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Industrial Battery Markets
in North America
2018 - 2027

2019 NAATBatt INTERNATIONAL ANNUAL MEETING & CONFERENCE

March 12th, 2019

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Industrial Markets North America

AVICENNE ENERGY US
Michael SANDERS

Presentation Outline

- The rechargeable battery market in 2018
- The Li-ion battery value chain
- Industrial battery markets
- Forecasts & conclusions

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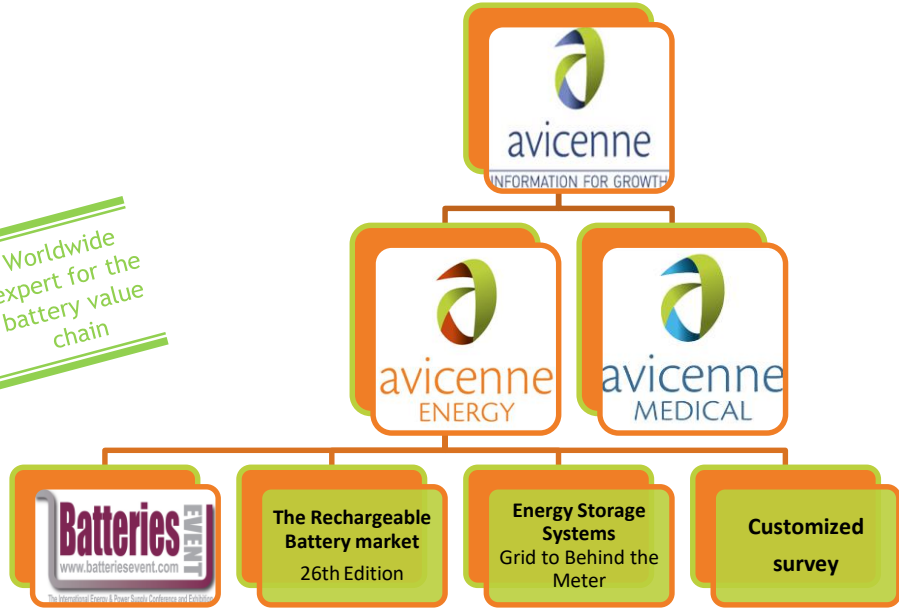
AVICENNE PROFILE

Information for Growth - Powering your company's market strategy with in-depth research

- Creation: 1992, by Ali MADANI
- Headquarter: Paris
- Liaison Office: Japan, USA, China
- AVICENNE Energy Director: Christophe Pillot
- 5 consultants
  - A Madani
  - C Pillot
  - JP Salvat
  - A Yassari
  - O Noel
- 2 Senior advisors
  - X Zhang
  - M. Sanders
- Database: >20 000 contacts in the battery value chain

Worldwide expert for the battery value chain



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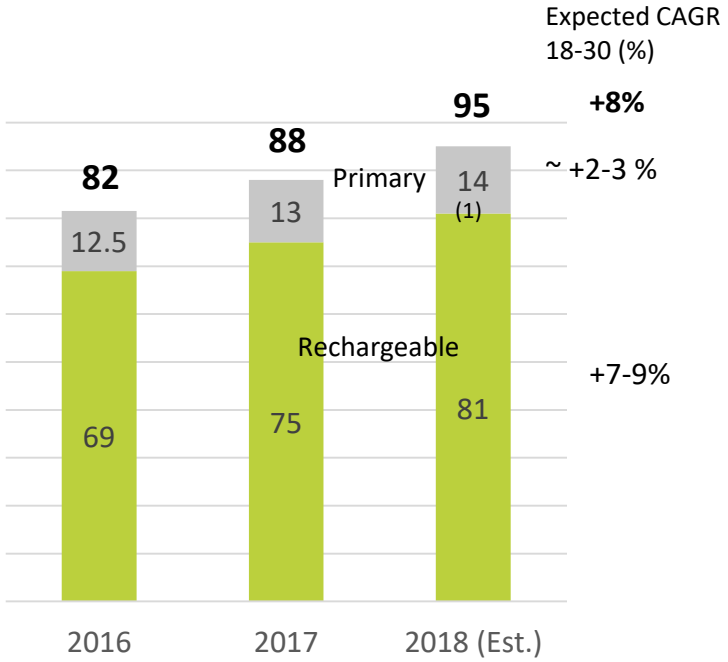
WORLDWIDE BATTERY MARKET OVERVIEW

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 2018

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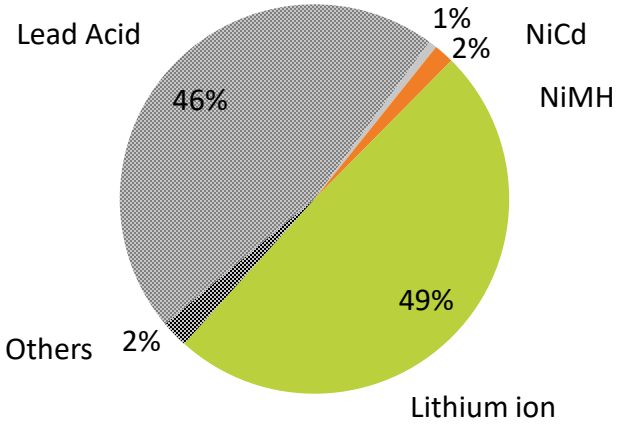
APPLICATIONS COVERED IN THE SURVEY

17 applications in detail:

- Electric Vehicles: Hybrids, Plug-in, Electric
- Start light and Ignition batteries (SLI) – Stop start, 48v batteries
- Stationary applications
- Cellular Phones & smartphones
- Computers
- Tablets
- Camcorders
- Digital Camera
- MP3 players
- Games
- Cordless Phones
- R/C Cars
- Household appliances
- Power Tools
- Security lighting systems
- E-Bikes
- Drones
- Others: Energy Storage, medical devices, radio, UPS, PDA, back-up systems etc...

The Global Battery Market Worldwide – 81 B$ in 2018



** Lead acid batteries is now included in the survey*

Source: AVICENNE ENERGY Analyses

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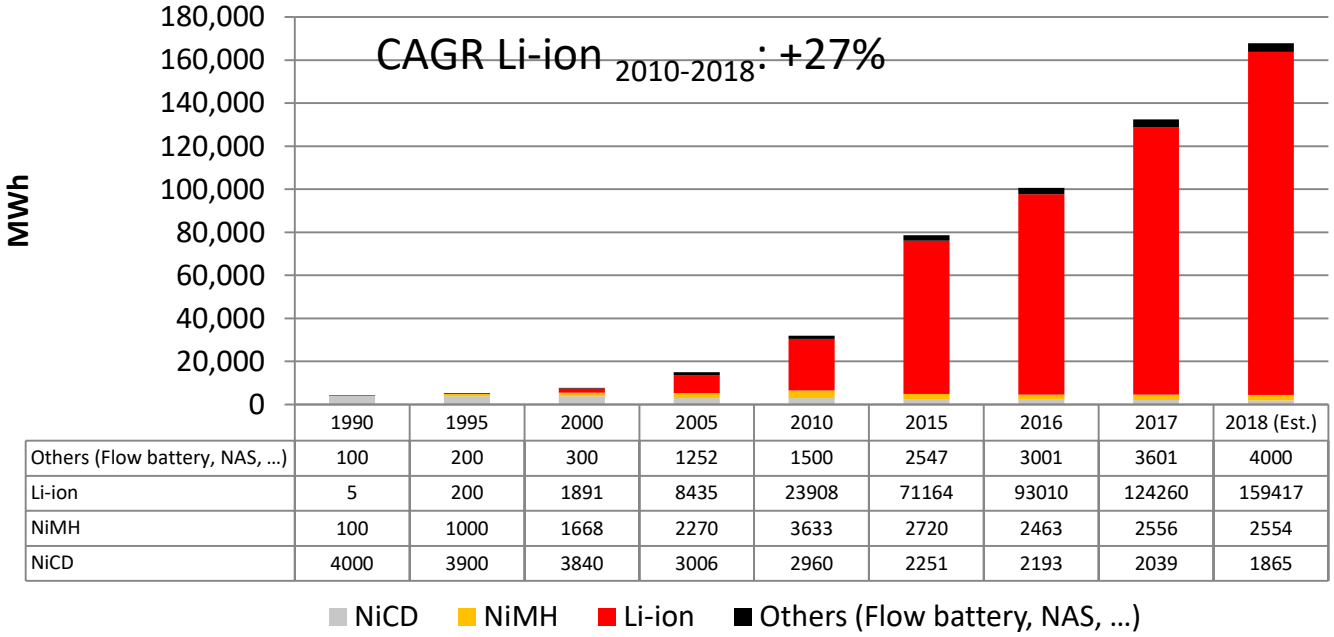
THE WORLDWIDE BATTERY MARKET 1990-2018

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



	1990	1995	2000	2005	2010	2015	2016	2017	2018 (Est.)
Others (Flow battery, NAS, …)	100	200	300	1252	1500	2547	3001	3601	4000
Li-ion	5	200	1891	8435	23908	71164	93010	124260	159417
NiMH	100	1000	1668	2270	3633	2720	2463	2556	2554
NiCD	4000	3900	3840	3006	2960	2251	2193	2039	1865

Source: AVICENNE ENERGY, 2018

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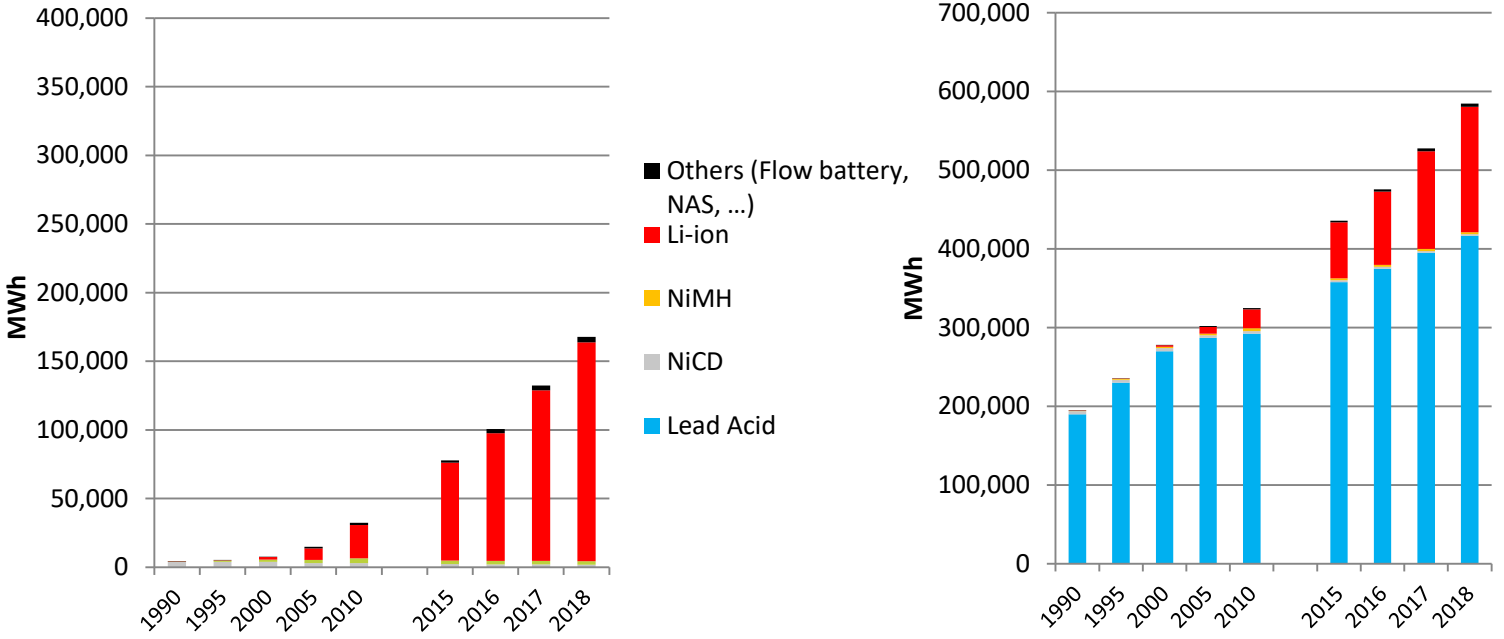
THE WORLDWIDE BATTERY MARKET 1990-2018

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, 2018

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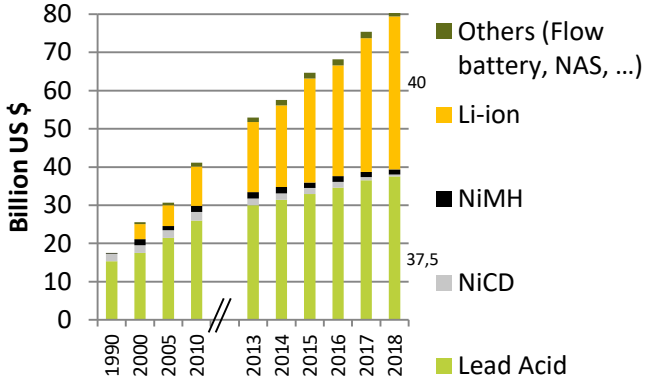
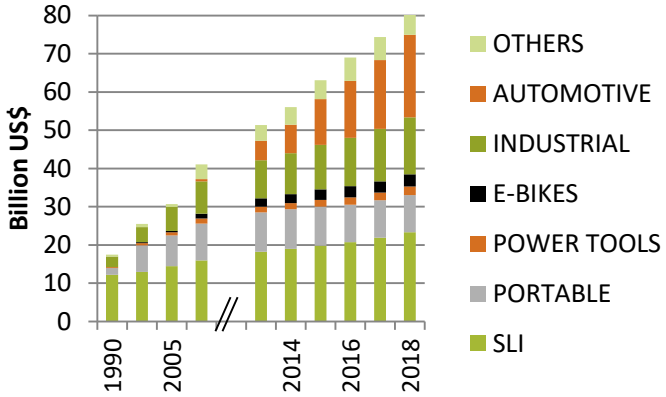
THE WORLDWIDE BATTERY MARKET 1990-2018

>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, 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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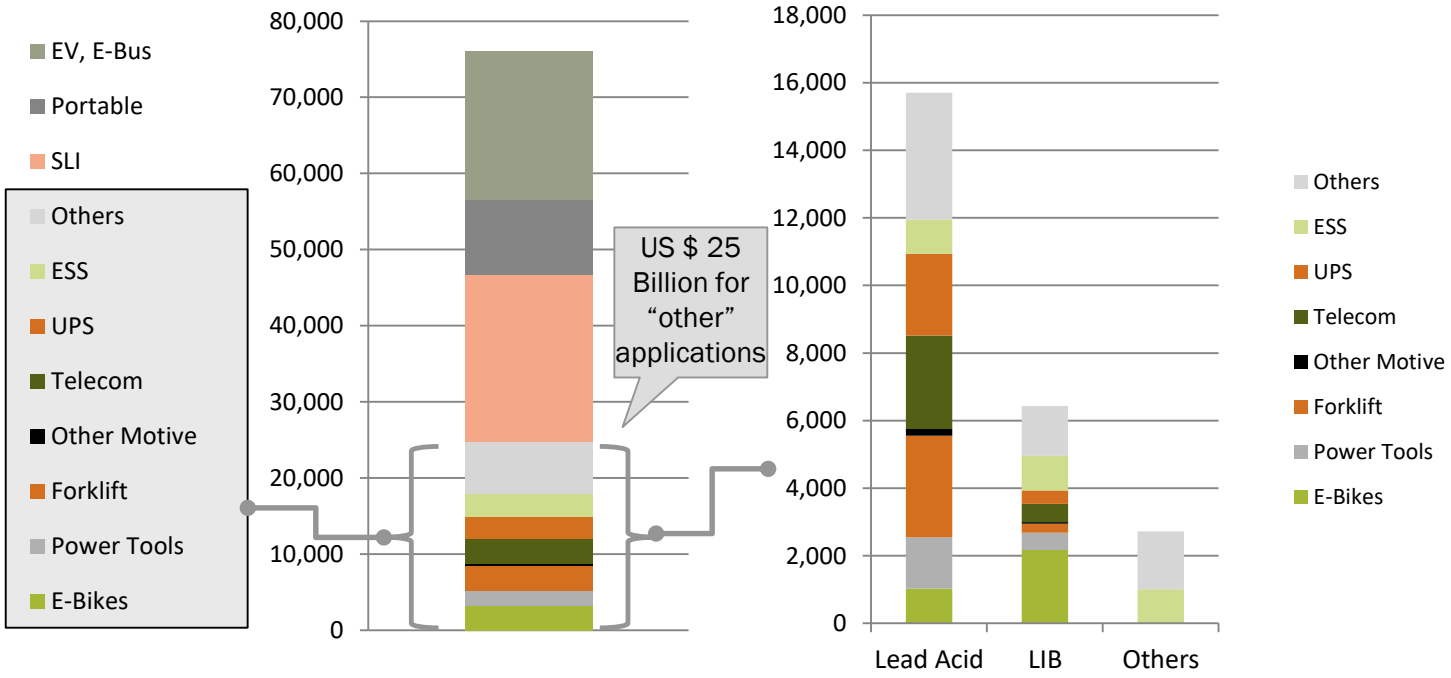
THE WORLDWIDE BATTERY MARKET IN 2017: US $ +75 BILLION

To be up-dated ?



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

Source: AVICENNE ENERGY, 2018

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THE MAIN TRENDS

Economical trends
Price decreases,
Investment,

Technical trends
new technologies, higher capacities, improving performances for raw materials,

Regulation trends
Products banned,
cyclability,

Applications trends
xEV, ESS, Stationary, Mobile - Portable PC - Digital Cameras - PDA - Power Tools - Toys - Cordless Phones - Home Appliances - Camcorders - Security systems - RC Cars – Drones…

Geographic Area
US - Western Europe - Japan - China - Latin America - Eastern Europe - Asia Pacific - Middle East - Row

& SAFETY

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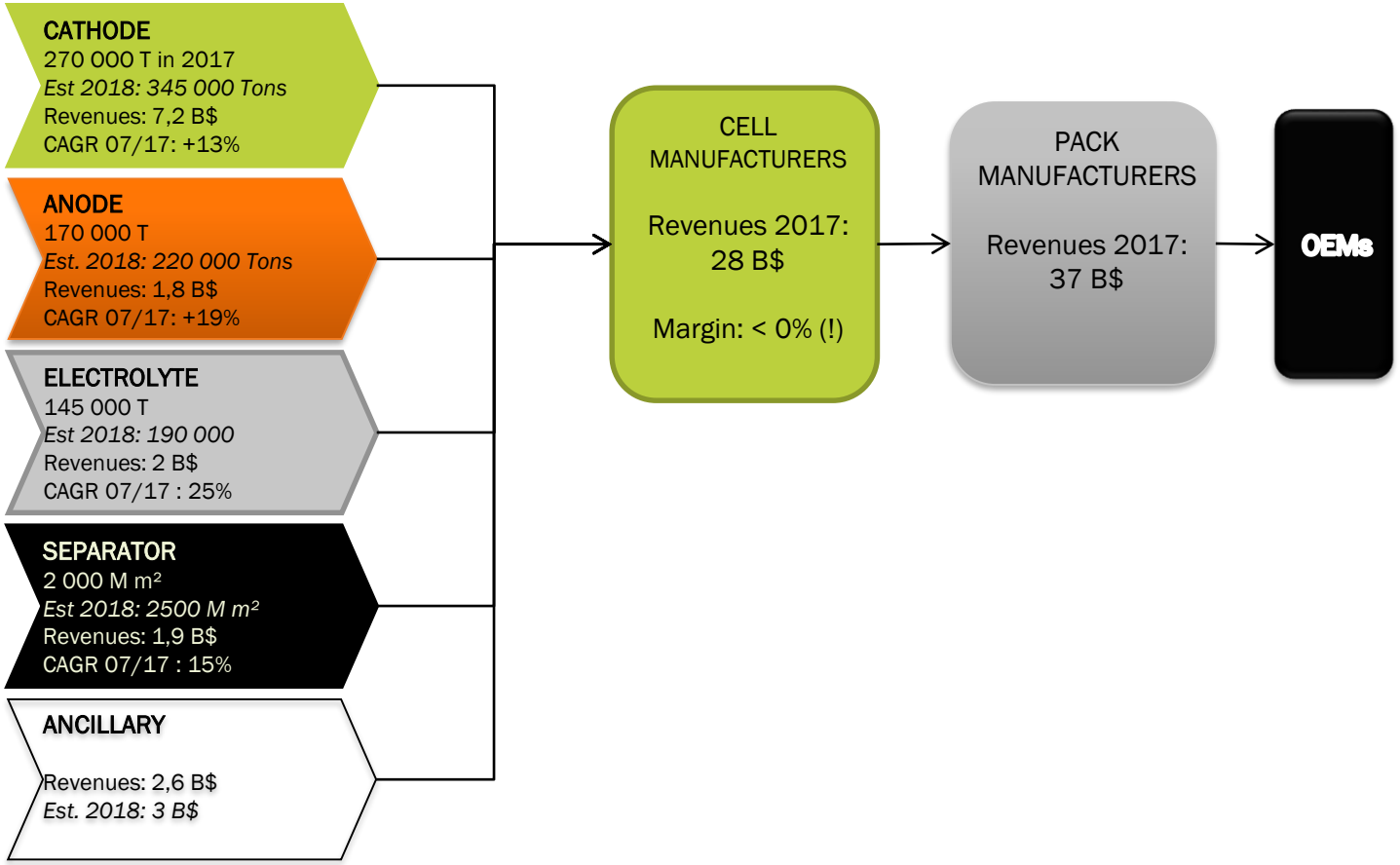
LI-ION VALUE CHAIN – MARKET DEMAND



Sources: AVICENNE ENERGY 2018

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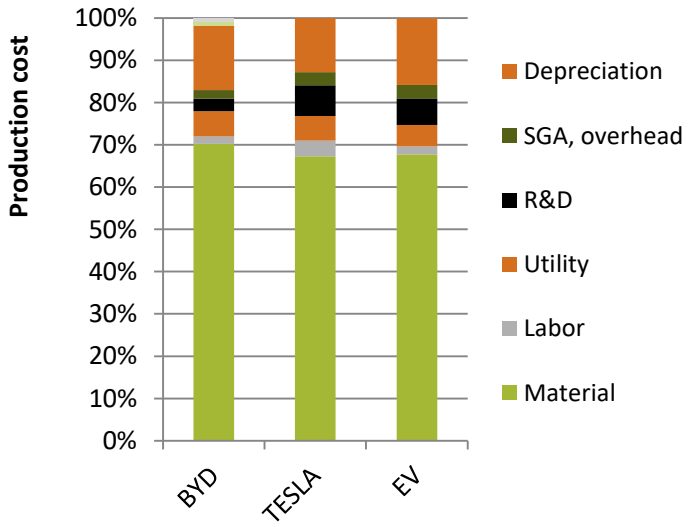
LIB: THE BIGGEST PART OF THE COST IS RAW MATERIALS

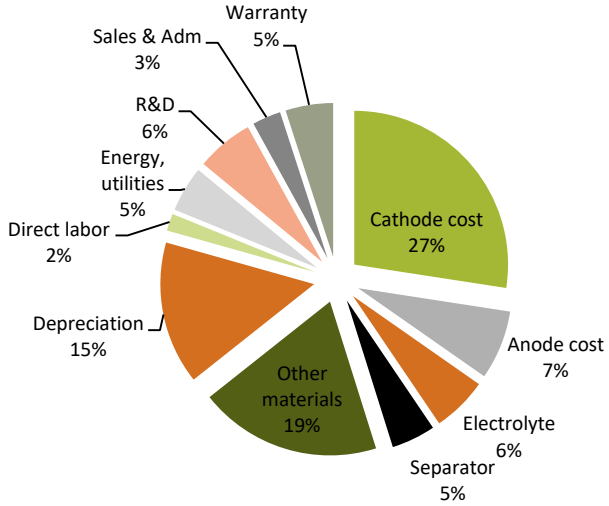
RAW MATERIALS ACCOUNT FOR 60 TO 70% OF LIB CELLS BUSINESS

RAW MATERIAL COST IMPACT DRASTICALY ON THE BATTERY MAKERS PROFIT

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 2018

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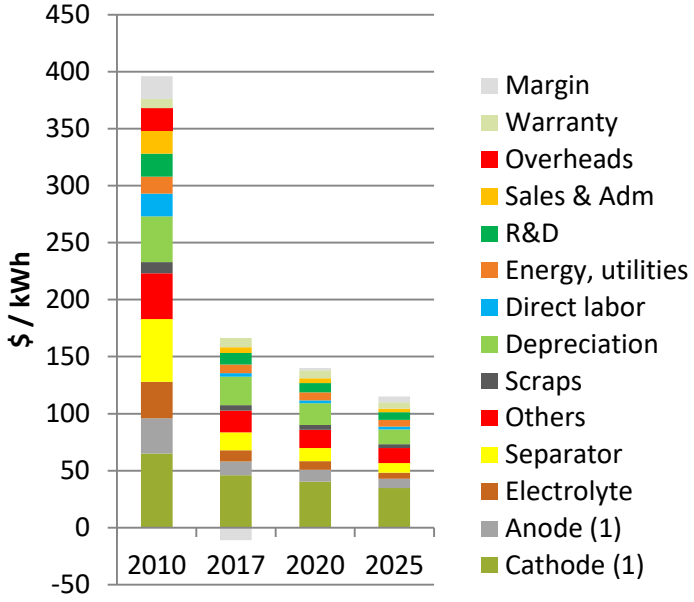
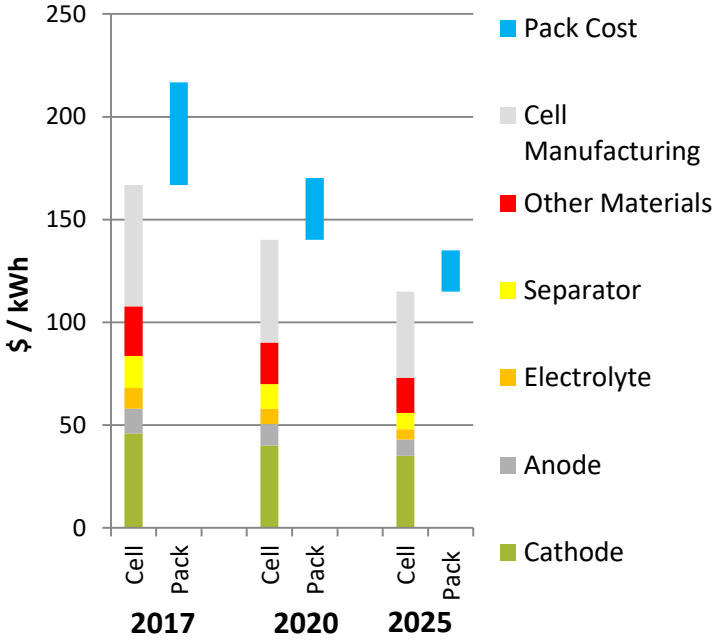
LI-ION BATTERY COST 2015-2025

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*

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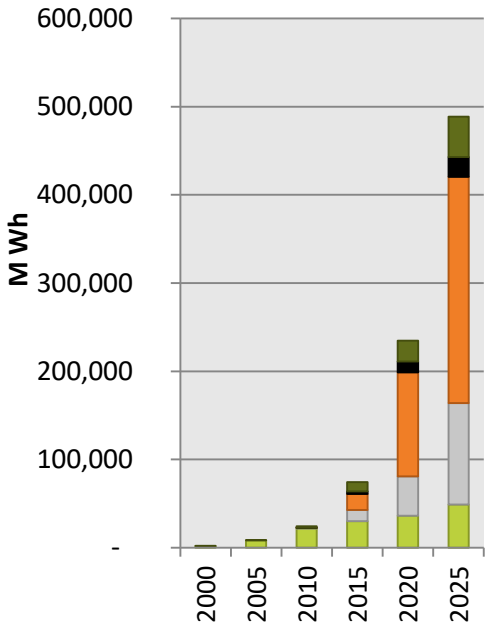
LI-ION BATTERY MARKET FORECASTS

From 120 GWh in 2017 to 490 GWh

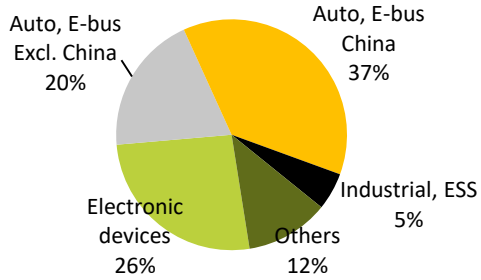
CAGR 2017/2025
+19 % per year in Volume

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

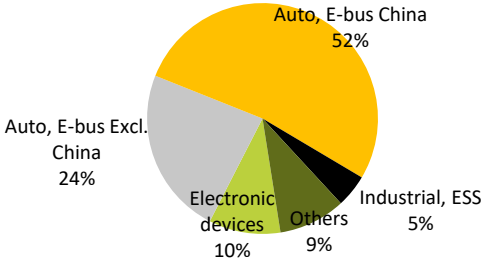


	CAGR 15/25 (Realistic)
Others	16%
Industrial, ESS	22%
Auto, E-bus China	30%
Auto, e-bus Excl. China	25%
Electronic devices	5%

2017: >120 GWh



2025: 490 GWh



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

Source: AVICENNE Energy 2018

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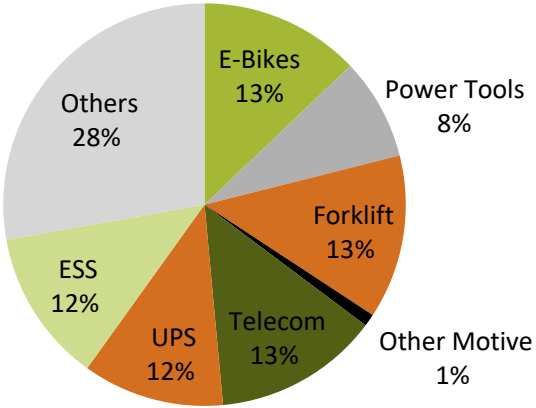
TOTAL POTENTIAL MARKET (M$, PACK LEVEL[1])

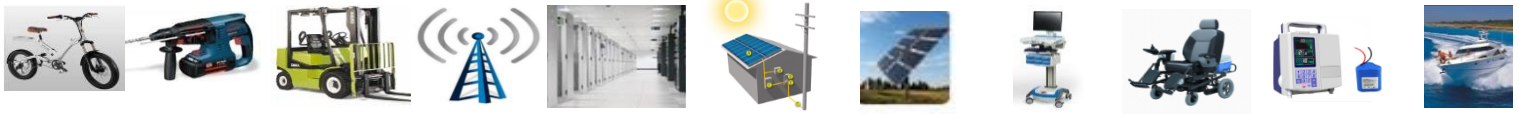
Application details

US$ 25 Billion in 2017 (1)



Source: AVICENNE ENERGY 2017

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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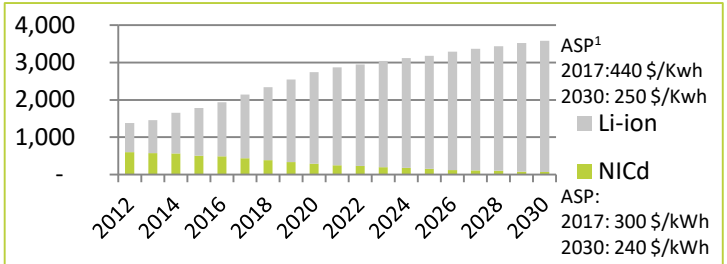
POWER TOOLS

LIB: FROM US$ 1,7 BILLION IN 2030[1] – $CAGR_{15-30}$: +7%

Market 2017-2025 (US $, Million) – CAGR:+5%



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.

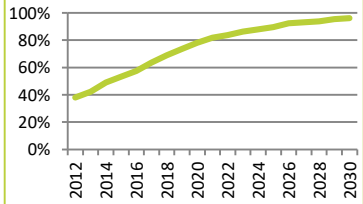
Competitors

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

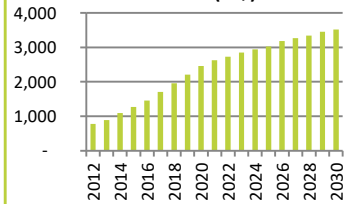
Customers

- 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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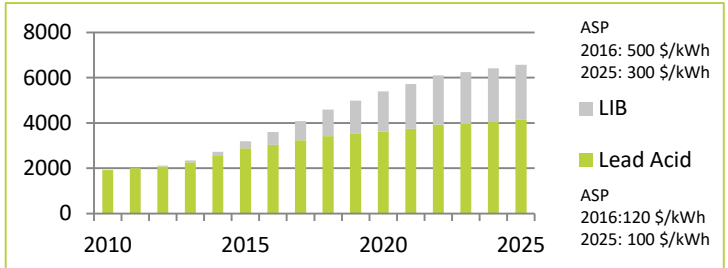
3- MOTIVE INDUSTRIAL: FORKLIFTS[2]

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

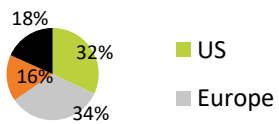
Market 2016-2020 (US $, Million) – CAGR:7%



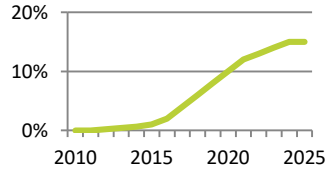
Battery 2016 by Area

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%)

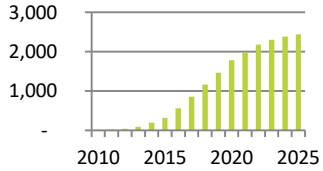
LIB 2025 by Area



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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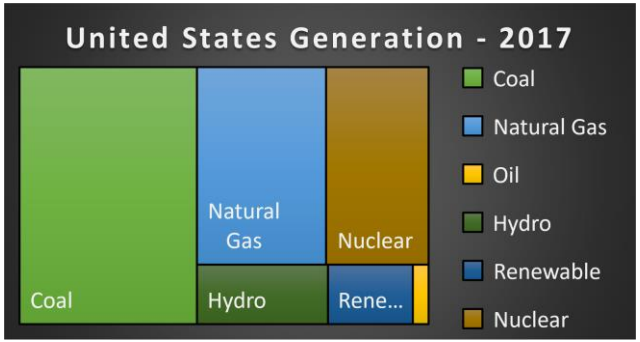
NORTH AMERICA – USA

Major Generation & Storage Drivers



- Up to 2017, at Federal level, the Investment Tax Credit (ITC) is applied to residential solar PV panel installations. Under the current ITC, homeowners can claim back 30% of the cost of installation.
- States play a critical leading role in developing energy storage and numerous States continue to define clear procurement targets, and help funding projects.
- Different incentive plans are available at State level mainly proposed as differential power rates with best case examples found in California, Arizona, Hawaii, Oregon, New York and Massachusetts.
- Although the current administration efforts to promote coal expansion, an estimated 25 coal powered plants representing ~20 GW of total capacity are set for closure between 2017 and 2018. This offers a gap-filling opportunity to develop further the energy storage ecosystem.

Federal Regulation & Incentives

- Bill S.1851, 115th Congress (2017-2018) sponsored by Senator Franken, AI (D-MN), named Advancing Grid Storage Act of 2017 was introduced to Congress on Oct 25th, 2017 to amend the Internal Revenue Code of 1986 to provide tax credits for energy storage technologies.
- Bill S.1851 of 2017 amends the Internal Revenue Code of 1986 and expands tax credits to energy storage equipment from batteries to systems - it includes compressed air, pumped hydropower, fuels cells, hydrogen storage, flywheel, thermal energy, capacitors, superconducting magnets.
- Bill S.1851 of 2017 sets clear system performance objectives and mentions that systems have to reach the capacity of minimum 5kWh for commercial and 3kWh for residential. Hearings are suspended for Bill S.1851 of 2017.
- 2018 import duties with a first year set at 30% on solar equipment made in China, to protect the remaining American manufacturers. President Trump approved a four year tariff plan starting at 30% in the first year and gradually dropping down to 15%. Price increases for solar panels are expected to be visible to homeowners quarter 2 in 2018.
- The new 2018 tax reforms constrain financing for solar and wind, which will slow down the technology transition of homeowners.

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NORTH AMERICA - USA

Energy Storage Leading Technologies

- 94% of energy storage systems installed in 2017, in the major and recent installations in USA, use Lithium-ion batteries.
- 4.9% of energy storage system installed in 2017 were flow batteries.
- Less than 1% of the energy storage systems used lead acid in 2017.
- Various US-based companies offer innovative non-Lithium-ion-based battery alternatives (Table 2).

Materials Roadmap and Needs

- The Long Beach 300MW Lithium-ion battery project raises the question of safety.
- Capitalizing on Lithium-ion weaknesses, companies are looking to capture new sources of growth through a new cycle of investments in new technologies.
- Development of hybrid systems using Li-ion batteries offering more scalable, customizable and flexible solutions for existing power generation put pressure to address weaknesses of Li-ion batteries.

Vizn Energy	Hybrid zinc-iron based flow battery in which alkaline electrochemical components are dissolved in the electrolyte
Eos Energy Storage	Low-cost DC battery system using zinc hybrid cathode
Fluidic Energy	Rechargeable zinc air batteries
FIAMM USA	High purity lead acid tin alloy battery
PBC Tech	Ultra thin hybrid supercapacitor
eChemion	Aqueous treated redox flow battery
Aquion	Aqueous Ion (AHI) battery
Primus Power	Zinc bromide flow battery with black start option

Table 2

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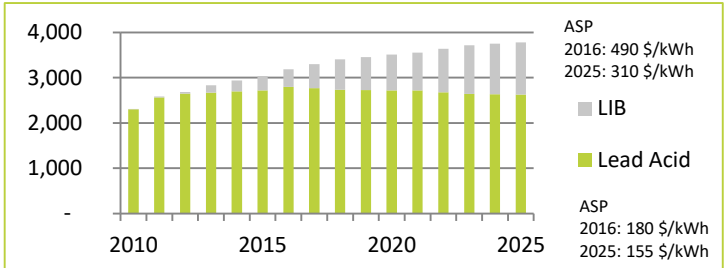
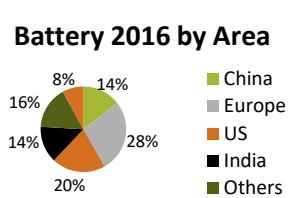
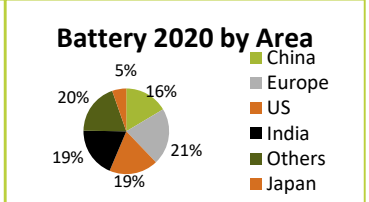
STATIONARY: TELECOM MARKET

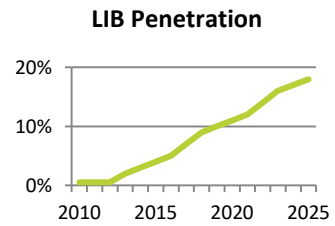
LIB: FROM US$ 0,5 BILLION IN 2017 TO 1,2 IN 2025[1] – $CAGR_{17-25}$: 10%

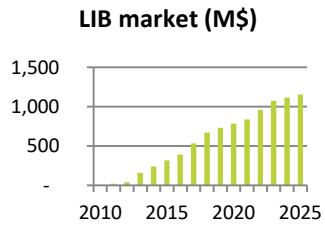
Market 2017-2025 (US $, Million) – CAGR: +2%











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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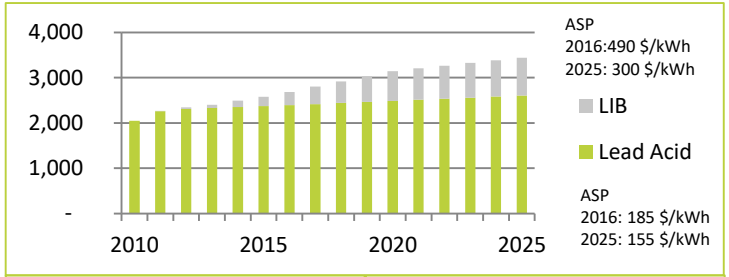
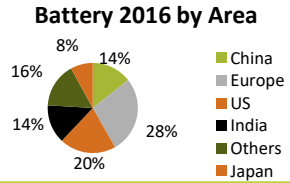
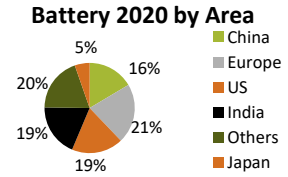
STATIONARY: UPS MARKET

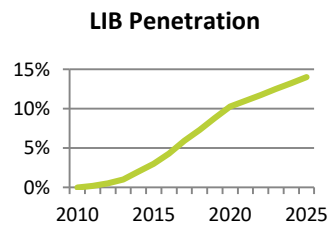
LIB: FROM US$ 0,4 BILLION IN 2017 TO 0,8 IN 2025[1] – $CAGR_{16-25}$: : 10%

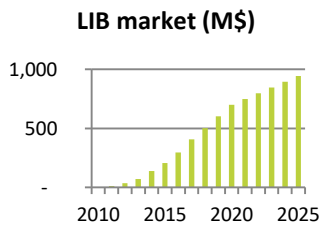
Market 2017-2025(US $, Million) – CAGR: +2,5%











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

Source: AVICENNE ENERGY Analyses

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

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ESS SEGMENTATION

Stationary Energy Storage - Potential segmentation

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

Existing markets # Emerging markets

Source: AVICENNE ENERGY 2017

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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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ENERGY STORAGE APPLICATIONS HAVE MANY WAYS TO ESTABLISH VALUE/DEMAND

Bulk Storage

- Wind Generation to Distributed Storage
- Community Energy Storage
- Flexible Peaking Resource
- Merchant Electricity Storage
- Reduction of Peak A/C Demand

Grid and Transmission

- Connected PV Integration
- Distributed Energy Resources – Plug-In Vehicles
- Frequency Regulation
- Spinning Reserve
- Transmission and Distribution Deferral
- Transmission Support and Charge Avoidance

End User Benefits

- Bill Management
- Uninterrupted Power Supply
- Microgrids

Establishment of value for applications change with demand, location, cost, policy changes, utility/grid operator system optimization and deployment of renewables.

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TYPES OF ENERGY STORAGE UTILIZED MAJOR TECHNOLOGIES

- Lead Acid Batteries
  - Standard
  - VRLA
  - AGM
- Lead Carbon Batteries
- Lithium Ion Batteries
- NiMH and NiCD Batteries
- Supercapacitors
- NaCL Batteries
- NaS Batteries

- Pumped Hydro and Compressed Gas
- Flow Batteries
  - Vanadium
  - Zinc
- NiZn Batteries
- Flywheels
- Hydrogen Generation

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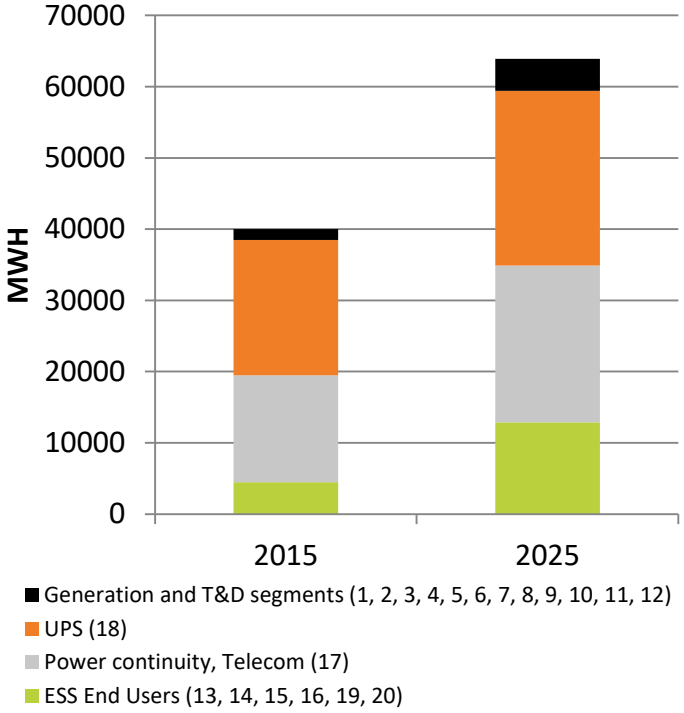
ESS MARKET & FORECASTS

From 40 GWh to 65 GWh in 2025

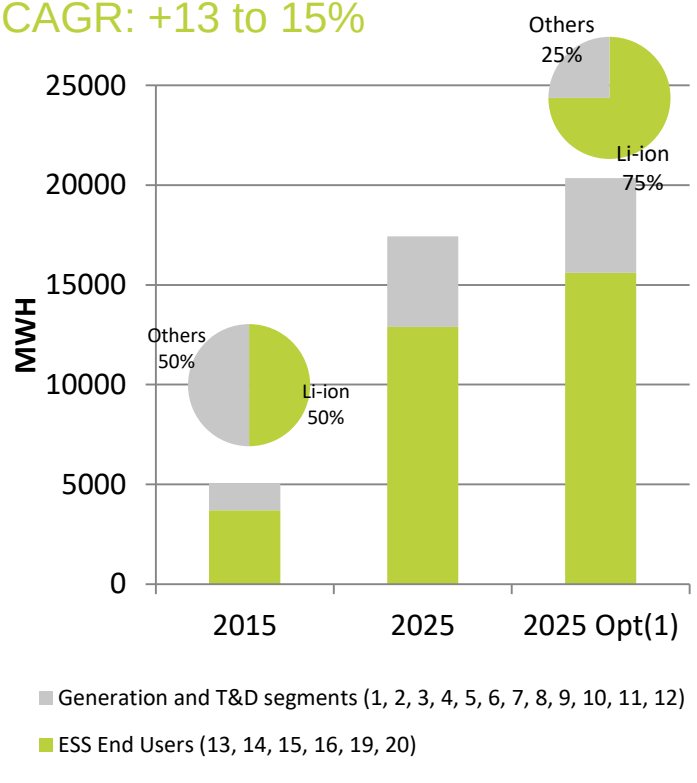
CAGR: +6%



Source: AVICENNE Energy, 2018

ESS 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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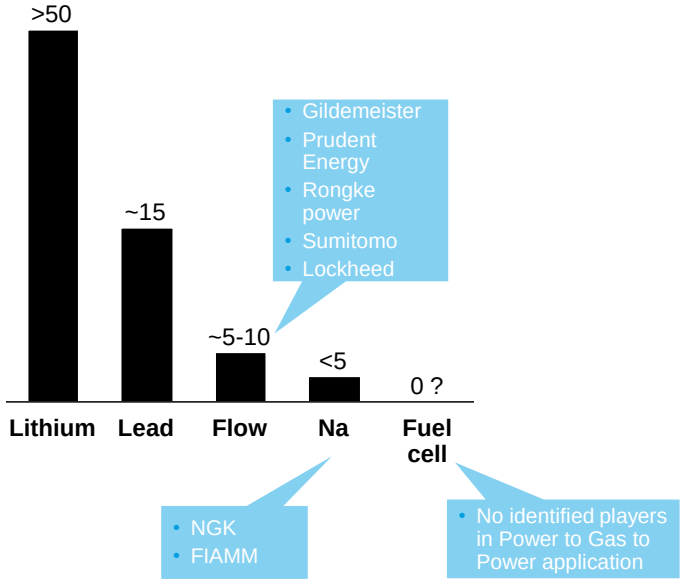
MOST PLAYERS ARE FOCUSING ON LI-ION, WHILE DOING TECHNOLOGY WATCH ON OTHER TECHNOLOGIES

Main battery vendors involved by technology (excl. start-ups)
(# ESS battery vendors, 2016)

Estimates



- Li-ion players originally in automotive pushing for ESS market as EV delayed emergence
- Strong historical presence of Pd-acid players in stationary storage with large distribution network
- Na and flow players mostly start-ups with only 2-4 main vendors actually on the market
- Large players doing technology watch on Na-ion and other technologies for the next generation (e.g. Naiades project on Na-ion batteries involving Saft with Solvay, CEA, CERN, etc.)
- No commercial activity on fuel cells for Power to Gas to Power applications
- “A player that want to develop flow technology should have strong financial back-up to sustain R&D” (ESS player)

Source: Avicenne

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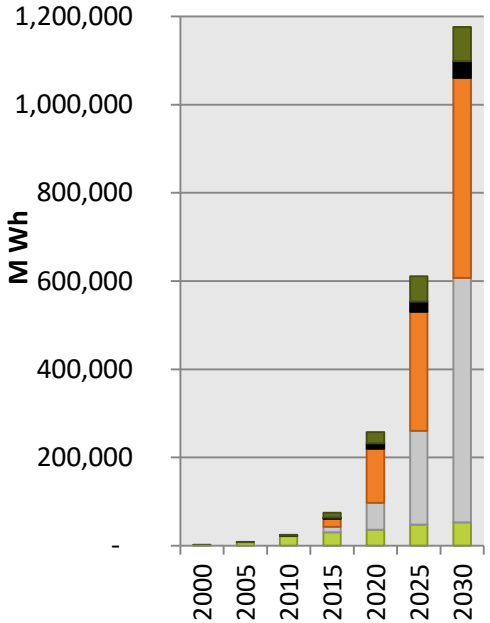
LI-ION BATTERY MARKET FORECAST

realistic scenario

From 120 GWh in 2017 to >1,2 TWh

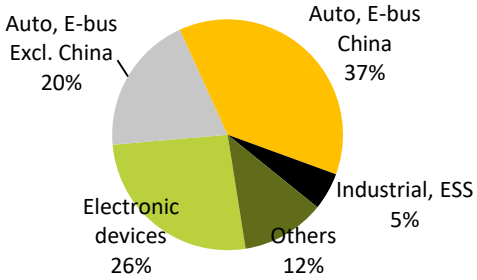
CAGR 2017/2030
+20 % per year in Volume

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

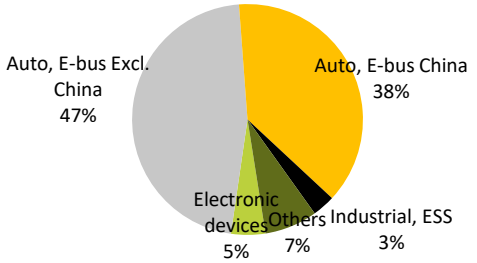


	CAGR 15/30 (Optimistic)
Others	14%
Industrial, ESS	18%
Auto, E-bus China	24%
Auto, e-bus Excl. China	29%
Electronic devices	4%

2017: >120 GWh



2030: 1200 GWh



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

Source: AVICENNE Energy 2018

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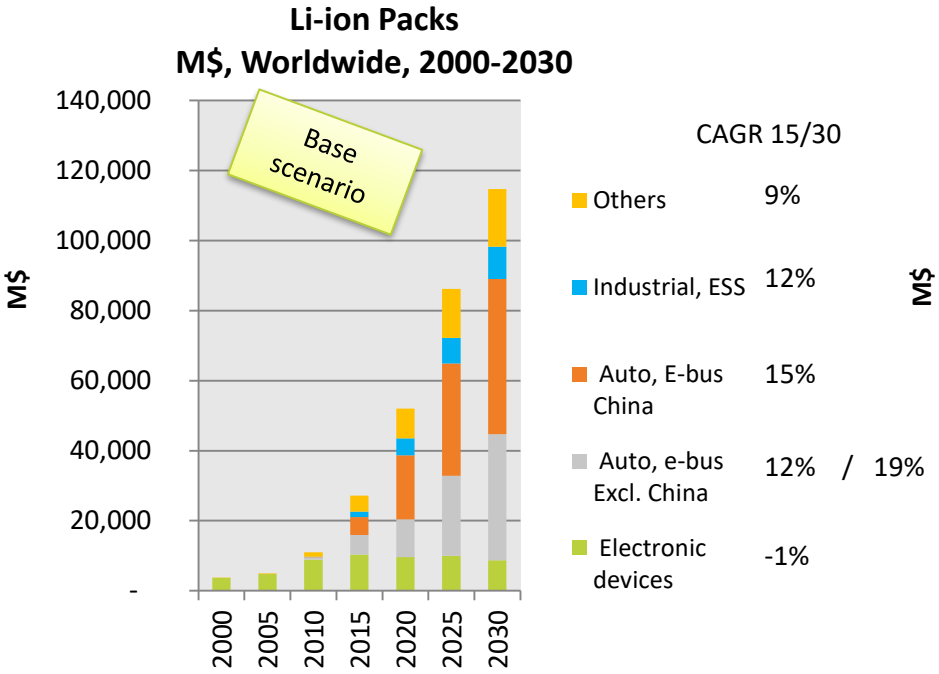
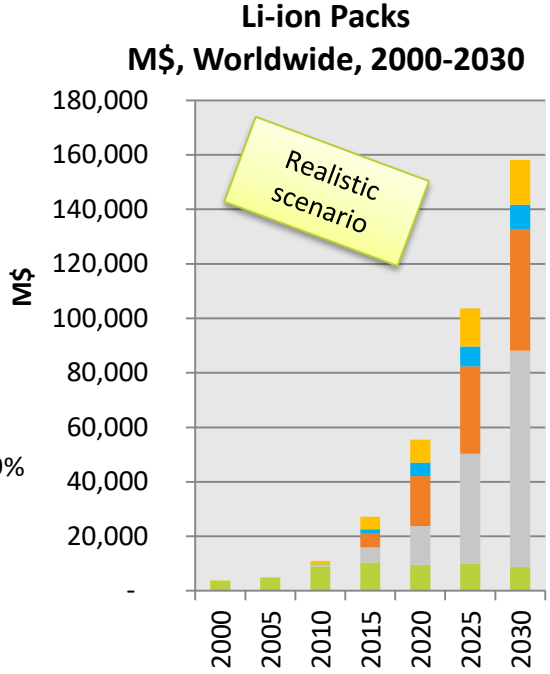
LI-ION BATTERY MARKET FORECASTS

CAGR 2015/2030: +18/20 % per year in Volume
Pack: +10/13% per year in value





Others: medical devices, power tools, gardening tools, e-bikes…
Source: AVICENNE Energy 2018

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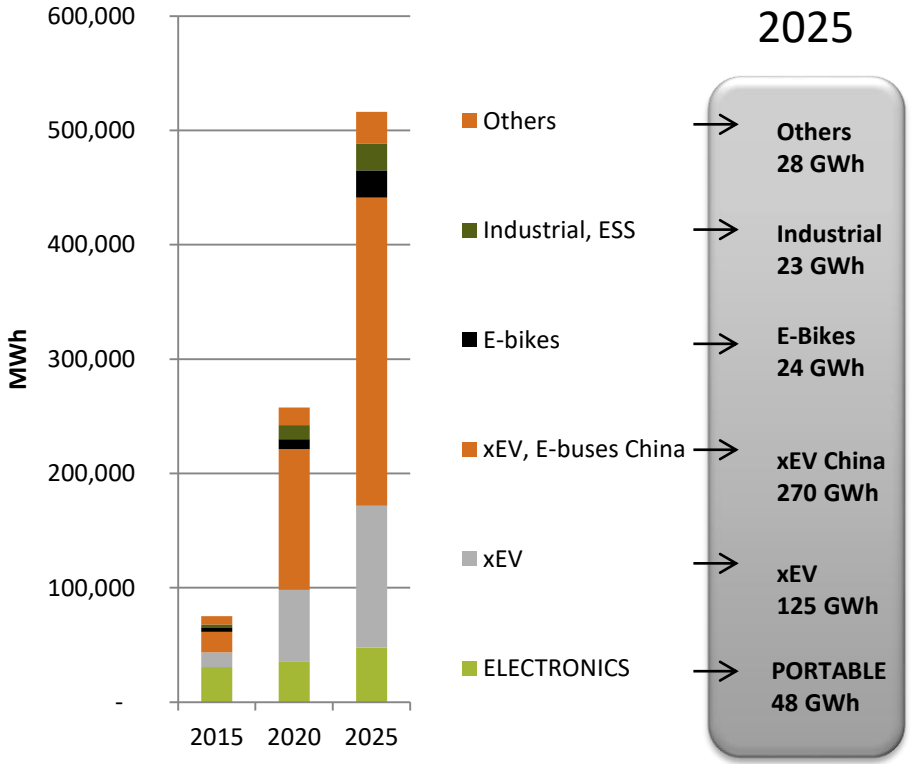
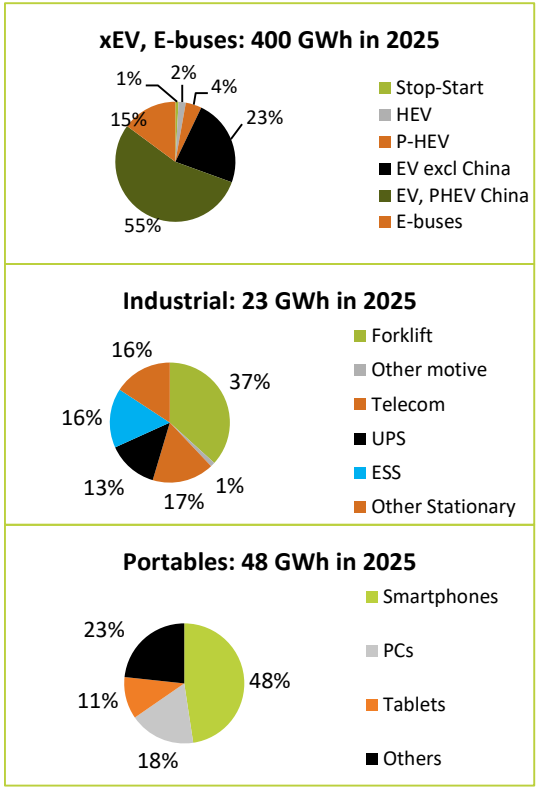
THE LITHIUM ION BATTERY MARKET WORLDWIDE 2015 - 2025

Base scenario





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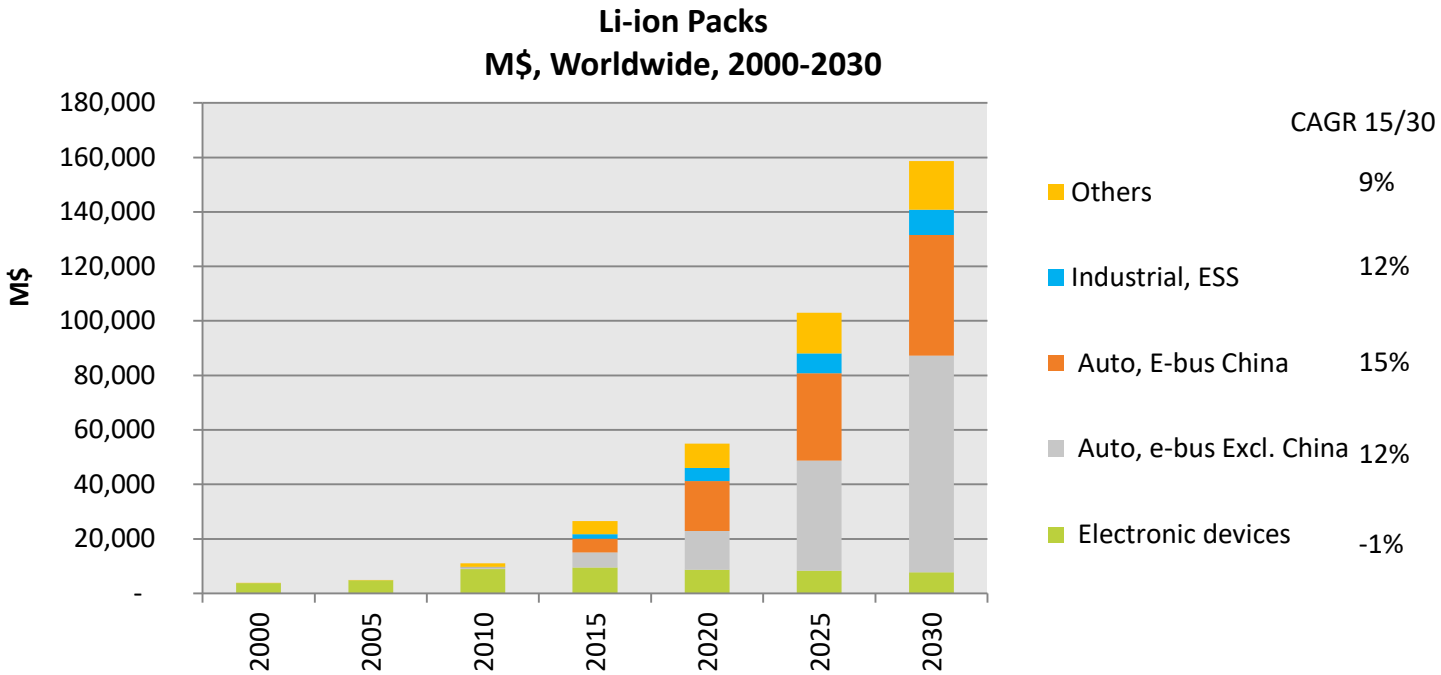
LI-ION BATTERY MARKET FORECAST

Realistic scenario

CAGR 2015/2030: +24 % per year in Volume
Pack: +11% per year in value



Others: medical devices, power tools, gardening tools, e-bikes…
Source: AVICENNE Energy 2018

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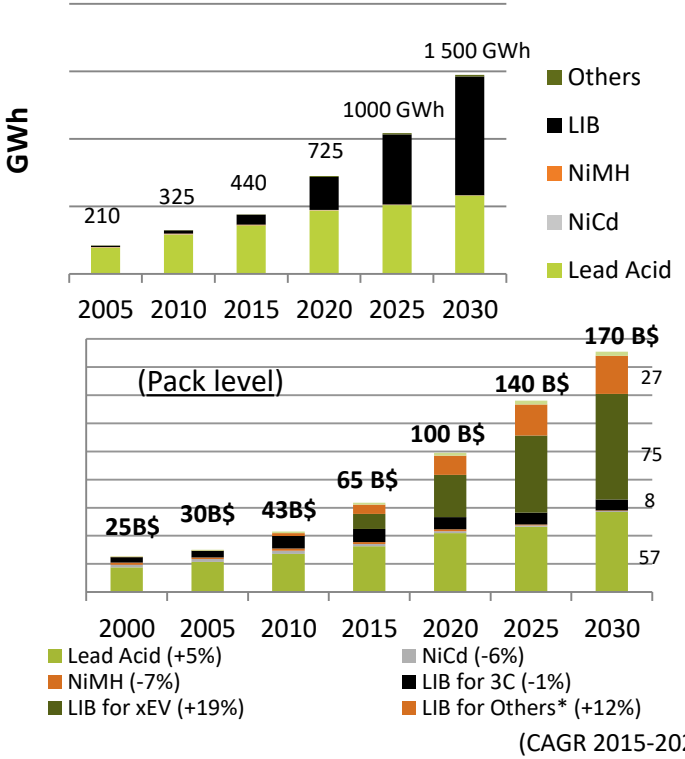
TAKEAWAYS

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