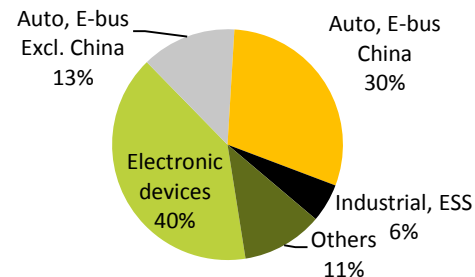
CAGR 2016/2025
 +13 % per year in Volume

**Li-ion Battery sales,
 MWh, Worldwide, 2000-2015**

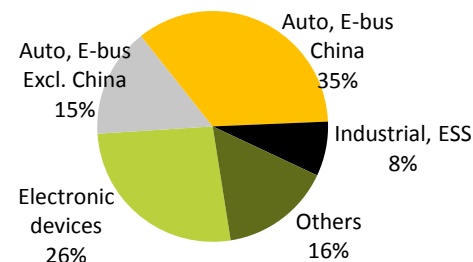


CAGR 15/25	
Others	16%
Industrial, ESS	17%
Auto, E-bus China	18%
Auto, e-bus Excl. China	13%
Electronic devices	6%

2016: 78 GWh



2025: 210 GWh



Others: medical devices, power tools, gardening tools, e-bikes...

Source: AVICENNE Energy 2016

The rechargeable battery market 2016-2025

Our clients
International Battery SEMINAR & EXHIBIT
ADVANCED BATTERY TECHNOLOGIES FOR CONSUMER, AUTOMOTIVE & MILITARY APPLICATIONS

March 20th, 2017
 Fort Lauderdale, FL, USA

CONTACT

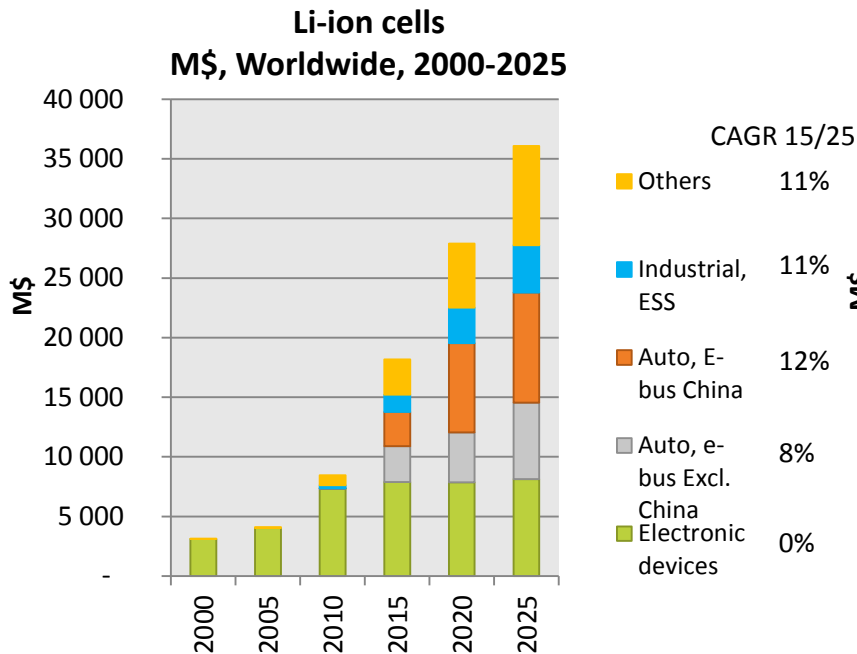
Christophe PILLOT
 + 33 1 47 78 46 00
c.pillot@avicenne.com

LI-ION BATTERY MARKET FORECASTS

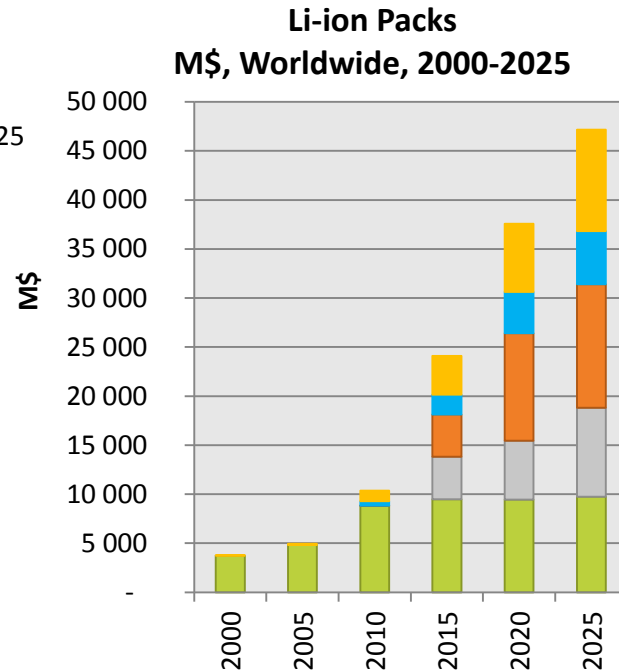
CAGR 2016/2025 +13 % per year in Volume

Cell: +7% per year in value

Pack: +8% per year in value



Others: medical devices, power tools, gardening tools, e-bikes...
 Source: AVICENNE Energy 2016



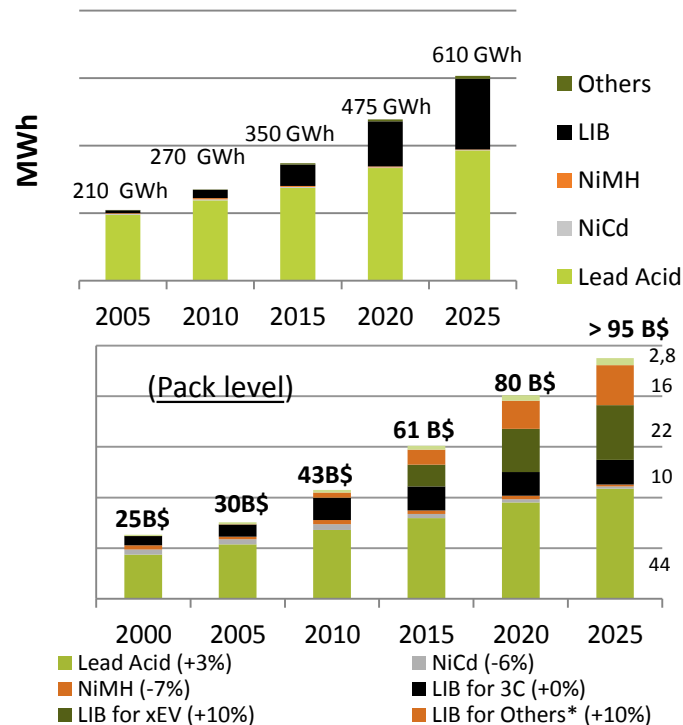
TAKEAWAYS

Battery Market 2010-2025

CAGR = +5% / Li-ion > +8%

- Li-ion battery is driven today by Automotive & Industrial applications
- In 2012, most of the car makers (except Toyota) switch to Li-ion for HEV
- P-HEV, EV and E-buses will be powered by Li-ion:
11 B\$ market in 2016 - 17 B\$ in 2020 & 22 B\$ in 2025 with high numbers in China (2016: US\$ 2,8 Billion for xEV and US\$ 3,7 Billion for xE-Buses)
- EV expectations attract large Chemical companies
- New materials are needed to meet Automotive standards
- HEV will account for less than 3% of the auto sales in 2020
- P-HEV & EV < 2% by 2020
- Micro-hybrid will achieve >50% in 2020/25
- Lead acid battery will be the first market in 2025 in volume, but Li-ion market will be higher than Lead acid from 2020.
- 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 > 10% in the next 15 years
- ESS will reach 10 Billion \$ market at the pack level in the next 5 years
- ESS market could be much more important if the price of LIB at the system level is under 150 \$/kWh

RECHARGEABLE BATTERY MARKET WORLDWIDE 2000-2025



(CAGR 2016-2025)

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

