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THE BATTERY SHOW NORTH AMERICA 2017

Novi, Michigan, USA

September 2017

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The Rechargeable Battery Market and Main Trends 2016 – 2025

Mike Sanders
AVICENNE ENERGY

Presentation Outline

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

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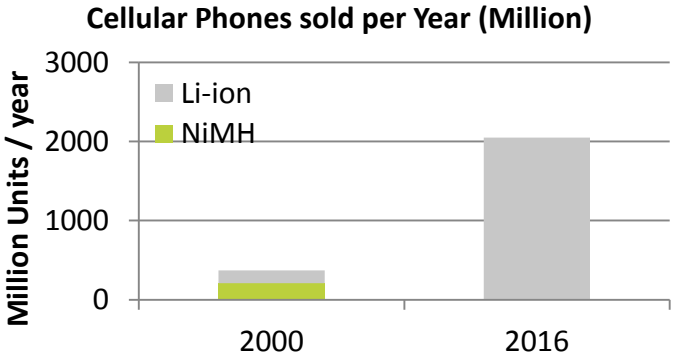
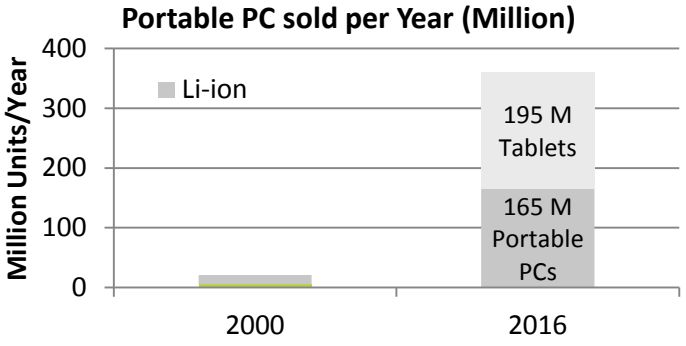
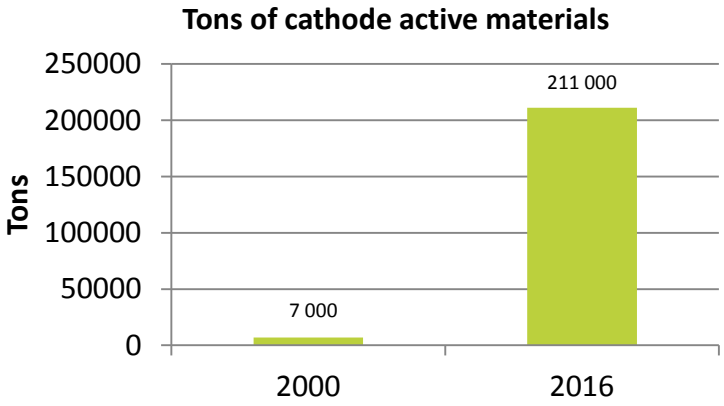
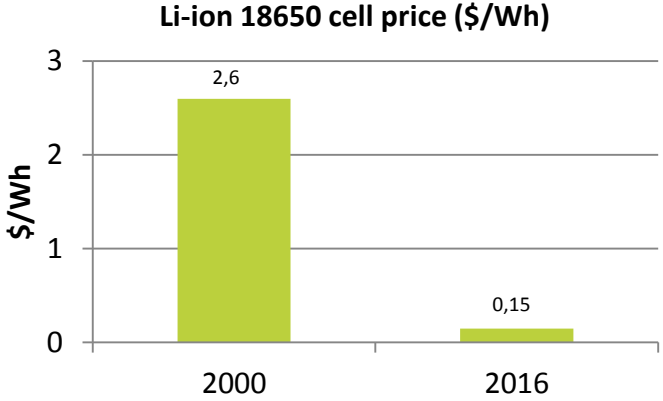
THE BATTERY MARKET IS REALLY DYNAMIC









Source: AVICENNE ENERGY, 2017

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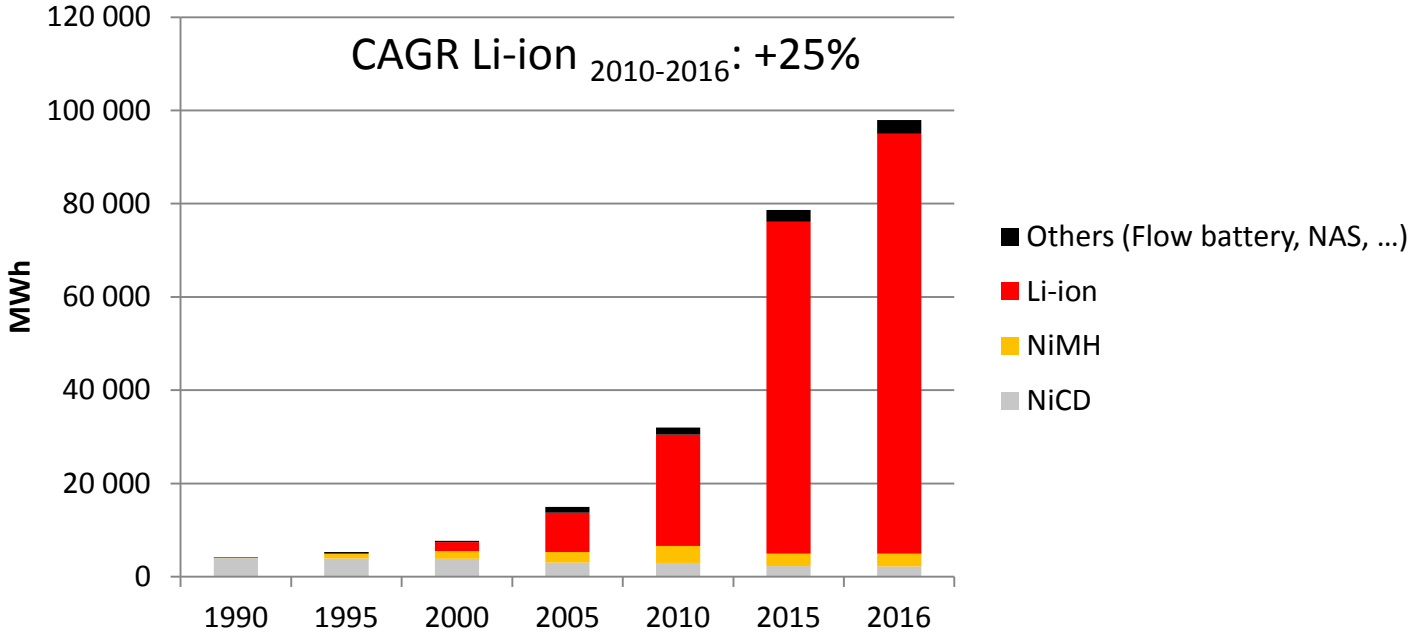
THE WORLDWIDE BATTERY MARKET 1990-2016

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



Source: AVICENNE ENERGY, 2017

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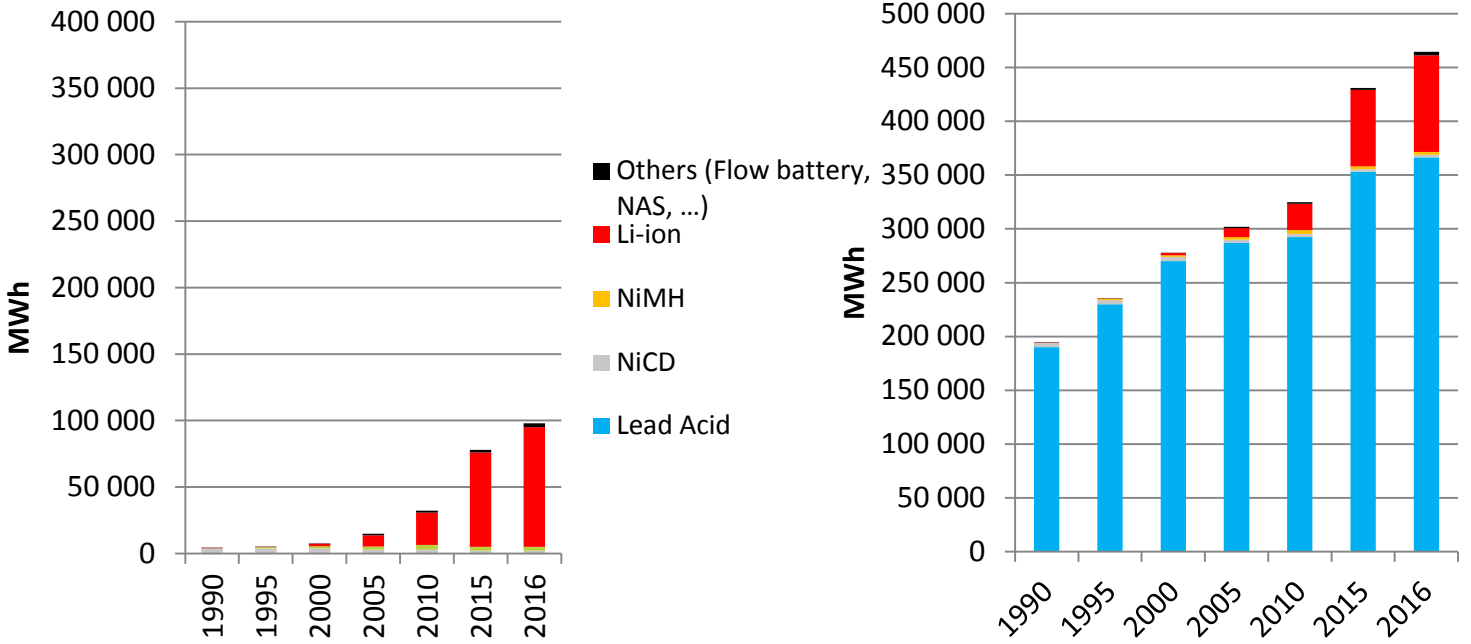
THE WORLDWIDE BATTERY MARKET 1990-2016

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



Source: AVICENNE ENERGY, 2017

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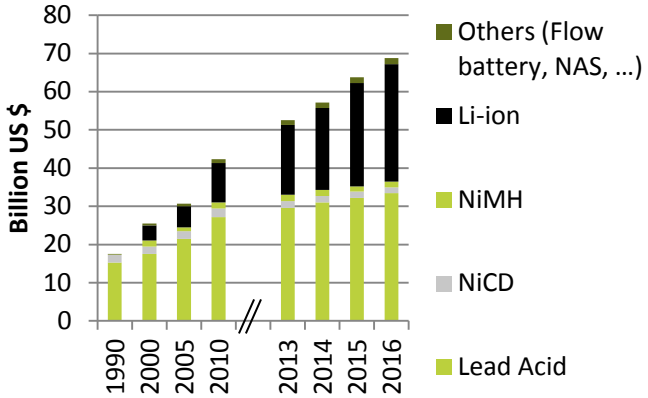
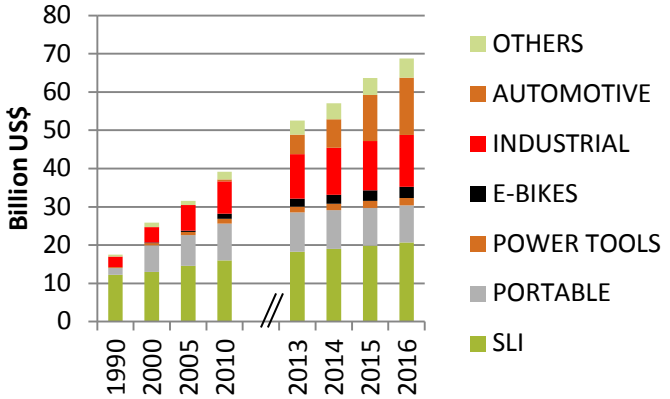
THE WORLDWIDE BATTERY MARKET 1990-2016

69 BILLION US$ in 2016 – Pack level[1]
8% AVERAGE GROWTH PER YEAR (2006-2016)





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, 2017

INDUSTRIAL
- MOTIVE: Forklift (95%), others
- STATIONARY: Telecom, UPS, Energy Storage System, Medical, Others (Emergency Lighting, Security, Railroad Signaling,, Diesel Generator Starting, Control & Switchgear,

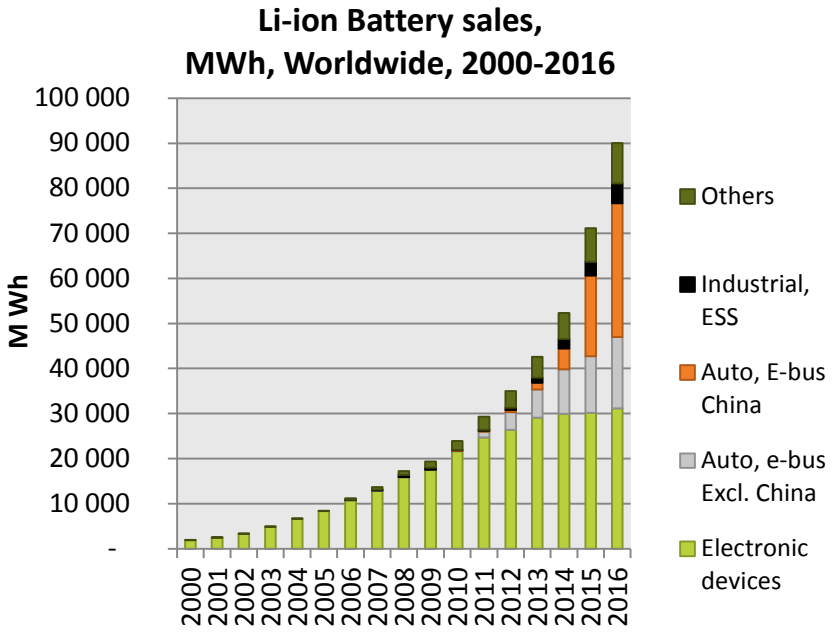
AUTOMOTIVE: HEV, P-HEV, EV

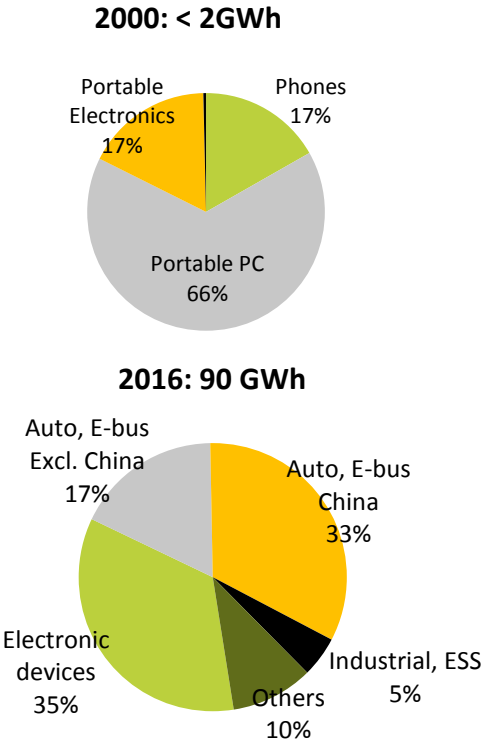
OTHERS: Medical: wheelchairs, medical carts, medical devices (surgical power tools, mobile instrumentation (x-ray, ultrasound, EKG/ECG, large oxygen concentrators

LI-ION IN 2016 - MAIN APPLICATIONS

90 000 MWh - 23 B$ (1)
5 675 M small cells

CAGR 2006/2016
+23 % per year in Volume





(1) Cell level
Others: medical devices, power tools, gardening tools, e-bikes…
Source: AVICENNE Energy 2017

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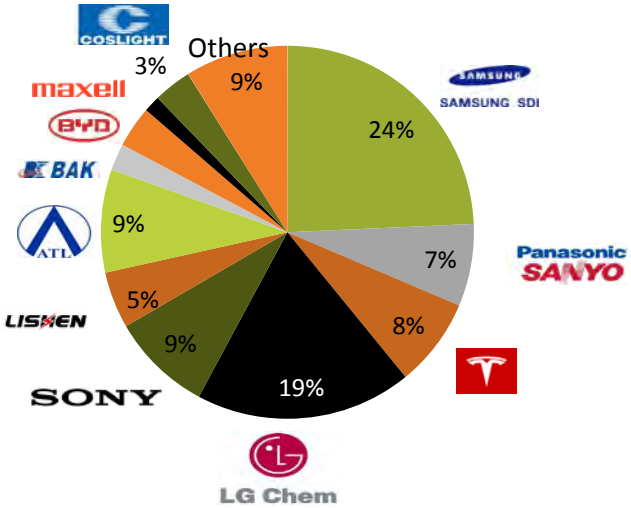
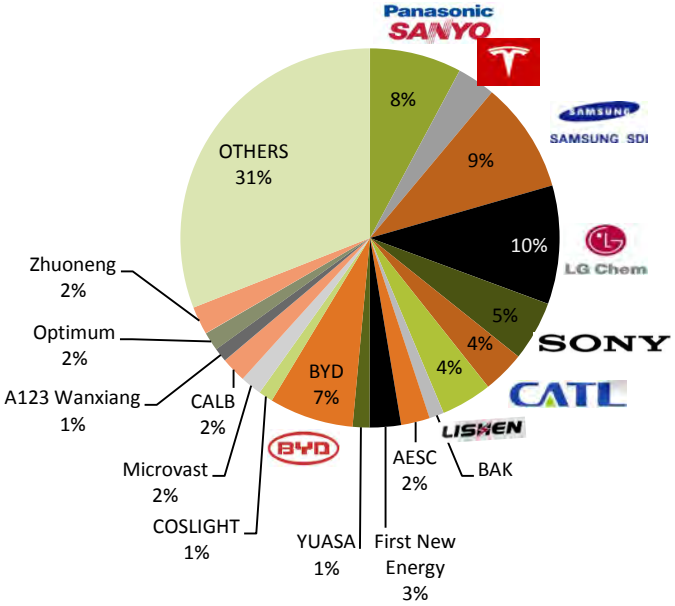
LI-ION BATTERY: MARKET SHARE IN 2016 WORLDWIDE

The worldwide Li-ion battery market Company market share in 2016 in volume (small cells only) 6,4 B cells



Others for Small cells: Chinese suppliers like Tenpower, DLG…

The worldwide Li-ion battery market Company market share in 2016 in value(1) Estimated at B$ 31 in 2016



(1) LIB battery pack market

Source: AVICENNE ENERGY Analyses 2017

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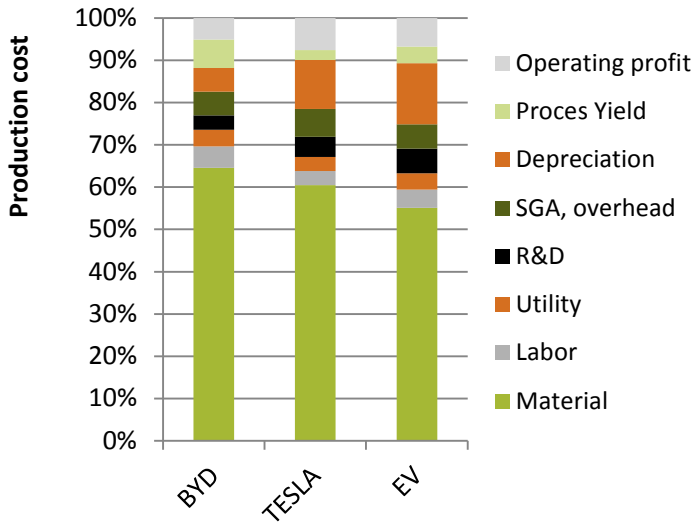
LIB: THE BIGGEST PART OF THE COST IS RAW MATERIALS

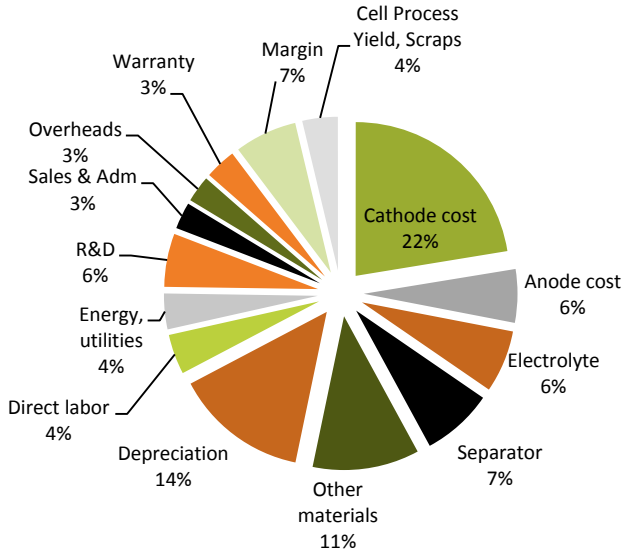
RAW MATERIALS ACCOUNT FOR 50 TO 70% OF LIB CELLS BUSINESS

RAW MATERIAL COST IMPACT DRASTICALY ON THE BATTERY MAKERS PROFIT

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



Average cost structure of Li-ion cell in 2016



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

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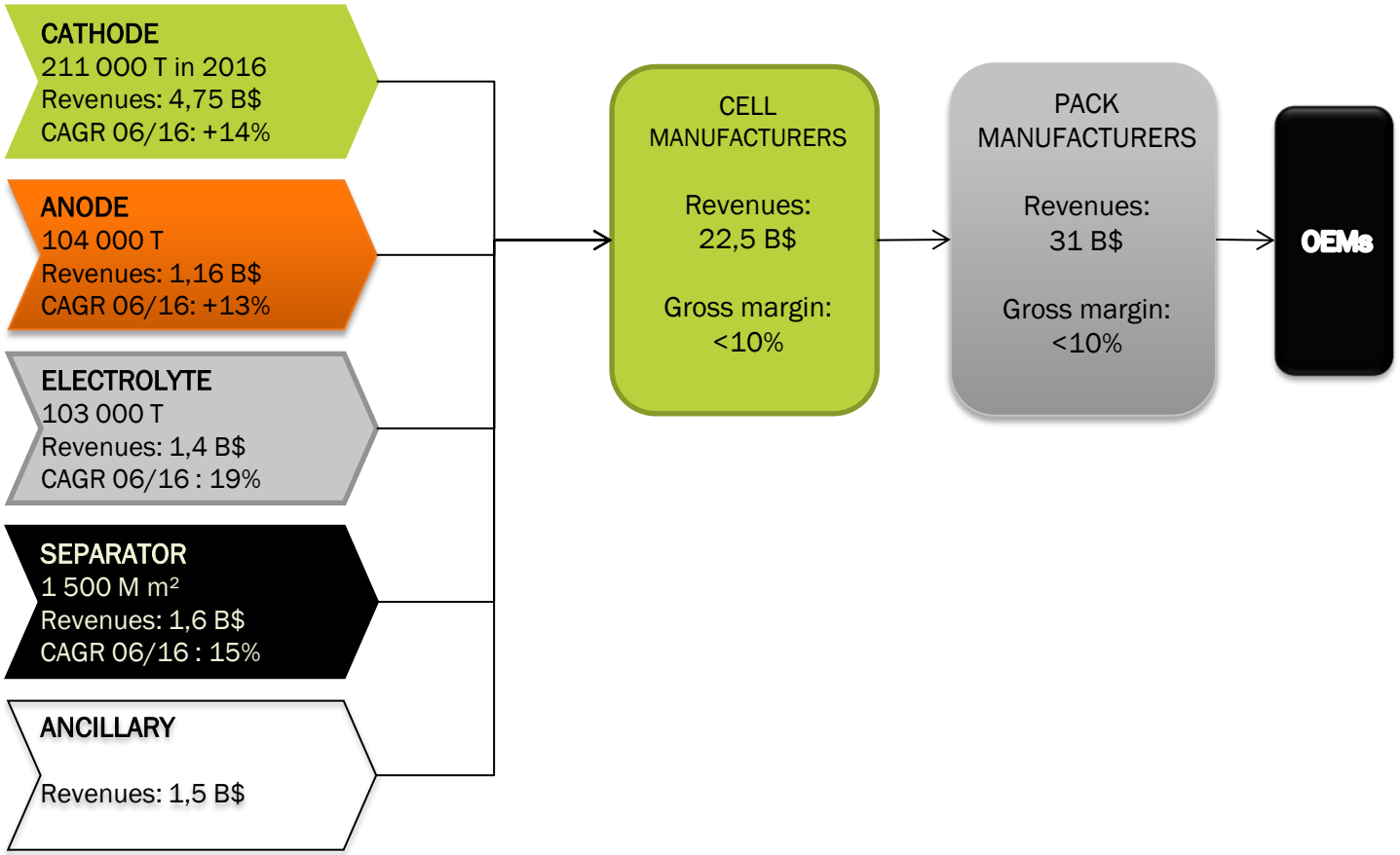
LI-ION VALUE CHAIN – MARKET DEMAND



Sources: AVICENNE ENERGY 2016

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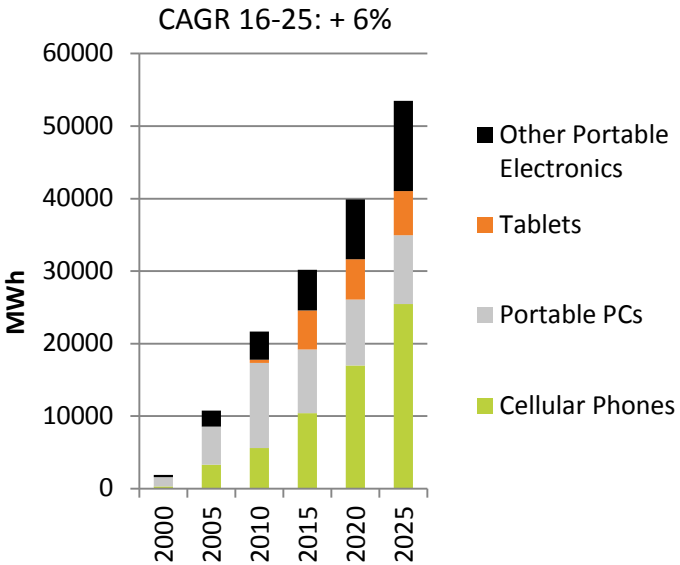
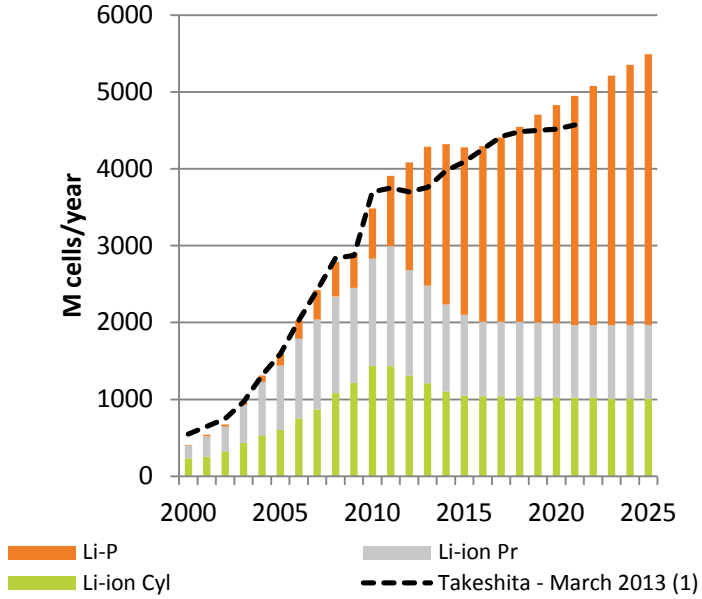
2025 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

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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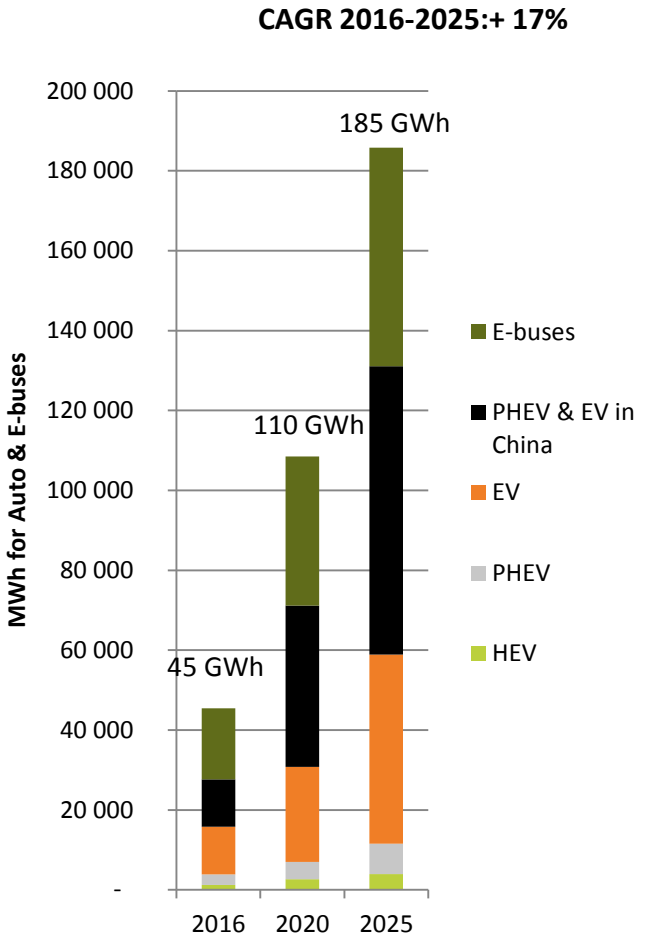
X-EV MARKET

- Why x-EV ?
- Definition & segmentation
- X-EV worldwide in 2016
  - 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



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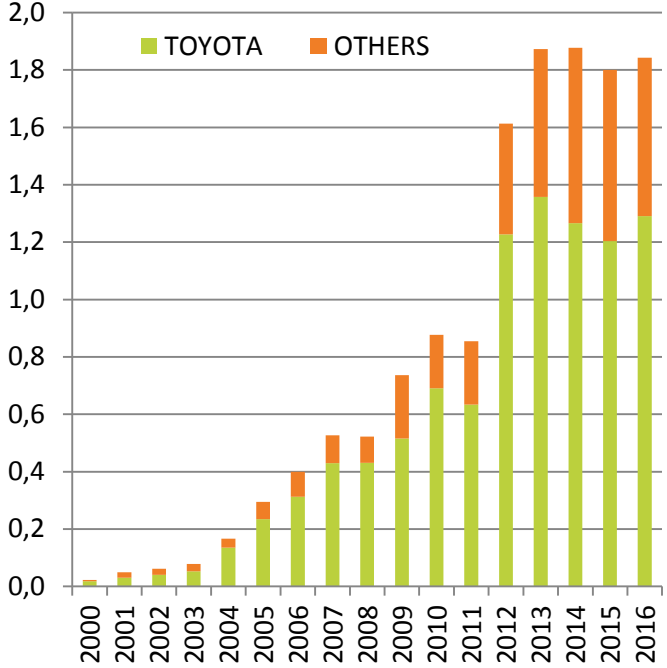
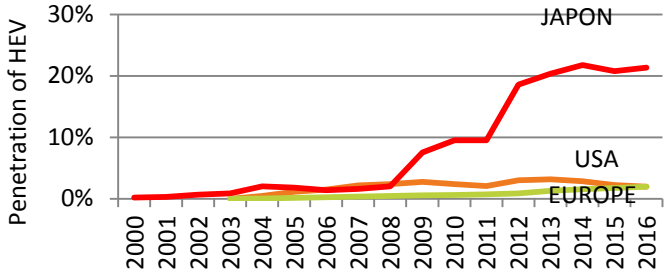
HEV WORLDWIDE IN 2016
1,8 M HEV

Growth 2015-2016: +2%
From 1,8 M to 1,84 M HEV

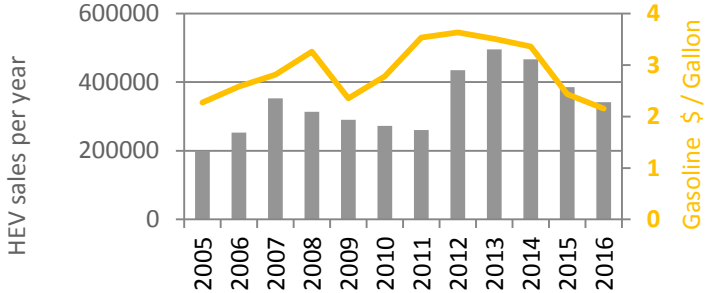
HEV sold per year, M units, worldwide, 2000 - 2016



Penetration of hybrids in the global sales, 2000-2016



Gazoline price impact on HEV market in the US



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

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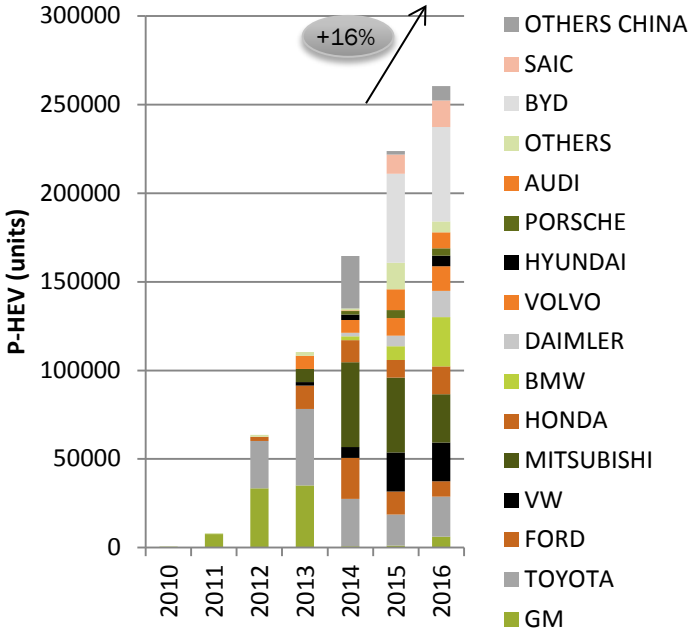
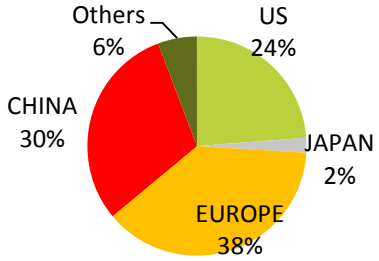
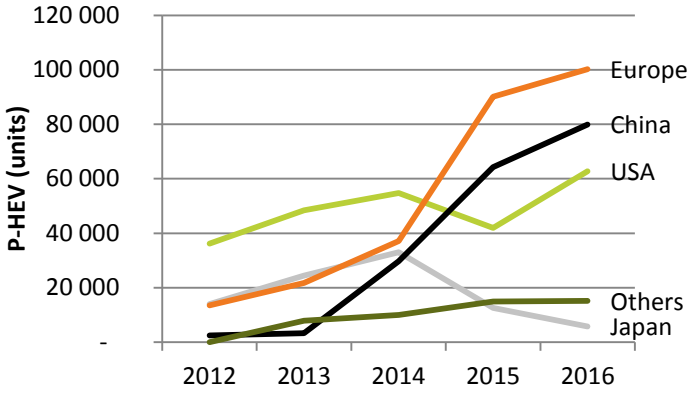
PHEV SOLD WORLDWIDE

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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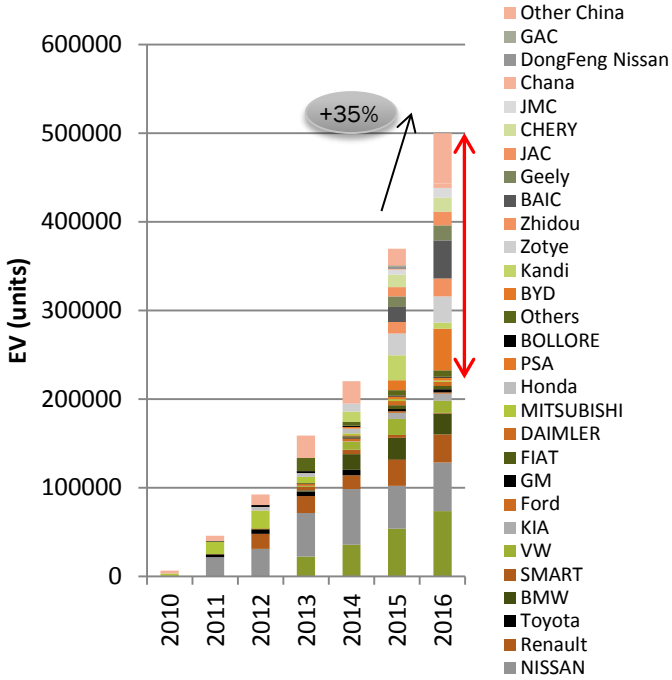
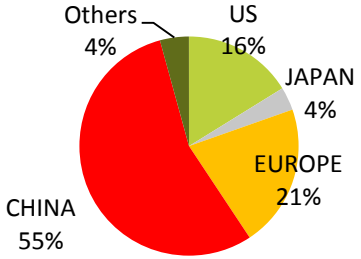
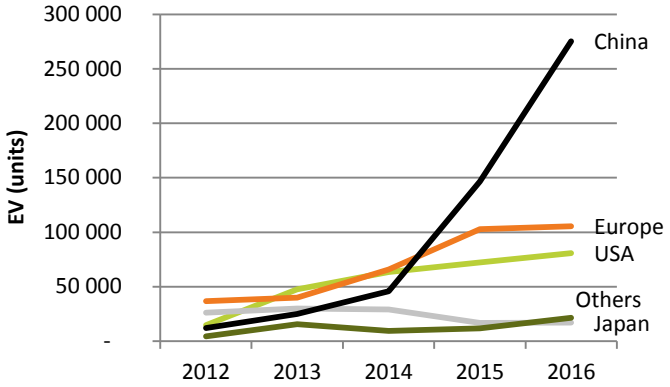
EV SOLD WORLDWIDE

World excl. China growth +14%
Chinese Growth + 68%



China is leading the EV market thanks to high incentives





Source: AVICENNE ENERGY Analysis, 2017

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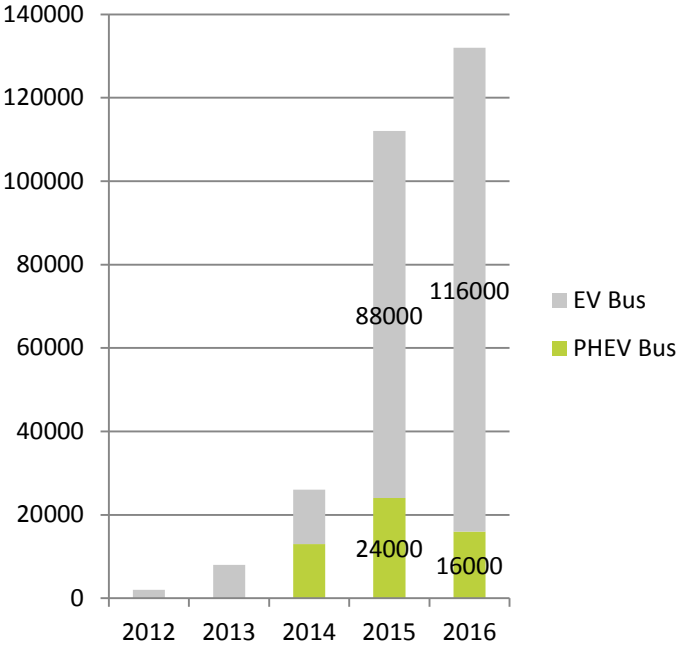
XEV BUSES MARKET IN CHINA

xEV buses market in China: 132 000 xEV Buses sold in 2016



Rationales

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

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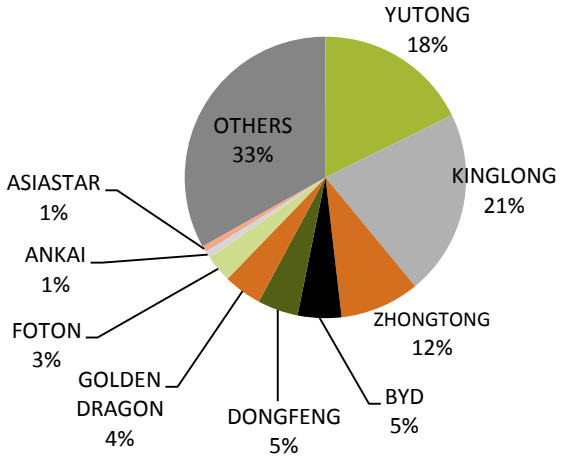
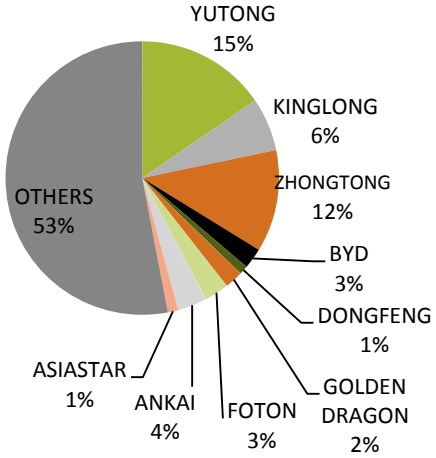
XEV BUSES MARKET IN CHINA

xEV buses market in China: 112 000 xEV Buses sold in 2015



132 000 xEV Buses sold in 2016



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

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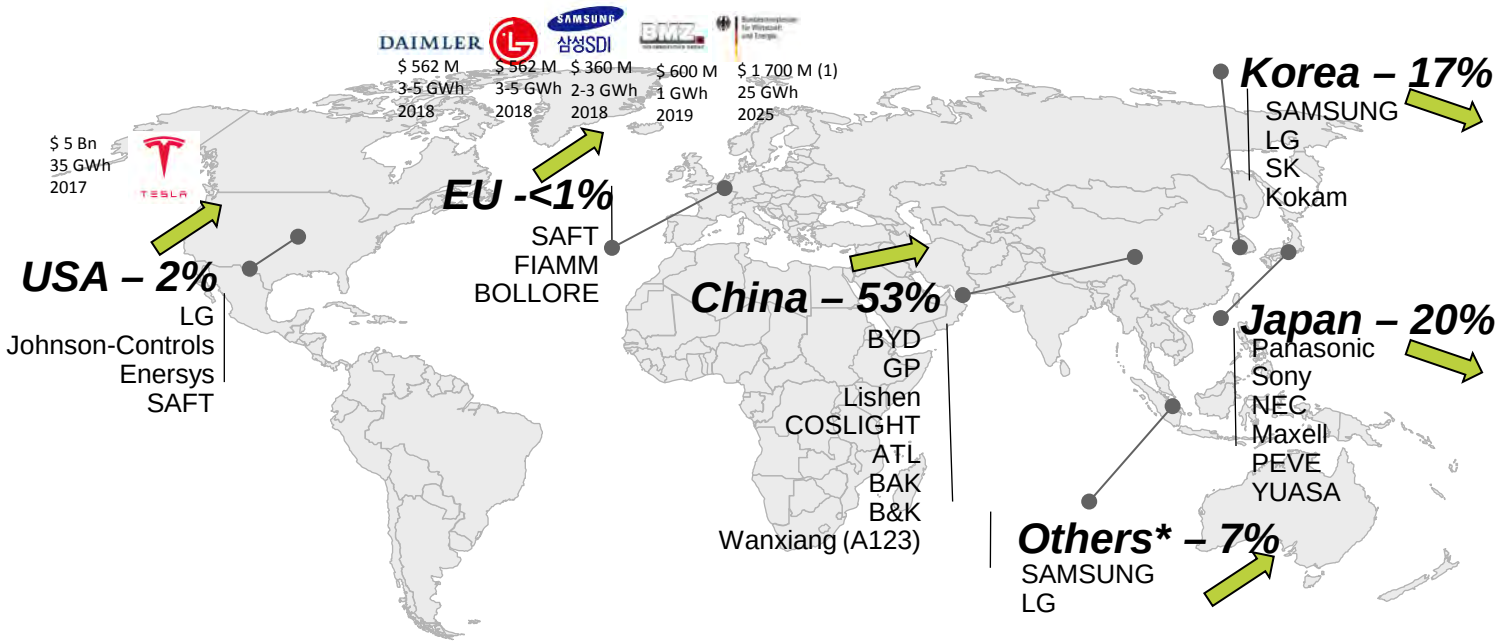
LITHIUM ION CELL PRODUCTION

Korean companies start to move in Malaysia

New production capacity in Europe and US



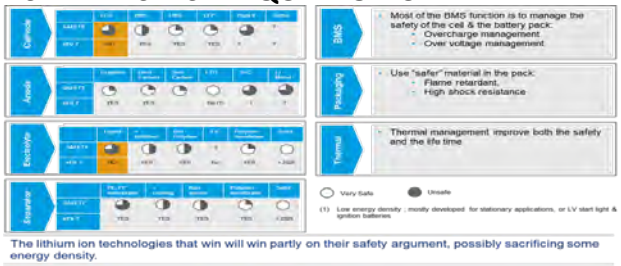
Source: AVICENNE 2017

** OTHERS: Malaysia mostly*
(1) Government subsidies only

THE LITHIUM ION BATTERY MARKET FORECASTS

3 major limiters on batteries, for the development of electric vehicle

1- SAFETY IS A SINE-QUA-NON CRITERIA

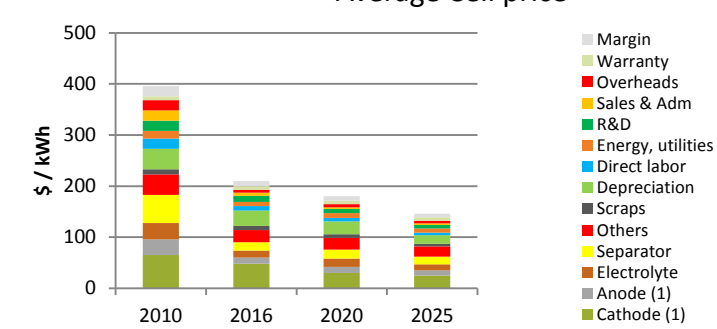


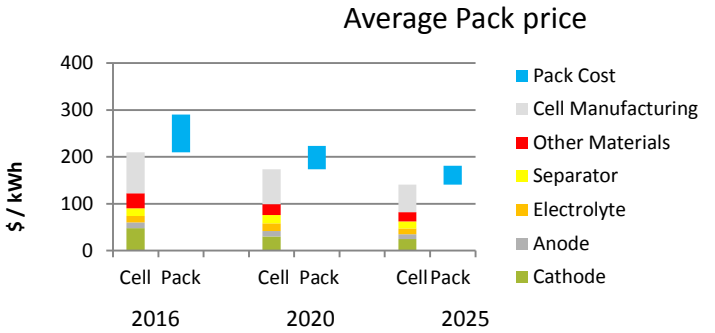
The lithium ion technologies that win will win partly on their safety argument, possibly sacrificing some energy density.

2- TIME TO MARKET

- 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.

3- BATTERY COST





(1) Active material only

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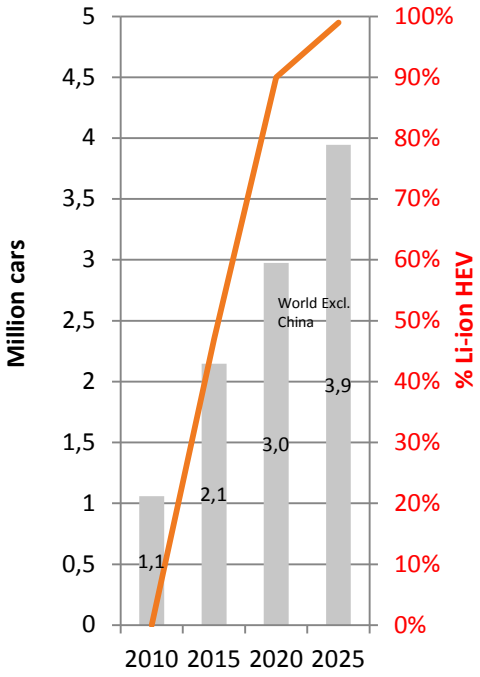
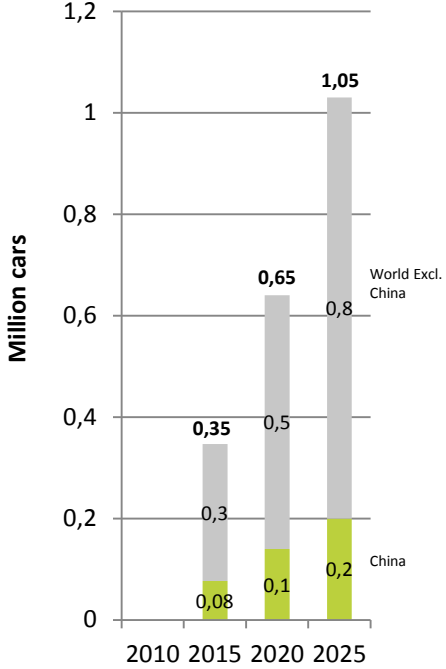
HEV, P-HEV, EV 2025 FORECASTS

HEV manufactured



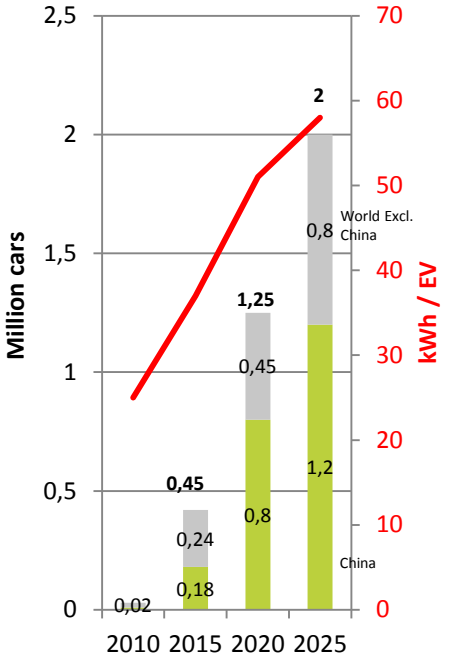
HEV: 1kWh battery / car

PHEV manufactured



PHEV: 12 kWh battery / car

EV manufactured



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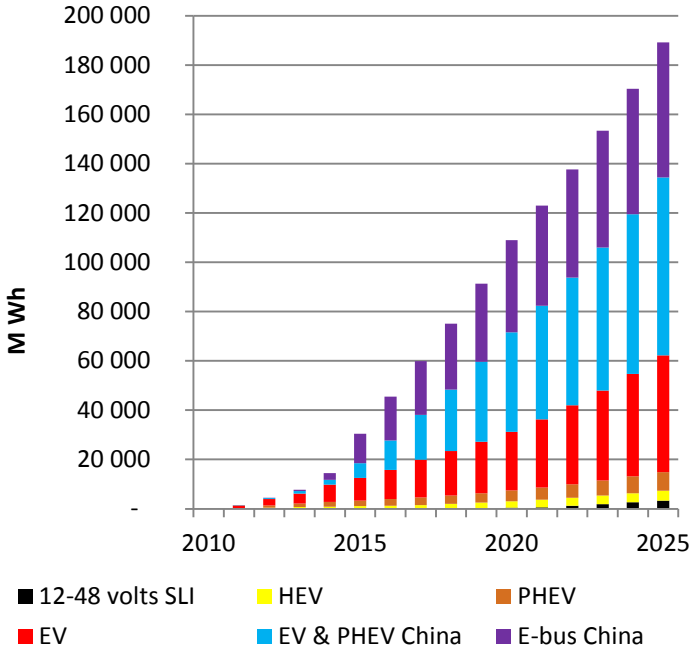
TOTAL BATTERY DEMAND 2025 FORECASTS

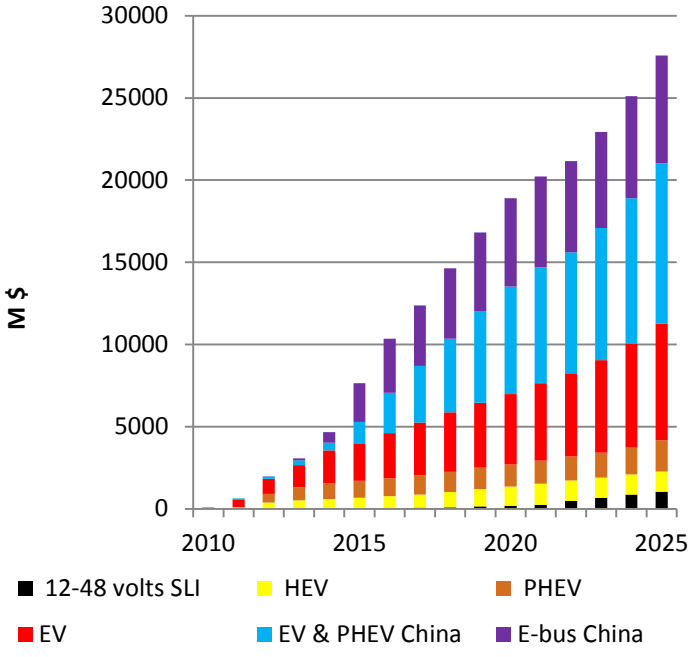
Li-ion for EV, HEV & P-HEV Battery needs (MWh)

CAGR 2016-2025: +17%



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

CAGR 2016-2025: +12%



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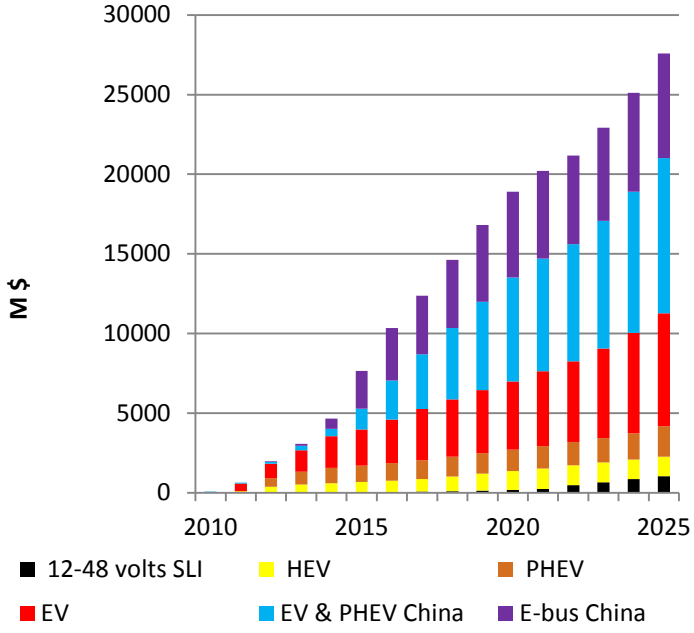
X-EV BATTERY MARKET 2000 – 2025 IN M$

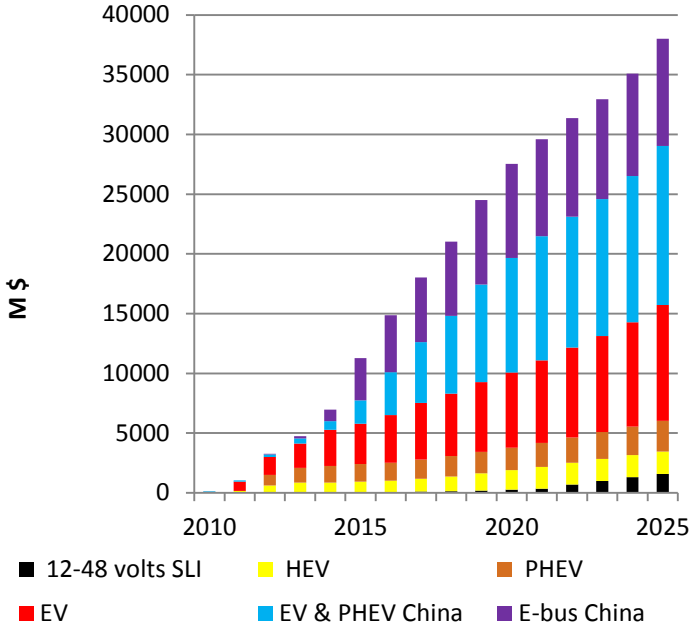
Cell Level

CAGR 2016-2025: +12%



Pack Level

CAGR 2015-2025: +11%



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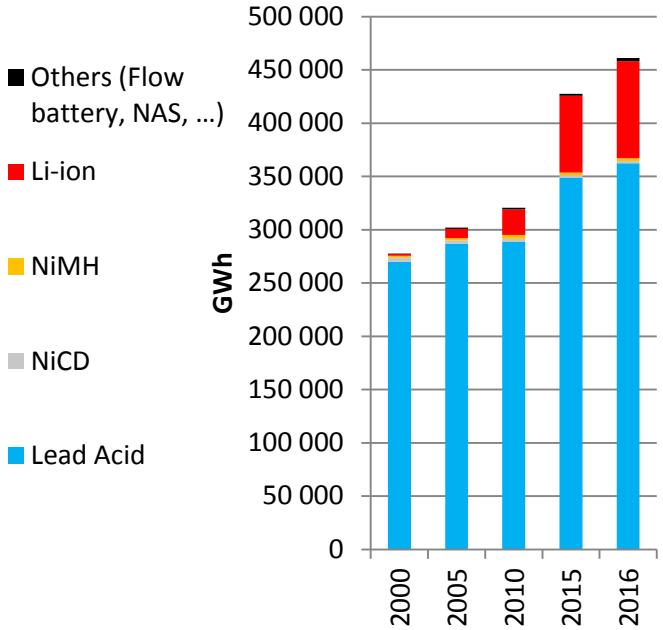
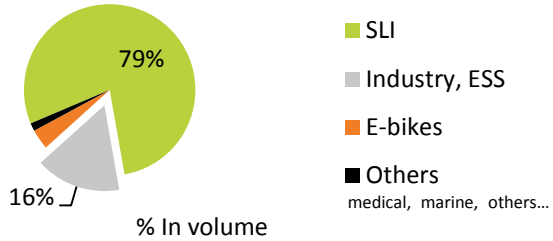
THE WORLDWIDE BATTERY MARKET 1990-2016

In volume (MWh)

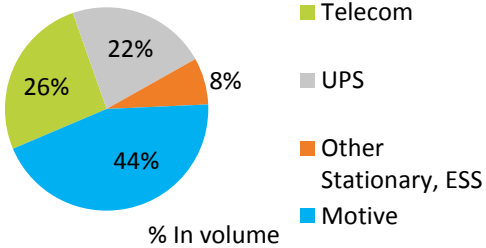


Source: AVICENNE ENERGY, 2017

Lead Acid Batteries 2016
+367 GWh for > US $ 33,4 Billion



Industrial Batteries – Lead acid batteries
58 GWh for US $ 10,4 Billion



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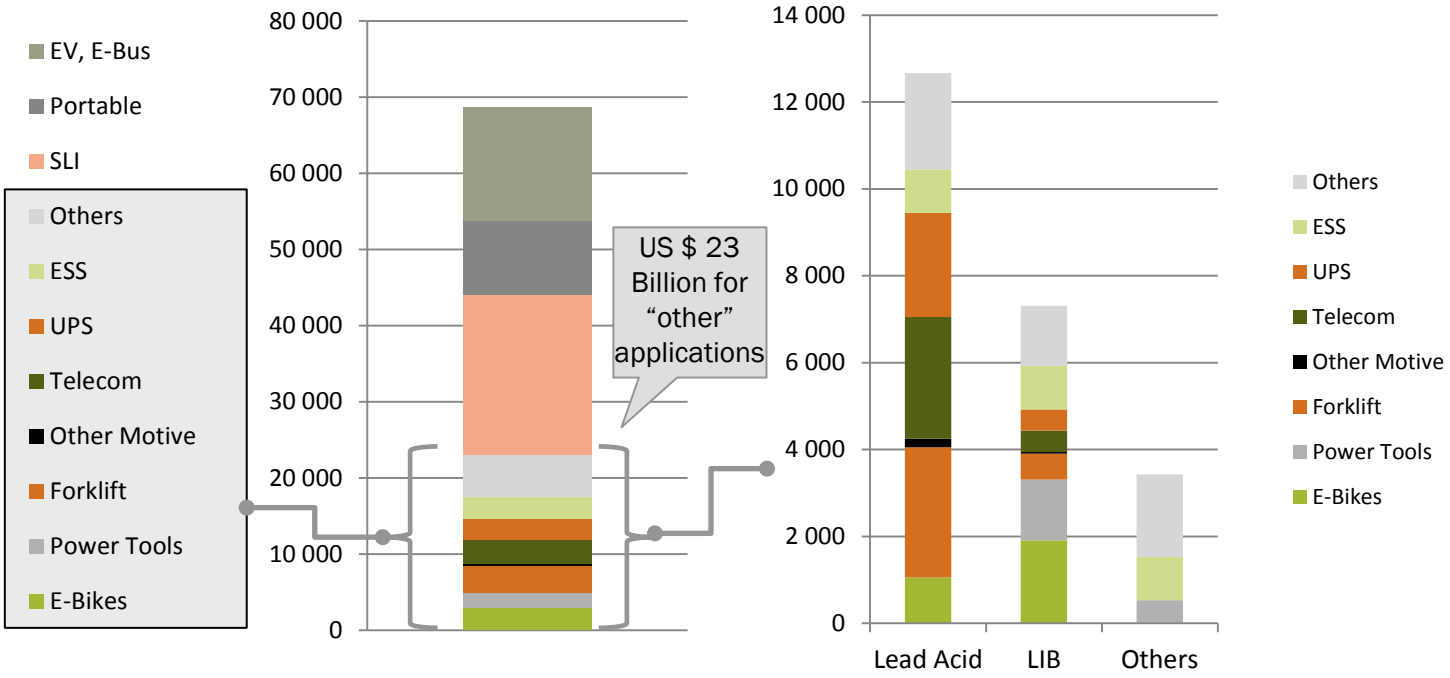
THE WORLDWIDE BATTERY MARKET IN 2016: US $ 69 BILLION



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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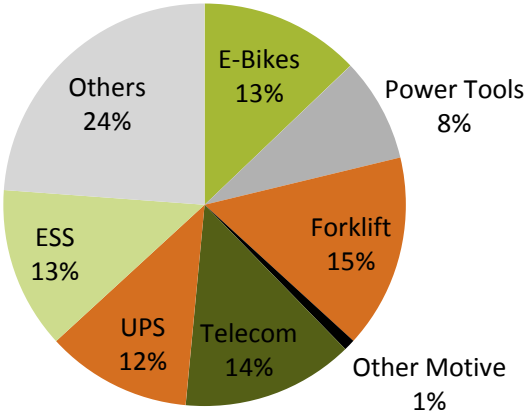
TOTAL POTENTIAL MARKET (M$, PACK LEVEL[1])

Application details

US$ 22,8 Billion in 2016 (1)



Source: AVICENNE ENERGY 2016

1 2 3 4 5 6 7 8 9 10 11

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

2- Other App: Military, aerospace, Oil & Gas, Railways, Aviation, Utility metering,…

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ESS SEGMENTATION

Services provided by Energy Storage System (ESS)

On grid services

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

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

Back-up and reserves
- Provide emergency power when utility power is not available
  - UPS (Uninterruptible power supply)
  - Power continuity
  - Reserves to face lose of one generator

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

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

Off grid services

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

Source: AVICENNE ENERGY 2016

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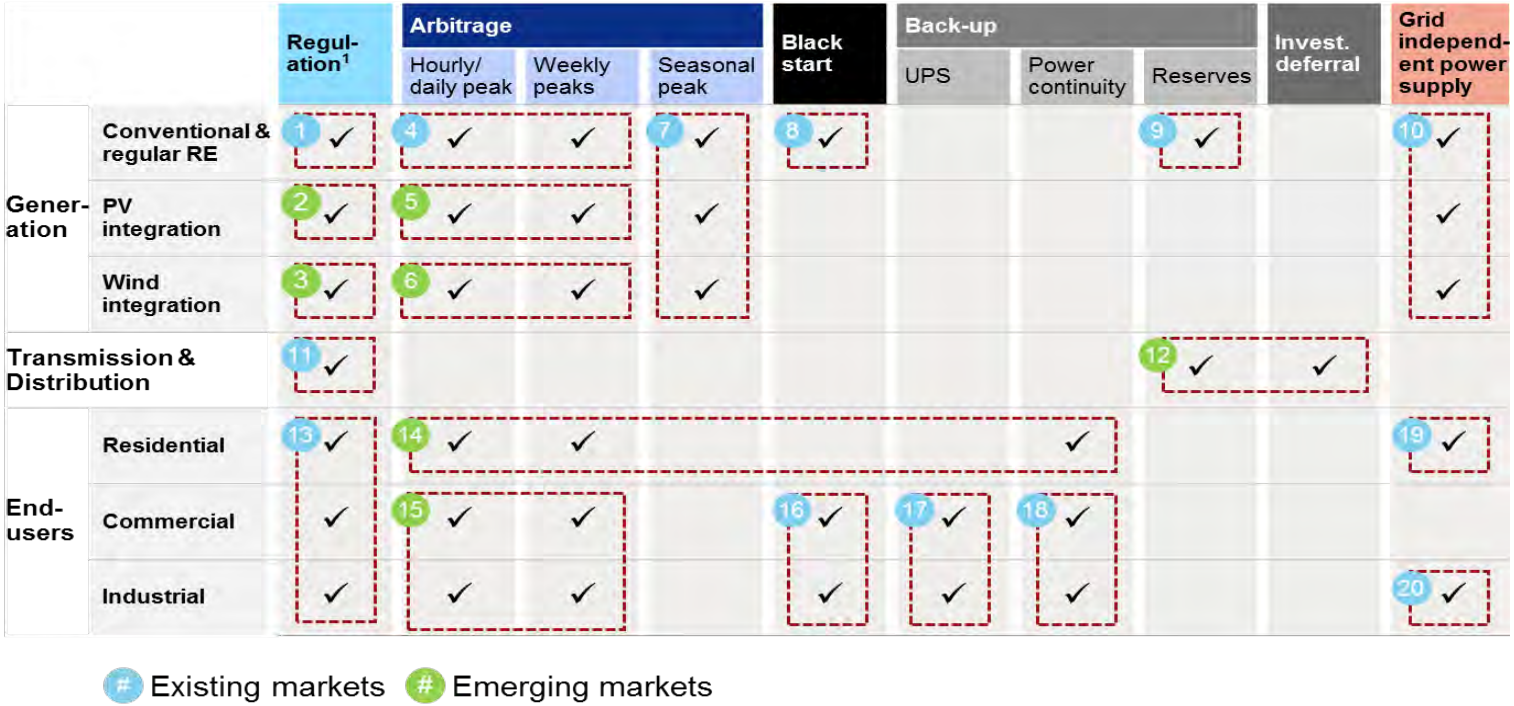
ESS SEGMENTATION

Stationary Energy Storage - Potential segmentation



Source: AVICENNE ENERGY 2016

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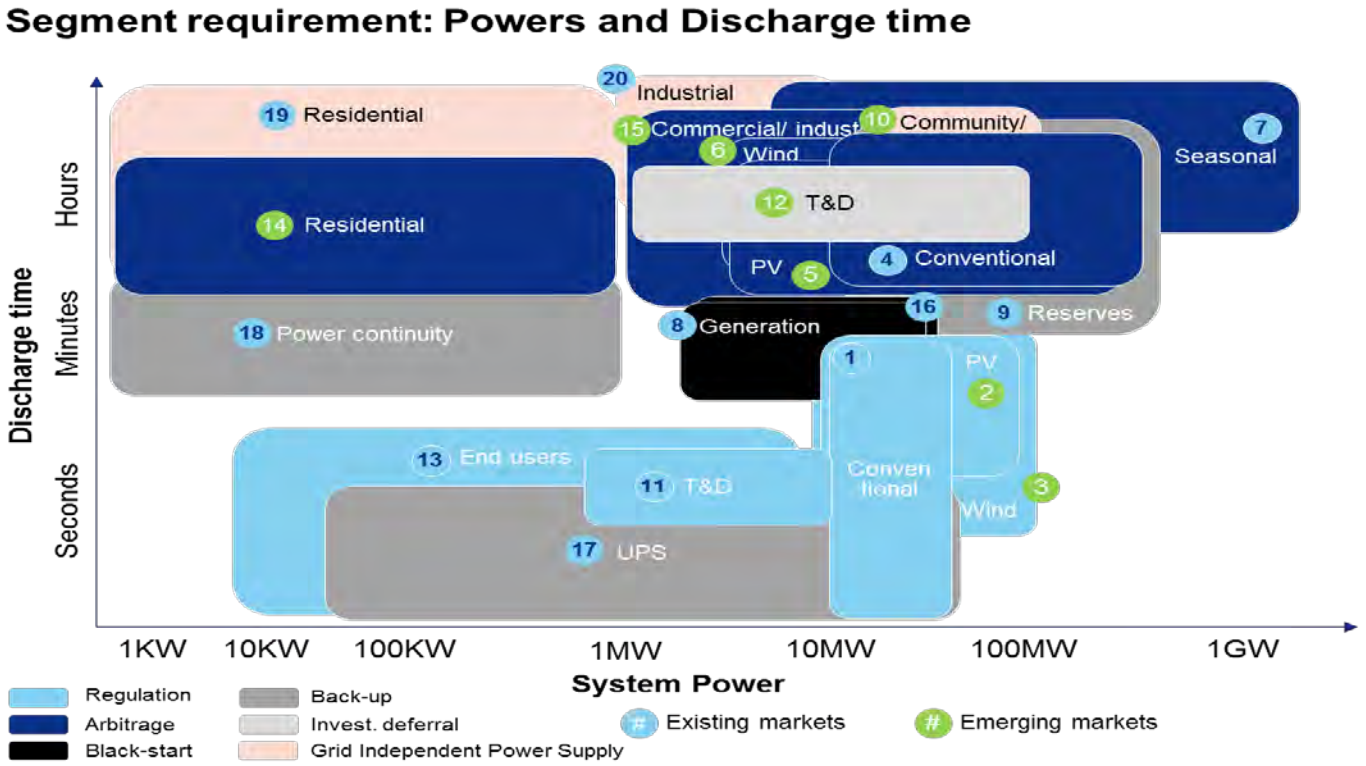
ESS REQUIREMENTS

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



Source : AVICENNE Energy, 2016

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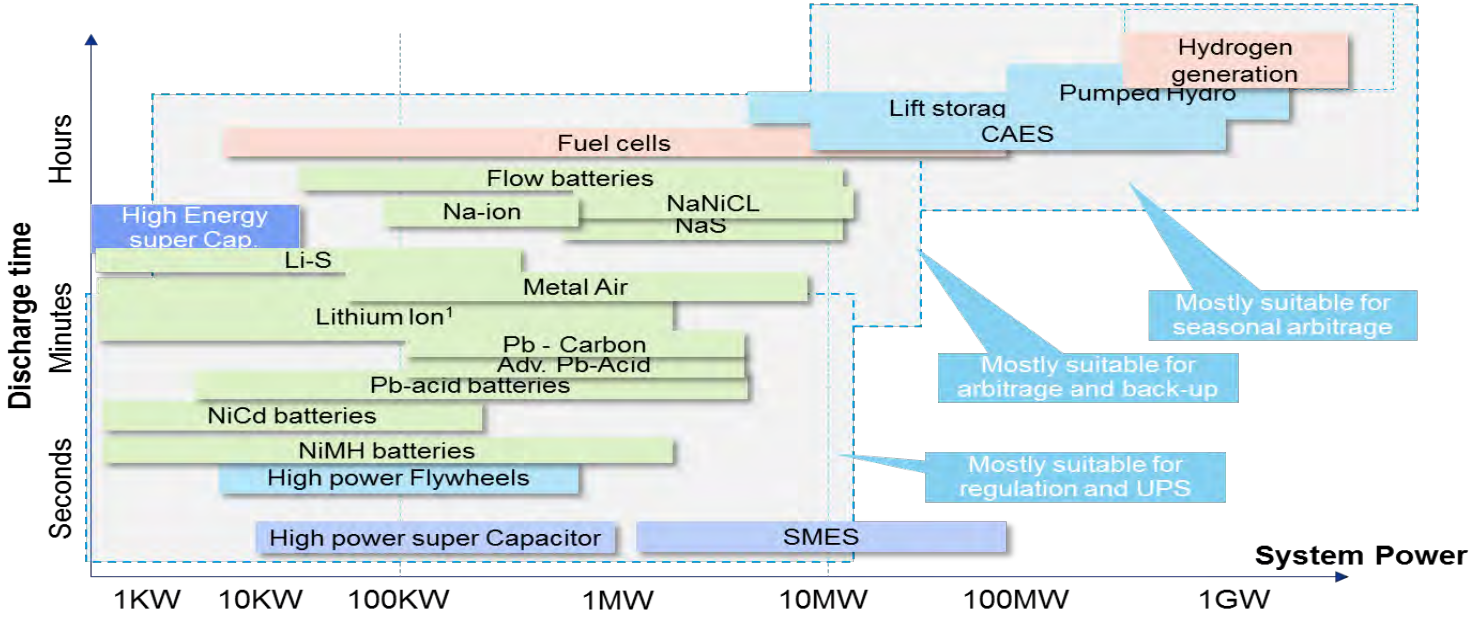
ENERGY STORAGE SOLUTIONS

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

System power and discharge time of energy storage technologies



Source: AVICENNE Energy, 2016

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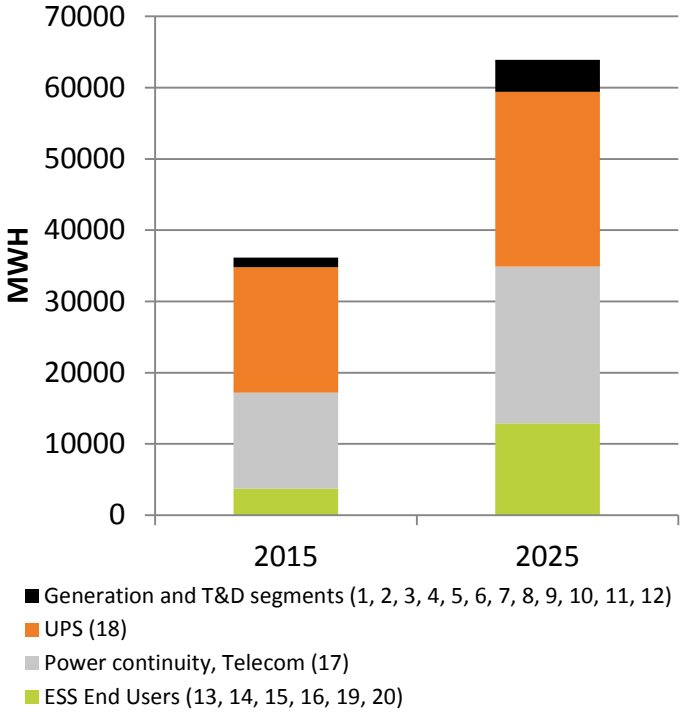
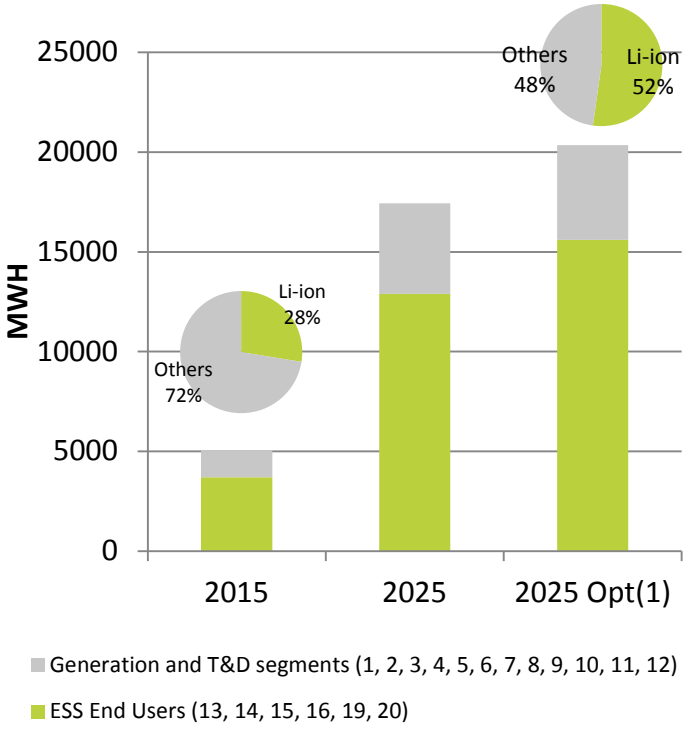
ESS MARKET & FORECASTS

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



Source: AVICENNE Energy, 2016

ESS (1) excl Telecom & UPS
CAGR: +13 to 15%



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

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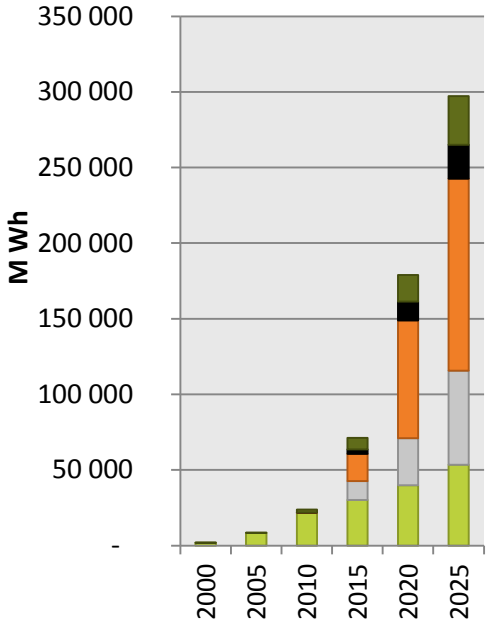
LI-ION BATTERY MARKET FORECASTS

From 90 GWh in 2016 to 300 GWh

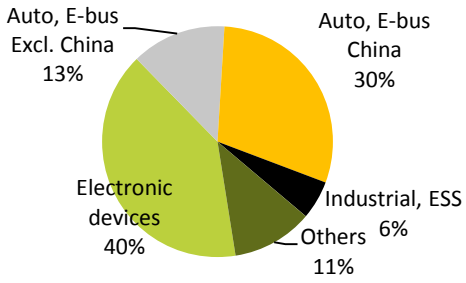
CAGR 2016/2025
+15 % per year in Volume

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

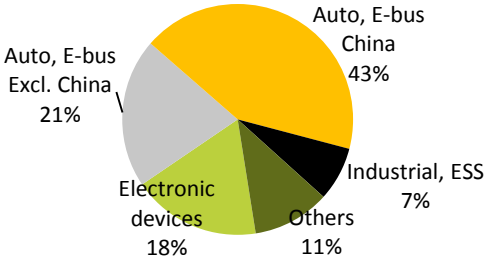


	CAGR 15/25 (Realistic)
Others	16%
Industrial, ESS	22%
Auto, E-bus China	22%
Auto, e-bus Excl. China	17%
Electronic devices	6%

2016: 90 GWh



2025: 300 GWh



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

Source: AVICENNE Energy 2016

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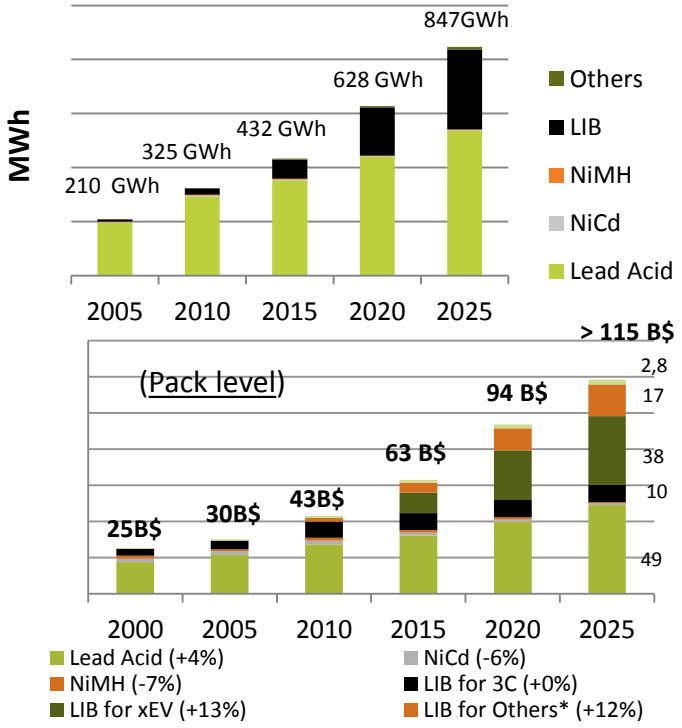
TAKEAWAYS

Battery Market 2015-2025
CAGR = +6% / Li-ion>+10%

- 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:
  15 B$ market in 2016 - 28 B$ in 2020 & 38 B$ in 2025 with high numbers in China (2016: US$ 3,6 Billion for xEV and US$ 4,8 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
- 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



(CAGR 2016-2025)

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

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THANK YOU

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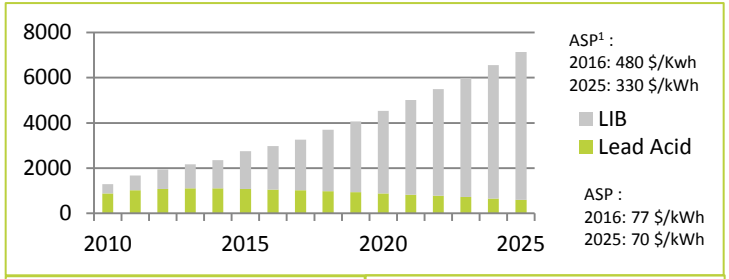
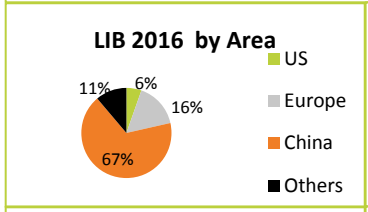
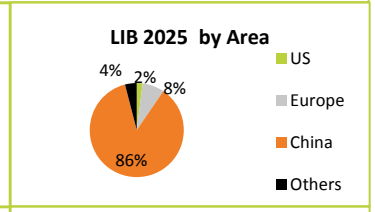
1- E-BIKES

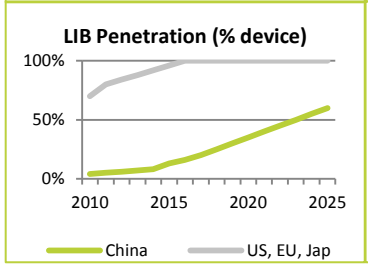
LIB: FROM US$ 1,9 BILLION IN 2016 TO 6,5 IN 2025[1] - $CAGR_{16-25}$: +15%

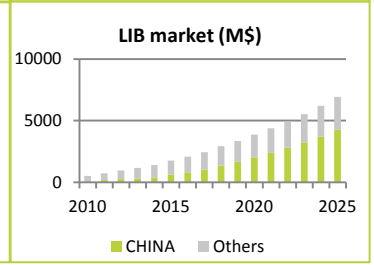
Market 2016-2025 (US $, Million) – CAGR: 10%











Main drivers

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

Main Limiters

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

Competitors

- BMZ (Germany)
- AXEON[2] (UK)
- HITECH (Taiwan)
- Phylion (China)

Customers

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

Battery needs

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

LIB needs

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

Source: AVICENNE ENERGY Analyses

Note: 1- Pack level – 2- A Johnson Matthey affiliate

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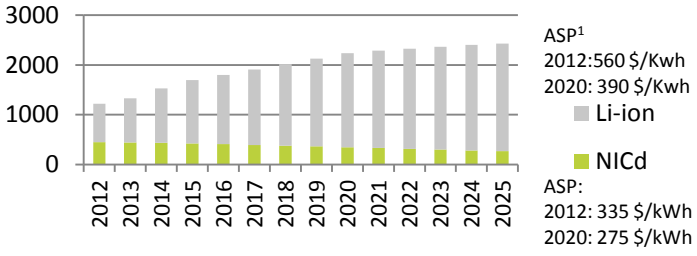
2- POWER TOOLS

LIB: FROM US$ 1,4 BILLION IN 2016 TO 2,2 B IN 2025[1] – CAGR:+6%

Market 2015-2025 (US $, Million) – CAGR:+4%



LIB Main drivers

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

LIB main Limiters

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

Battery 2013 by Area

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

LIB 2020 by Area

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

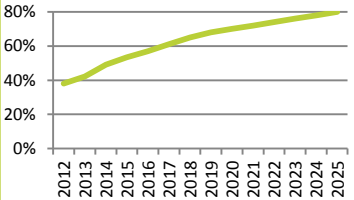
Competitors

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

Customers

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

LIB Penetration



LIB market (M$)

Battery needs

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

LIB needs

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

Source: AVICENNE ENERGY Analyses

Note: : 1- Pack level

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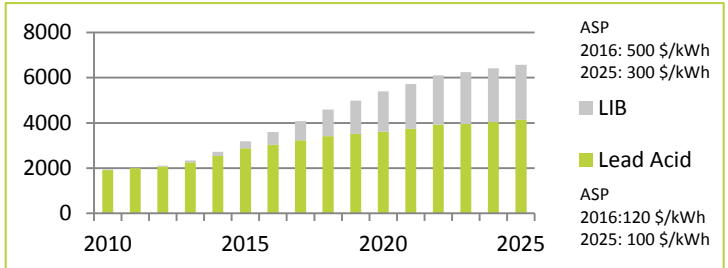
3- MOTIVE INDUSTRIAL: FORKLIFTS[2]

LIB: FROM US$ 0,56 BILLION IN 2016 TO 2,4 IN 2025[1] - $CAGR_{16-25}$: 18%

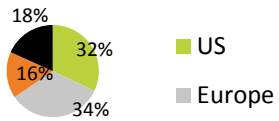
Market 2016-2020 (US $, Million) – CAGR:7%



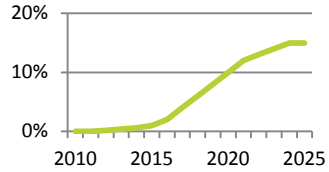
Battery 2016 by Area

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

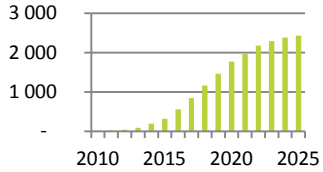
LIB 2025 by Area



LIB Penetration



LIB market (M$)



Main drivers

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

Main Limiters

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

Competitors

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

Customers

For lead acid, After market represent 60% of the market: lot of different customers (industrials)

For LIB, OEM Forklift: TOYOTA, Kion , Jungheinrich, NACCO , Crown, Mitsubishi Caterpillar

Battery needs

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

LIB needs

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

Source: AVICENNE ENERGY Analyses *Note: : 1- Pack level 2- Including all kind of Material handling equipment*

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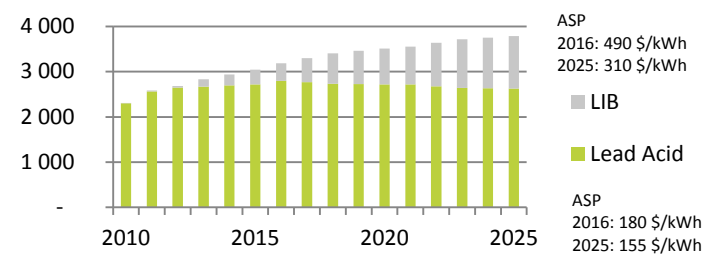
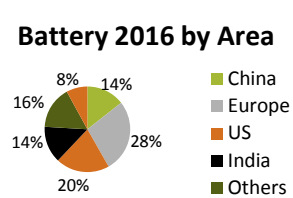
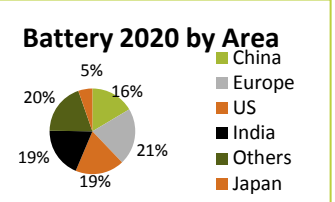
4- STATIONARY: TELECOM MARKET

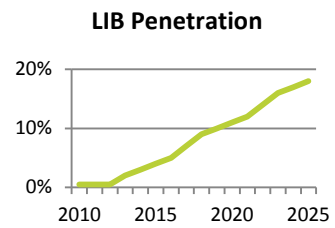
LIB: FROM US$ 0,4 BILLION IN 2016 TO 1,2 IN 2025[1] – $CAGR_{16-25}$: 13%

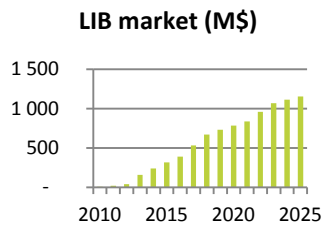
Market 2016-2025 (US $, Million) – CAGR: +2%











Main drivers

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

main Limiters

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

Competitors

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

Customers

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

Battery needs

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

LIB needs

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

Source: AVICENNE ENERGY Analyses

Note: : 1- Pack level

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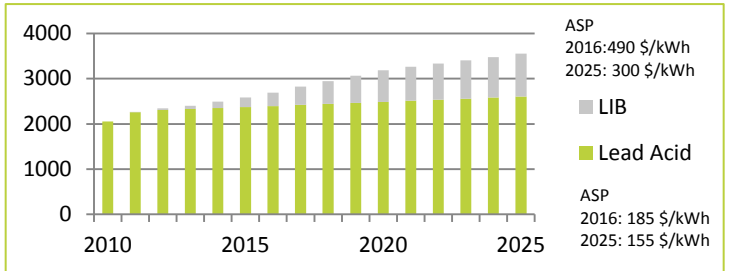
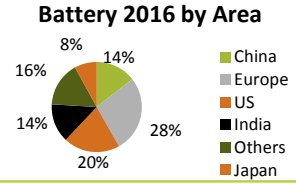
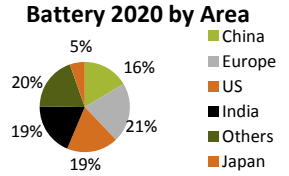
5- STATIONARY: UPS MARKET

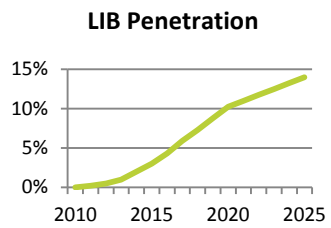
LIB: FROM US$ 0,27 BILLION IN 2016 TO 0,9 IN 2025[1] – $CAGR_{16-25}$: : 14%

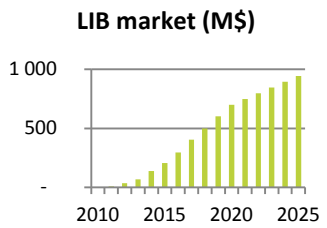
Market 2016-2025(US $, Million) – CAGR: +3%











Source: AVICENNE ENERGY Analyses

Main drivers

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

main Limiters

- Safety could be an important issue here

Competitors

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

Customers

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

Battery needs

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

LIB needs

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

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

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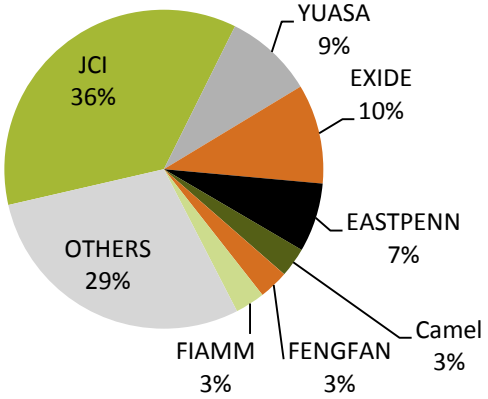
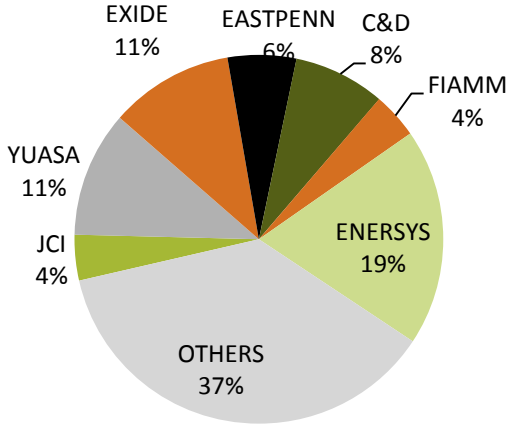
LEAD ACID BATTERY SUPPLIERS 2016

Lead Acid battery Market share : JCI is leading the SLI market (B$ 20,7)



Lead Acid battery Market share : Enersys is leading the Industrial market (B$ 11,7)



Over the past 15th years, the global lead-acid battery industry has experienced significant consolidation and currently the main international players are EnerSys, Exide Technologies, Johnson Controls, Inc., and GS Yuasa Corporation (“GS Yuasa”).

Source: AVICENNE ENERGY, 2017

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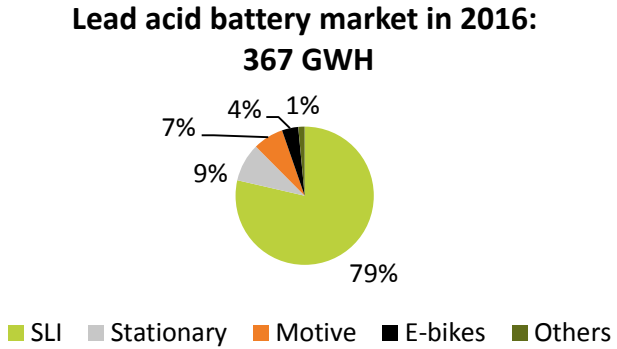
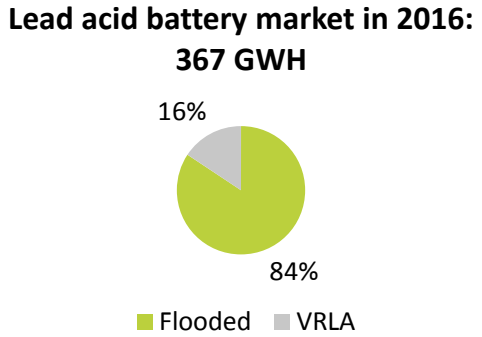
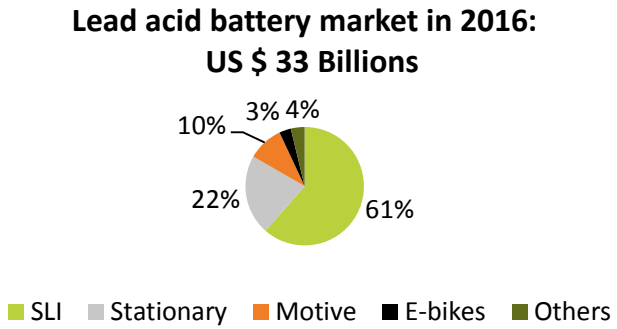
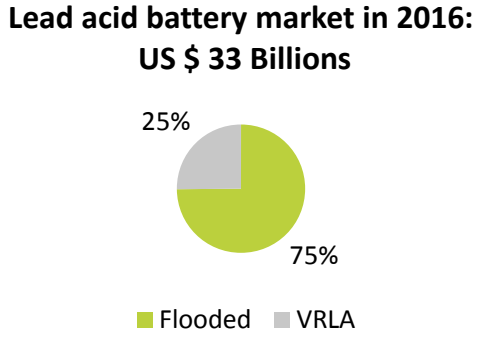
THE LEAD ACID BATTERY MARKET BY APPLICATION AND TECHNOLOGY IN 2016









Source: AVICENNE ENERGY, 2017

The rechargeable battery market 2016-2025

SEPTEMBER 2017

26th Edition

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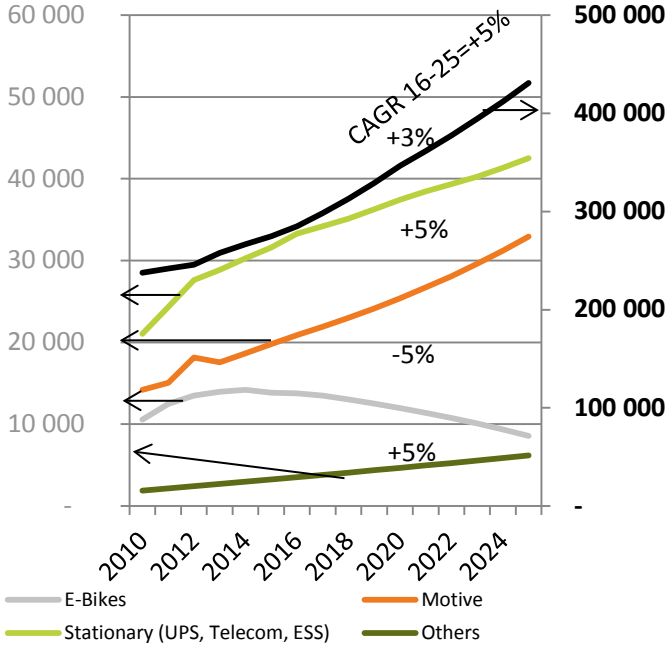
LEAD ACID MARKET FORECASTS BY APPLICATION

Lead acid battery demand (2010-2025) – MWh – $CAGR_{16-25}$: +4%



Source: AVICENNE ENERGY, 2017

Rationales

- SLI: $CAGR_{2016-25}$: +5% thanks to
  - After market (80% of the market)
  - Micro-hybrid growth
  - In development countries
- Motive (85% Forklift): $CAGR_{2016-25}$: +5%
  - Forklift market increase is small (+2%)
  - But more and more electrical forklift (80% in Europe, 65% in the US and 35% in Asia)
  - In development countries
- UPS & Telecom: $CAGR_{2016-25}$: +3%
  - "Big data"
  - Mobile communications
  - Energy Storage systems growth
- E-bike
  - 100% of the market in China – Lead acid replaced by Li-ion (15% LIB e-bike sold in 2016 to 60% in 2025)

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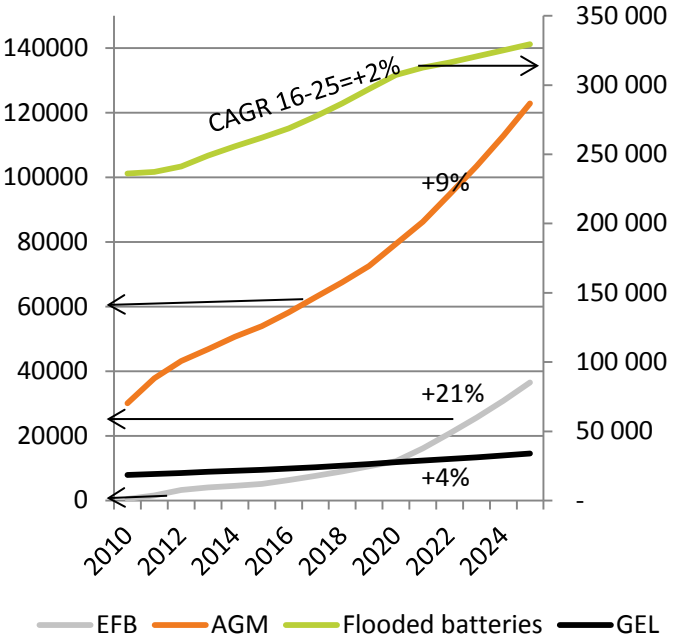
LEAD ACID MARKET FORECASTS BY TECHNOLOGY

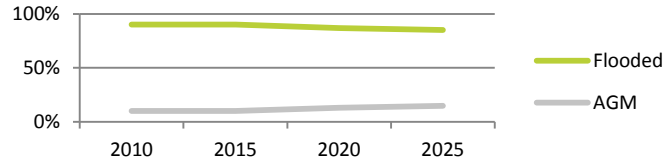
Lead acid battery demand (2010-2025) – MWh – $CAGR_{16-25}$: +4%



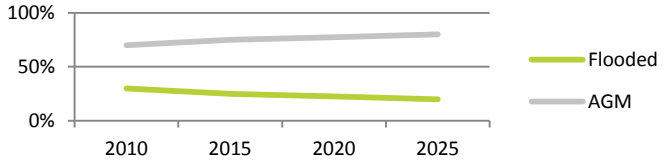
Source: AVICENNE ENERGY, 2017

Rationales

- Motive Battery technology



- Stationary Battery technology



- E-bikes: almost 100% AGM batteries
- Motorcycles: almost 100% GEL batteries