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ENERGY

INFORMATION FOR GROWTH

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January 30th, 2017

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Lithium ion battery raw material Supply & demand 2016-2025

Christophe PILLOT

Director, AVICENNE ENERGY

Presentation Outline

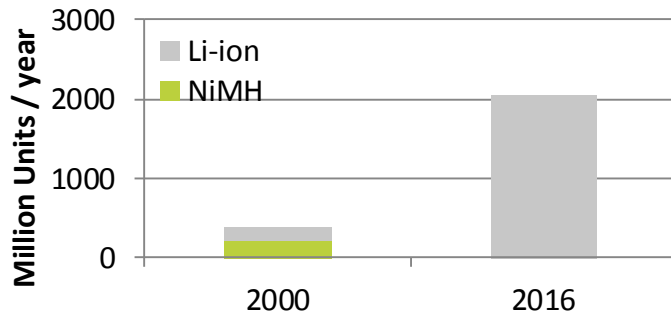
- The rechargeable battery market in 2016
- The Li-ion battery value chain
- Li-ion battery material market
- Forecasts & conclusions



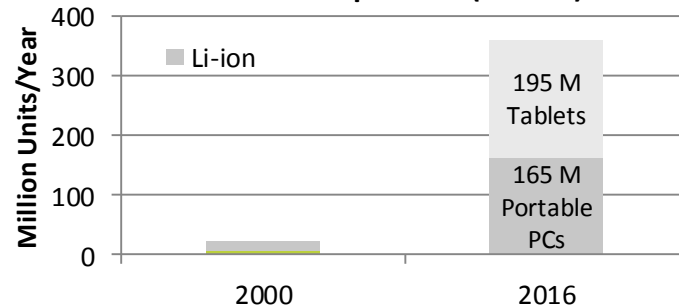
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THE BATTERY MARKET IS REALLY DYNAMIC

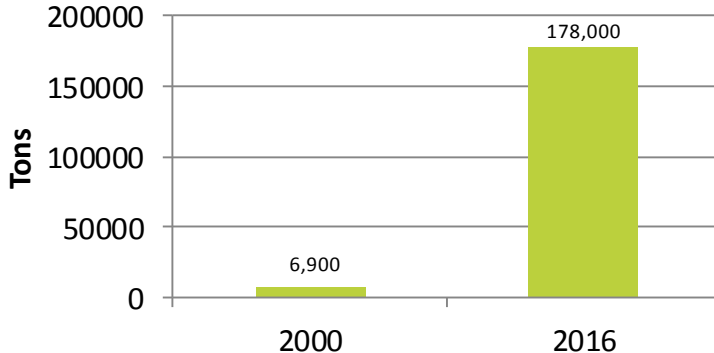
Cellular Phones sold per Year (Million)



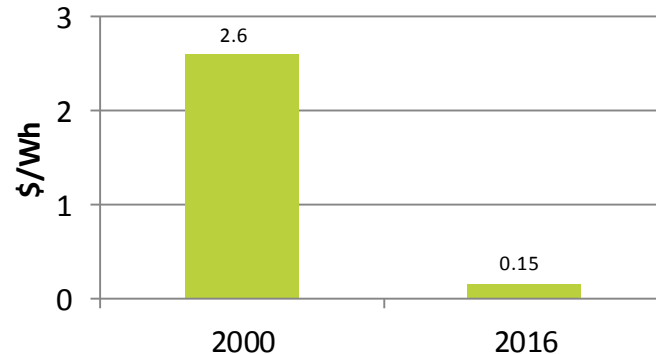
Portable PC sold per Year (Million)



Tons of cathode active materials



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

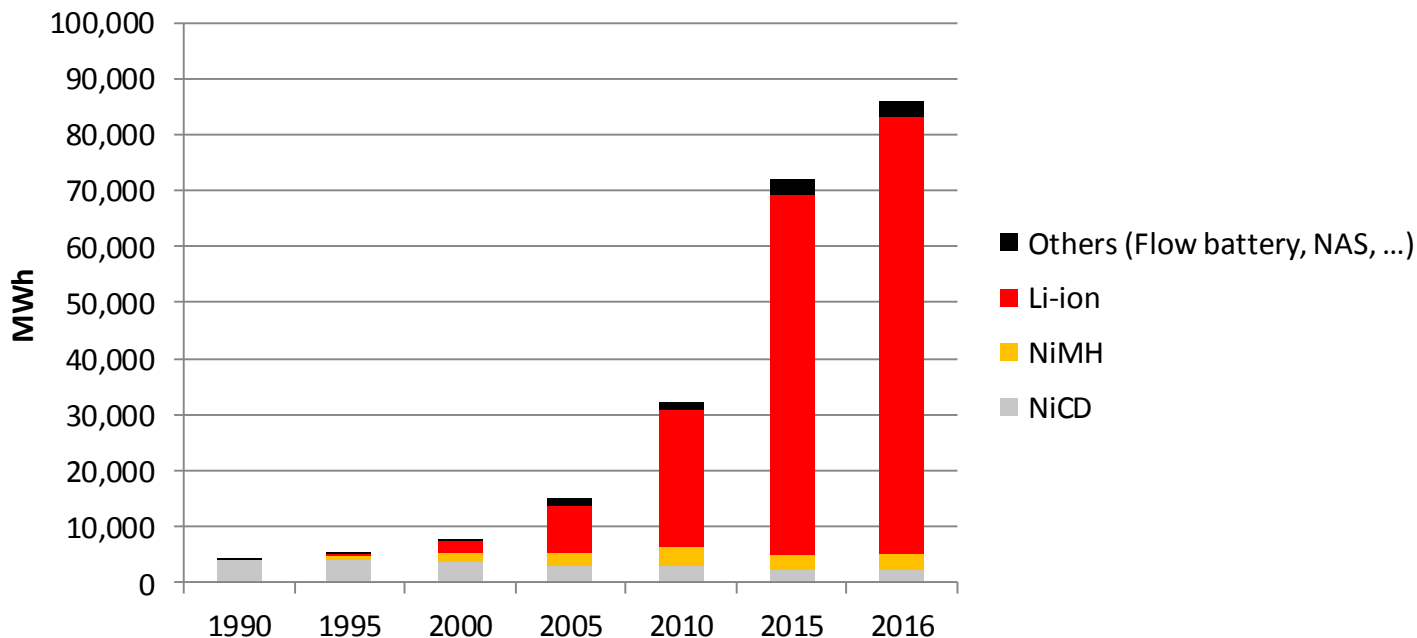




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THE WORLDWIDE BATTERY MARKET 1990-2016

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

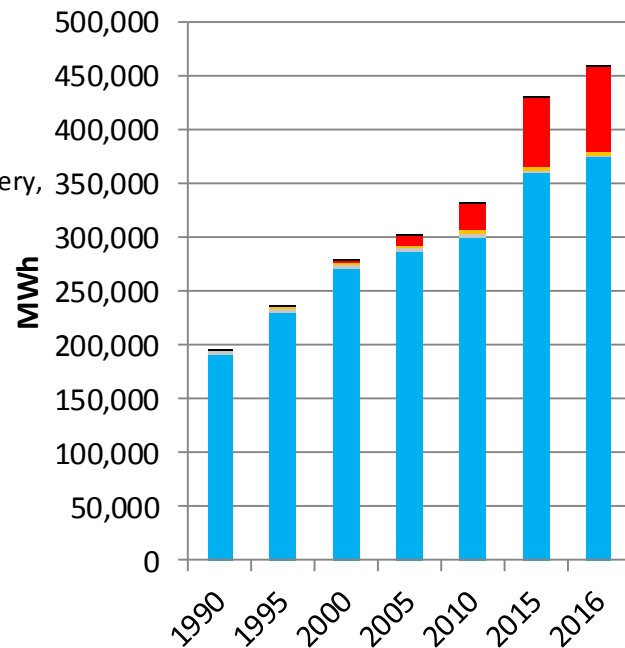
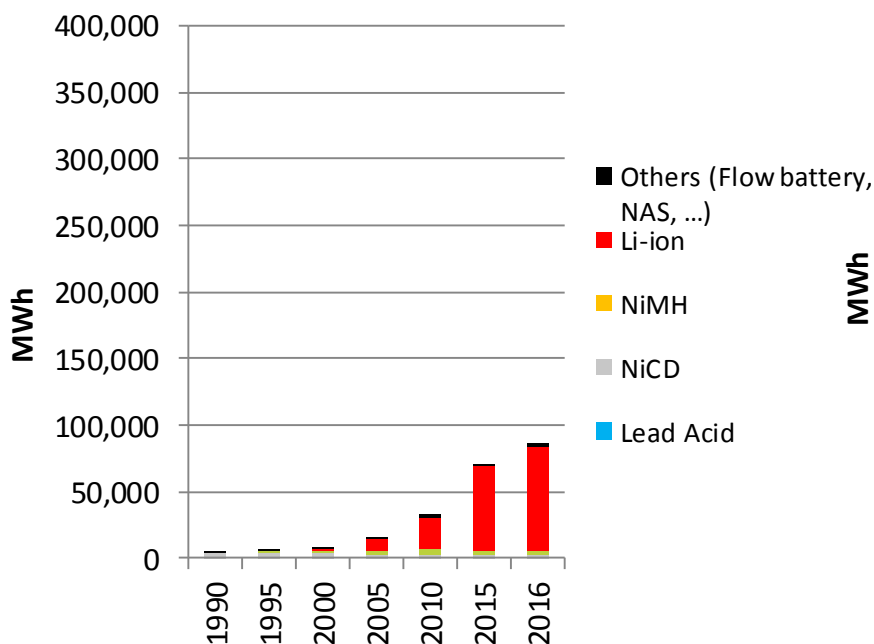




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THE WORLDWIDE BATTERY MARKET 1990-2016

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



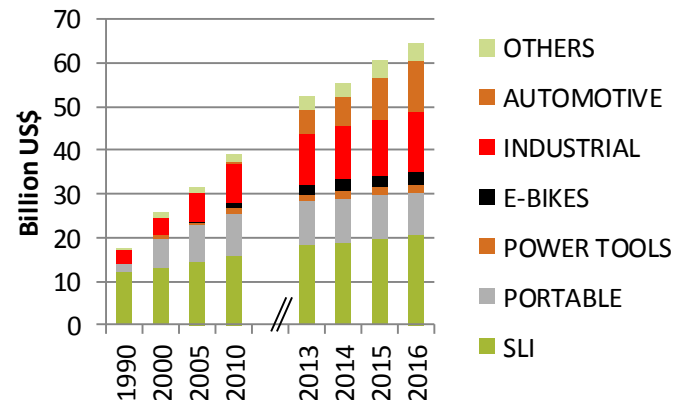
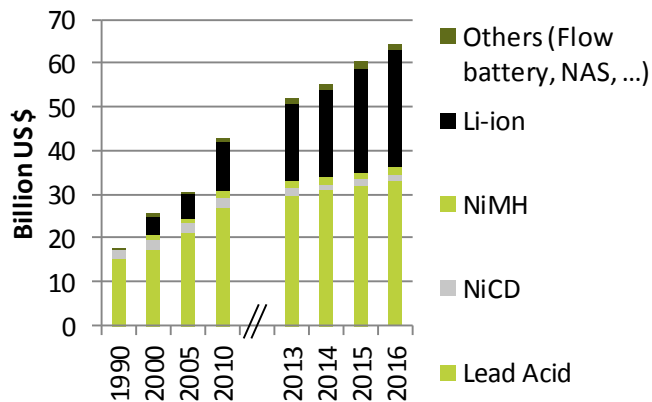
THE WORLDWIDE BATTERY MARKET 1990-2016

65 BILLION US\$ in 2016 – Pack level¹
5% AVERAGE GROWTH PER YEAR (2000-2016)

Lithium ion battery raw
material Supply & demand
2016-2025



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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

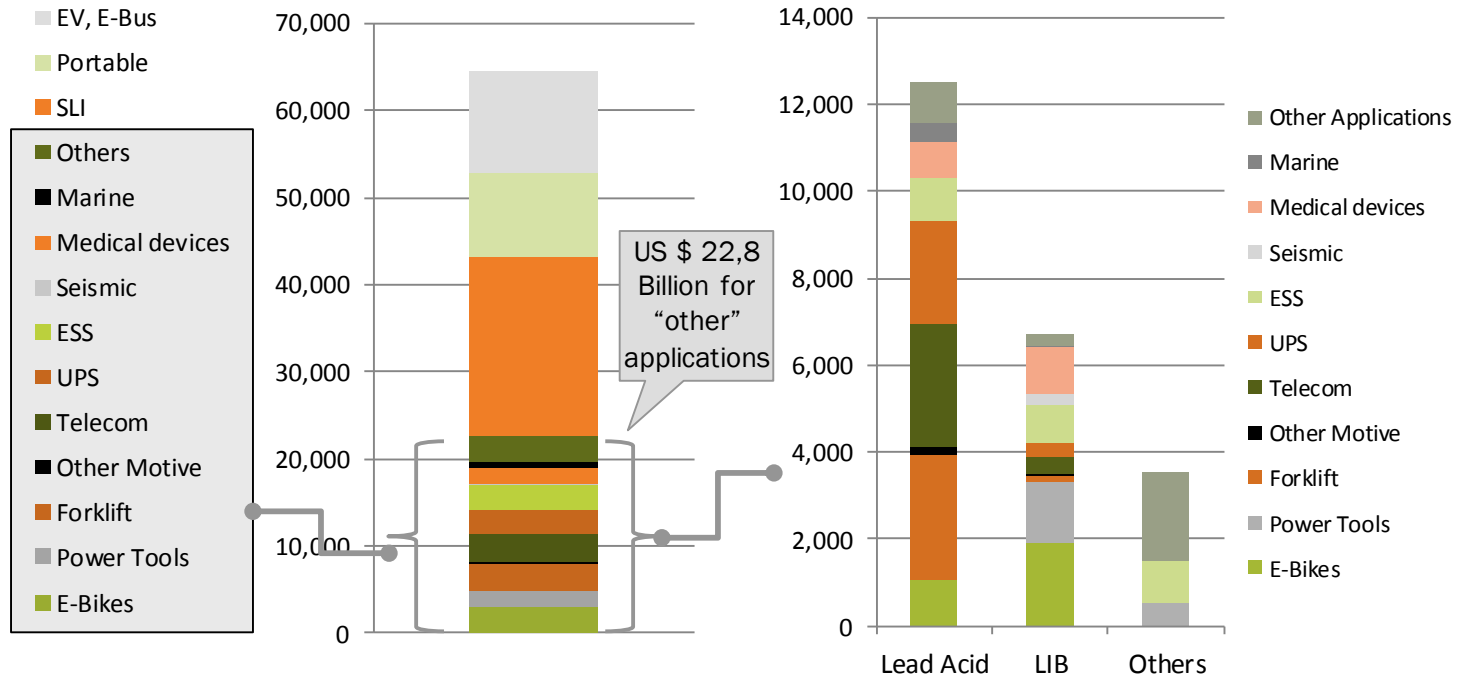
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THE WORLDWIDE BATTERY MARKET IN 2016: US \$ 65 BILLION



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

Source: AVICENNE ENERGY, 2017



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LI-ION IN 2016 - MAIN APPLICATIONS

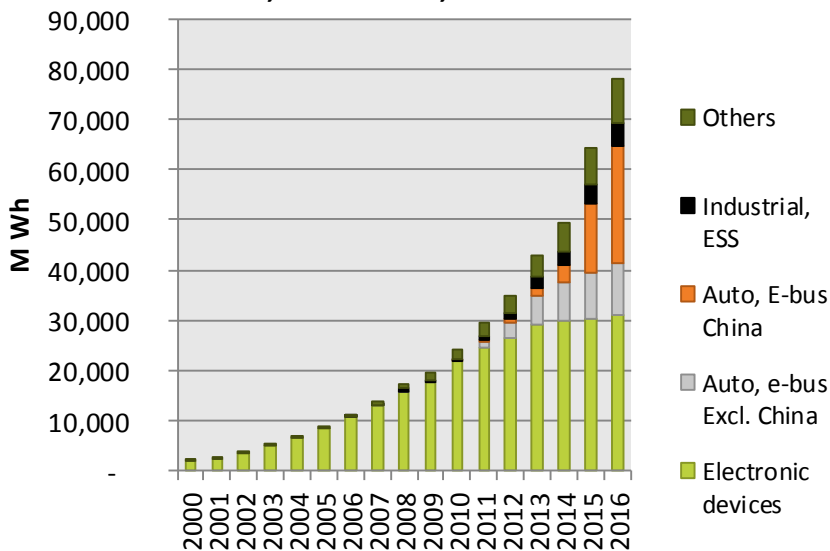
+78 000 MWh - 20 600 M\$ (1)

5 675 M small cells

CAGR 2006/2016

+22 % per year in Volume

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

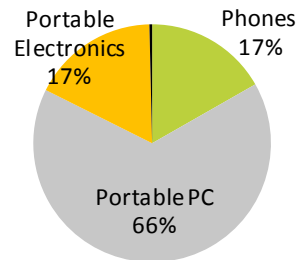


(1) Cell level

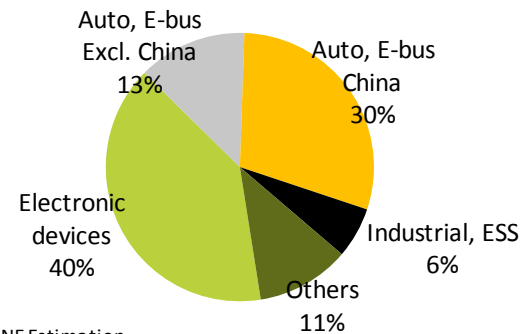
Others: medical devices, power tools, gardening tools, e-bikes...

Source: AVICENNE Energy 2017

2000: < 2GWh



2016: 78 GWh



2016: AVICENNE Estimation

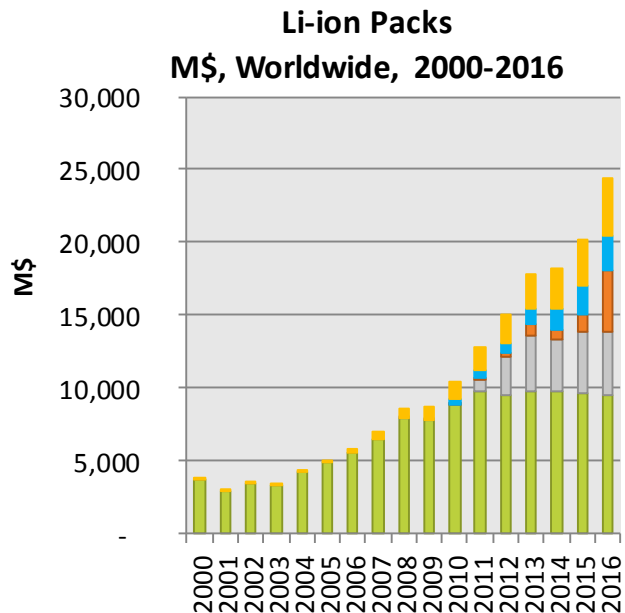
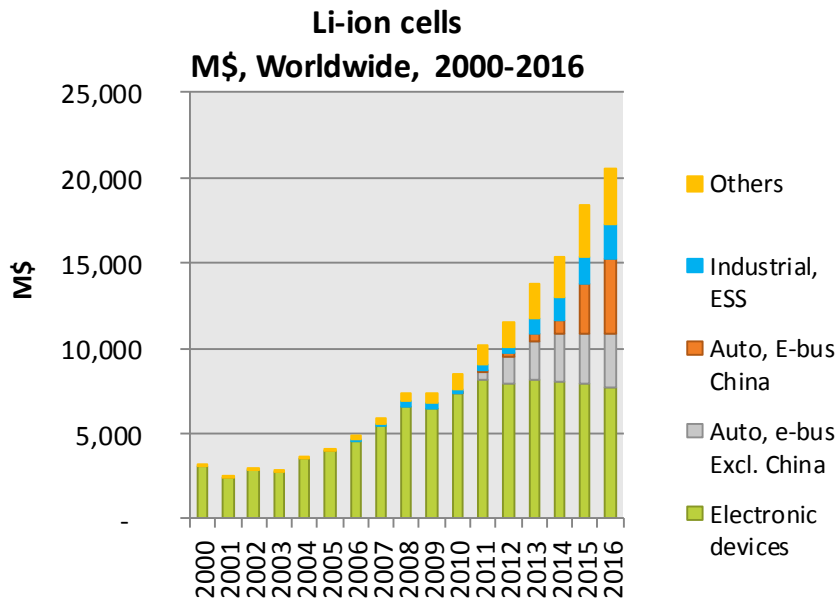


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LI-ION IN 2016 - MAIN APPLICATIONS

+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 2017

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

Lithium ion battery raw material Supply & demand 2016-2025

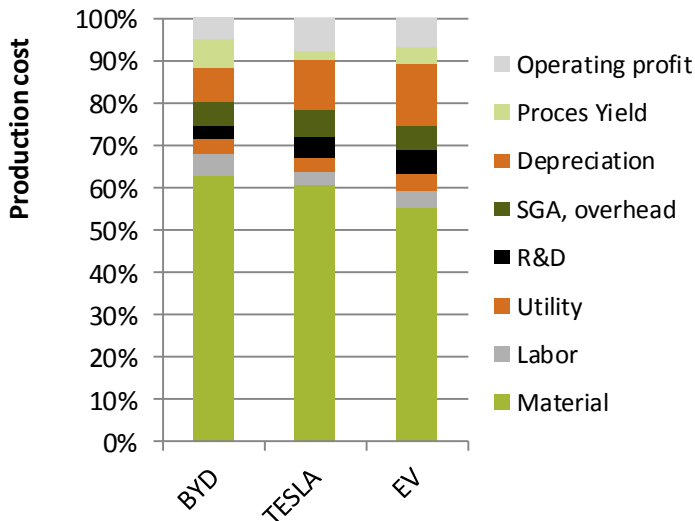


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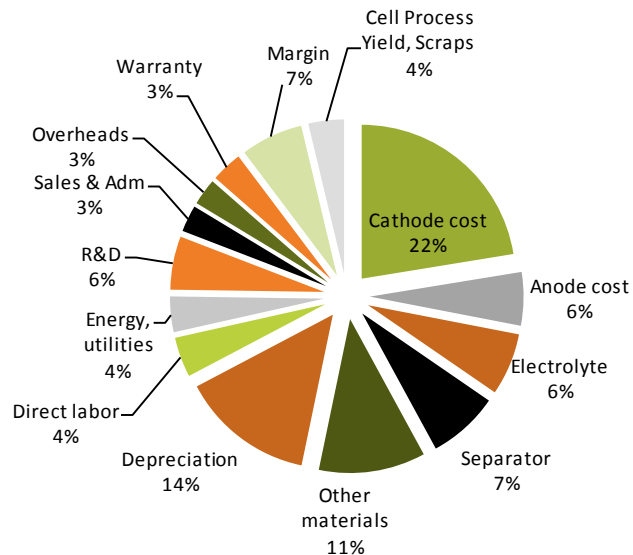
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LIB Cost structure for TESLA & 40 Ah EV pouch cell NMC



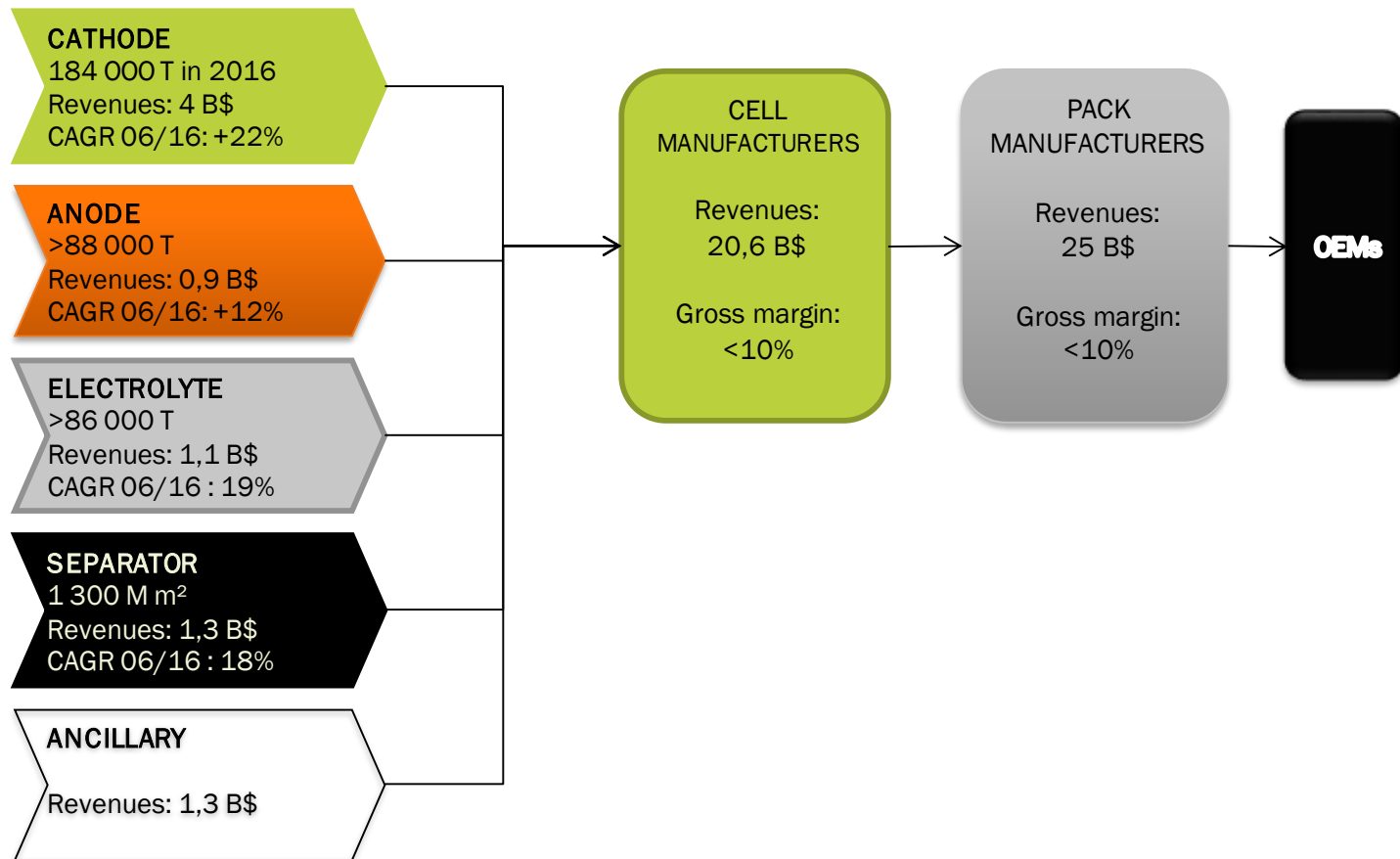
Average cost structure of Li-ion cell in 2016



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



LI-ION VALUE CHAIN – MARKET DEMAND

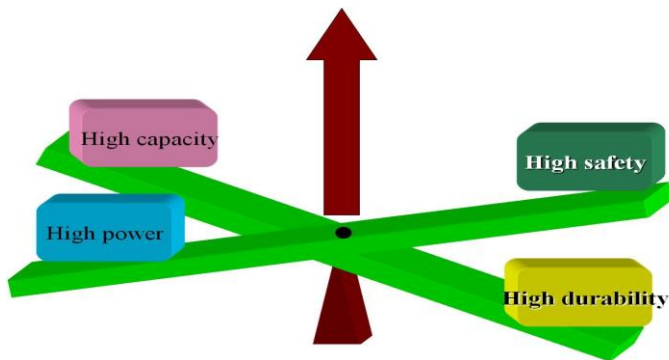


LIB CATHODE MATERIAL

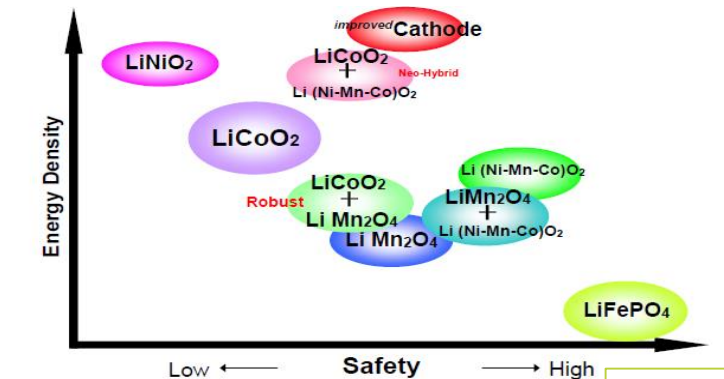
⌚ Cathode raw materials market

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

(1) M= Fe or Mn

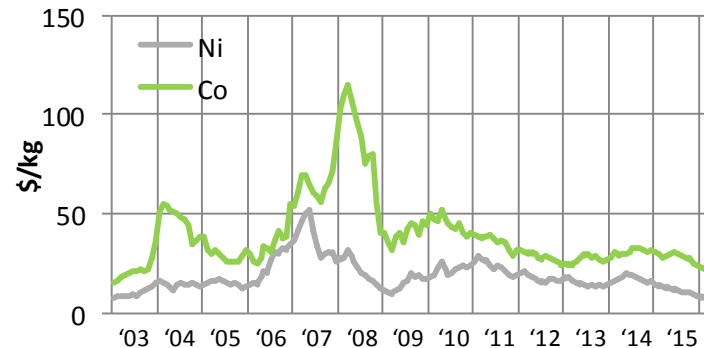


Source: Mitsubishi, Batteries 2012 – Nice



Source: SANYO, March 2011

Ni & Co price 2003-2015



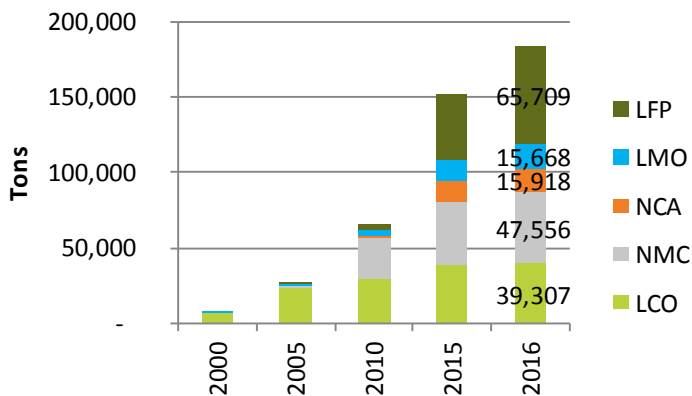
Source: LME



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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



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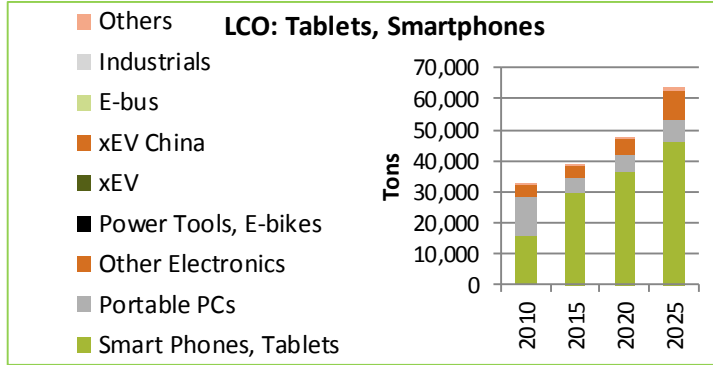
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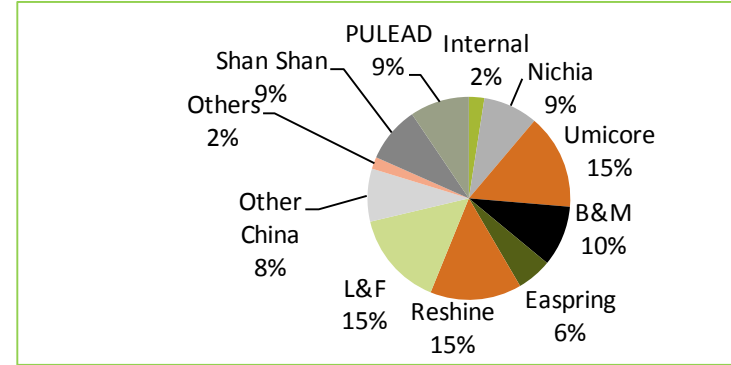
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LCO DEMAND: CAGR 2015-2025: +5%

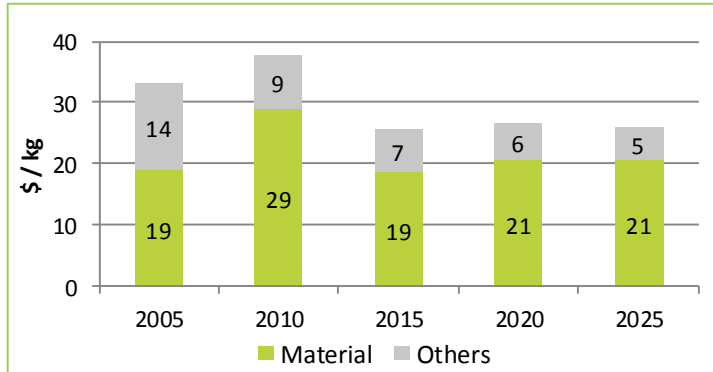
LCO demand details



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:
 - 🔗 In 2015, 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 material 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.

Sources: AVICENNE ENERGY 2017



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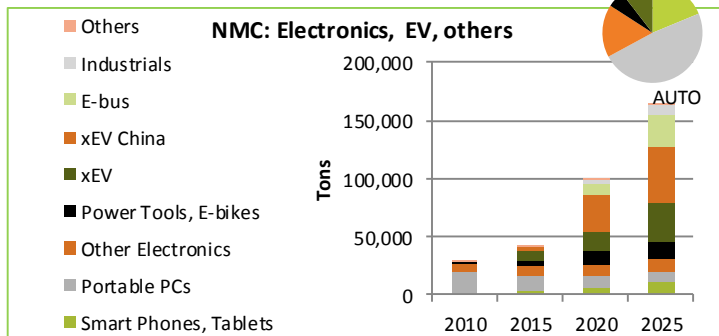
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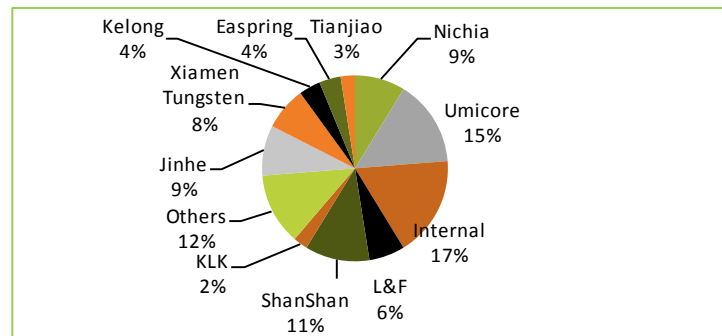
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NMC DEMAND: CAGR 2015-2025: +15%

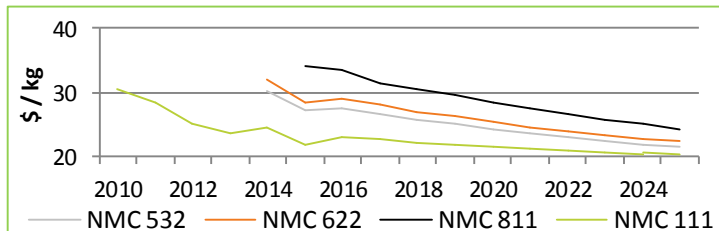
NMC demand details



NMC Offer in 2015

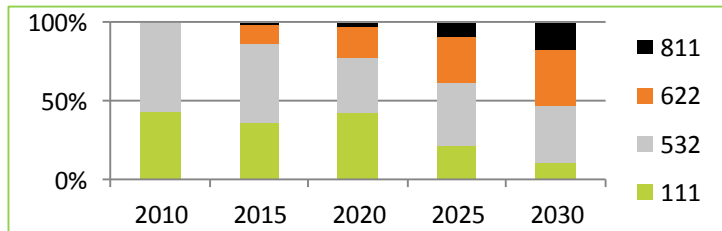


NMC Price forecasts



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

NMC evolution

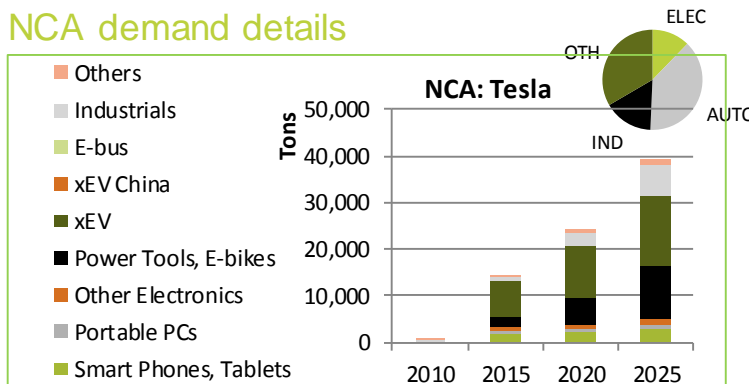


NMC summary of outlook

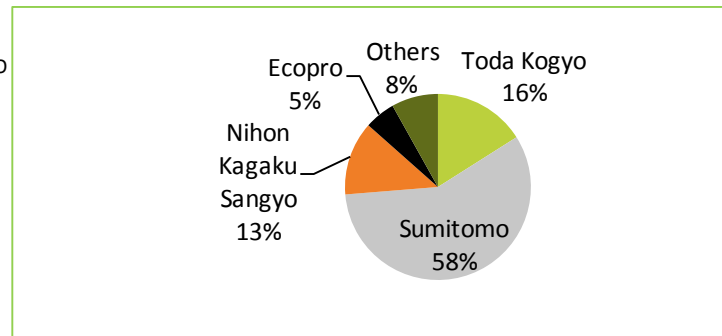
Demand: Except xEV in China, **NMC** is driven by xEV: **Nissan** will switch from NCA-LMO to NMC for example. Then, **Toyota, Mitsubishi, Honda** all choose NMC. From 2012 to 2016 the clear trend was to switch from LMO-NMC 75/25 to LMO-NMC 25/75. **LG, Panasonic and Samsung** agreed that NMC will be 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 markets since 2011. There market share may increase.

NCA DEMAND: CAGR 2015-2025: +11%

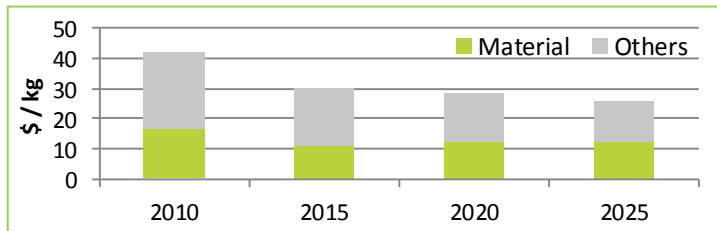
NCA demand details



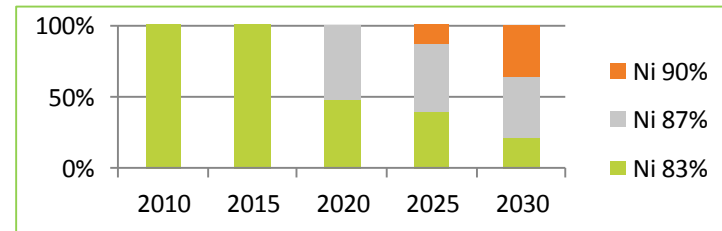
NCA Offer in 2015



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.



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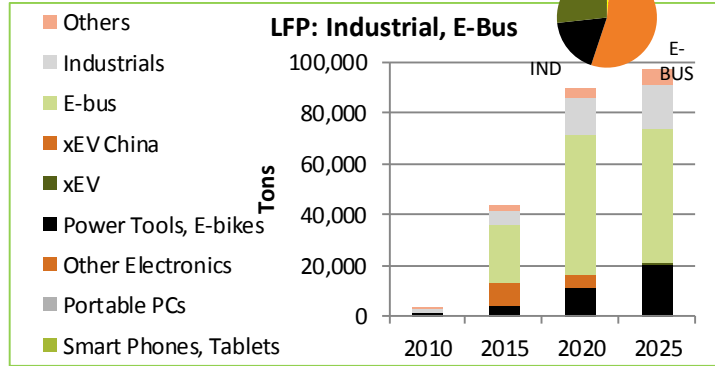
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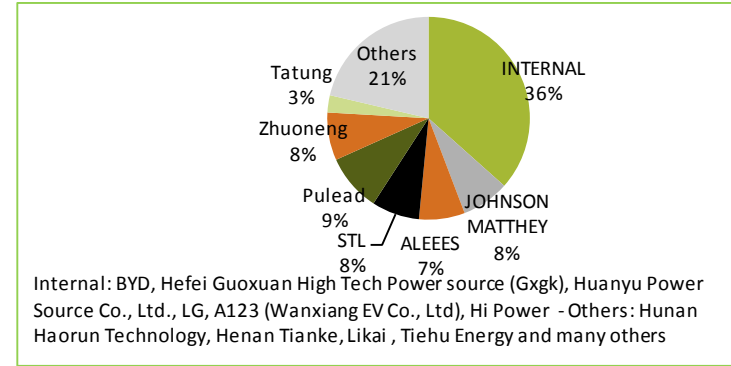
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LFP DEMAND: CAGR 2015-2025: +8%

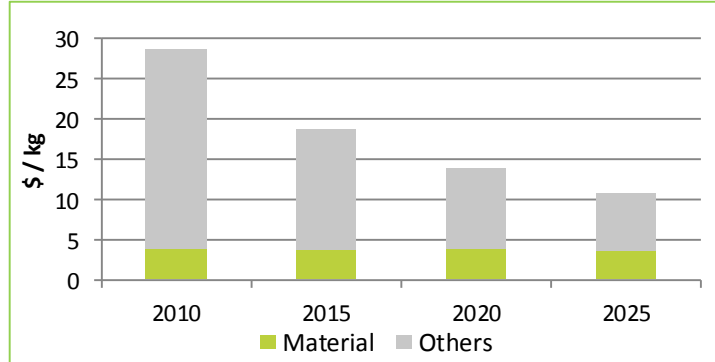
LFP demand details



LFP Offer in 2015



LFP Price forecasts



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

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.



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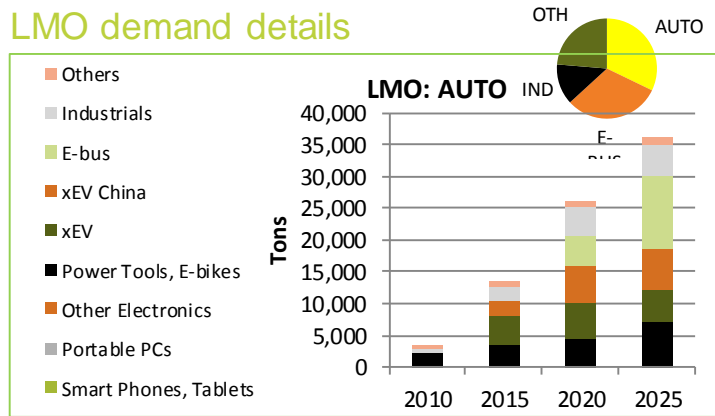
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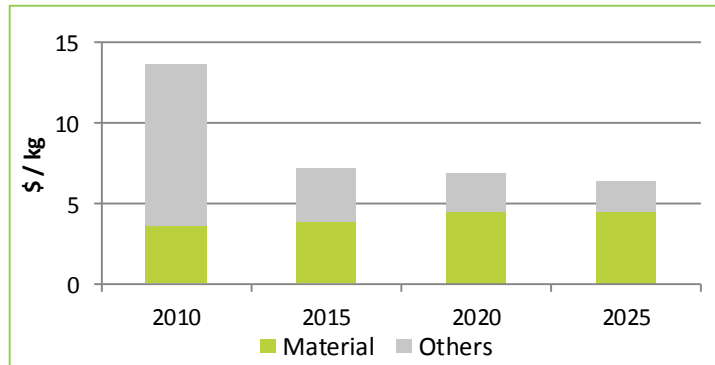
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LMO DEMAND: CAGR 2015-2025:+10%

LMO demand details

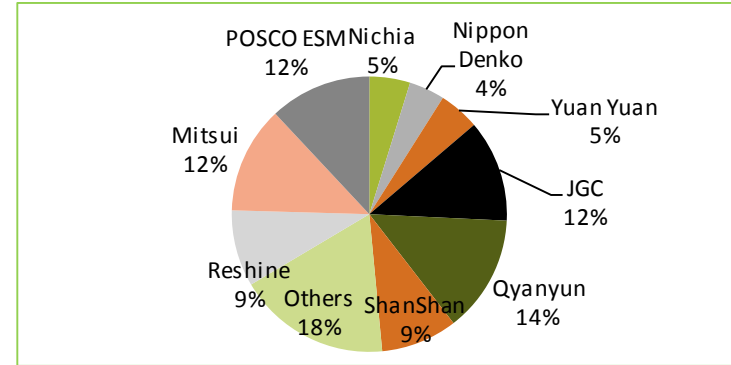


LMO Price forecasts



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).

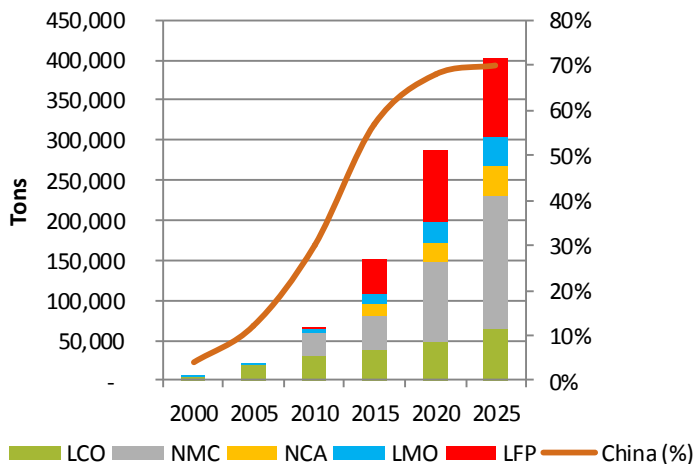
Price: LMO price decreased a lot from 2010 to 2015. We think we almost achieve the lowest possible level.

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



CATHODE ACTIVE MATERIAL FORECASTS 2000-2025

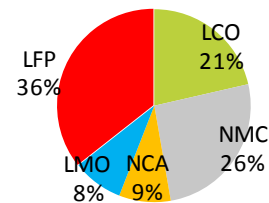
Cathode active materials 2000-2025 - Tons



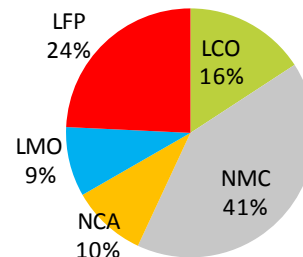
ASSUMPTIONS:

- 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

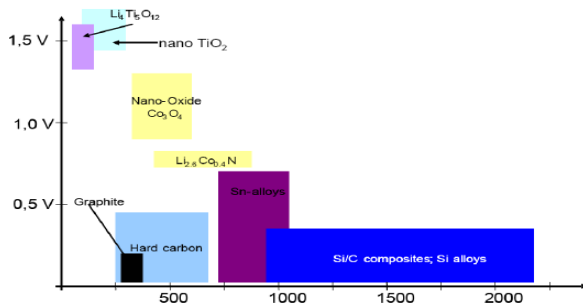


Assumption: Tesla keep NCA chemistry and have a relative success
(200 000 EV sold per year in 2025 – TESLA forecast 500 000)

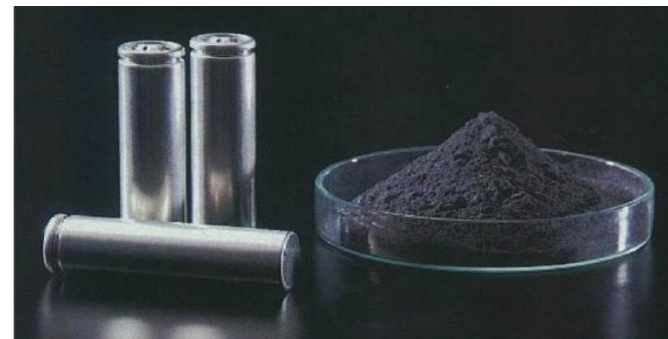
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ANODE ACTIVE MATERIALS > 88 000 TONS IN 2016

LIB Anode Materials

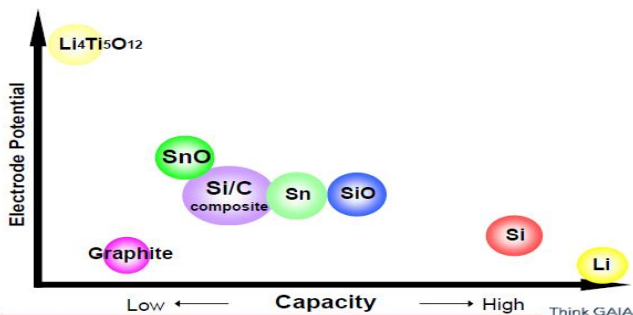


Source: A. Jossen, IRES 2007



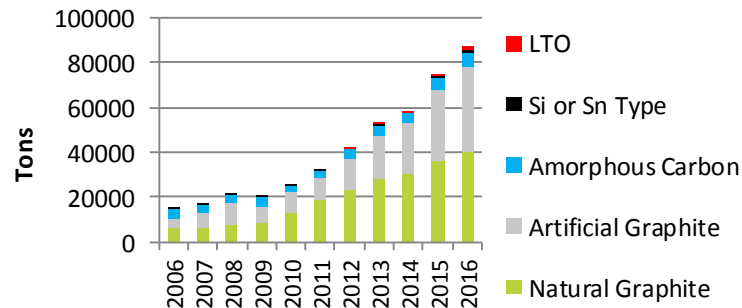
Source: Hitachi Chemical

LIB Anode Materials



Source: Sanyo, March 2013

LIB Anode market, (Tons)



Sources: AVICENNE ENERGY 2017 19



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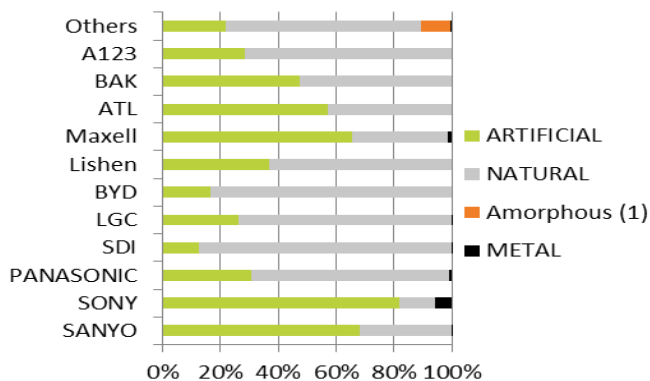
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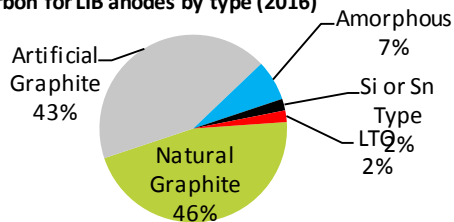
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ANODE FOR LIB IN 2016

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:



HITACHI

Nippon Carbon

NEW ENTRANTS ON THE FIELD:



(...)

Sources: AVICENNE ENERGY 2017



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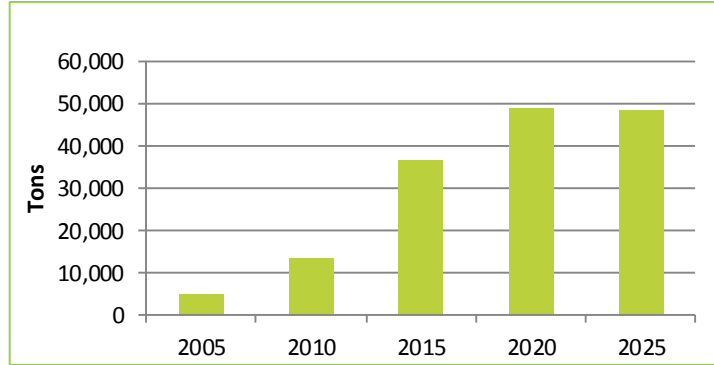
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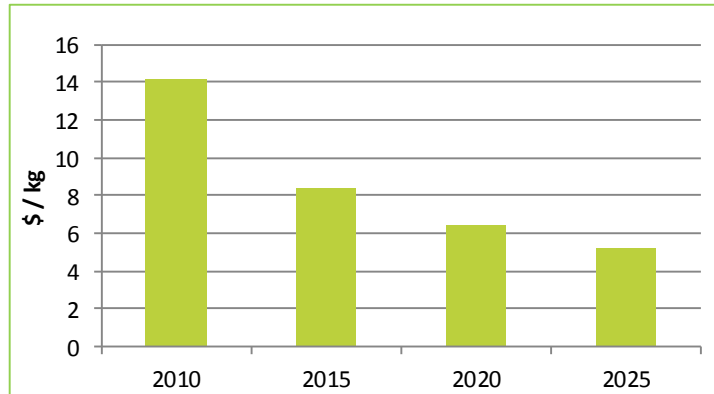
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NATURAL GRAPHITE: CAGR 2015-2025: +3%

Natural Graphite demand details

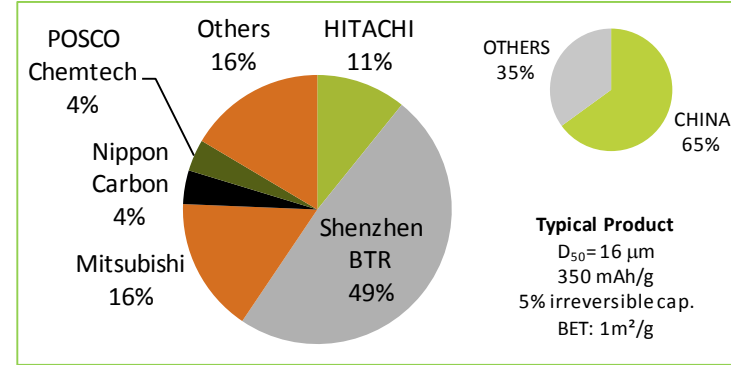


NG Price forecasts



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



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Lithium ion battery raw
material Supply & demand
2016-2025



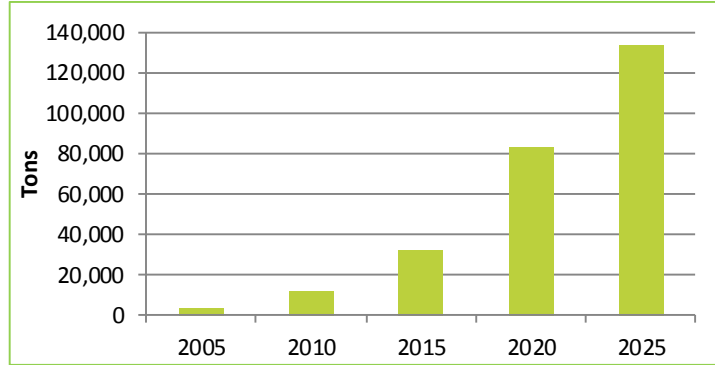
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Mainz, Germany

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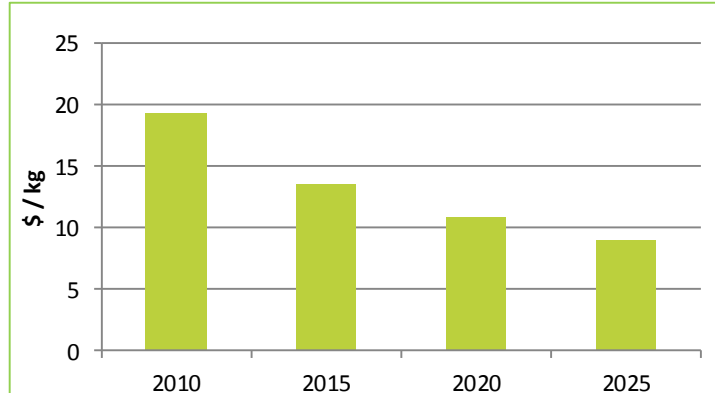
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ARTIFICIAL GR.:CAGR 2015-2025: +15%

Artificial Graphite demand details

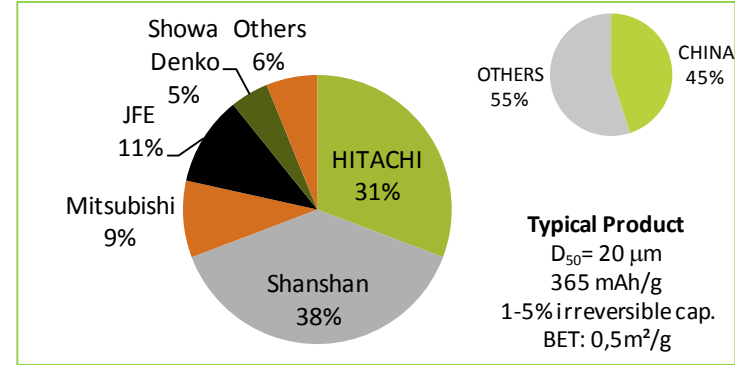


Artificial Graphite Price forecasts



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



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material Supply & demand
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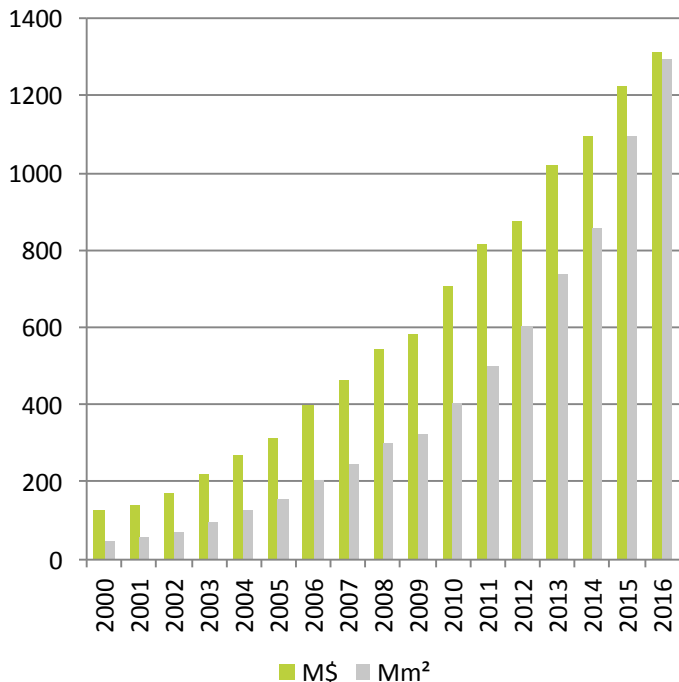
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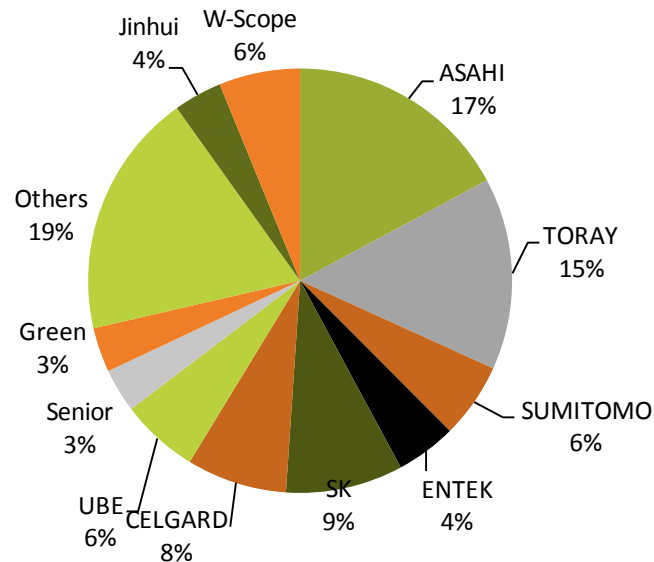
LIB SEPARATOR MARKET 2016

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...

ELECTROLYTE SUPPLIERS/CUSTOMERS > 86 000 TONS IN 2016

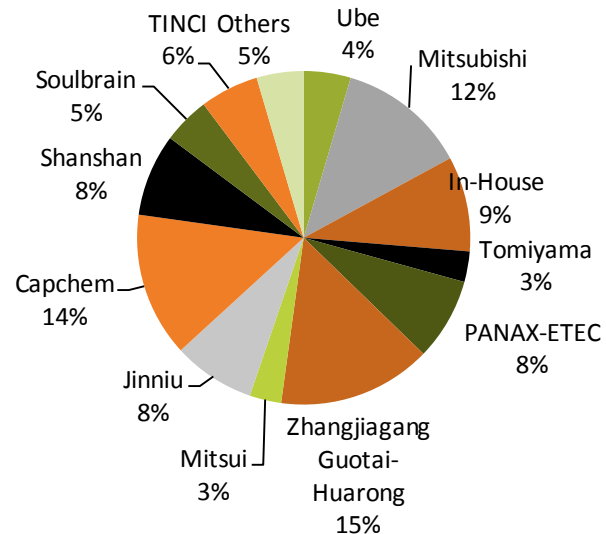
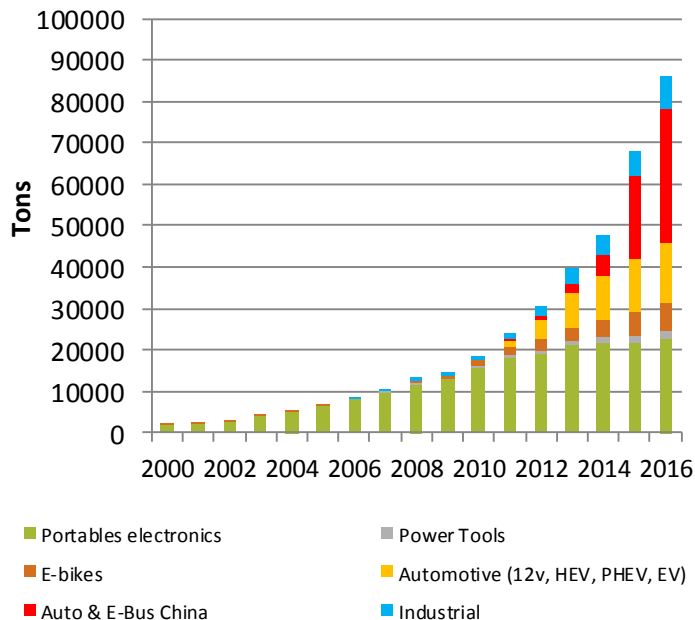
LIB electrolyte market, Tons,
CAGR 2006/2016: +26%

LIB electrolyte supplier, market share in
2016

Lithium ion battery raw
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2016-2025



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BATTERY MARKET FORECASTS 2016-2025

Applications covered

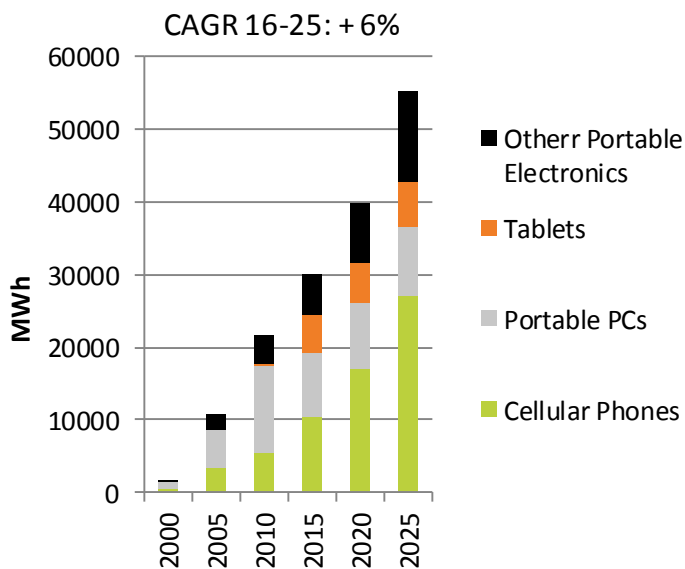
- 🔋 Portable PCs, net-book, Ultra-book
- 🔋 Cellular Phones, Smart-phones
- 🔋 Tablets
- 🔋 Camcorders
- 🔋 Cordless Tools, Gardening tools
- 🔋 Digital Camera
- 🔋 Games, MP3
- 🔋 Cordless Phones
- 🔋 Shavers, Toothbrush,
- 🔋 RC Cars
- 🔋 E-bikes
- 🔋 Power tools
- 🔋 Security lighting
- 🔋 Vehicles: HEV, P-HEV,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

Parameters analysis

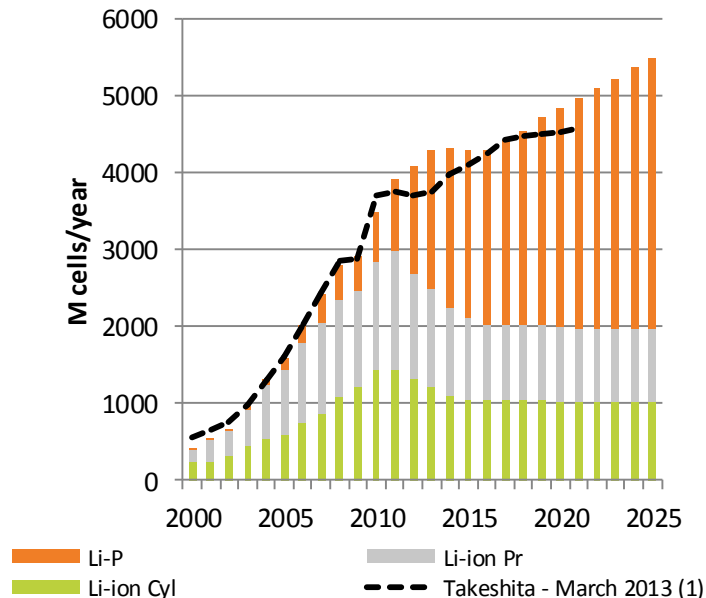
- 🔋 Main segment trends
- 🔋 Power need trends (volume, weight, capacity, running time)
- 🔋 Penetration rate for each Chemistry, each form factor,
- 🔋 2016 -2025 Forecasts
- 🔋 OEM strategies and positions
- 🔋 Main drivers & limiters

2025 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

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



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



Lithium ion battery raw material Supply & demand 2016-2025



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Source: AVICENNE ENERGY Analyses 2017

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



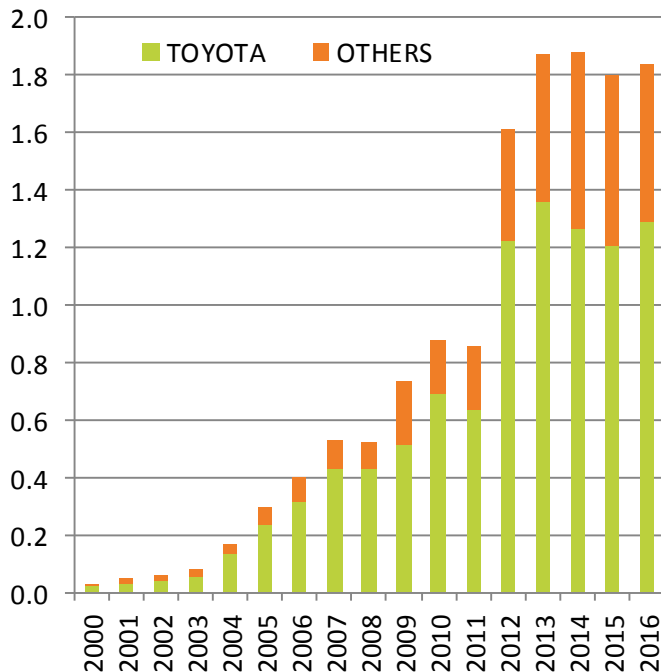
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HEV WORLDWIDE IN 2016

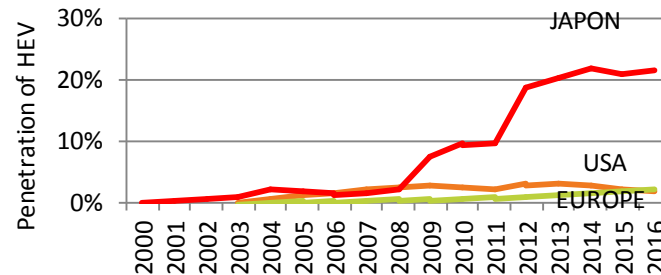
1,8 M HEV

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

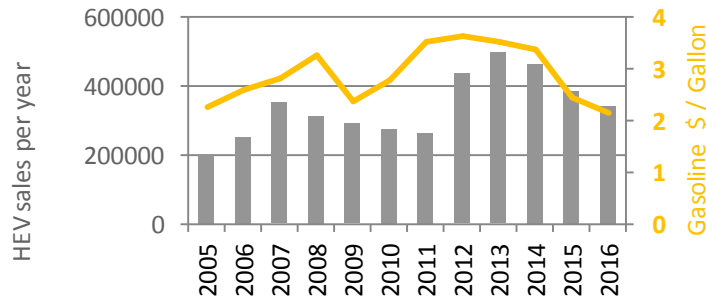
HEV sold per year, M units, worldwide,
2000 - 2016



Penetration of hybrids in the global sales,
2000-2016



Gazoline price impact on HEV market in
the US





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Lithium ion battery raw
material Supply & demand
2016-2025



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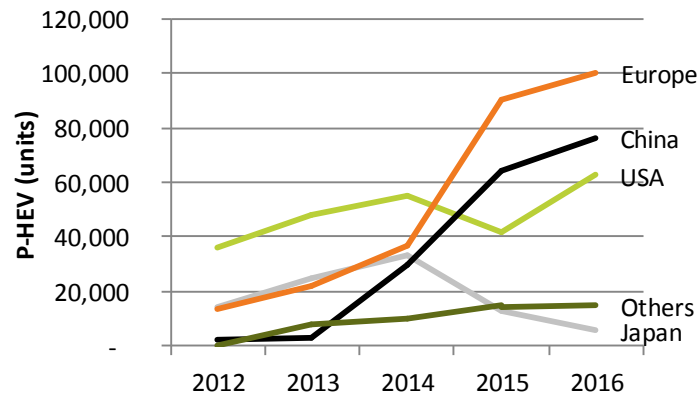
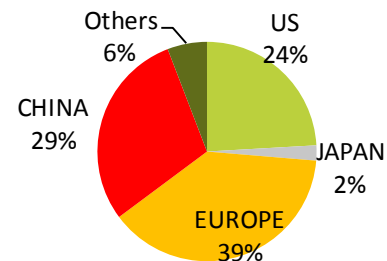
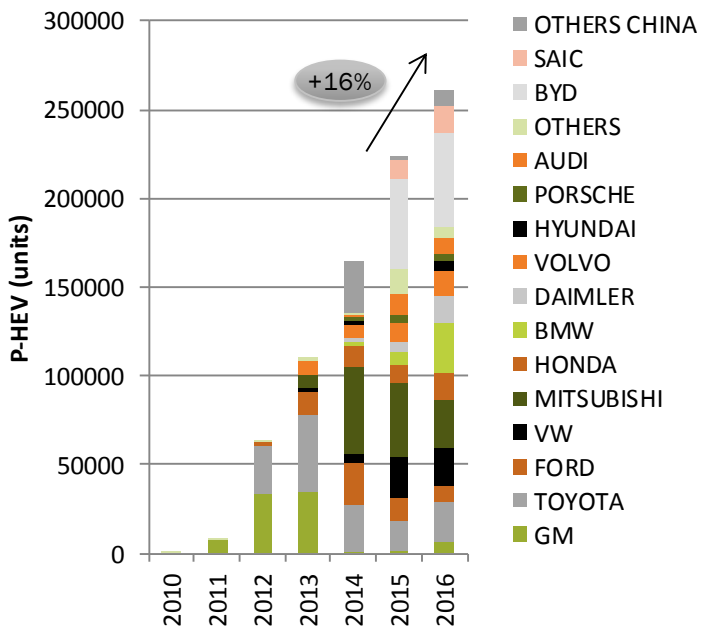
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PHEV SOLD WORLDWIDE

World excl. China growth +14%
Chinese Growth + 21%

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



Source: AVICENNE ENERGY Analysis, 2017

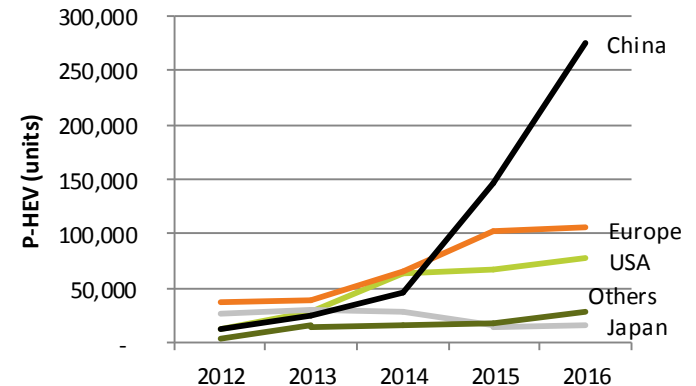
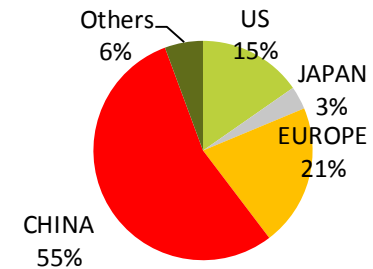
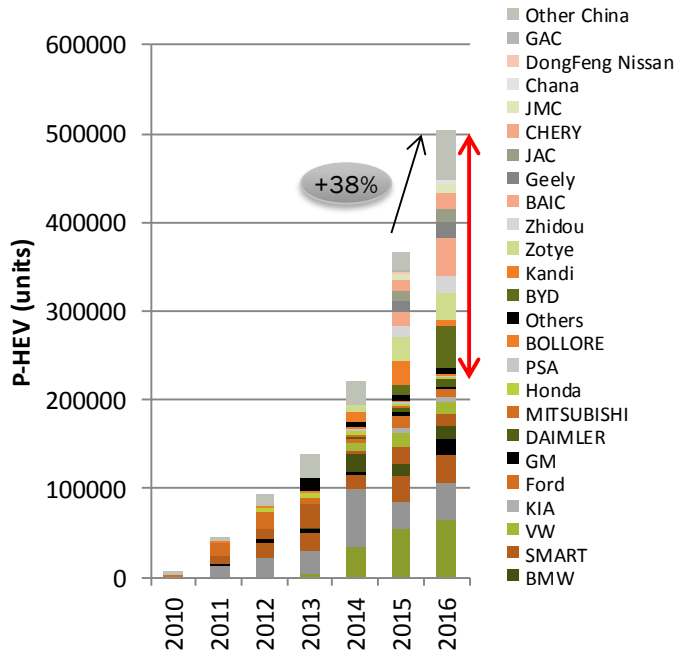


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EV SOLD WORLDWIDE

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

China is leading the EV market
thanks to high incentives



Lithium ion battery raw
material Supply & demand
2016-2025



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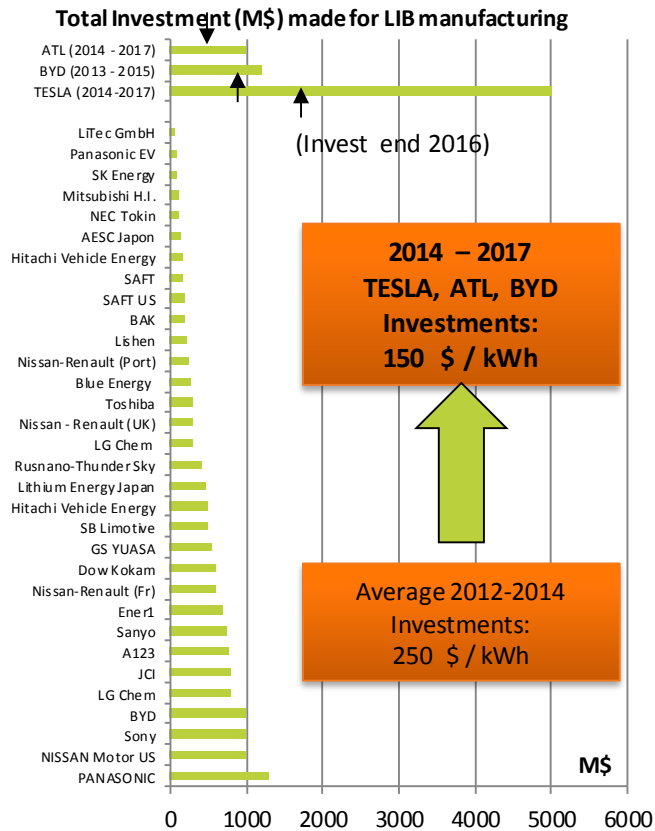
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LIB MANUFACTURING INVESTMENTS 2009-2015

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

TIME TO MARKET FOR NEW MATERIALS IN LIB INDUSTRY



- ⌚ The research and development in this industry is very long and time consuming.
- ⌚ Time to market to commercialize a new material is long. Remember that the first Li-ion battery was 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.

TIME TO MARKET FOR NEW MATERIALS



Lithium ion battery raw
material Supply & demand
2016-2025



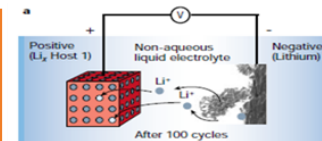
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	2000	2005	2010	2015	2020	2025	2030
CATHODE	LCO		NMC/NCA LMO LFP	LiNiMnO ₂ High voltage	5v spinel LiNiPO ₄ , 5v LiCoPO ₄ , 5v LiMnPO ₄ , 4v	Sulfur	Air
ANODE	Graphite Hard Carbon		Soft Carbon Li ₄ Ti ₅ O ₁₂		C/Alloy Composite Non Si Alloys	Li Metal 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

SAFETY ISSUES

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

Background	<p>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</p>
Mobile	<p>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 their profit-to-date</p>
Automotive	<p>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)</p>
Aircraft	<p>Boing 787: The fire that burned near the tail of a parked Boeing 787 in Boston was caused by an overheating Lithium ion battery pack. The battery fire could have been hot enough to melt the carbon-fiber reinforced plastic that makes up the plane's shell. <u>CONSEQUENCES:</u> All the 787 worldwide are grounded. Considerable losses for Boing.</p>



Safety is a sine-qua-non selection criteria for batteries. The lithium ion technologies that win will win partly on their safety argument, possibly sacrificing some energy density.

Source: AVICENNE ENERGY 2016



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LIB BATTERY COST

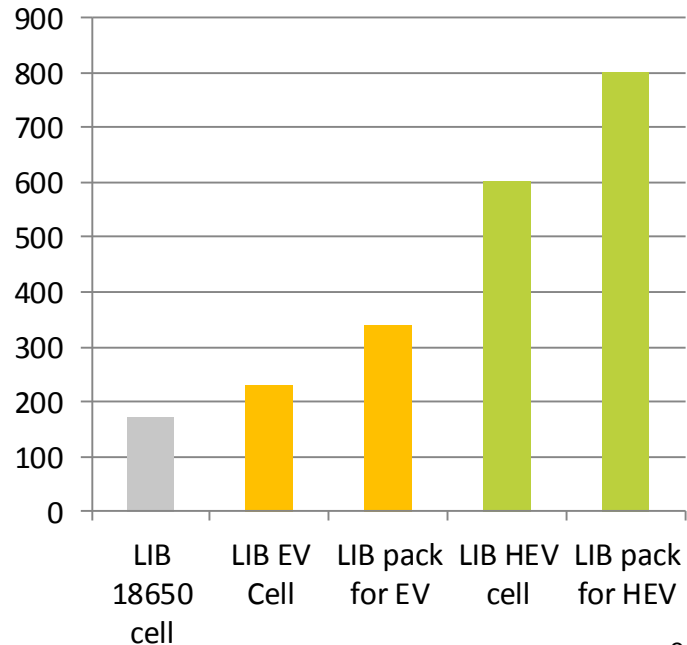
Costs analysis

- ⌚ 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 2017

Battery price in 2016

\$/kWh

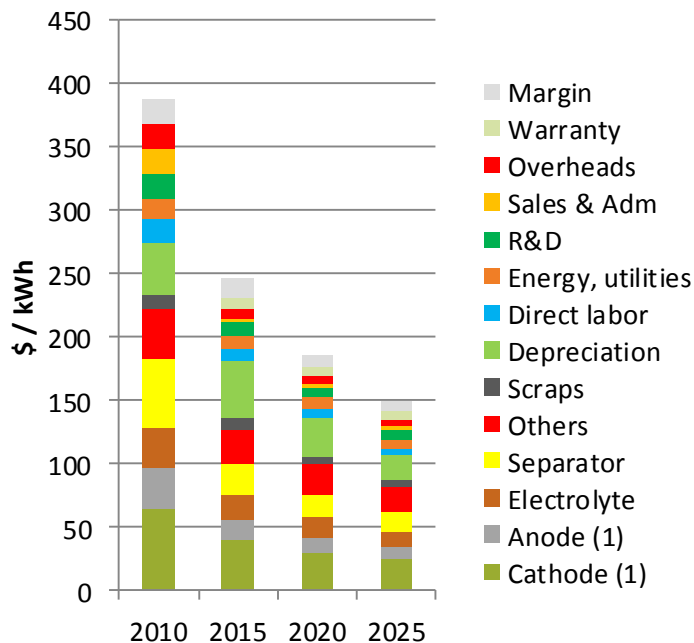




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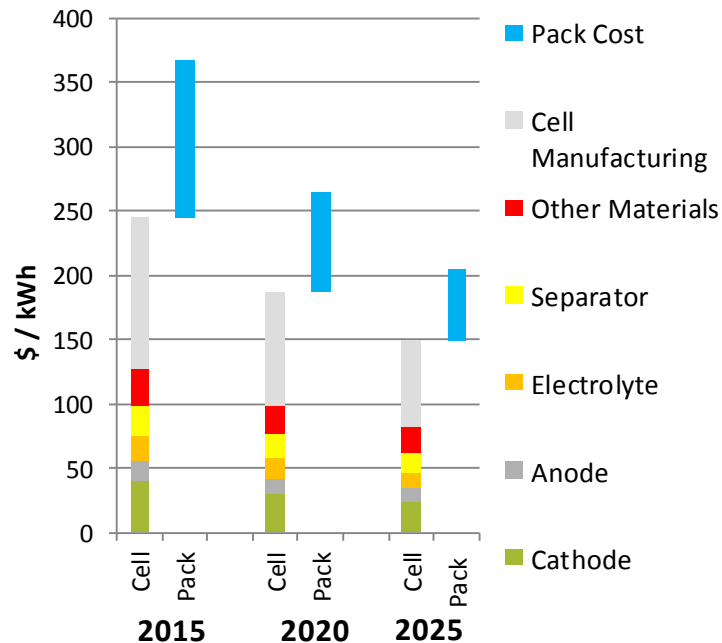
LI-ION BATTERY COST 2015-2025

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



(1) Active materials only
Source: AVICENNE ENERGY 2017

LI-ION BATTERY PACK COST FOR
EV



* For Production > 100 000 packs/year



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Lithium ion battery raw
material Supply & demand
2016-2025

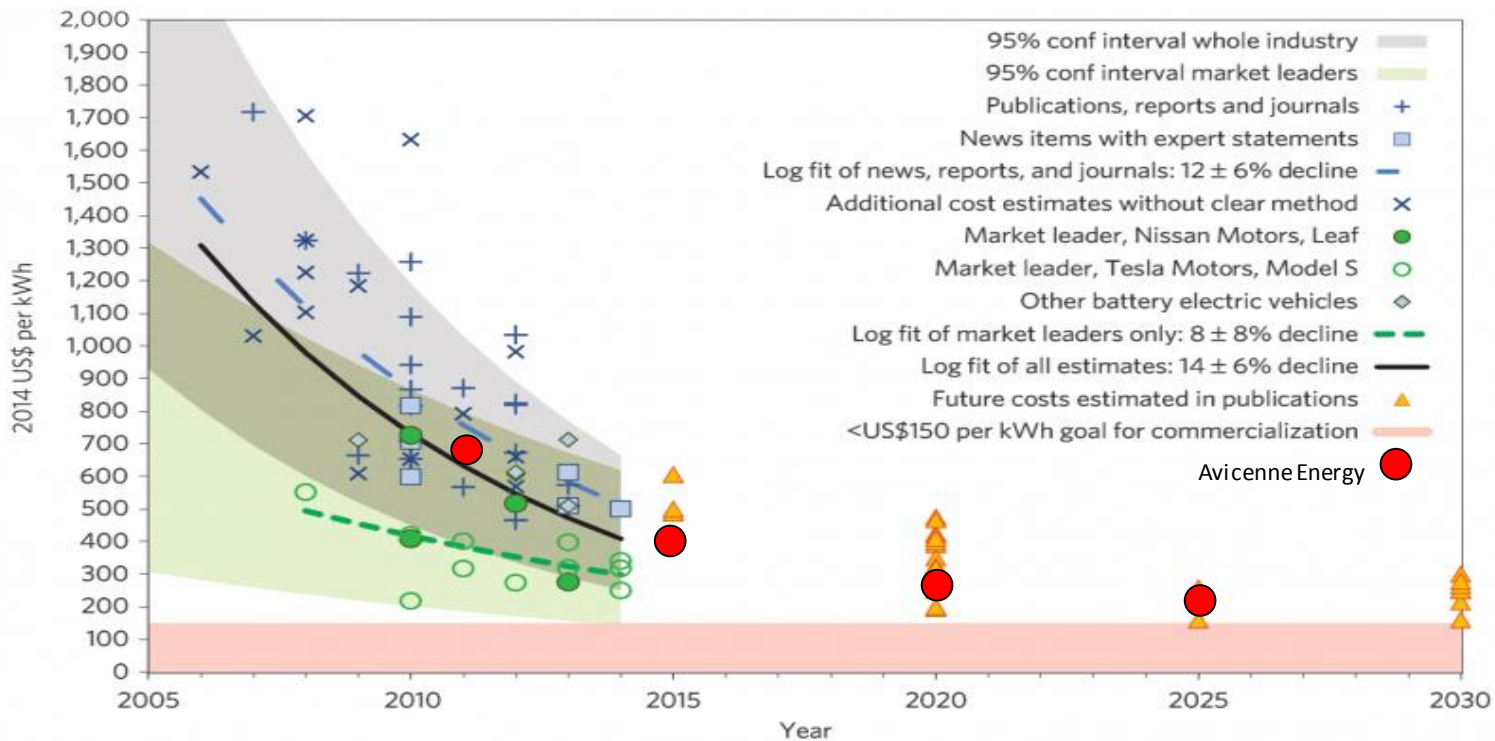


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LIB PRICE FORECASTS



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

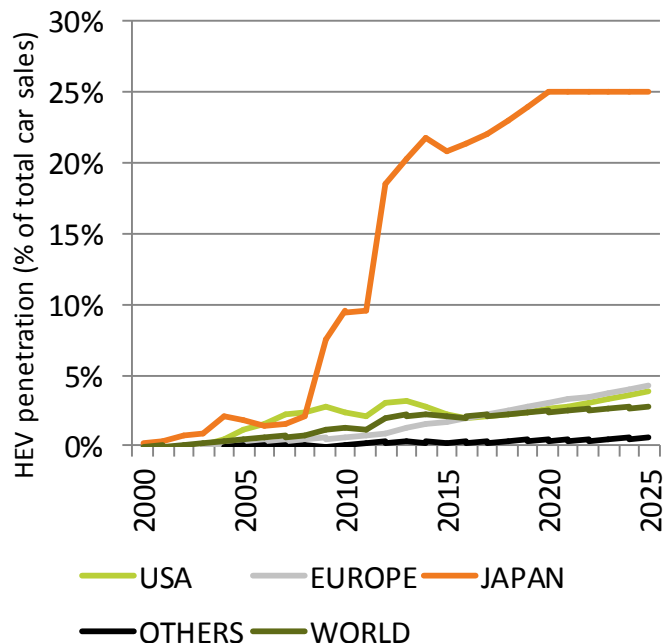
HEV FORECASTS 2000-2020

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

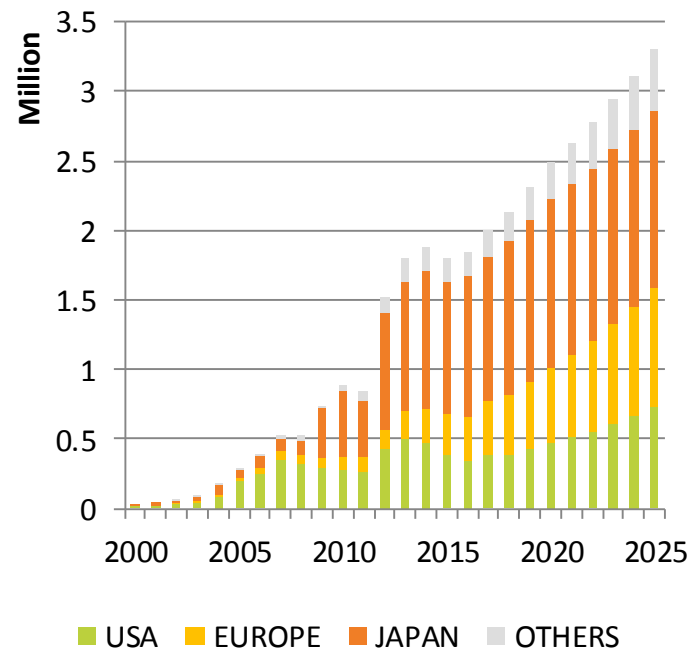
Lithium ion battery raw
material Supply & demand
2016-2025



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Micro hybrid not included



Source: AVICENNE ENERGY Analyses 2017

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

Lithium ion battery raw
material Supply & demand
2016-2025

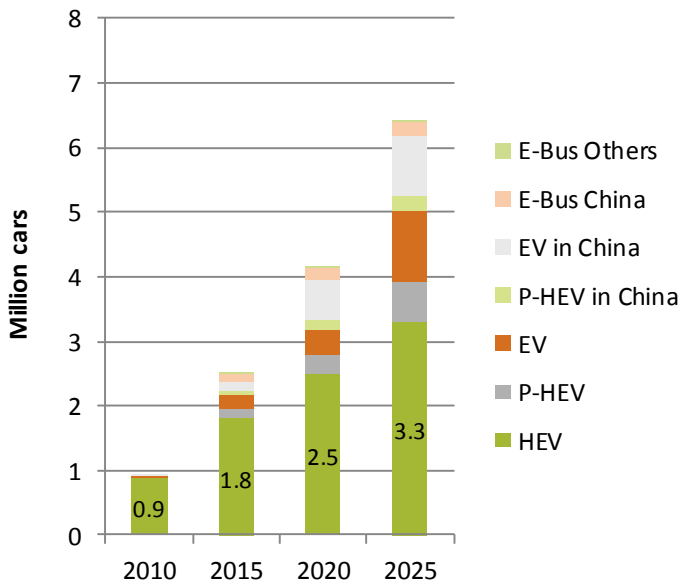


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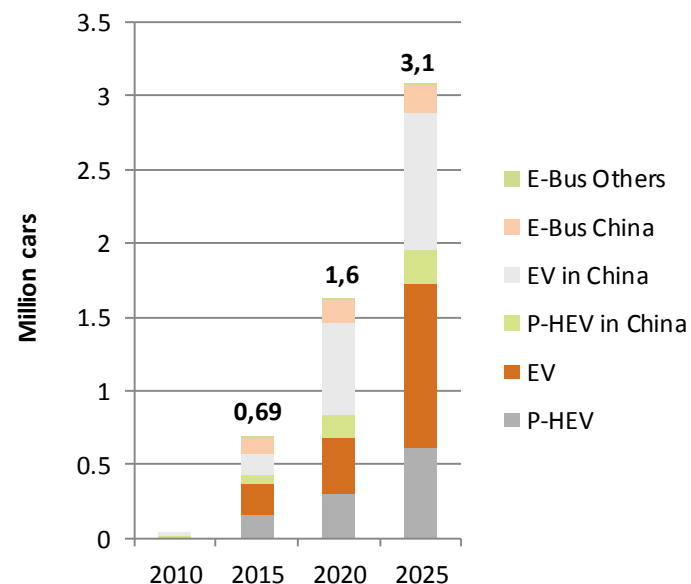
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HEV, PHEV, EV & E-Bus



PHEV, EV & E-Bus

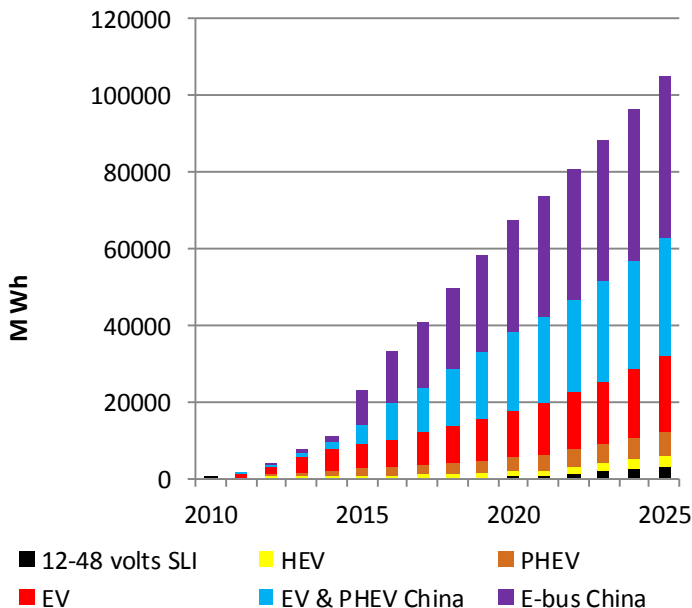




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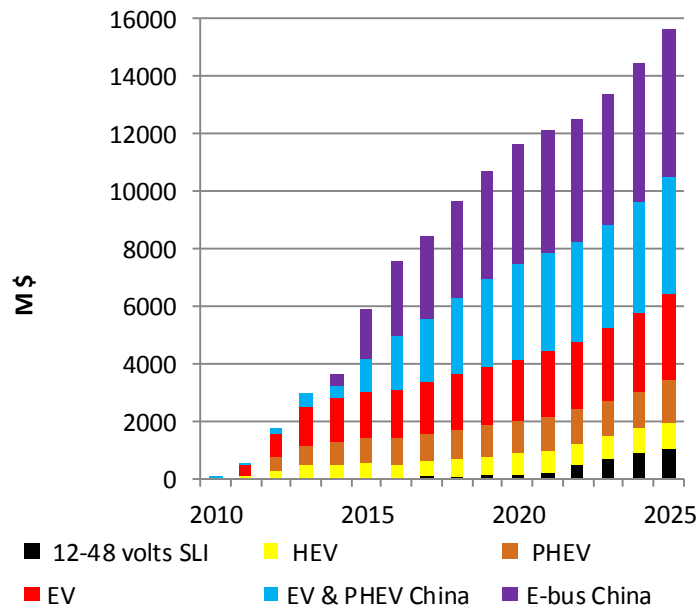
TOTAL BATTERY DEMAND FOR XEV 2025 FORECASTS

Li-ion for E-Buses, EV, HEV & P-HEV
Battery needs (MWh)
CAGR 2016-2025: +14%



Source: AVICENNE ENERGY Analyses 2017

Li-ion for E-Buses, EV, HEV & P-HEV
Battery needs (M\$)
CAGR 2016-2025: +8%



LI-ION BATTERY MARKET FORECASTS

From 78 GWh in 2016 to
210 GWh

CAGR 2016/2025
+13 % per year in Volume

Lithium ion battery raw
material Supply & demand
2016-2025

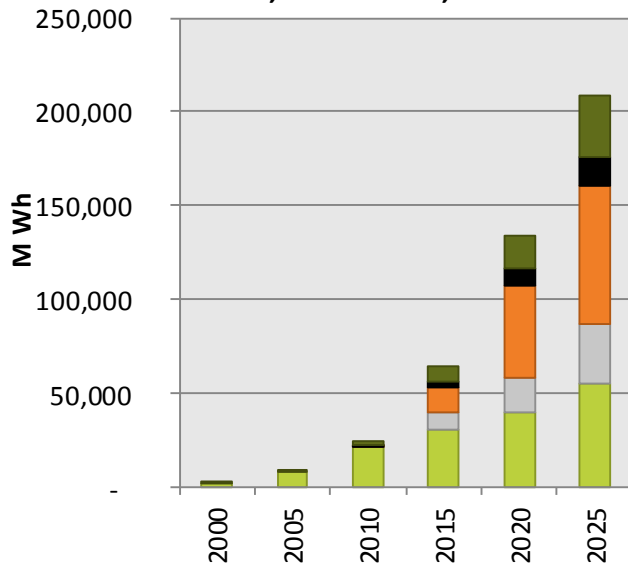


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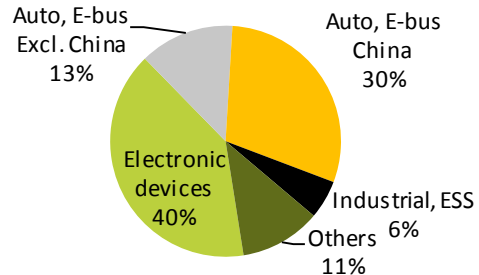
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Li-ion Battery sales,
MWh, Worldwide, 2000-2015

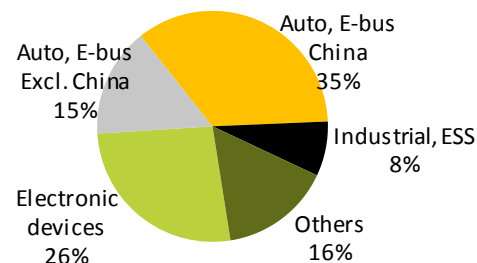


Category	CAGR 15/25
Others	16%
Industrial, ESS	17%
Auto, E-bus China	18%
Auto, e-bus Excl. China	13%
Electronic devices	6%

2016: 78 GWh



2025: 210 GWh



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

Source: AVICENNE Energy 2016



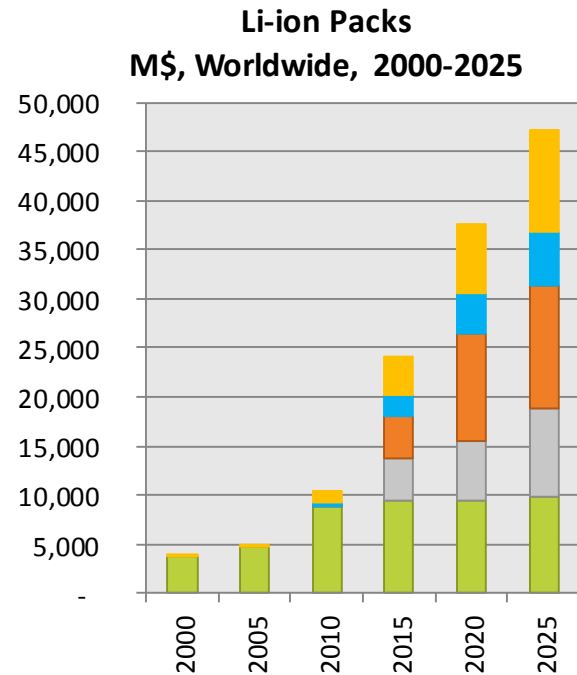
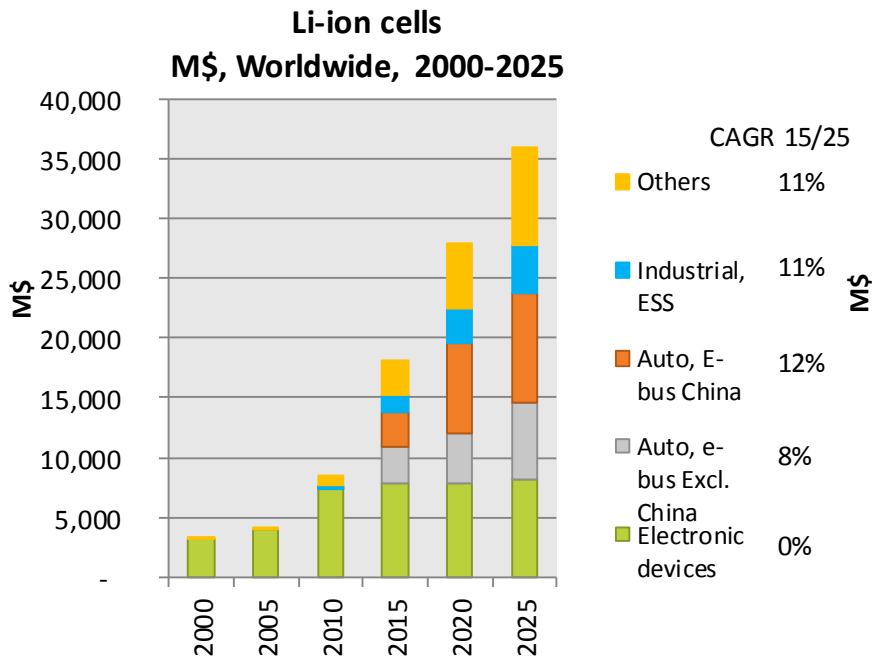
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LI-ION BATTERY MARKET FORECASTS

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



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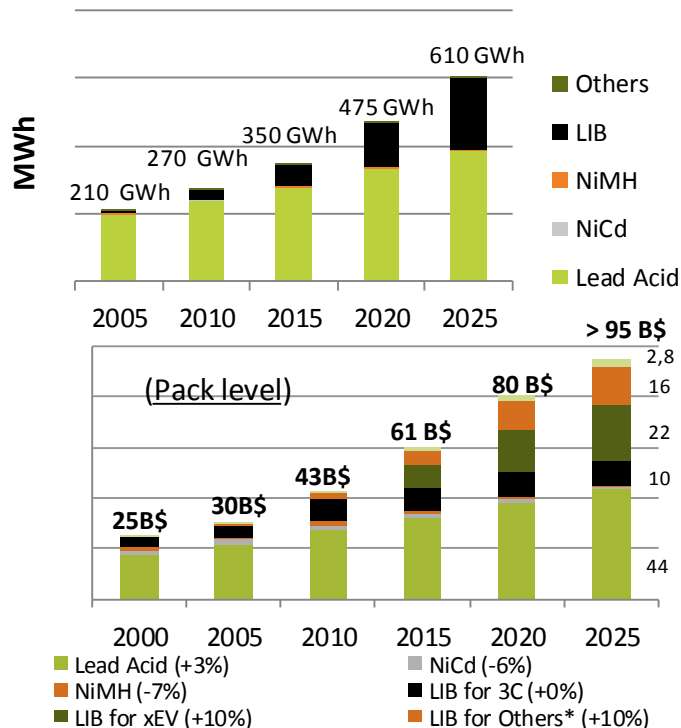
TAKEAWAYS

Battery Market 2010-2025

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

- 🕒 Li-ion battery is driven today 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, ... 42



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THANK YOU



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