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# Current Status and Future Trends of the Global Li-ion Battery Market

**Christophe PILLOT**

AVICENNE ENERGY

## Presentation Outline

- The rechargeable battery market in 2017
- The Li-ion battery value chain
- Li-ion Battery market Forecasts



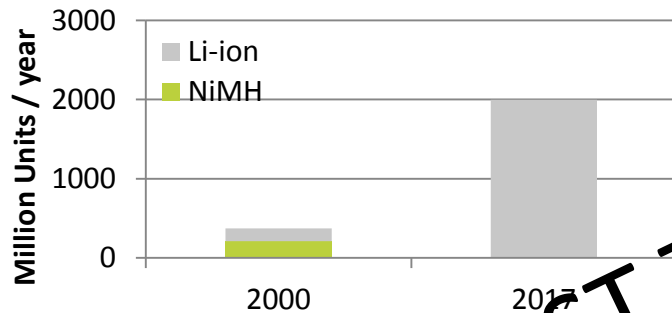
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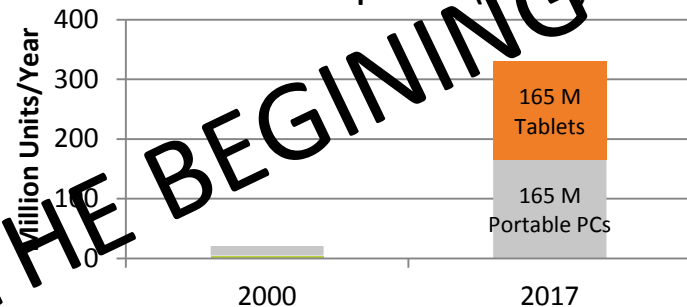
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# THE BATTERY MARKET IS REALLY DYNAMIC

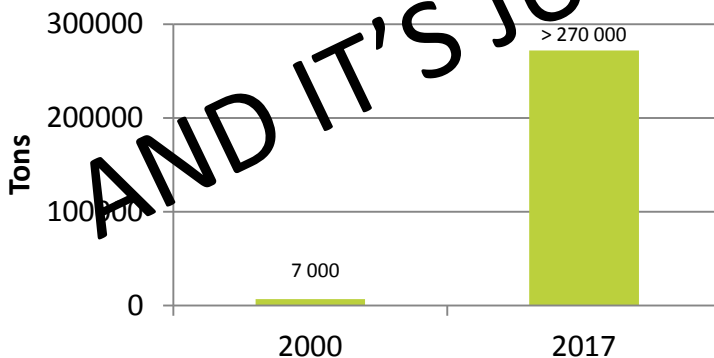
Cellular Phones sold per Year (Million)



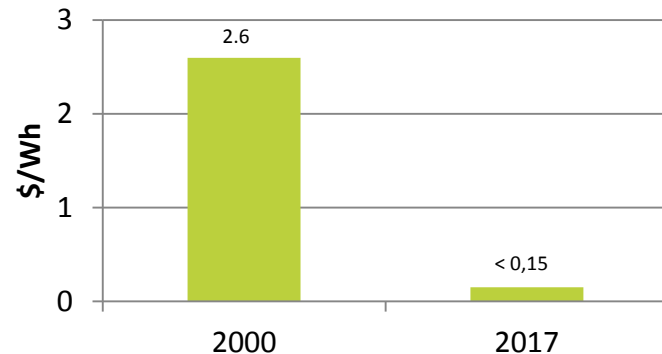
Portable PC sold per Year (Million)



Tons of cathode active materials



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



Source: AVICENNE ENERGY, 2018

AND IT'S JUST THE BEGINNING!



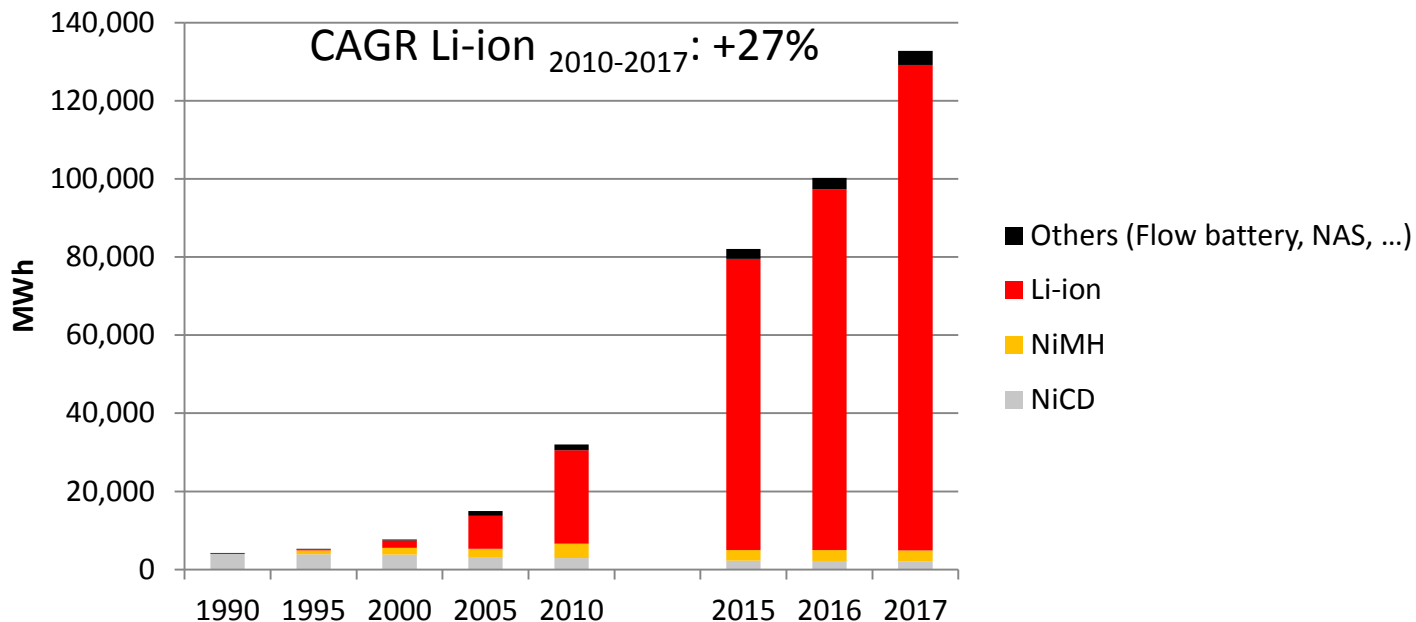
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# THE WORLDWIDE BATTERY MARKET 1990-2017

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



Source: AVICENNE ENERGY, 2018

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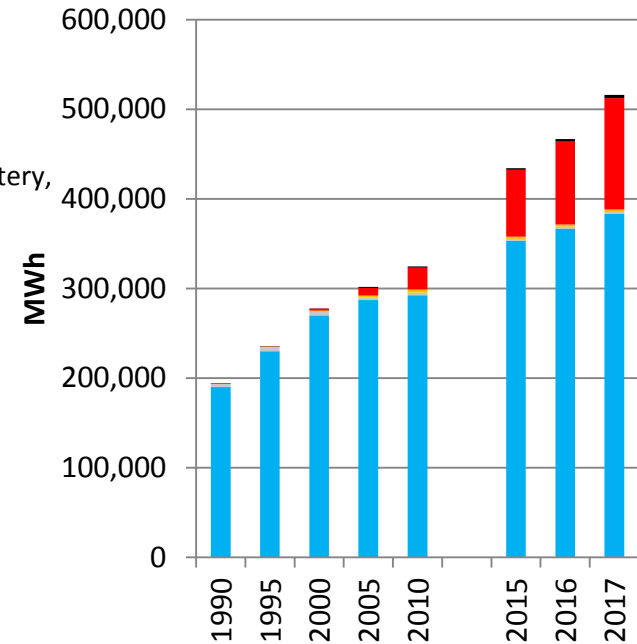
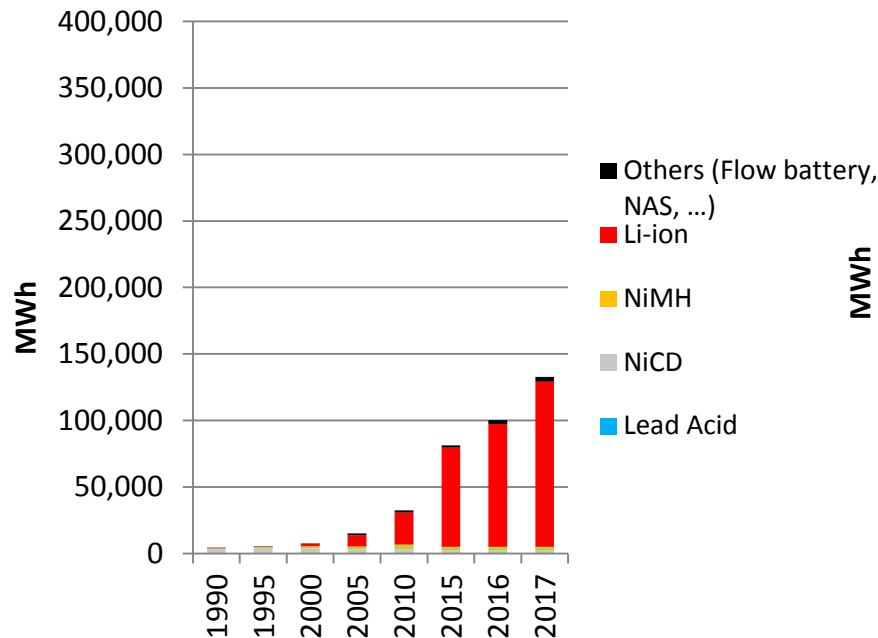
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# THE WORLDWIDE BATTERY MARKET 1990-2017

Lithium Ion Battery: Highest growth & major part of the investments  
Lead acid batteries: By far the most important market (75% market share)



Source: AVICENNE ENERGY, 2018

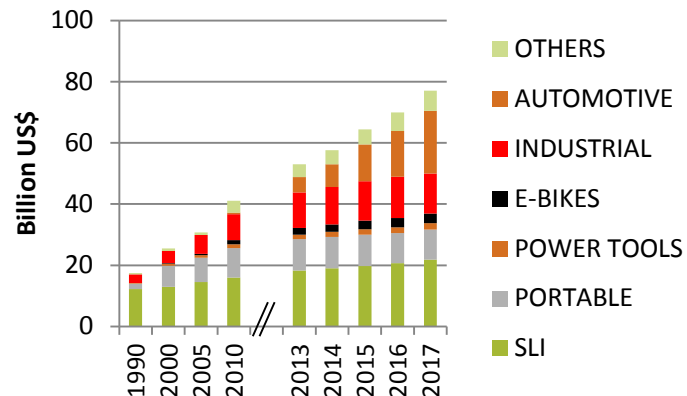
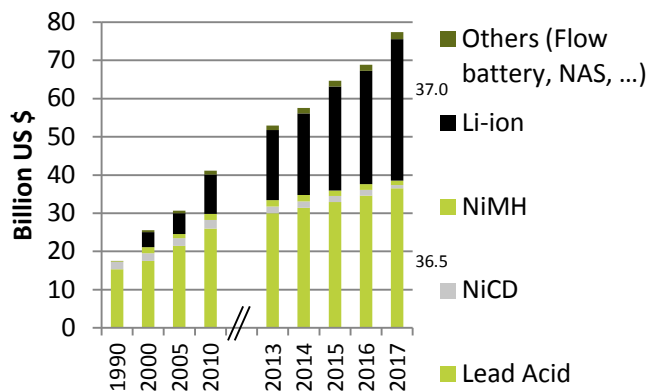
# THE WORLDWIDE BATTERY MARKET 1990-2017

>75 BILLION US\$ in 2017 – Pack level<sup>1</sup>  
9% AVERAGE GROWTH PER YEAR (2010-2017)

Current Status and Future  
Trends of the Global Li-ion  
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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, 2018

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, drones, Light Electric Vehicles, Hoverboard, ...

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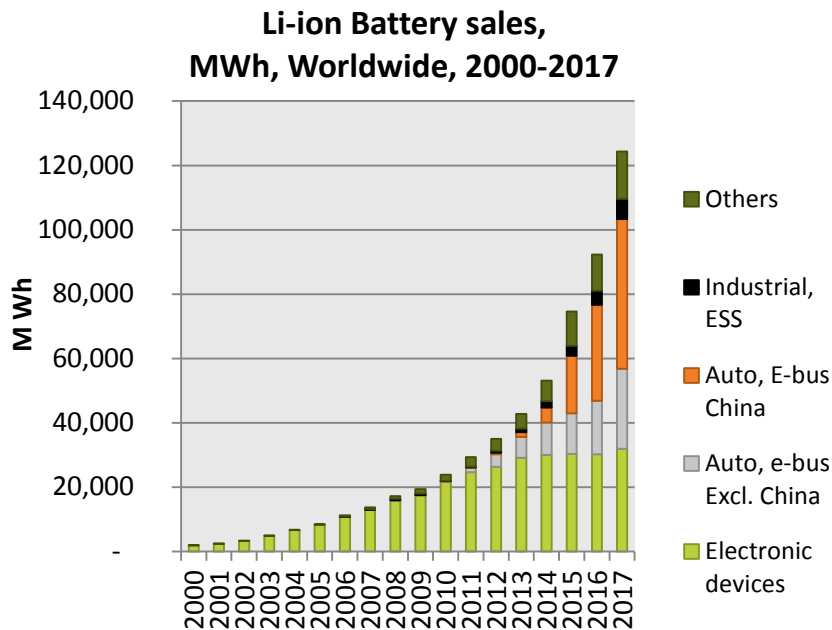
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# LI-ION IN 2017 - MAIN APPLICATIONS

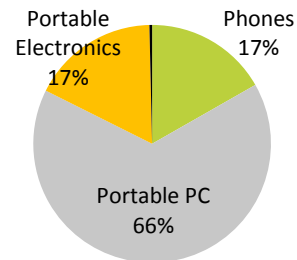
>120 000 MWh - 28 B\$ (1)

CAGR 2007/2017  
+25 % per year in Volume

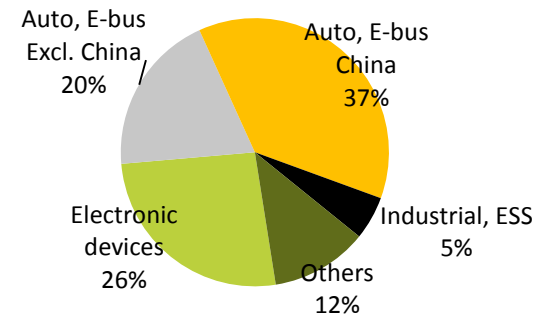


(1) Cell level  
Others: medical devices, power tools, gardening tools, e-bikes...  
Source: AVICENNE Energy 2018

**2000: < 2GWh**



**2017: >120 GWh**





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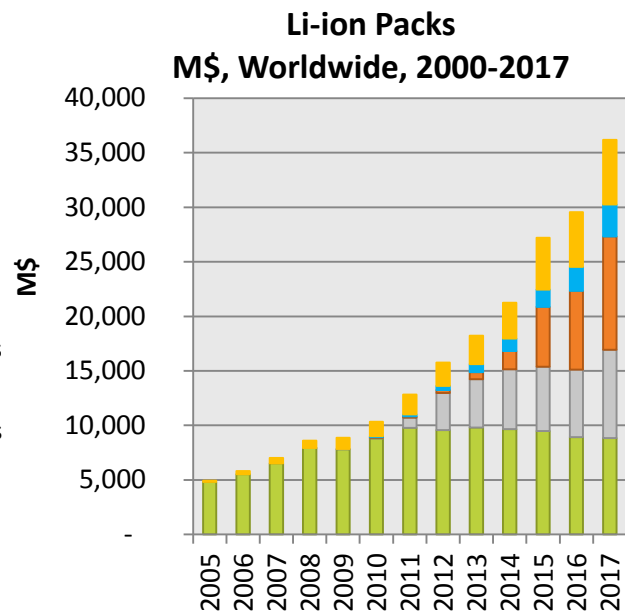
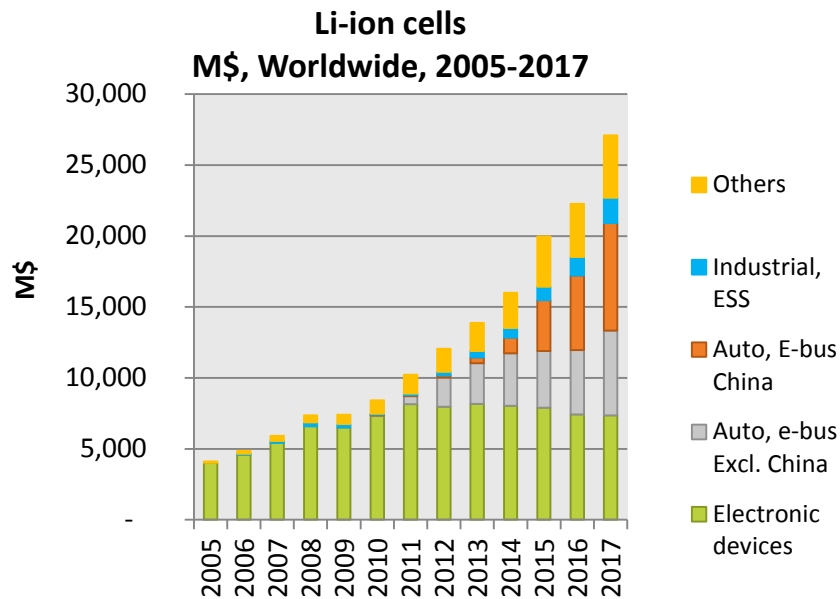
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# LI-ION IN 2017 - MAIN APPLICATIONS

+120000 MWh - 27 B\$ (1)  
7 300 M small cells

CAGR 2007/2017  
+25% per year in Volume  
Cell: +16% per year in value  
Pack: +18% per year in value



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

Source: AVICENNE Energy 2018

# LIB: THE BIGGEST PART OF THE COST IS RAW MATERIALS

RAW MATERIALS ACCOUNT FOR 60 TO 70% OF LIB CELLS BUSINESS

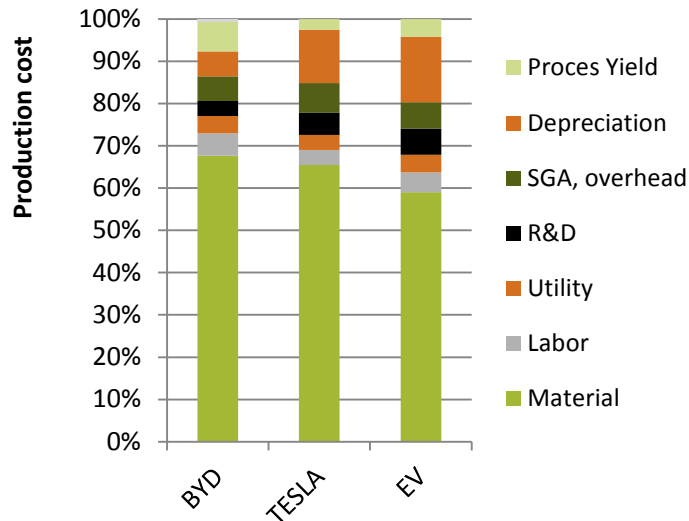
RAW MATERIAL COST IMPACT DRASTICALLY ON THE BATTERY MAKERS PROFIT

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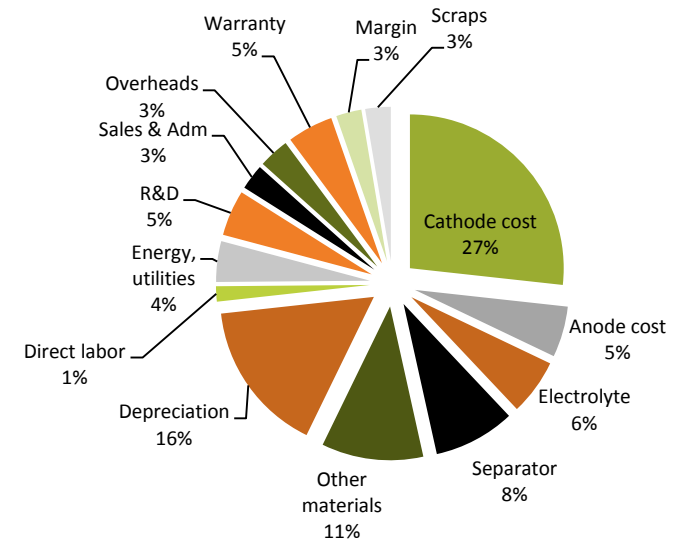


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LIB Cost structure for TESLA & 40 Ah EV pouch cell NMC



Average cost structure of Li-ion cell



Note: Average mix of cylindrical, prismatic & laminate cells

Sources: AVICENNE ENERGY 2017

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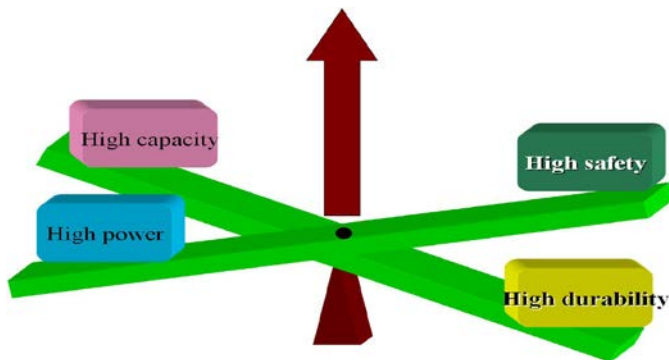
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# LIB CATHODE MATERIAL

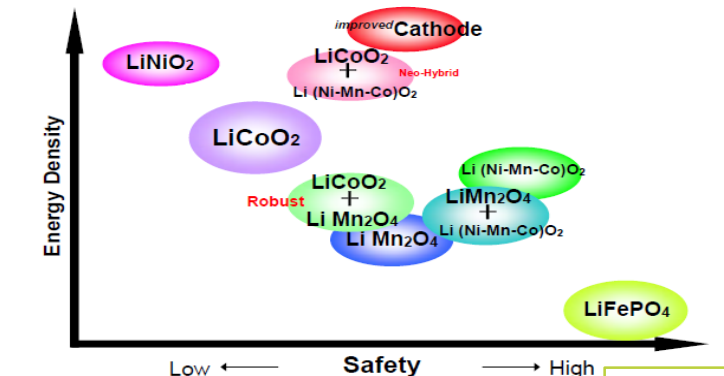
## ☞ Cathode raw materials market

- ☞ LiCoO<sub>2</sub> (LCO)
- ☞ LiMn<sub>2</sub>O<sub>4</sub> (LMO)
- ☞ LiMPO<sub>4</sub><sup>(1)</sup> (LFP)
- ☞ Li[NixMnyCoz]O<sub>2</sub> - NMC
- ☞ Li[NixCoyAlz]O<sub>2</sub> - NCA

(1) M= Fe or Mn

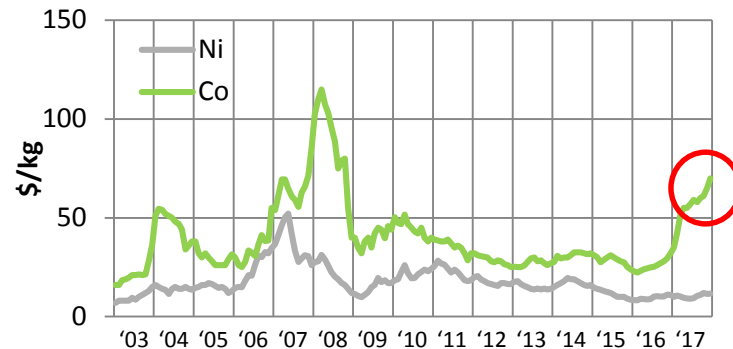


Source: Mitsubishi, Batteries 2012 – Nice



Source: SANYO, March 2011

## Ni & Co price 2003-2017



Source: LME



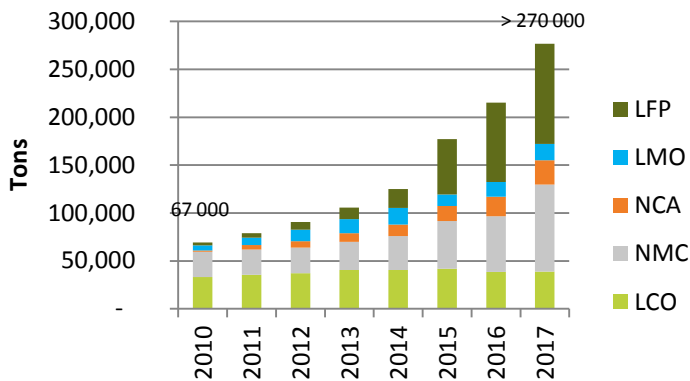
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# CATHODE ACTIVE MATERIALS NEEDS

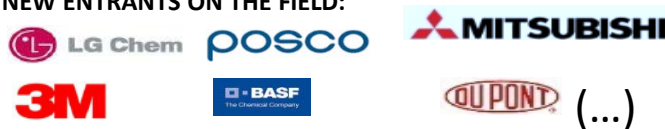
Cathode active materials for LIB in Tons, 2010-2017 (Demand)



LEADERS:



NEW ENTRANTS ON THE FIELD:



## Rationales

- In 2017, 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



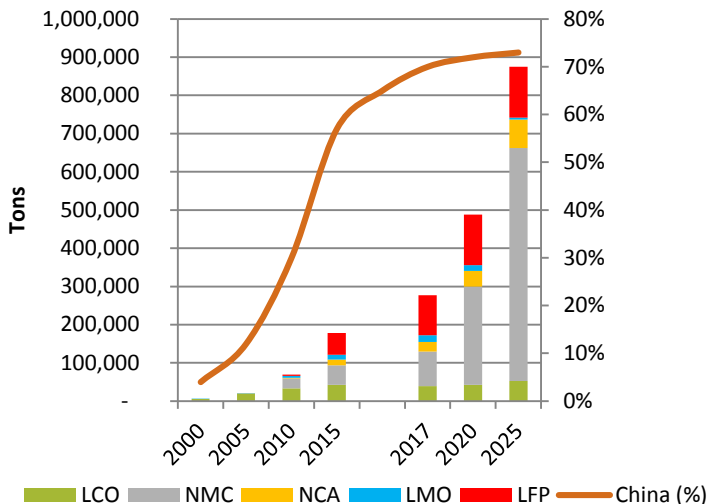
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# CATHODE ACTIVE MATERIAL FORECASTS 2000-2025

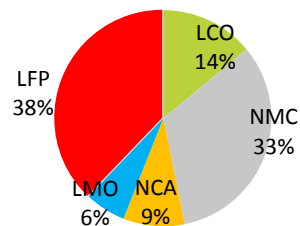
## Cathode active materials 2000-2025 - Tons



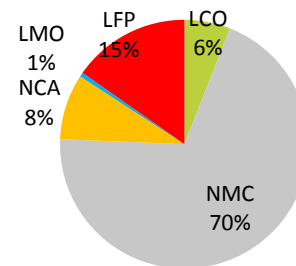
**ASSUMPTIONS:**

- Portable devices: 2017-2025: +5-6% per year in volume
- HEV: 3 M HEV/year in 2020, 4,2 M HEV in 2025
- P-HEV: 0,65 M P-HEV/year in 2020, 1,4 M in 2025
- EV: 1,9 M EV/year in 2020 (1,3 M in China) / 4 M/year in 2025 (2,8 M in China) 100% LIB
- Industrial, stationary & other applications 2016-2025: +16% per year

## Cathode active materials in 2017 > 275 000 Tons



## Cathode active materials in 2025 875 000 Tons



Assumption: Tesla keep NCA chemistry and have a relative success  
(+350 000 EV sold per year in 2025 – TESLA forecast 500 000)

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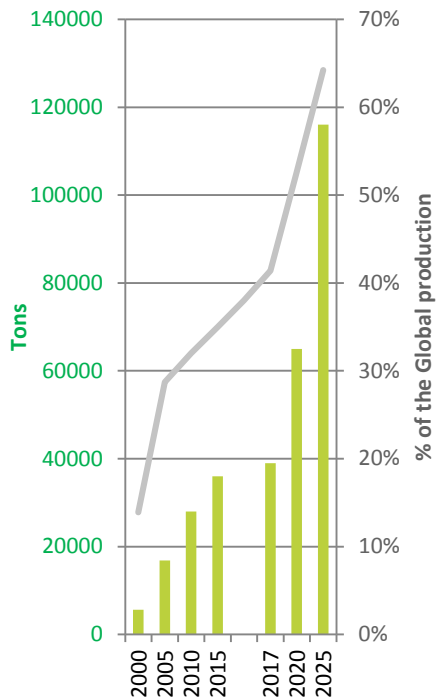
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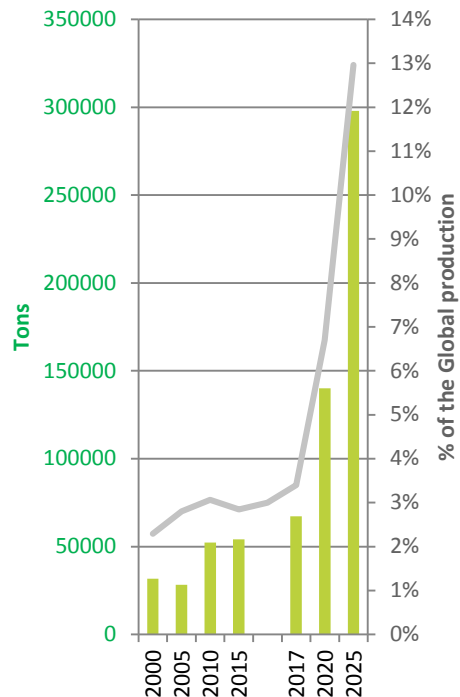
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# METAL NEEDS FOR RECHARGEABLE BATTERY WILL INCREASE RAPIDLY

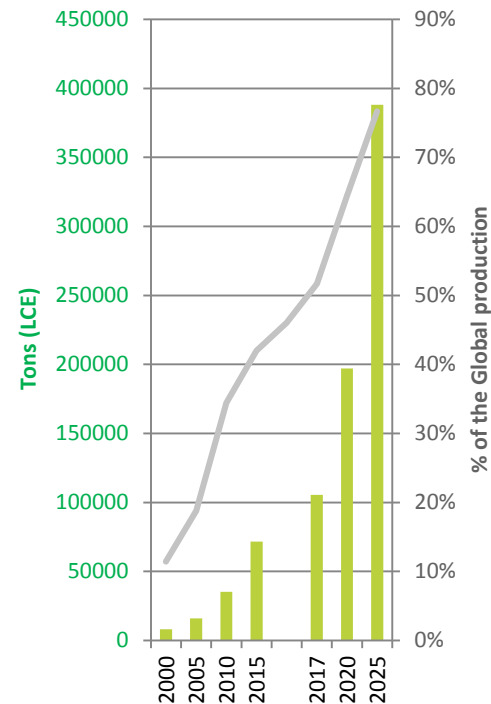
## Cobalt



## Nickel



## Lithium



Sources: AVICENNE ENERGY 2018

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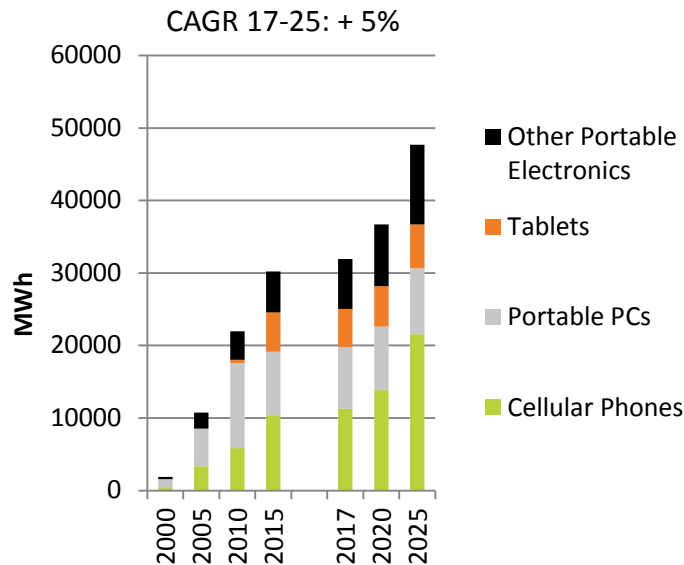
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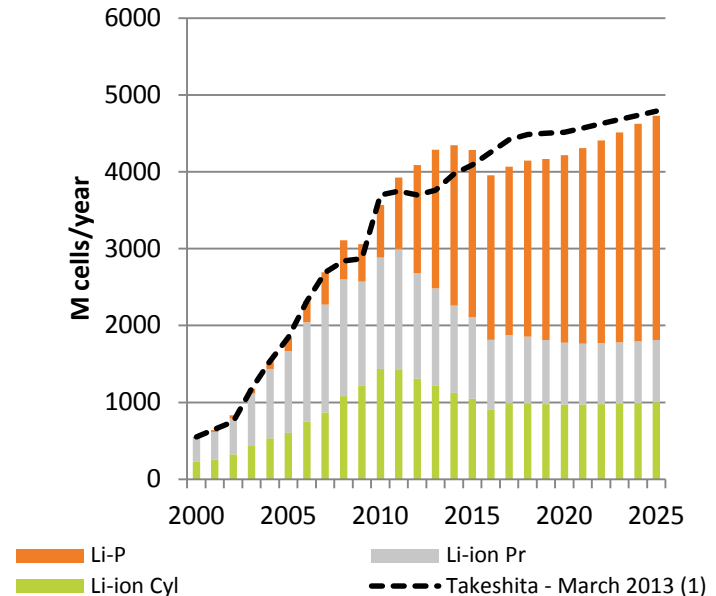
# 2025 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

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



Source: AVICENNE ENERGY Analyses

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



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



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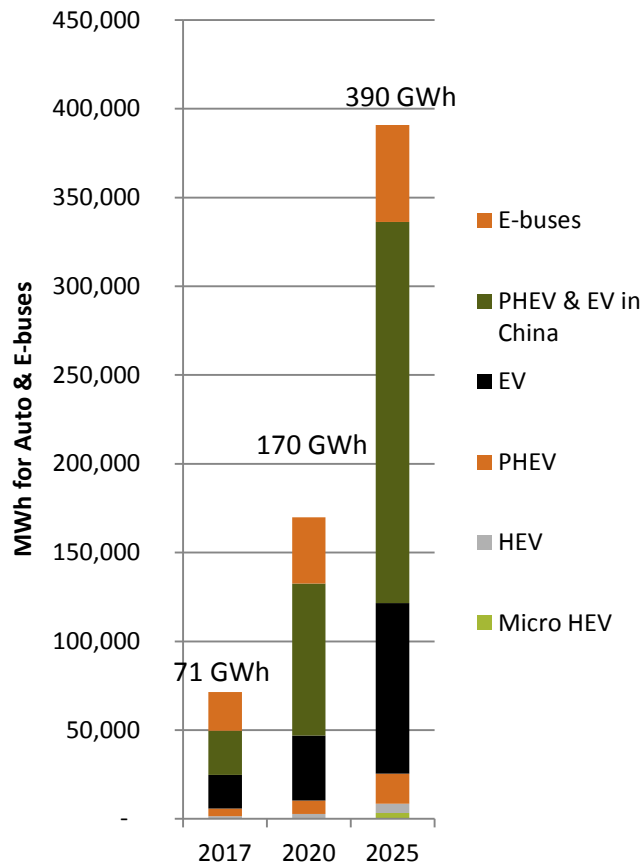
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# X-EV MARKET

- 📌 Why x-EV ?
- 📌 Definition & segmentation
- 📌 X-EV worldwide in 2017
  - 📌 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

CAGR 2017-2025: + 24%





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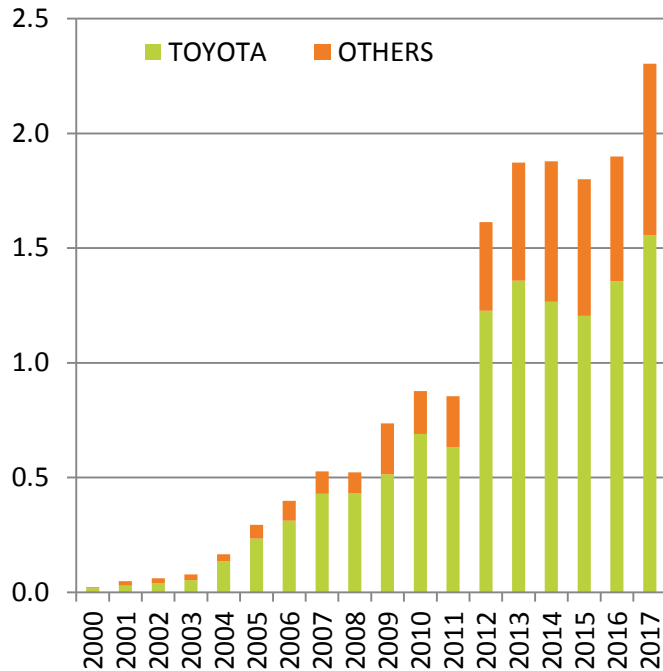
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# HEV WORLDWIDE IN 2017

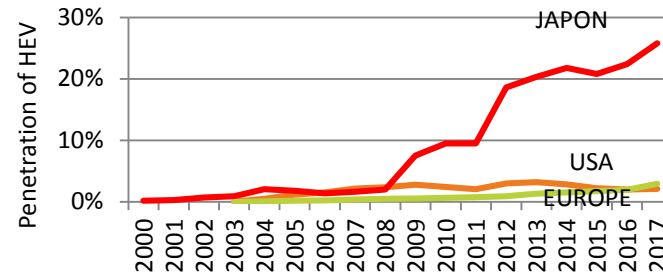
## 2,3 M HEV

Growth 2016-2017: +20%  
From 1,9 M to 2,3 M HEV

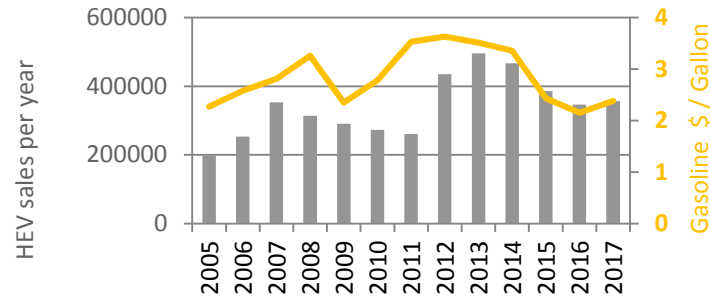
HEV sold per year, M units, worldwide, 2000 - 2017



Penetration of hybrids in the global sales, 2000-2017



Gazoline price impact on HEV market in the US



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

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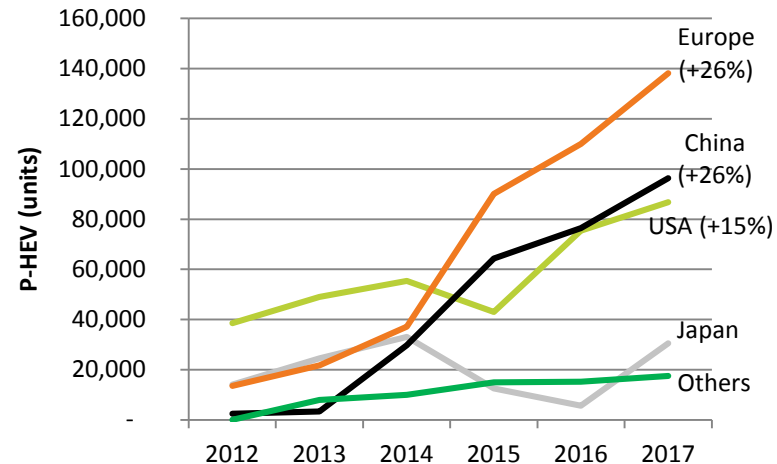
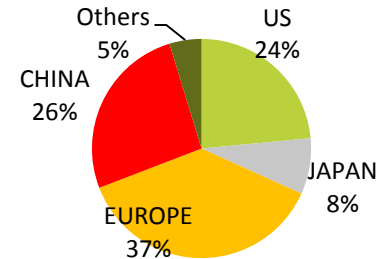
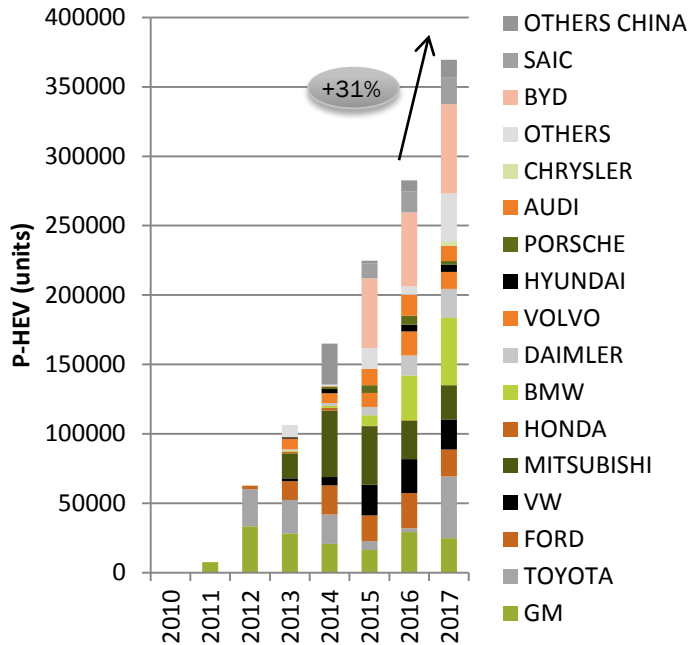
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# PHEV SOLD WORLDWIDE > 370 000 IN 2017

World excl. China growth +32%  
Chinese Growth + 26%

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



Source: AVICENNE ENERGY Analysis, 2017



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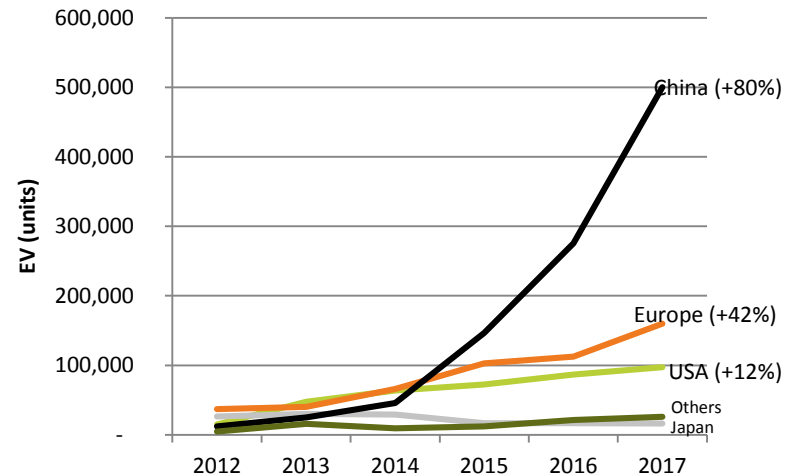
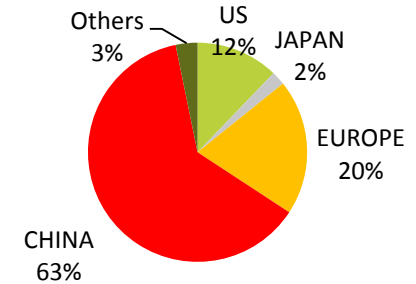
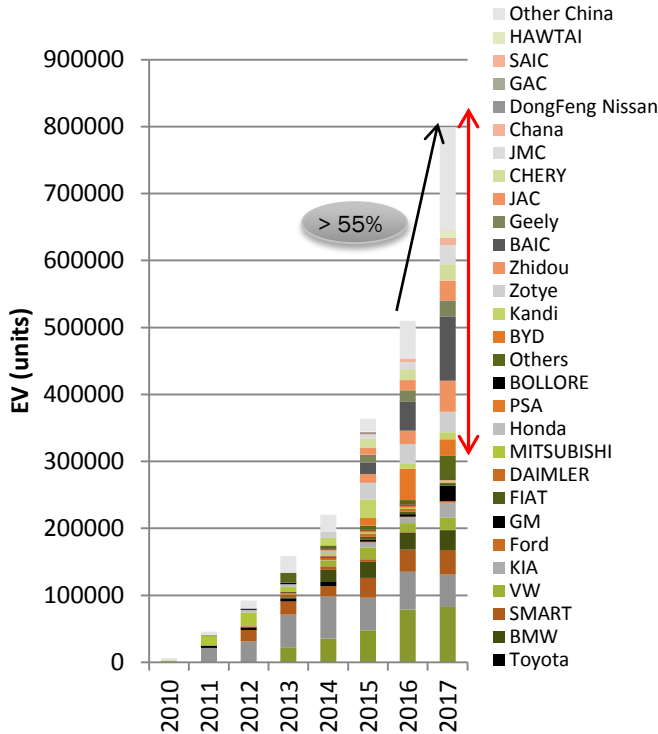
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# EV SOLD WORLDWIDE > 800 000 IN 2017

World excl. China growth >26%

Chinese Growth > 80%

China is leading the EV market thanks to high incentives



Source: AVICENNE ENERGY Analysis, 2017



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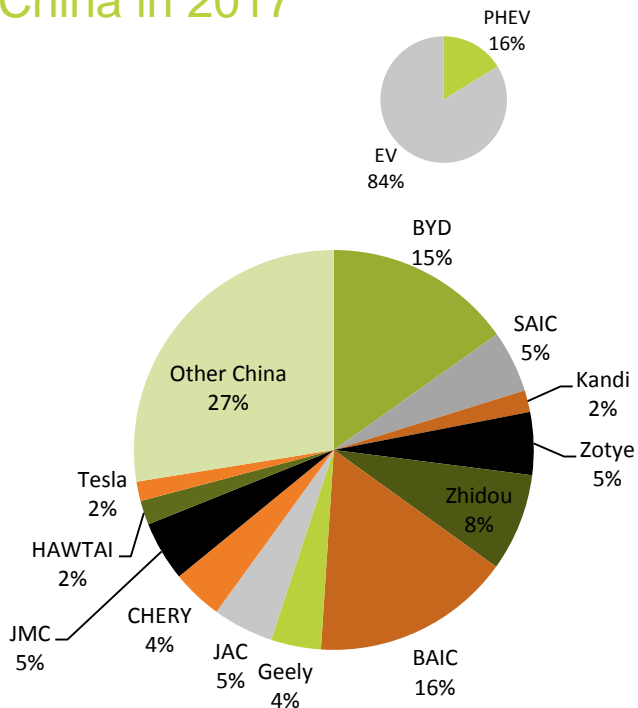
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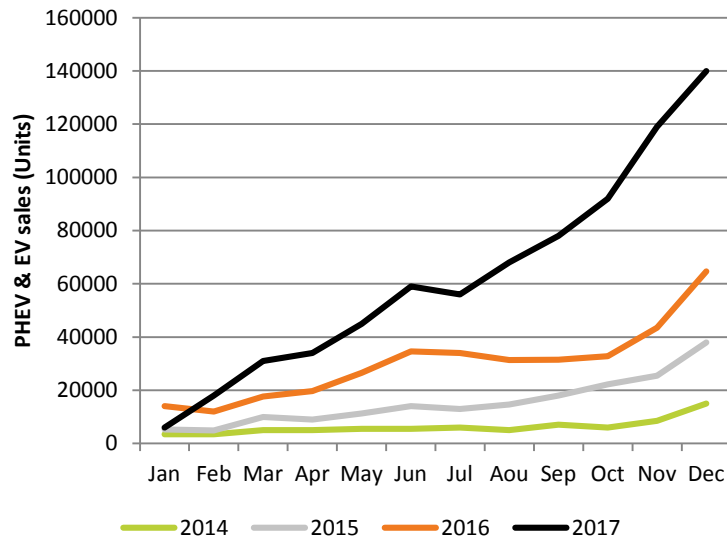
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# NEV\* DEVELOPMENT IN CHINA

>600 000 PHEV & EV sold in  
China in 2017



PHEV & EV evolution



\*NEV=PHEV+EV (New Energy Vehicles)

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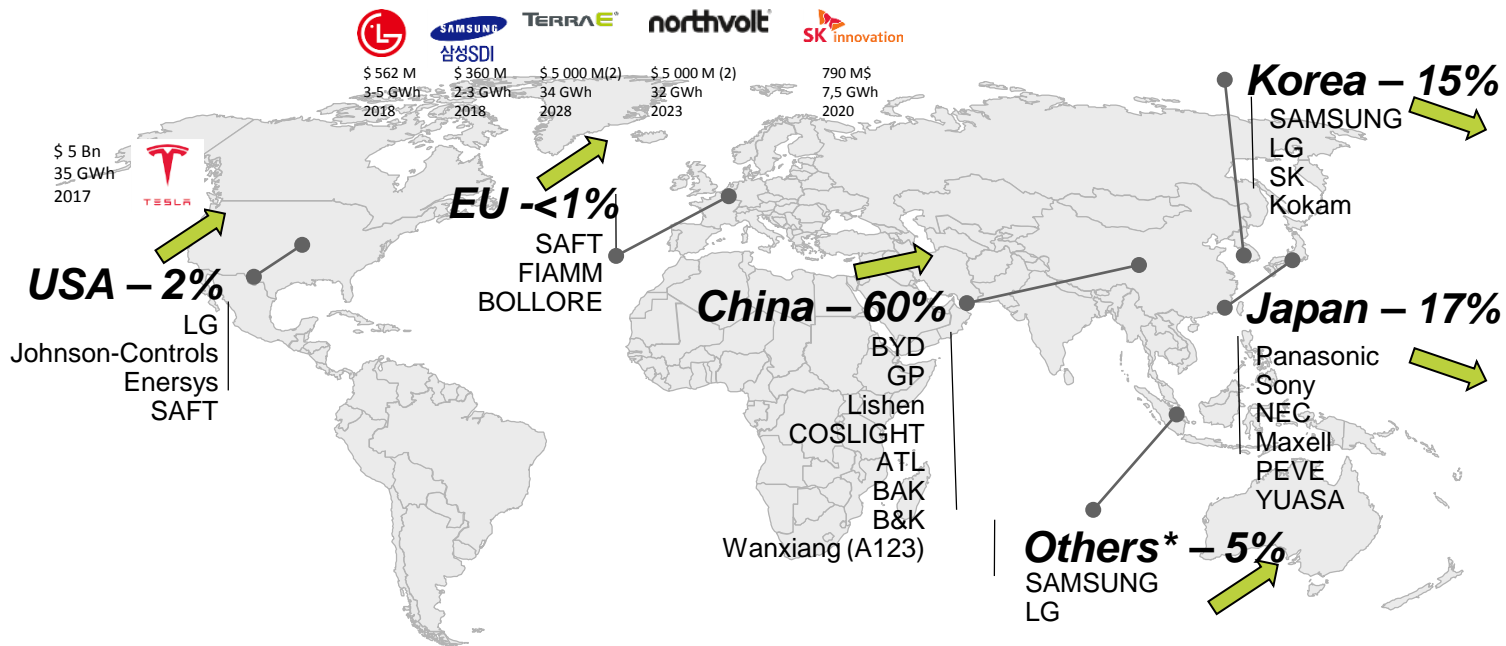
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# LITHIUM ION CELL PRODUCTION

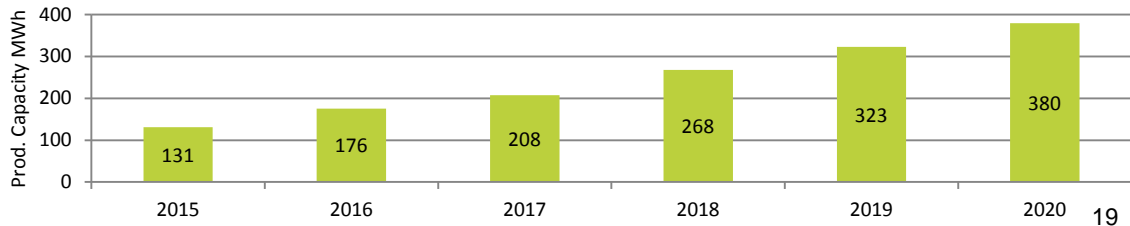
Korean companies start to move in Malaysia

New production capacity in Europe and US



Source: AVICENNE 2017

\* OTHERS: Malaysia mostly  
(1) Government subsidies only  
(2) AVICENNE Estimation





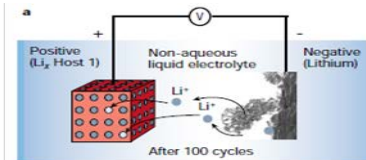
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# SAFETY ISSUES

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

### Background

In the 80's, lithium metal batteries were put into the markets (Moli Energy). Their further development has for a long time been slow because of a low cycle efficiency and safety issues: High chemical reactivity and a low melting point enable strong chemical reactions, even explosions. In the charging-discharging process, lithium metal can form dendrite and accumulate on electrodes. The growing lithium dendrite could puncture the separator and result in an internal short circuit. 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 their profit-to-date



### Automotive

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



### Aircraft

Boeing 787: The fire that burned near the tail of a parked Boeing 787 in Boston was caused by an overheating Lithium ion battery pack. The battery fire could have been hot enough to melt the carbon-fiber reinforced plastic that makes up the plane's shell.  
CONSEQUENCES: All the 787 worldwide are grounded. Considerable losses for Boeing.





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# 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	S/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**

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

**Packaging**

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

**Thermal**

- 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

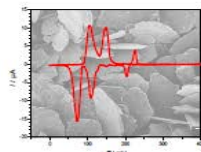


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# TIME TO MARKET FOR NEW MATERIALS IN LIB INDUSTRY



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,  $\text{LiPF}_6$  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.



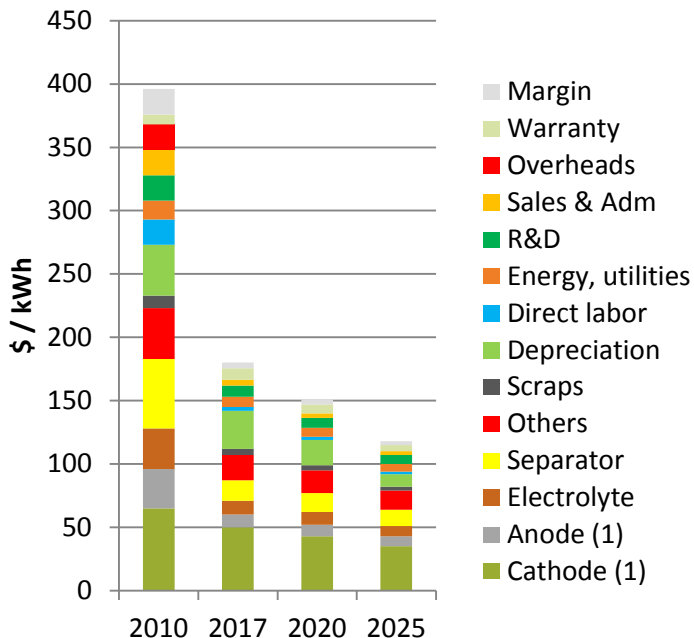
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London

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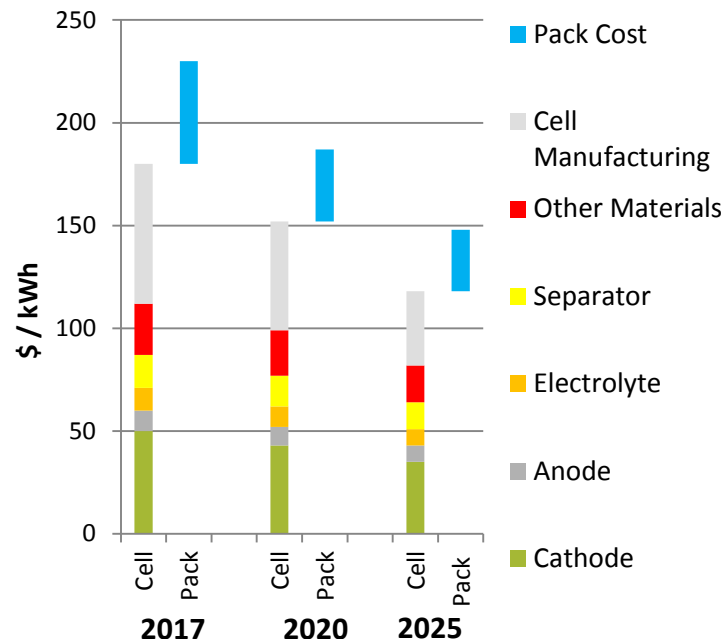
# LI-ION BATTERY COST 2015-2025

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



(1) Active materials only  
Source: AVICENNE ENERGY 2018

LI-ION BATTERY PACK COST FOR  
EV



\* For Production > 100 000 packs/year

# HEV, P-HEV, EV 2025 FORECASTS

Current Status and Future Trends of the Global Li-ion Battery Market

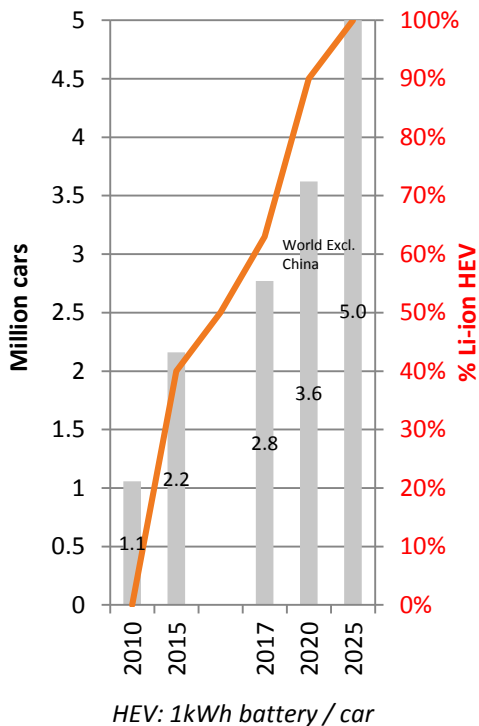


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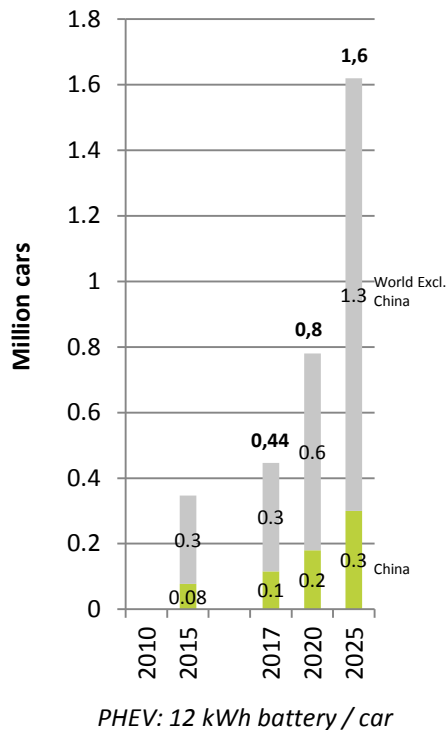
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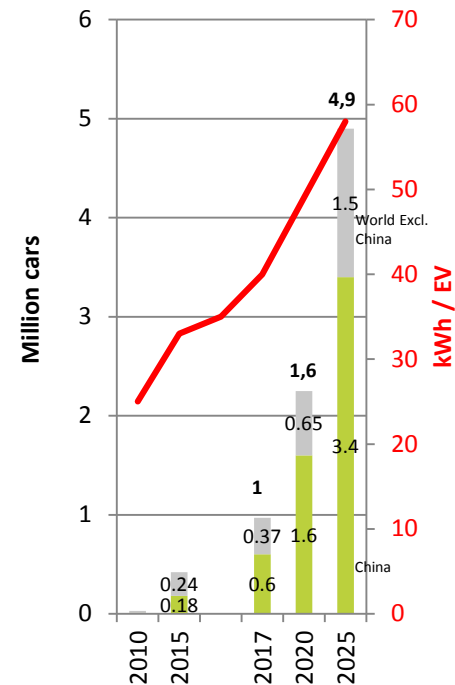
## HEV manufactured



## PHEV manufactured



## EV manufactured





Current Status and Future Trends of the Global Li-ion Battery Market



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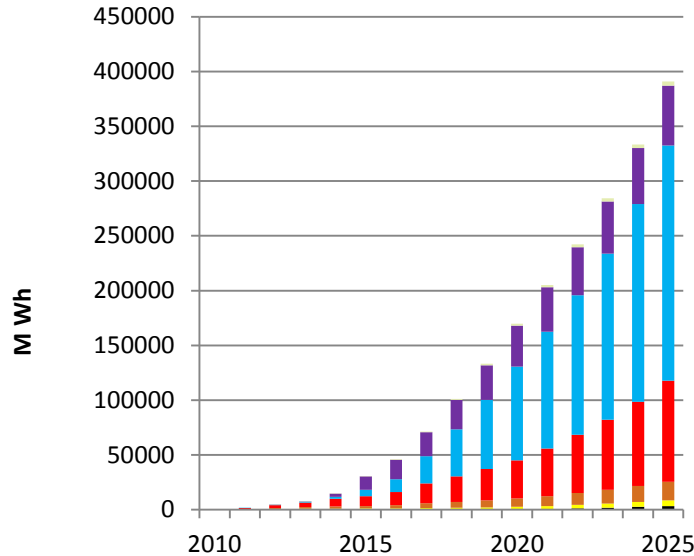
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# BATTERY DEMAND - XEV 2025 FORECASTS

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

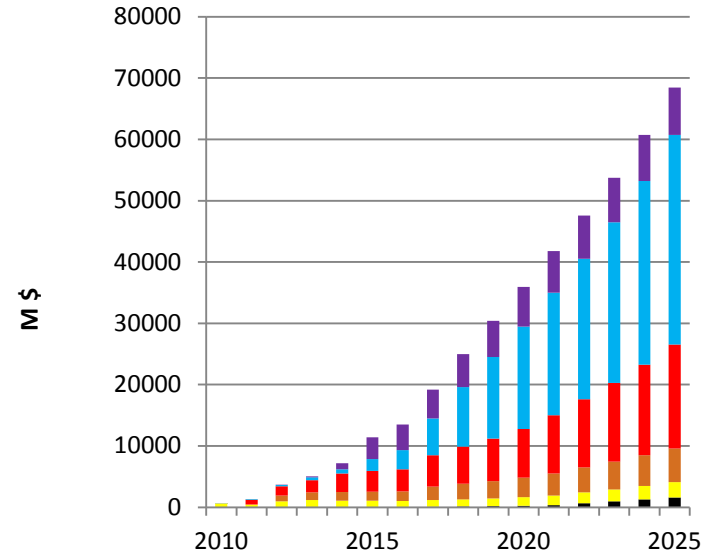
CAGR 2017-2025: +24%



■ 12-48 volts SLI    ■ HEV    ■ PHEV  
 ■ EV    ■ EV & PHEV China    ■ E-bus China  
 ■ E-bus excl. China

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

CAGR 2017-2025: +17%



■ 12-48 volts SLI    ■ HEV    ■ PHEV  
 ■ EV    ■ EV & PHEV China    ■ E-bus China

# LI-ION BATTERY MARKET FORECASTS

From 120 GWh in 2017 to 520 GWh

CAGR 2017/2025  
+21 % per year in Volume

Current Status and Future Trends of the Global Li-ion Battery Market

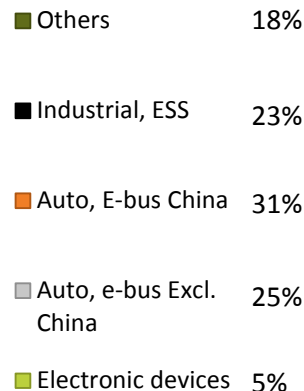
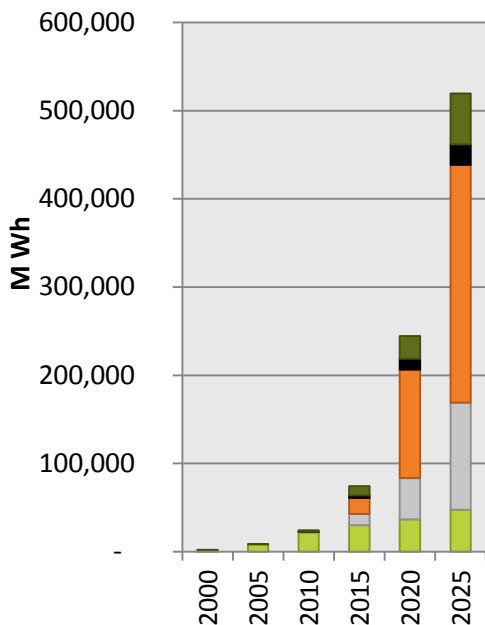


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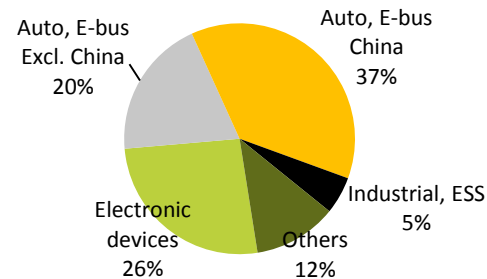
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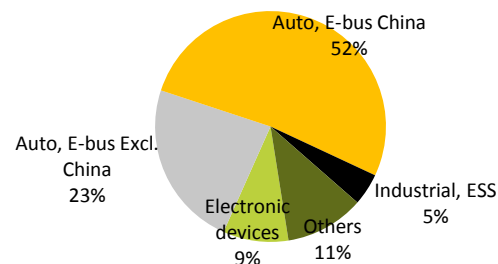
**Li-ion Battery sales,  
MWh, Worldwide, 2000-2025**



**2017: >120 GWh**



**2025: 520 GWh**



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

Source: AVICENNE Energy 2018



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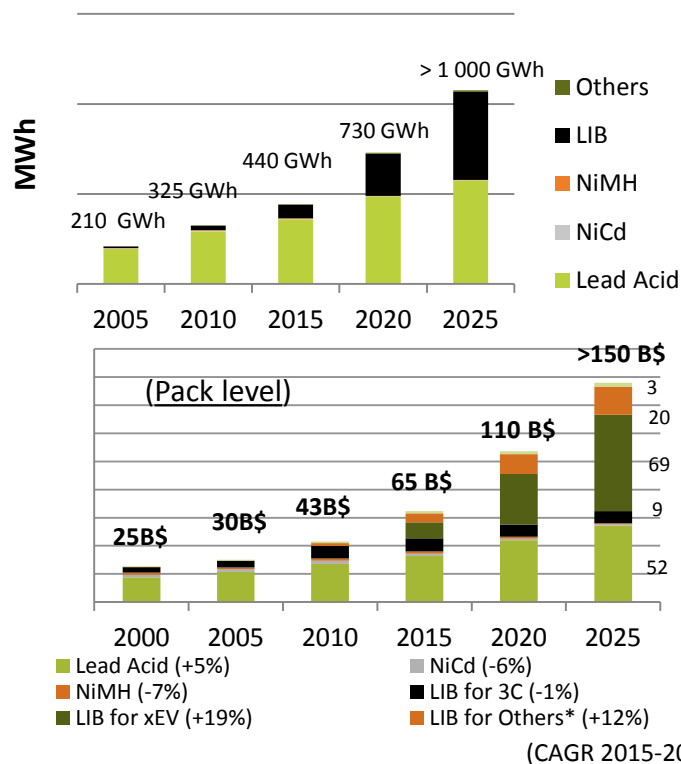
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# TAKEAWAYS

Battery Market 2015-2025 - CAGR = +9% / Li-ion > +13%

- 🔋 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: 18 B\$ market in 2017 - 34 B\$ in 2020 & 65 B\$ in 2025 with high numbers in China (2017: US\$6 Billion for xEV and US\$ 5 Billion for xE-Buses)
- 🔋 EV expectations attract large Chemical companies
- 🔋 New materials are needed to meet Automotive standards
- 🔋 HEV will account for 3% of the auto sales in 2020
- 🔋 P-HEV & EV for 2% to 3% 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 in value from 2018.
- 🔋 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, hoverboard, drones: CAGR > 10% in the next 15 years
- 🔋 Lithium battery for other application (ESS, stationary, industrial...) 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



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



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# THANK YOU



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