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Berlin, Germany

May 24th, 2019

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The Rechargeable Battery Market and Main Trends 2018-2030

Christophe PILLOT
Director, AVICENNE ENERGY

Presentation Outline

- The rechargeable battery market in 2018
- The Li-ion battery value chain
- Battery for Automotive forecasts
- Industrial battery forecasts
- Conclusions

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OEM INVESTMENT IN VEHICLE ELECTRIFICATION

January 2018 news

Carmakers to invest more than $90 Billion in EV

- **Ford** will invest **$11 billion** by 2022 to launch 40 new electric cars and hybrids worldwide
- **Volkswagen** plan to spend **$40 Billion** by 2030 to build electrified versions of its 300-plus global models
- **Daimler** will spend at least **$11,7 billion** to introduce 10 pure electric 40 hybrid models
- **Nissan** pledged to launch 8 new electric vehicles and hit annual sales of 1 million electrified vehicles by 2022
- **Toyota** will launch 10 Evs by the early 2020s and sell 5,5 million electrified vehicles, including hybrids and hydrogen fuel cell vehicles, by 2030
- **BMW** will offer 25 electrified (12 fully electric) vehicles by 2025
- **GM** pledging to sell 20 all-electric vehicles by 2023
- **Honda** says two-thirds of total car sales to be electrified models by 2030
- **Chinese automakers**, all have publicized aggressive investment plans

Source: Ted Miller, Ford, AABC Japan 2018 (From Reuters Jan 2018 Publication) – Avicenne Energy

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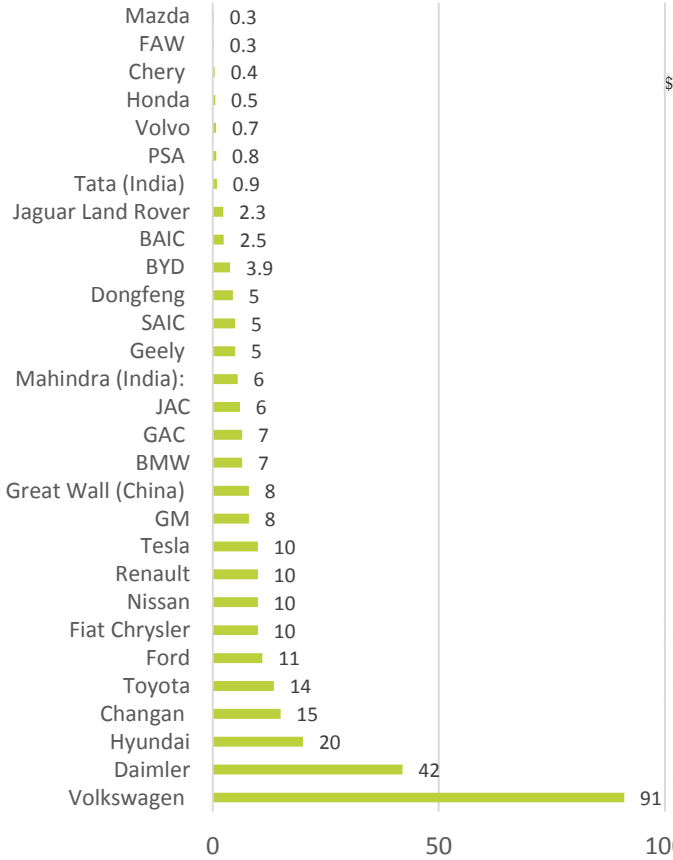
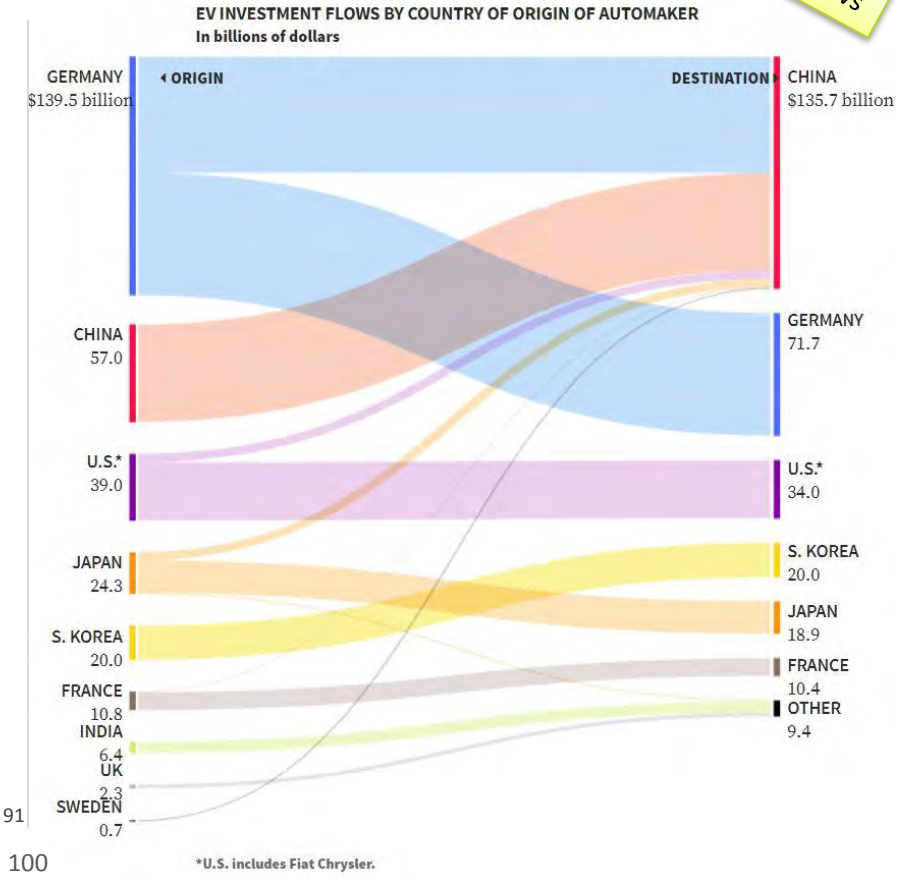
CARMAKERS TO INVEST MORE THAN $300 BILLION IN ...

January 2019 news





Source: Reuters January 2019, Avicenne Energy

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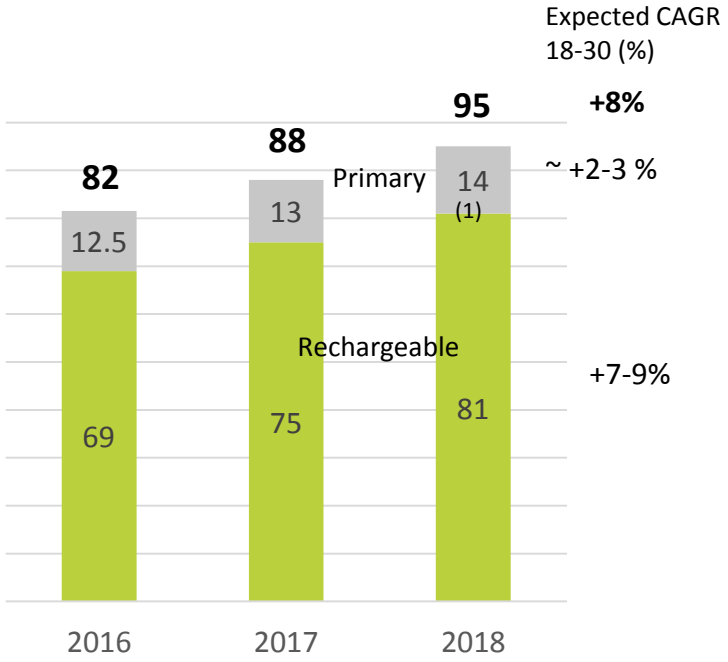
WORLDWIDE BATTERY MARKET OVERVIEW

Battery market in value (2016-2018, global, $bn, all market segments, all technologies)



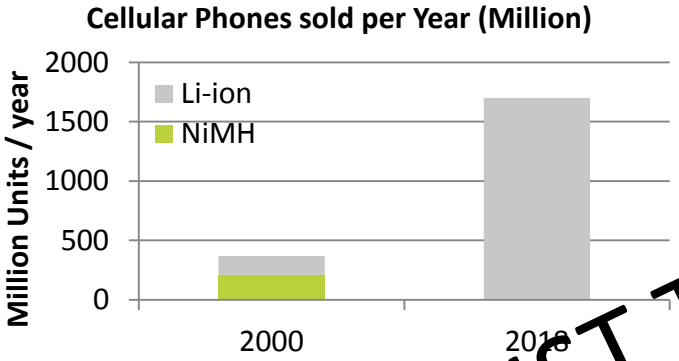
Macro-trends driving the battery market

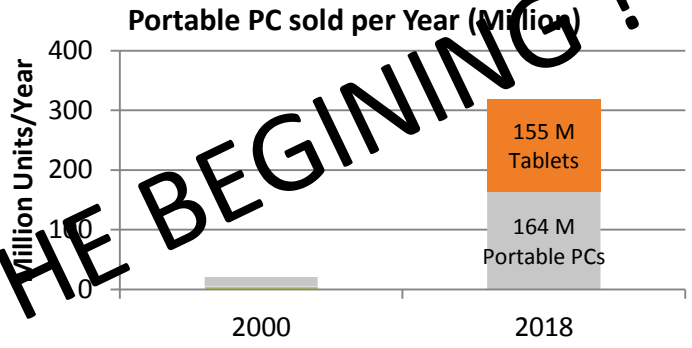
- Battery is a key technology for new concepts of mobility and energy (e.g. electric mobility, stationary storage) supported by the following trends:
  - **Population increase and city growth challenging existing mobility and energy solutions**
  - **Shift in energy production** with an increasing focus on renewable energies as an alternative to fossil fuel and nuclear
  - **Global awareness** regarding global warming **pushing for adoption of green solutions** (global objective of CO_2 emissions reduction, government regulations and incentives, social pressure for environmental-friendly solutions)

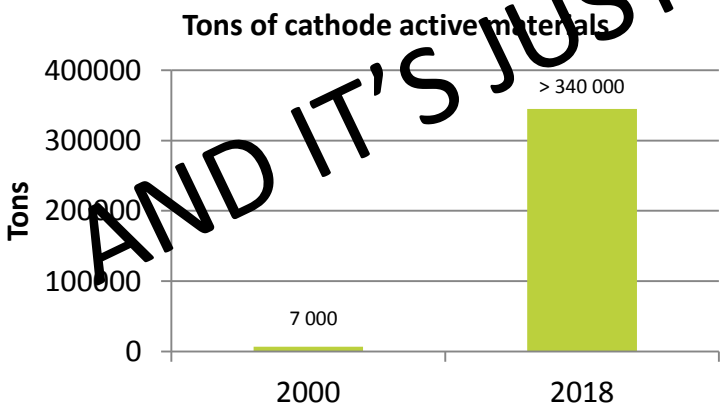
(1) Non rechargeable – Source: AT Kearney, Duracell, Avicenne – Based on selling price from manufacturer to retailer

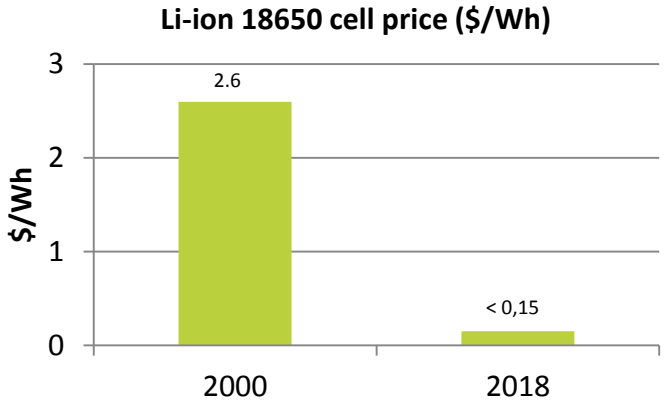
Source: AT Kearney, Duracell, AVICENNE ENERGY 2019

THE BATTERY MARKET IS REALLY DYNAMIC









AND IT'S JUST THE BEGINING !

Source: AVICENNE ENERGY, 2019

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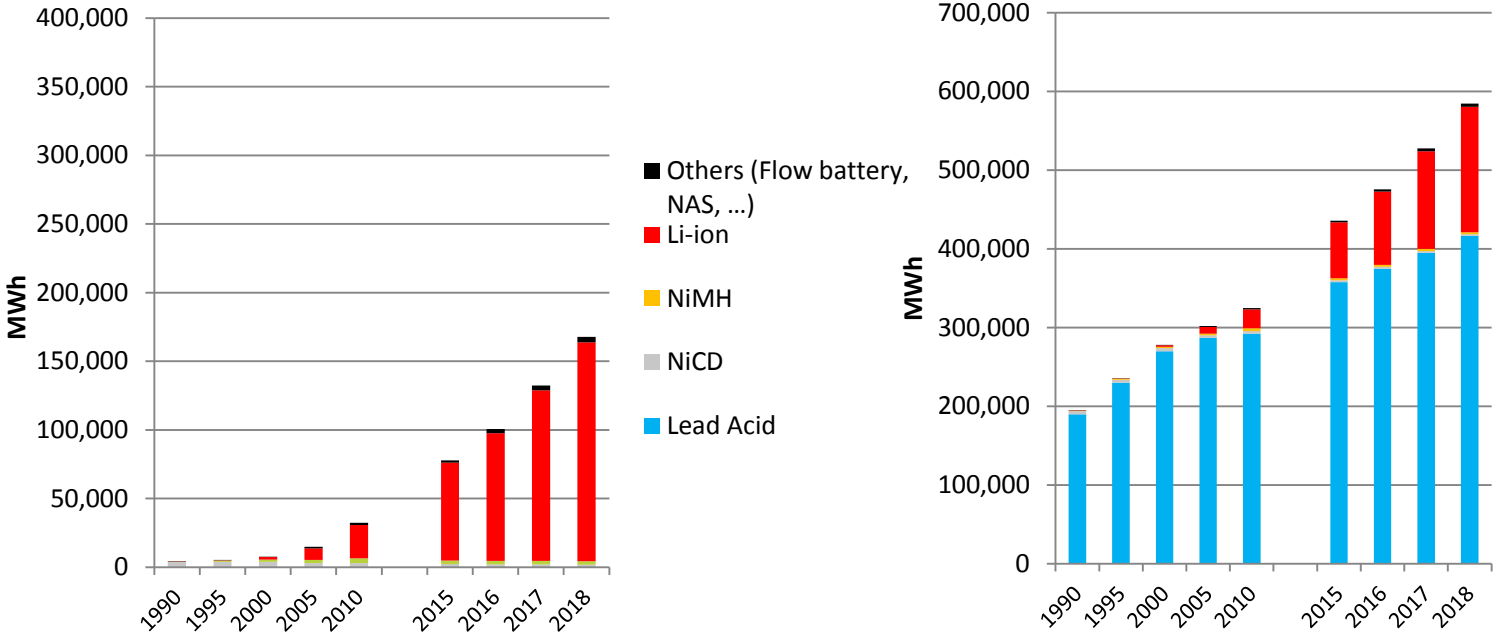
THE WORLDWIDE BATTERY MARKET 1990-2018

Lithium Ion Battery: Highest growth & major part of the investments
Lead acid batteries: By far the most important market (>70% market share)



Source: AVICENNE ENERGY, 2019

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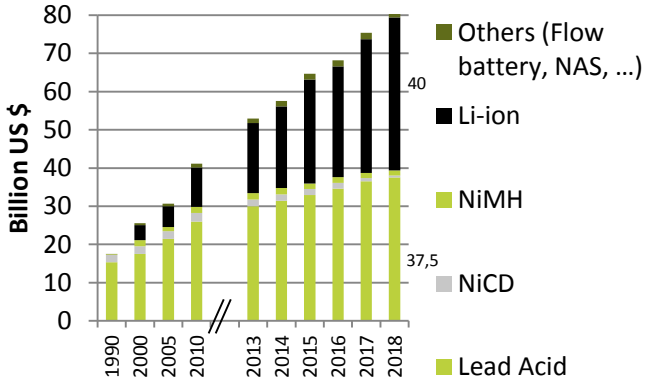
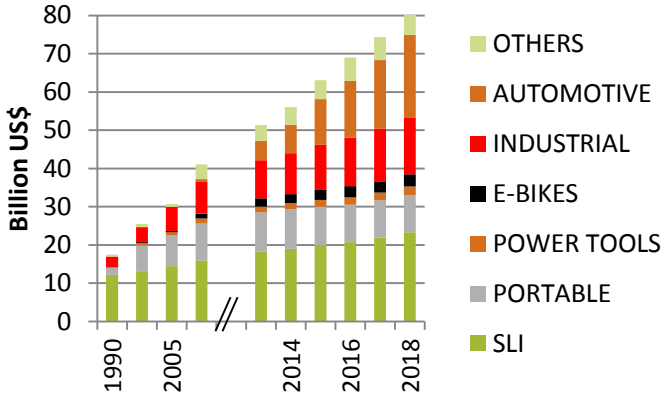
THE WORLDWIDE BATTERY MARKET 1990-2018

80 BILLION US$ in 2018 – Pack level[1]
9% AVERAGE GROWTH PER YEAR (2010-2018)





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

PORTABLE: concumer electronics (cellular, portable PCs, tablests, 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, 2019

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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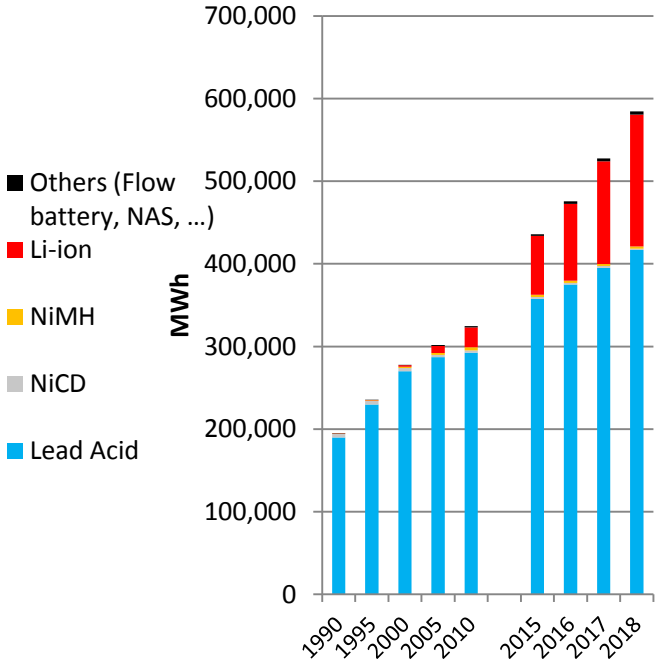
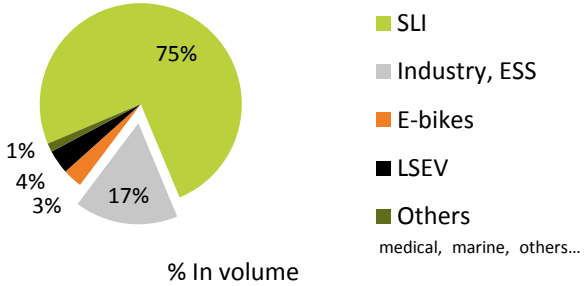
THE WORLDWIDE BATTERY MARKET 1990-2018

In volume (MWh)



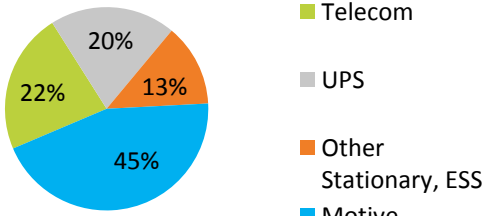
Source: AVICENNE ENERGY, 2019

Lead Acid Batteries 2018
420 GWh for > US $ 37 Billion



% In volume

Industrial Batteries – Lead acid batteries
69 GWh for US $ 11 Billion

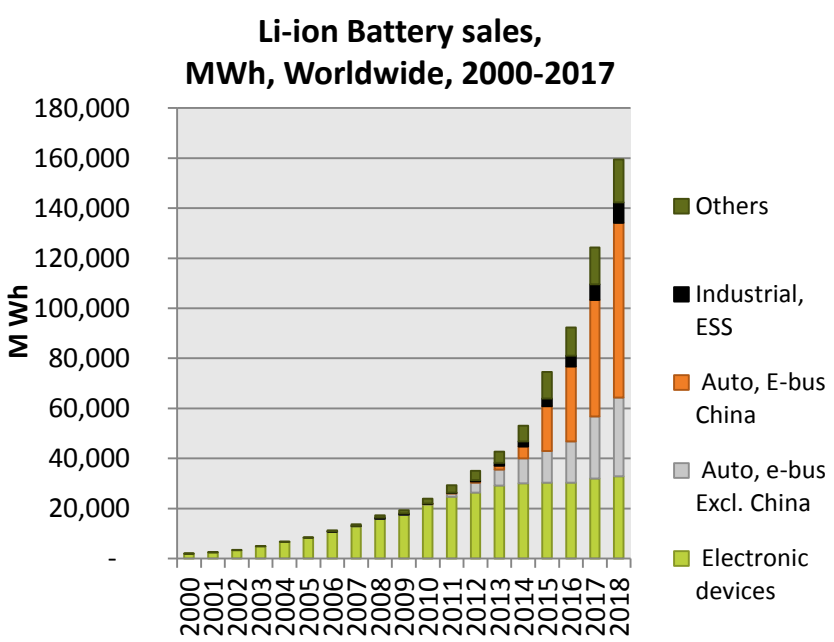


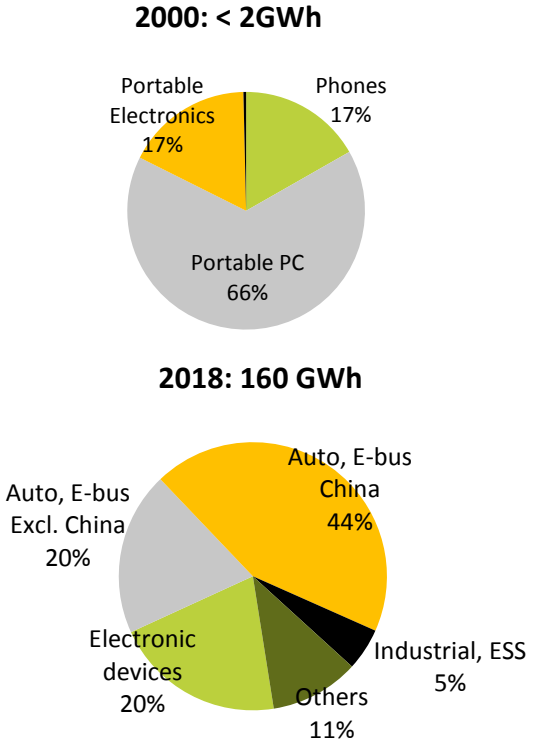
% In volume

LI-ION IN 2018 - MAIN APPLICATIONS

>160 000 MWh - 31 B$ (1)

CAGR 2008/2018
+24 % per year in Volume





(1) Cell level
Others: medical devices, power tools, gardening tools, e-bikes…
Source: AVICENNE Energy 2019

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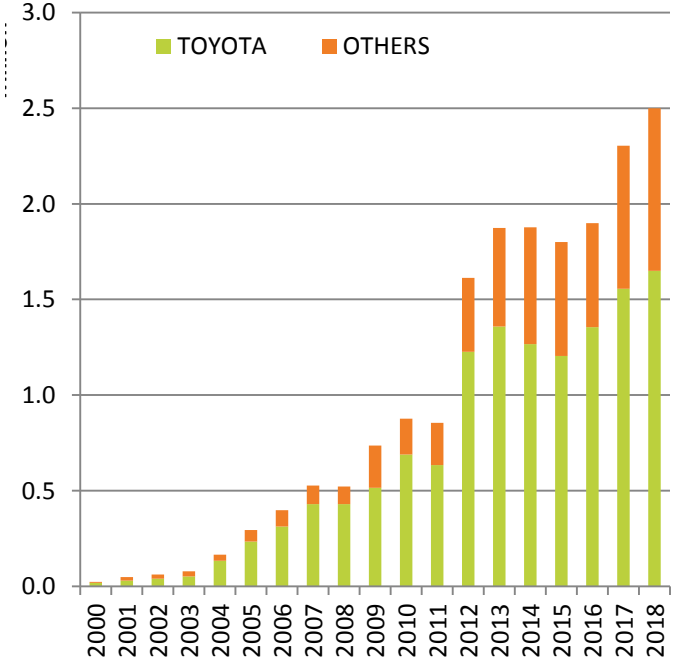
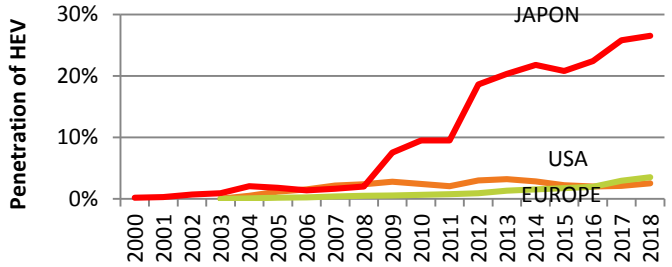
HEV WORLDWIDE IN 2018
2,5 M HEV

Growth 2017-2018: +9%
From 2,3 M to 2,5 M HEV

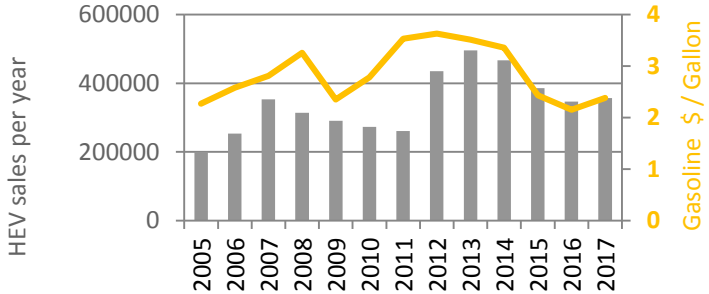
HEV sold per year, M units, worldwide, 2000 - 2018



Penetration of hybrids in the global sales, 2000-2018



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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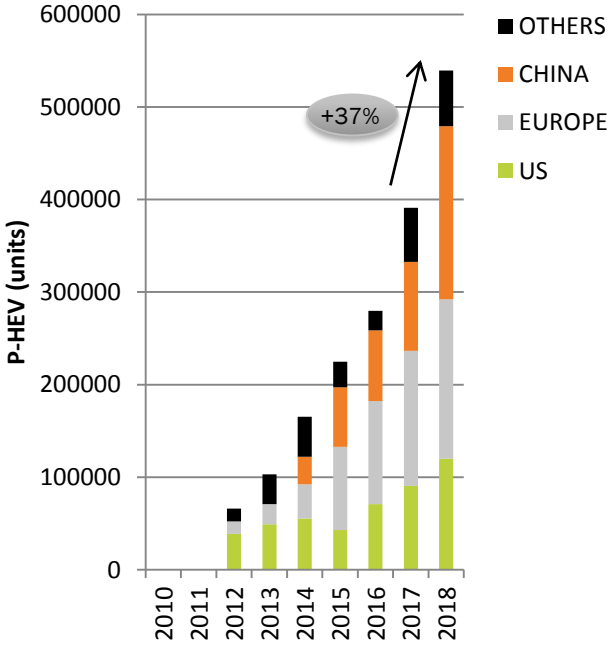
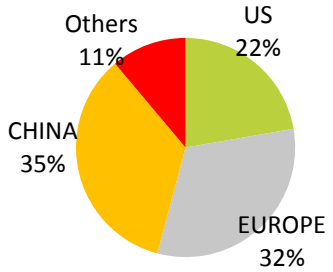
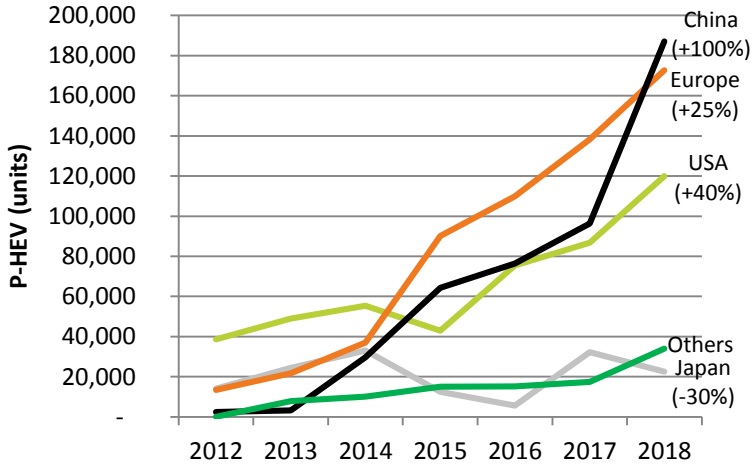
PHEV SOLD WORLDWIDE > 535 000 IN 2018

World excl. China growth +18%
Chinese Growth + 100%



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





Source: AVICENNE ENERGY Analysis, 2019

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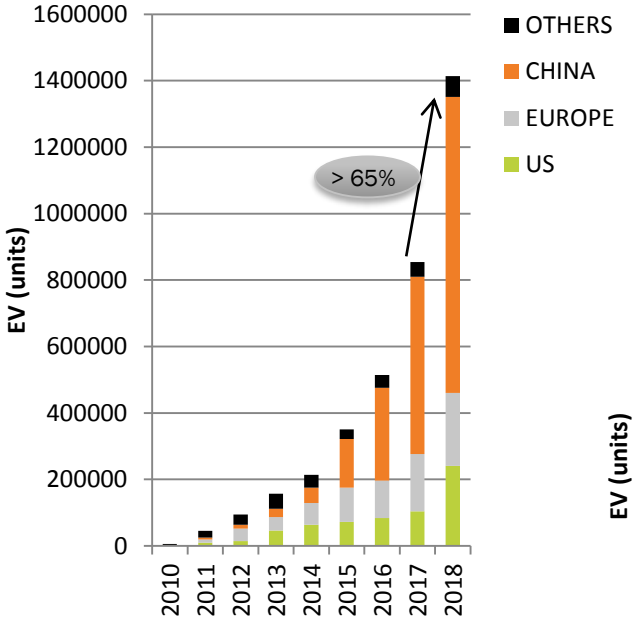
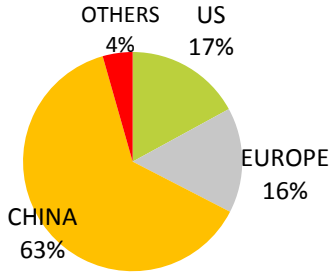
EV SOLD WORLDWIDE> 1,4 M IN 2018

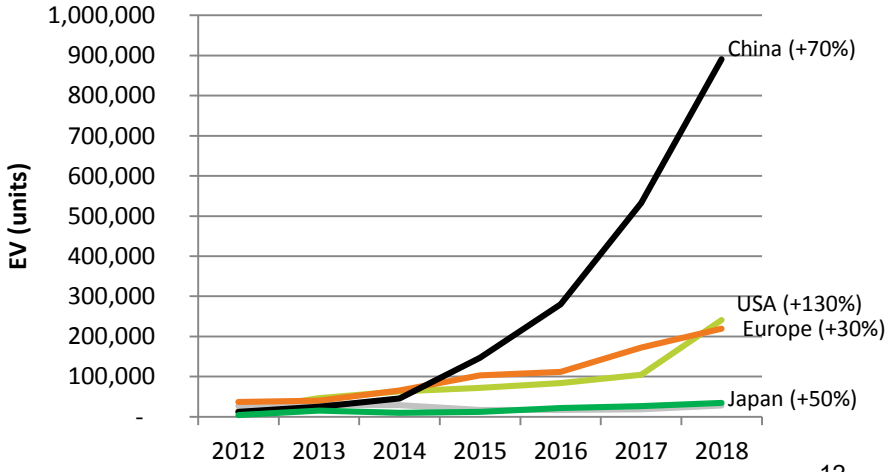
World excl. China growth > 65%

Chinese Growth > 65%



China is leading the EV market thanks to high incentives

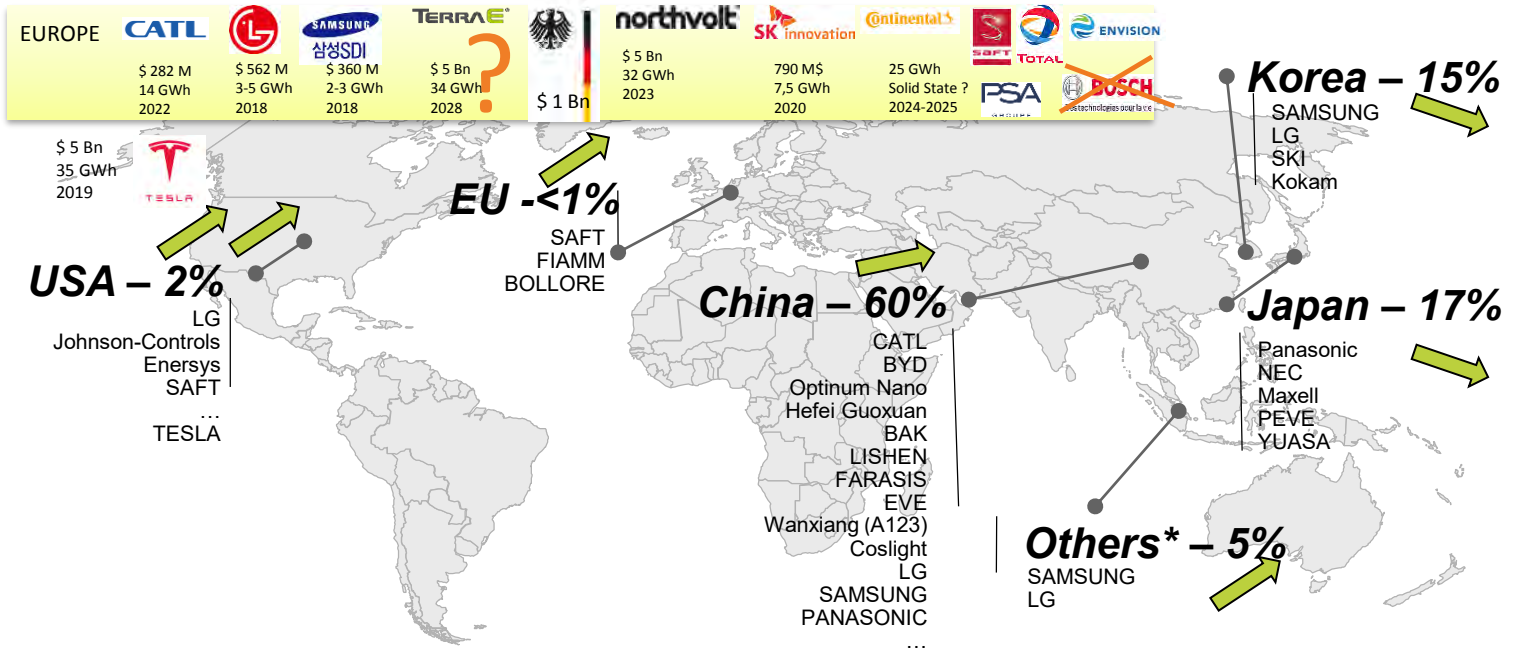


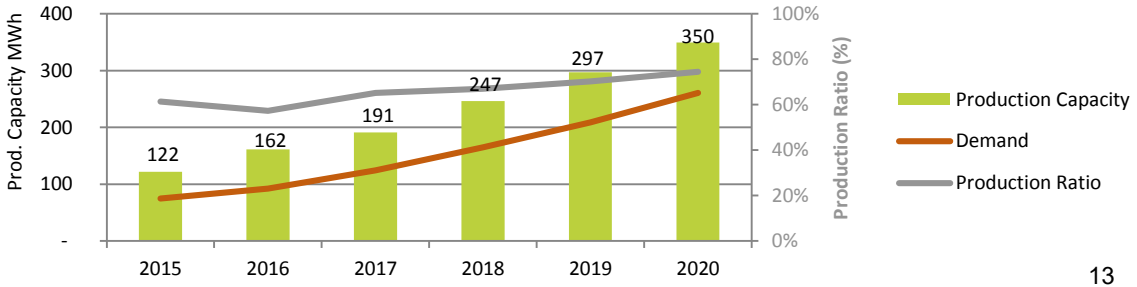


Source: AVICENNE ENERGY Analysis, 2019

LITHIUM ION CELL PRODUCTION

European market demand
150 GWh in 2025





Source: AVICENNE 2019

** OTHERS: Malaysia mostly*

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BATTERY MARKET FORECASTS 2018-2030

Applications covered

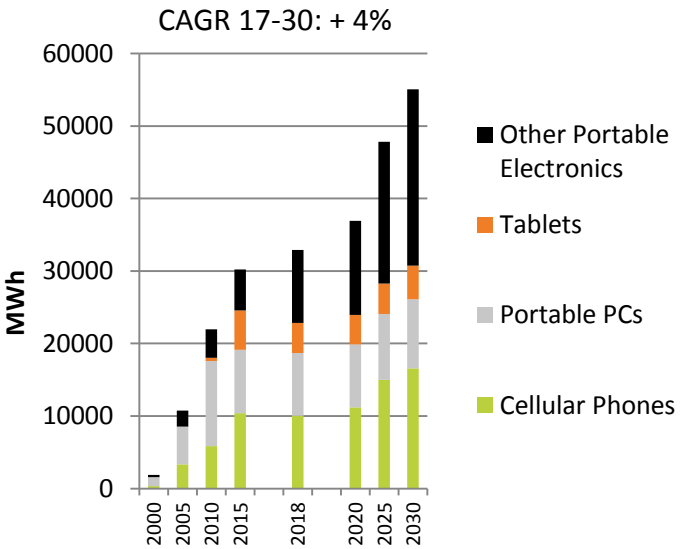
- Portable PCs, net-book, Ultra-book
- Cellular Phones, Smart-phones
- Tablets
- Power Bank
- Camcorders
- Cordless Tools, Gardening tools
- Digital Camera
- Games, MP3
- Cordless Phones
- Shavers, Toothbrush,
- RC Cars, Toys
- Drones
- Hoverboard
- E-bikes
- Power tools
- Security lighting
- Vehicles: HEV, P-HEV, EV, E-buses
- 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,
- 2018 -2030 Forecasts
- OEM strategies and positions
- Main drivers & limiters

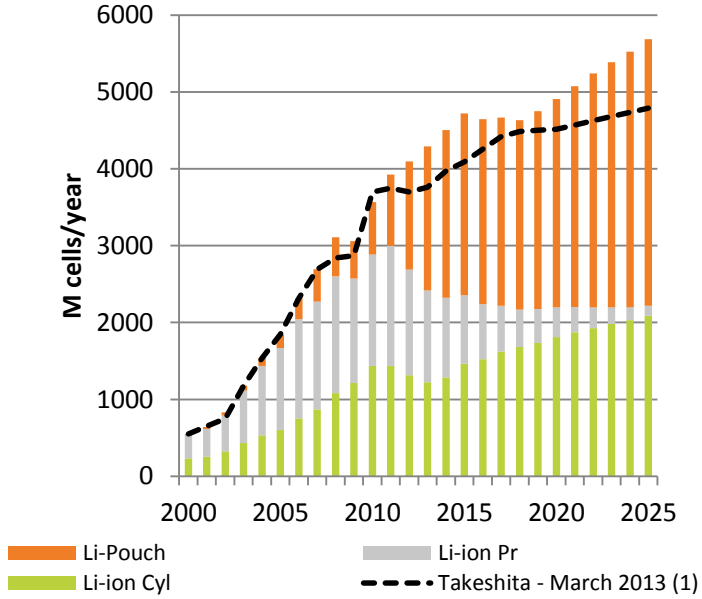
2030 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

2000-2030 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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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 27 years ago.
- LTO was invented by Matsushita in 1993 (25 years ago)
- Lithium iron phosphate was invented in 1995 (23 years ago).
- So, it takes between 10 & 20 years to commercialize a new material in the battery industry.

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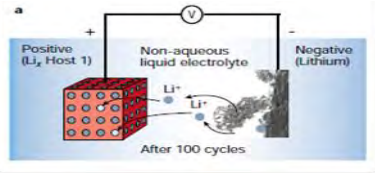
SAFETY ISSUES

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 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

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

Source: AVICENNE ENERGY

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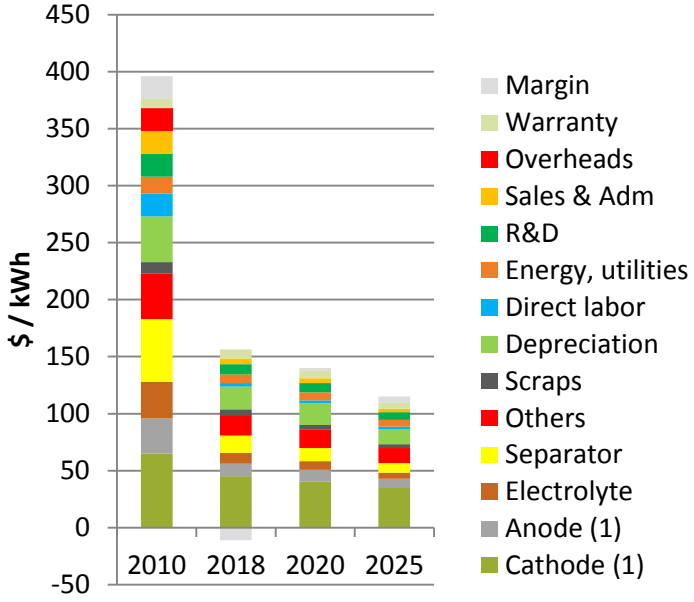
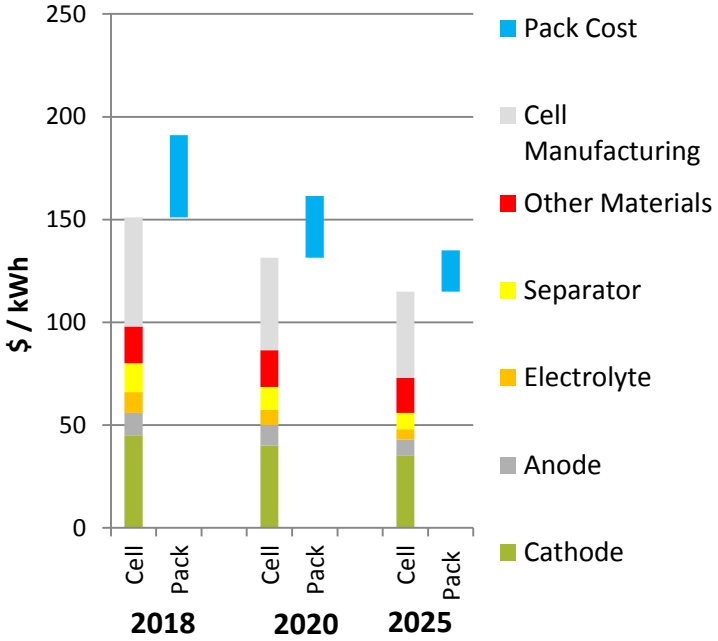
LI-ION BATTERY COST 2018-2025

LIB cell average **cost** (40 Ah pouch) (EV design ; NMC622 cathode)



(1) Active materials only
Source: AVICENNE ENERGY 2019

LI-ION BATTERY PACK **COST** FOR EV



** For Production > 100 000 packs/year*

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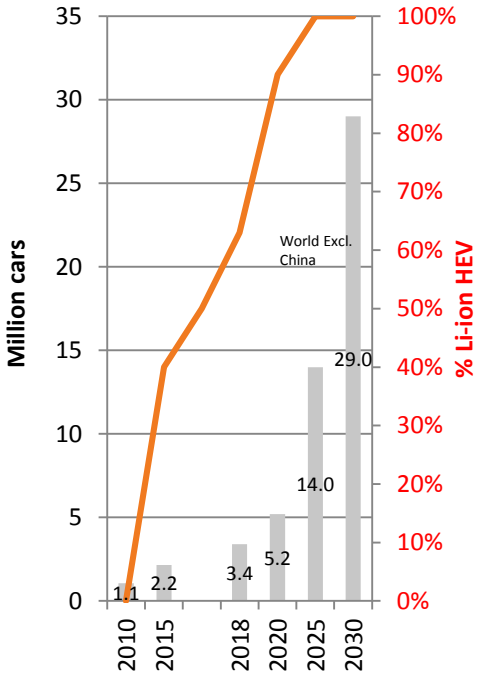
HEV, P-HEV, EV 2030 FORECASTS

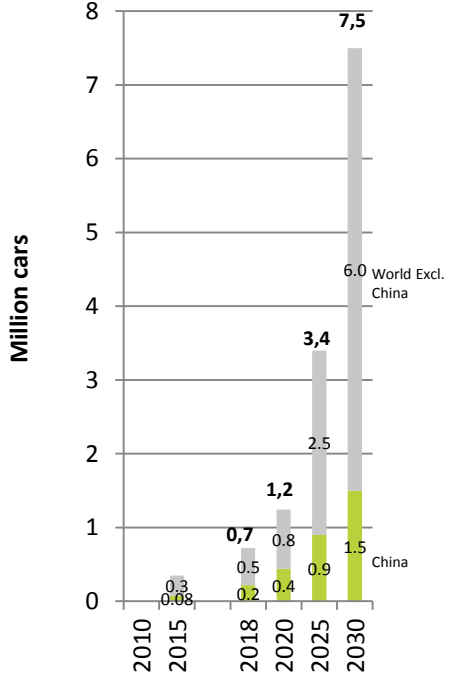
Realistic Scenario

HEV manufactured



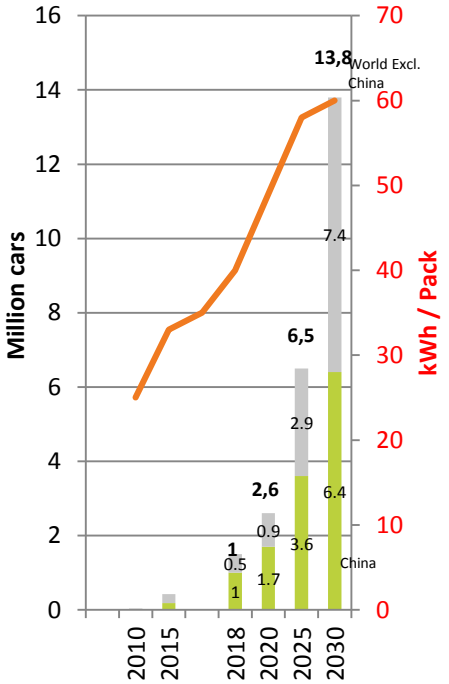
HEV: 1kWh battery / car

PHEV manufactured



PHEV: 12 kWh battery / car

EV manufactured



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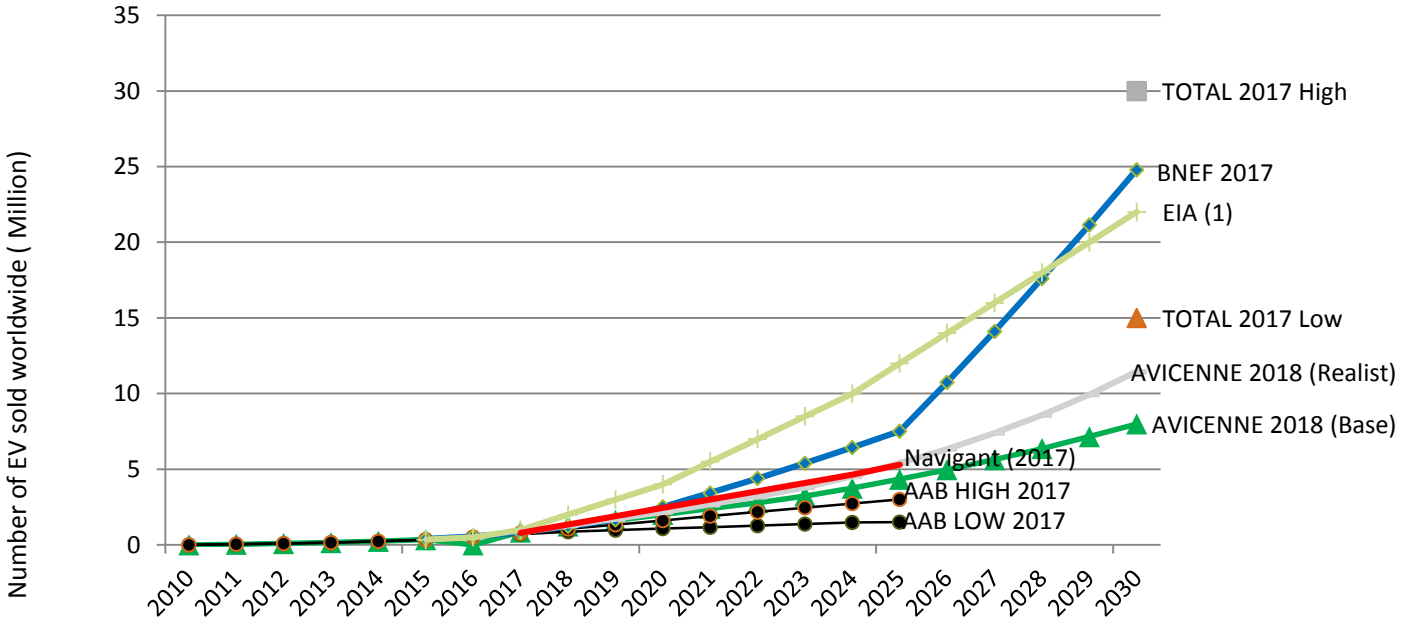
LONG TERM EV FORECAST

EV sold, in million units, worldwide, 2010 – 2030



AAB, AABC US, June 2017
BNEF, BATTERIES 2017, October 2017
AVICENNE Analysis 2018

(1) EIA – Avicenne estimation based on "Stock" numbers

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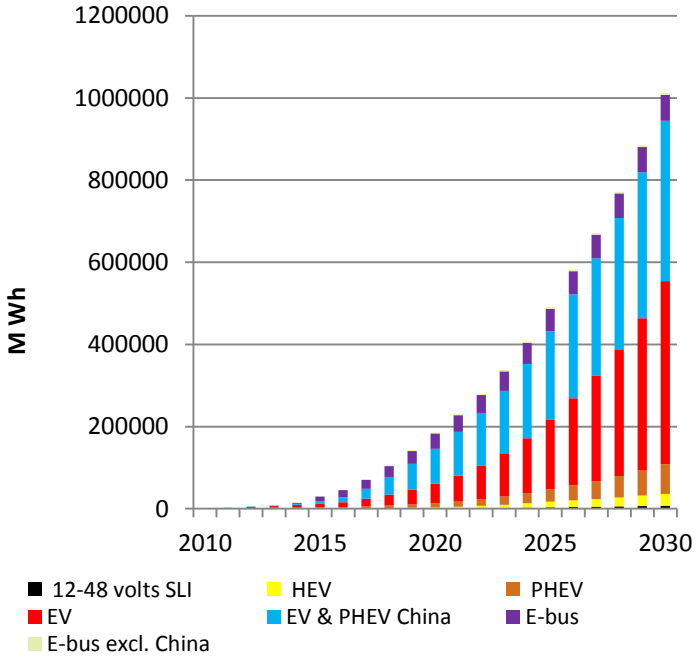
TOTAL BATTERY DEMAND FOR XEV 2030 FORECASTS

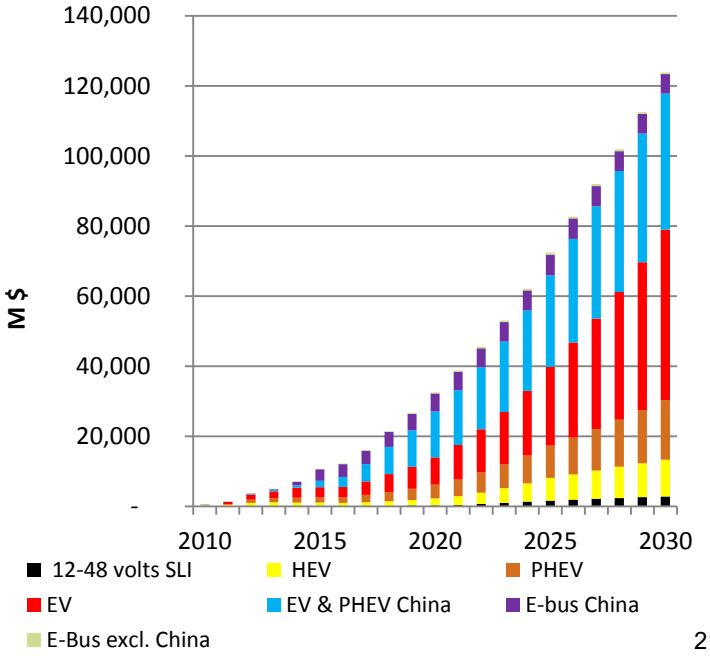
Li-ion for EV, HEV & P-HEV Battery needs (MWh)

CAGR 2015-2030: +26%



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

CAGR 2015-2030: +18%



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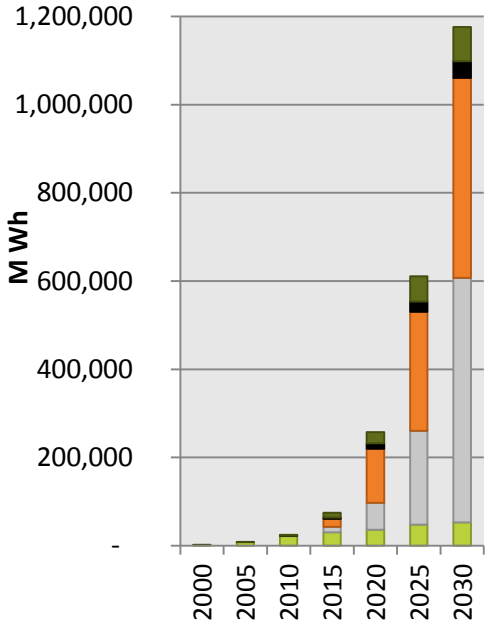
LI-ION BATTERY MARKET FORECASTS

From 160 GWh in 2018 to >1,2 TWh

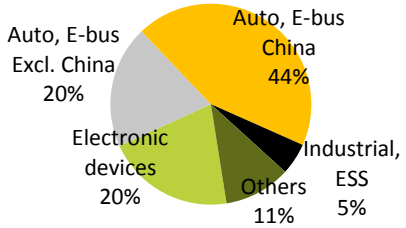
CAGR 2015/2030 +20 % per year in Volume

Li-ion Battery sales, MWh, Worldwide, 2000-2030

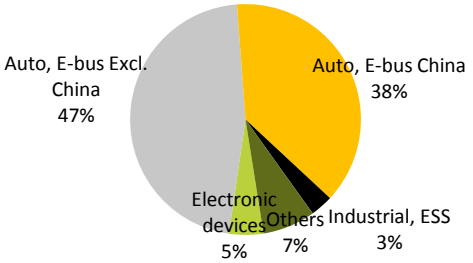


	CAGR 15/30 (Optimistic)
Others	14%
Industrial, ESS	18%
Auto, E-bus China	24%
Auto, e-bus Excl. China	29%
Electronic devices	4%

2018: >160 GWh



2030: 1200 GWh



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

Source: AVICENNE Energy 2019

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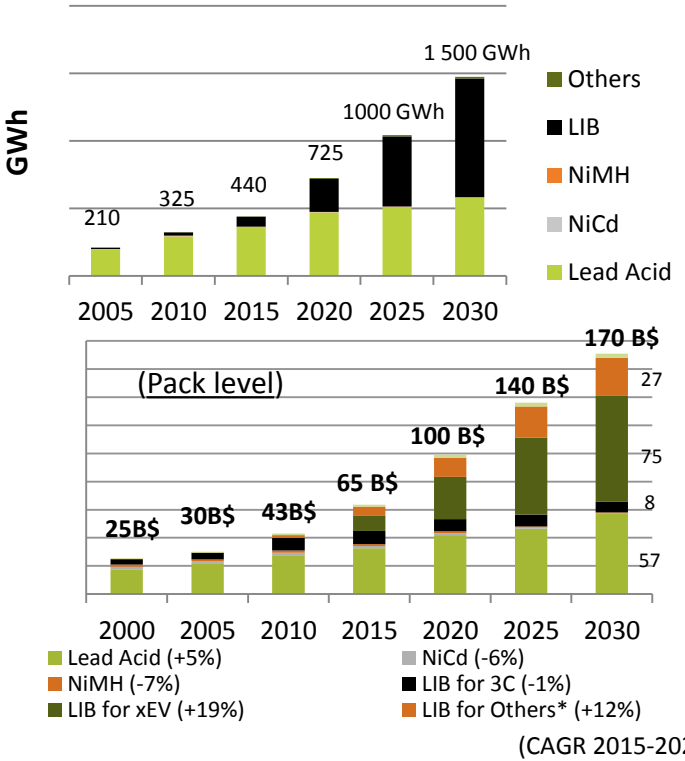
TAKEAWAYS

Battery Market 2015-2030 - CAGR = +7% / Li-ion>+10%

- Li-ion battery is driven today by Automotive: 1% of the automotive market consume 60% of the LIB
- 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 - 36 B$ in 2020 & 75 B$ in 2030 with high numbers in China (2017: US$5 Billion for xEV and US$ 4 Billion for xE-Buses)
- EV expectations attract large Chemical companies
- New materials are needed to meet Automotive standards
- HEV will account for 4% of the auto sales in 2020
- P-HEV & EV for 2-3% 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 (US$ 40 Bn) will be higher than Lead acid in value in 2018 (US$ 38 Bn)
- 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 (base scenario)



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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