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Lithium-Ion Battery Market Expansion Beyond Consumer and Automotive

Christophe PILLOT

Director, AVICENNE ENERGY

AABC 2015

January 26 - 29

Mainz

Presentation Outline

- The rechargeable battery market in 2013
- Lithium ion battery Battery beyond Consumer & Automotive in 2013
- Forecasts & conclusions

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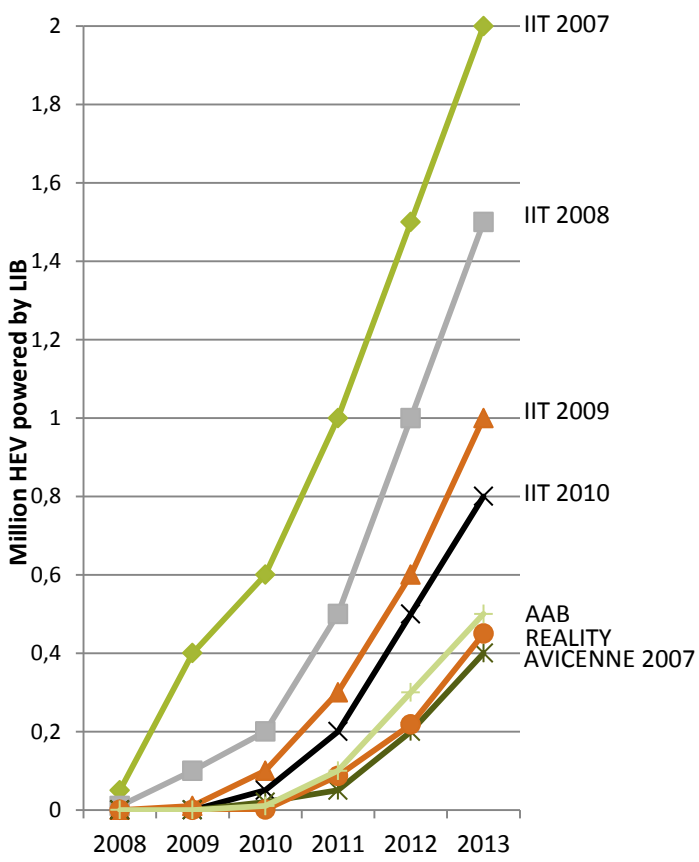
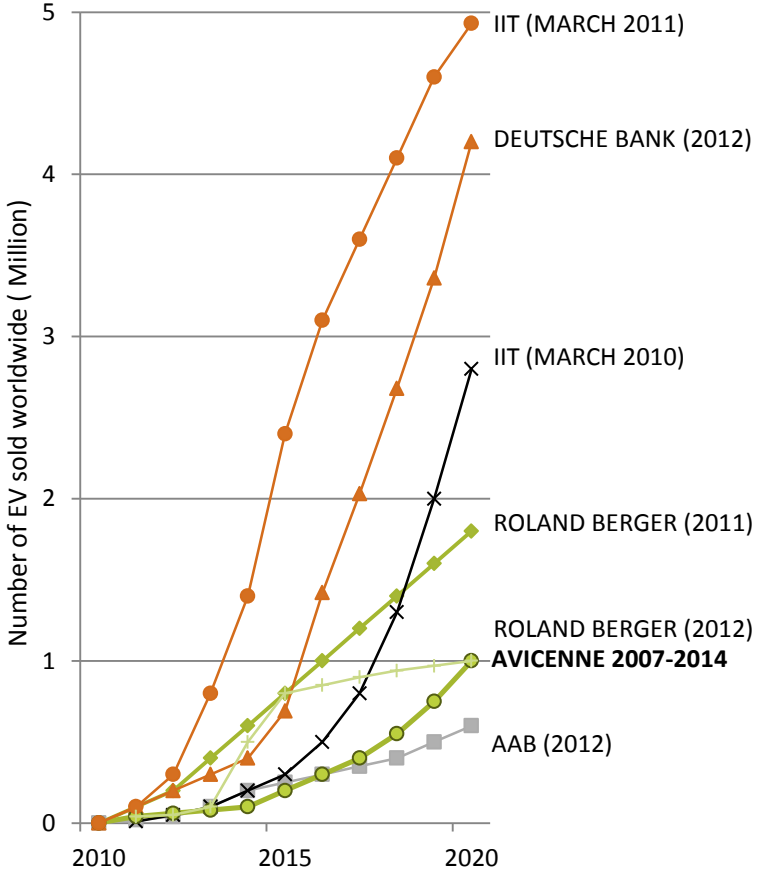
AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

HEV powered by Lithium ion battery forecasts from 2008 to 2013



EV sold, in million units, worldwide, 2010 - 2020



Source : International Battery Conference, Fort Lauderdale 2007, 2008, 2009, 2010 & 2011
AABC June 2007, AABC Asia, May 2014

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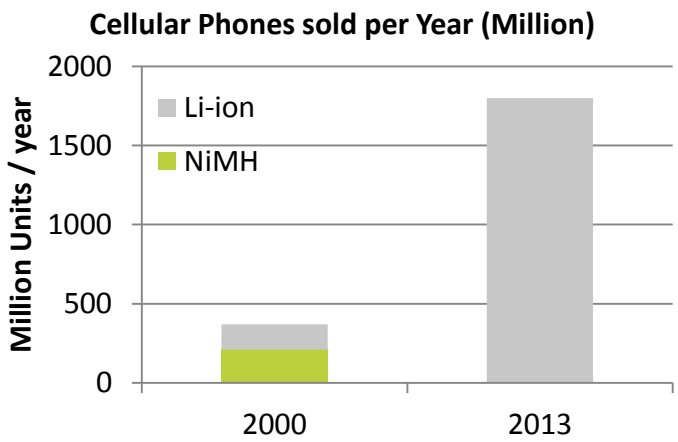
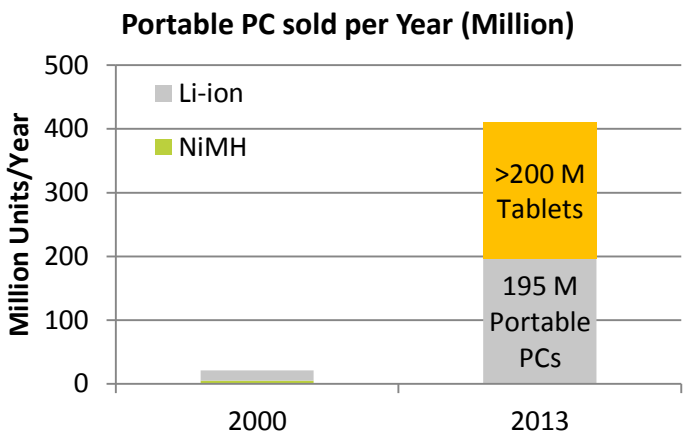
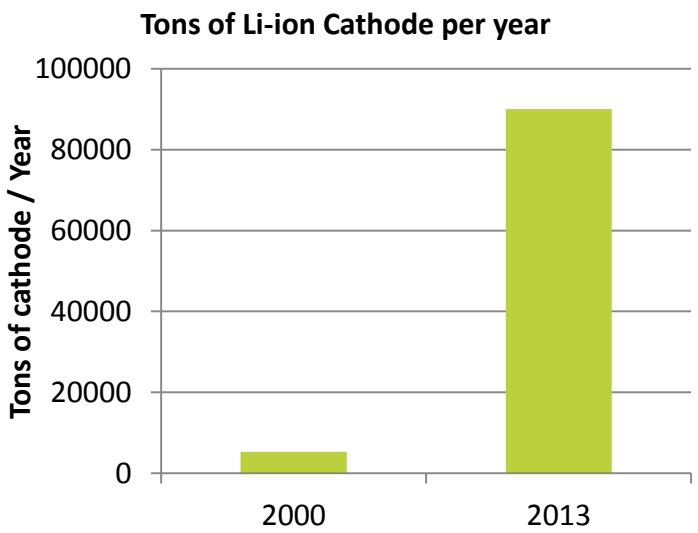
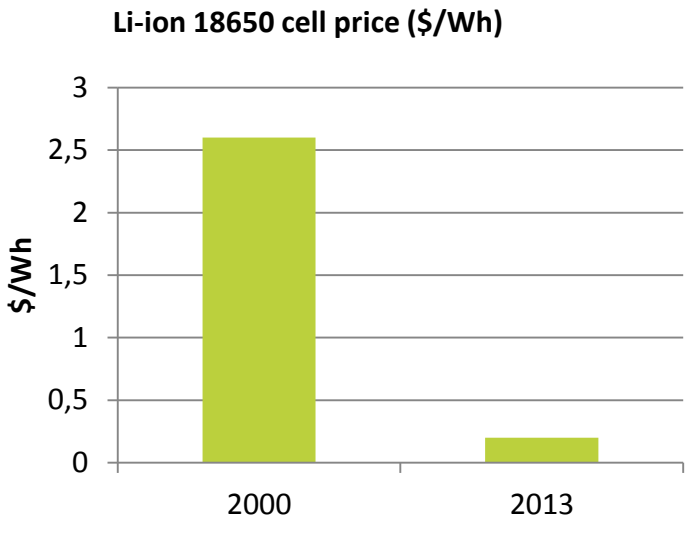
THE BATTERY MARKET IS REALLY DYNAMIC









Source: AVICENNE ENERGY Analyses 2014

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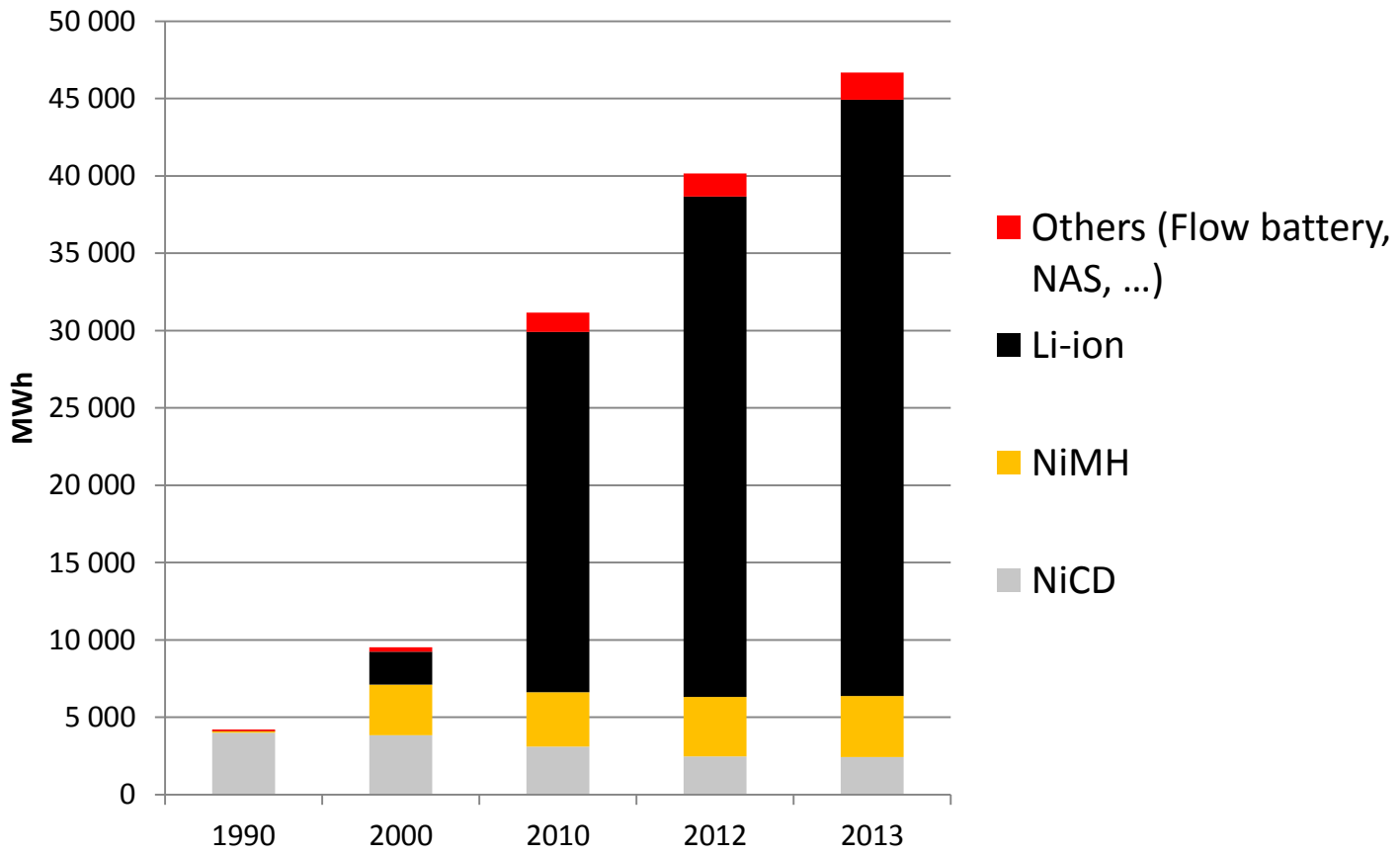
THE WORLDWIDE BATTERY MARKET 1990-2013

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



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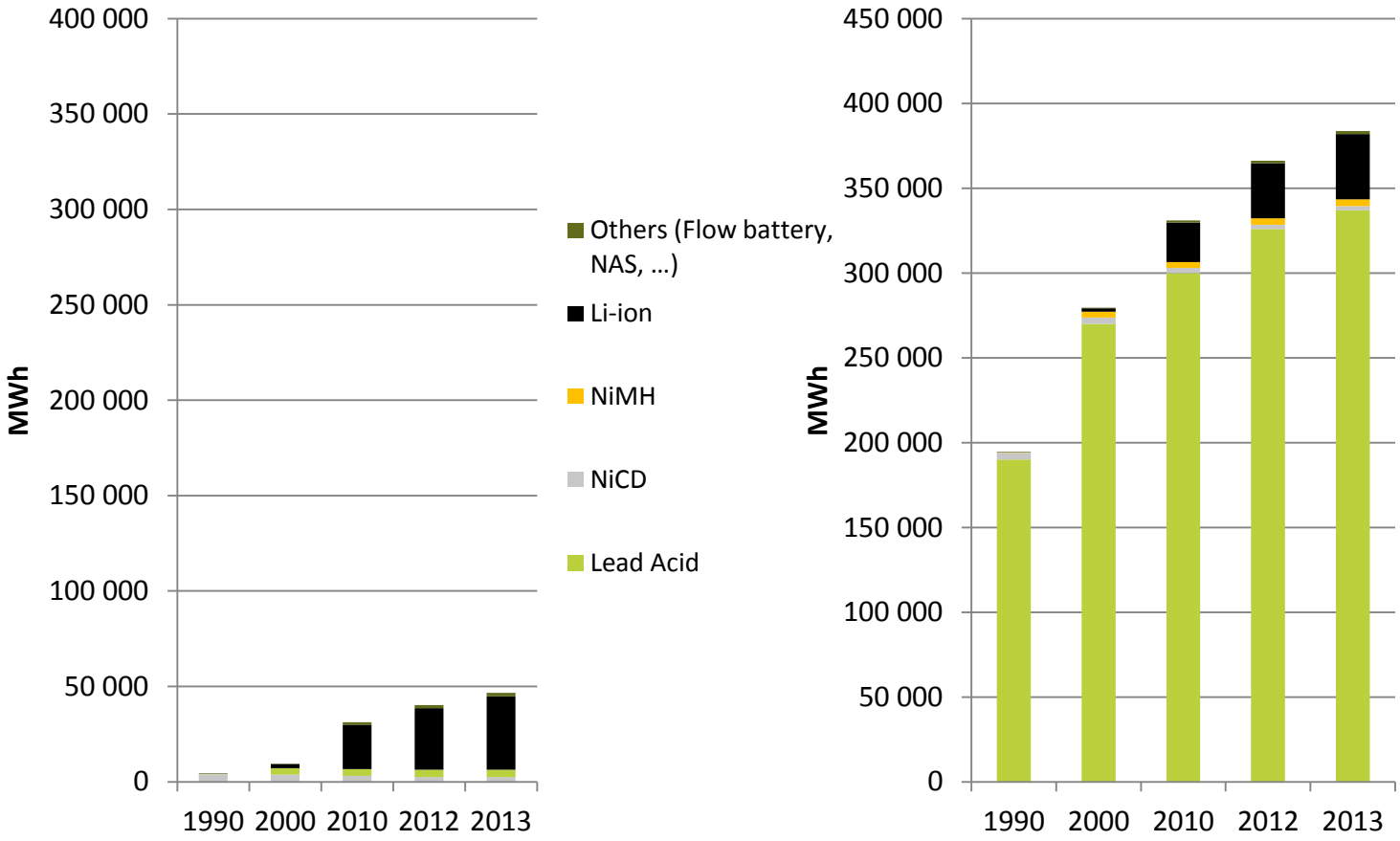
Lithium Ion Battery: Highest growth & major part of the investments
Lead acid batteries: By far the most important market (90% market share)



Source: AVICENNE ENERGY, 2014

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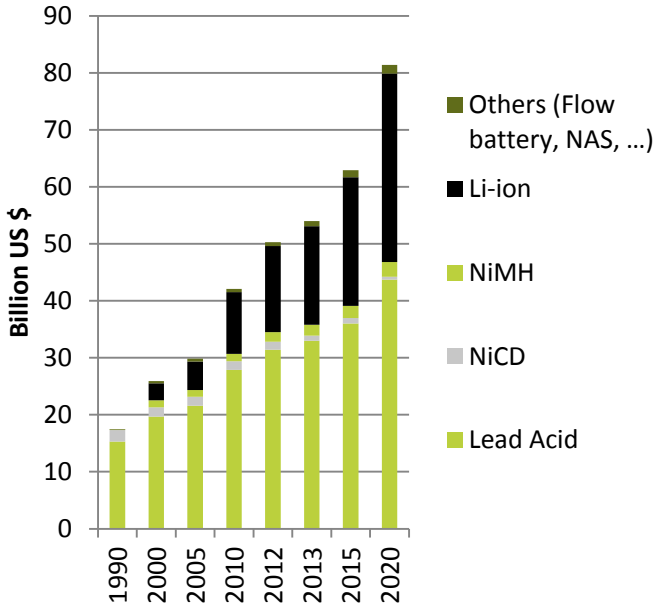
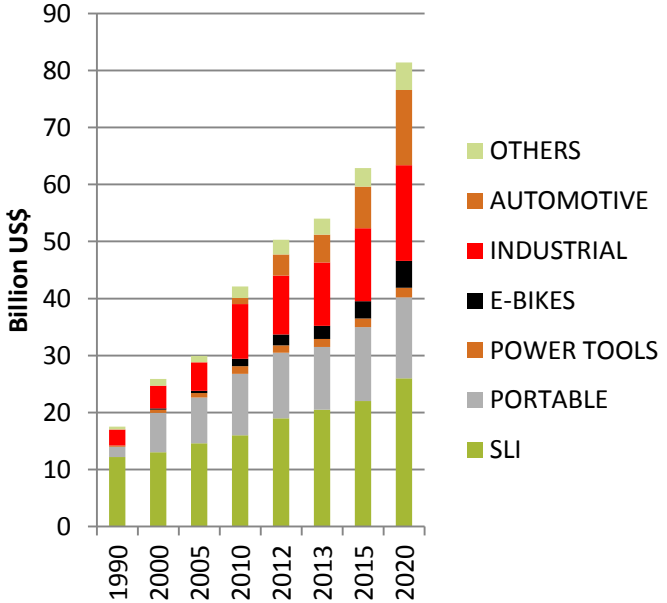
THE WORLDWIDE BATTERY MARKET 1990-2020

54 BILLION US$ in 2013 – Pack level[1]
5% AVERAGE GROWTH PER YEAR (1990-2013)





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

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

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

Source: AVICENNE ENERGY, 2014

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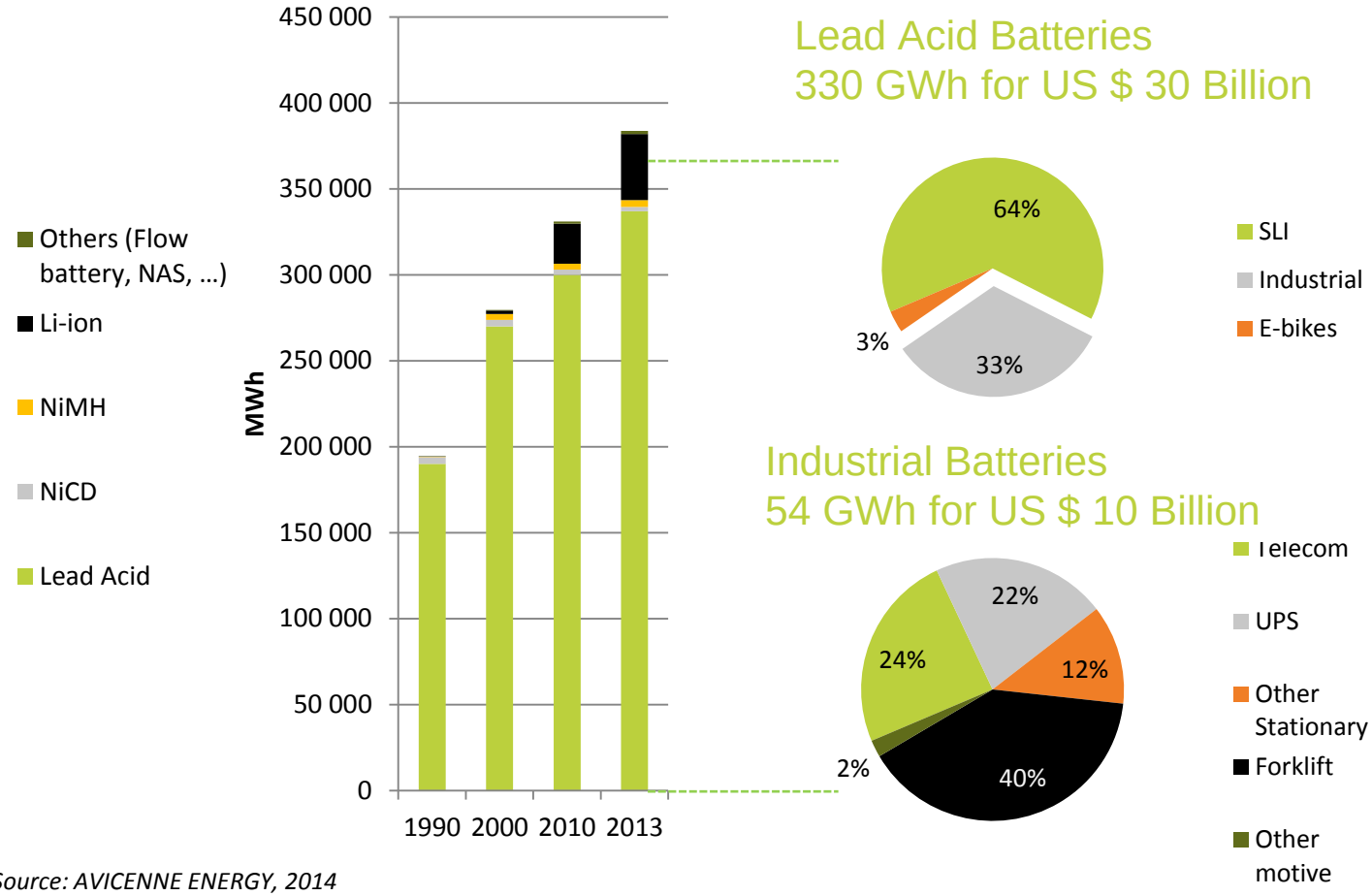

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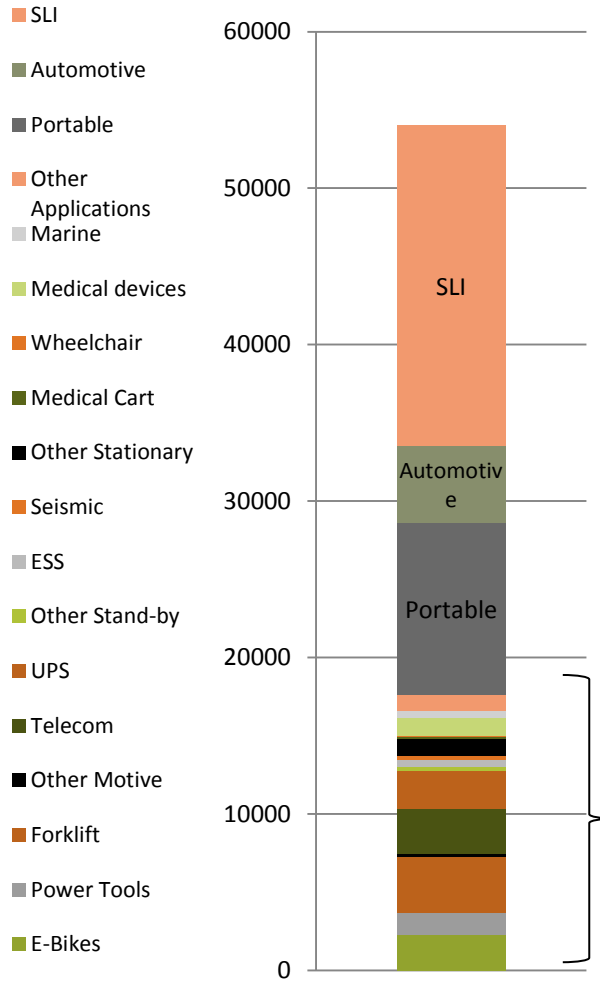
BATTERY FOR OTHER APPLICATION US$ 18 BILLION[1] MARKET

Battery market in 2013 (M$)



Battery Market			M$
Power Tools			1400
E-bikes			2290
Industrial	Motive	Forklifts	3 570
		Others	180
		TOTAL MOTIVE	3 750
	Stationary	Telecom back-up	2 900
		UPS	2 400
		Misc. Standby	315
		ESS	450
		Seismic (1)	210
		Other Stationary	1090
		Total STATIONARY	7 370
	TOTAL INDUSTRIAL		11 120
Medical Cart			150
Wheelchair			47
Medical Device (1)			1150
Marine			450
Others			1 000
TOTAL			17 600

(1) 500 M$ for Li-ion - Source: Zprime 2011

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

Source: AVICENNE ENERGY, 2014

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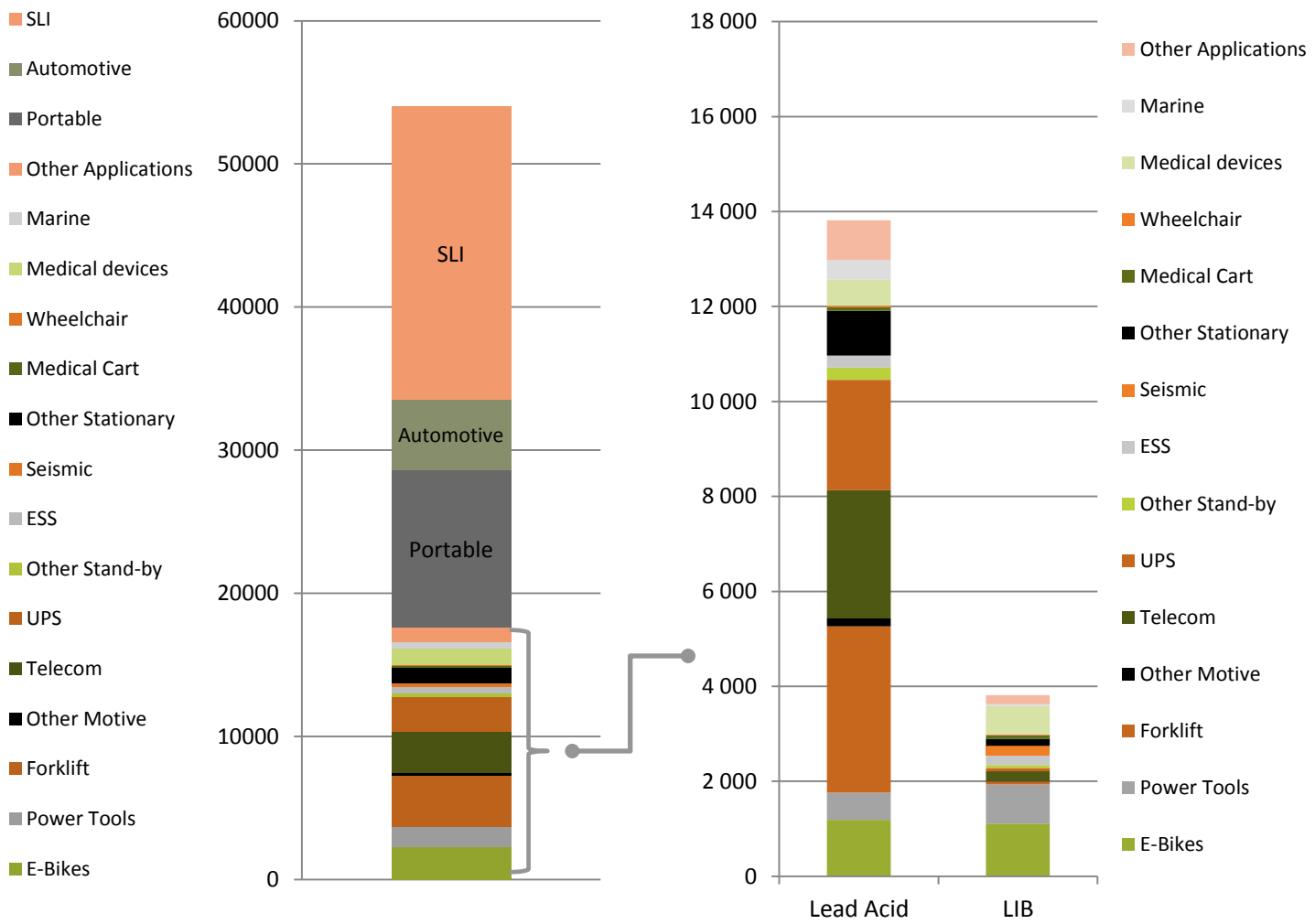
THE WORLDWIDE BATTERY MARKET IN 2013: US $ 54 BILLION

Battery market in 2013 (M$)



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TOTAL POTENTIAL MARKET ANALYZED IN THE SURVEY (M$, PACK LEVEL[1])

Application details

Battery Market			M$
Power Tools			1400
E-bikes			2290
Industrial	Motive	Forklifts	3 570
		Others	180
		TOTAL MOTIVE	3 750
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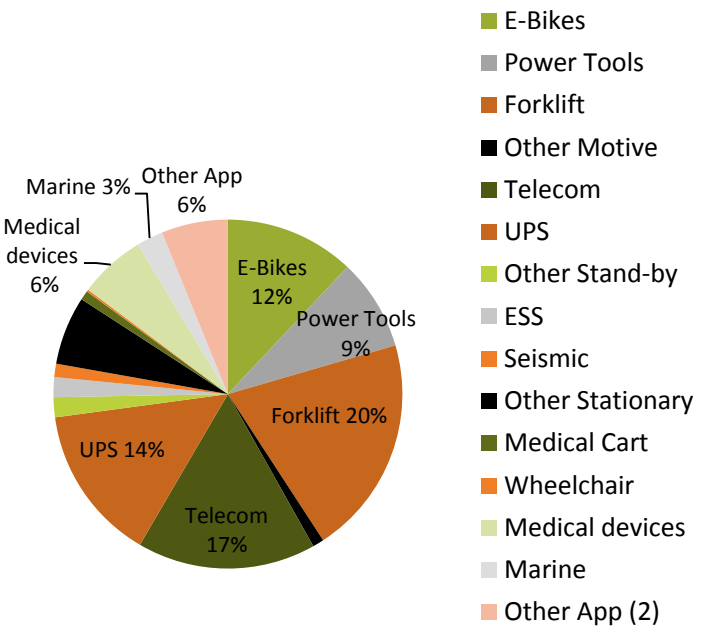
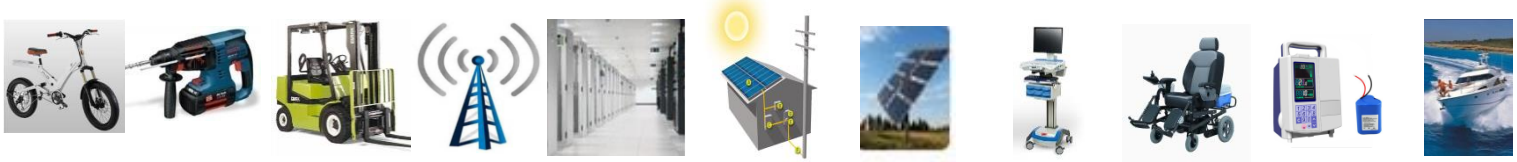
US$ 18 Billion in 2013



1 2 3 4 5 6 7 8 9 10 11



Source: AVICENNE ENERGY 2013

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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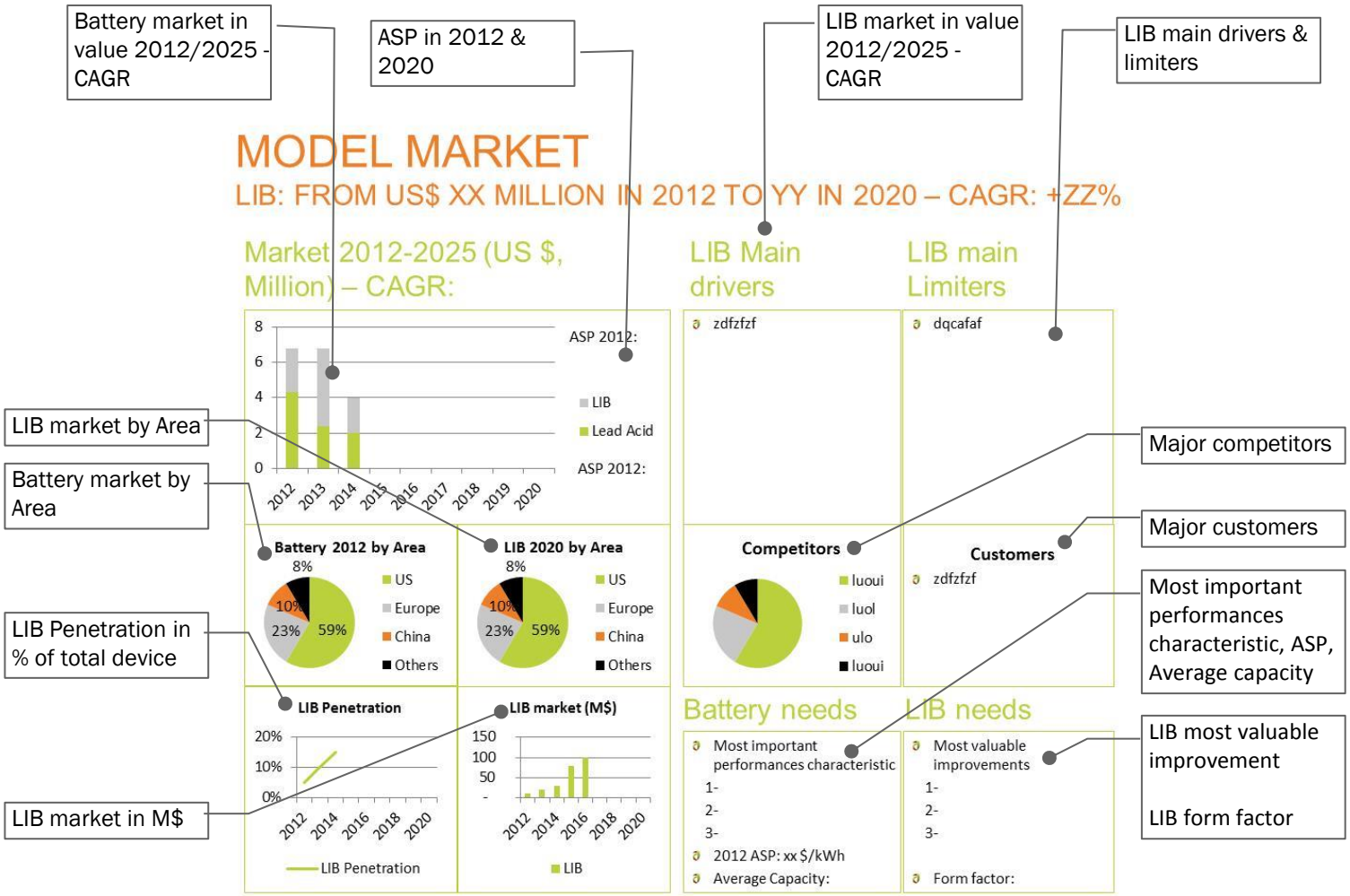
MARKET SEGMENT SYNTHESIS TEMPLATE



Source: AVICENNE ENERGY Analyses

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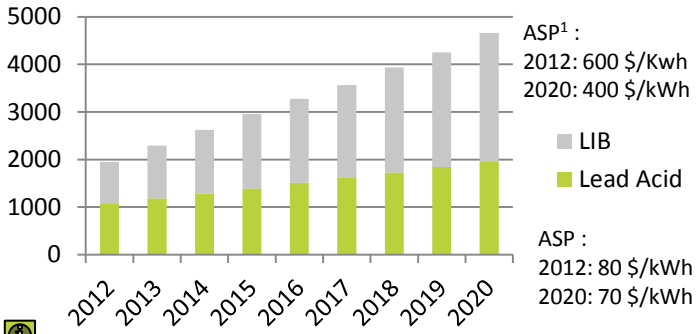
1- E-BIKES

LIB: FROM US$ 1,1 BILLION IN 2013 TO 2,7 IN 2020[1] – CAGR: +18%

Market 2013-2020 (US $, Million) – CAGR: 13%



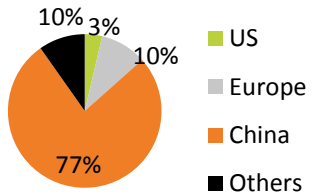
Main drivers

- 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%

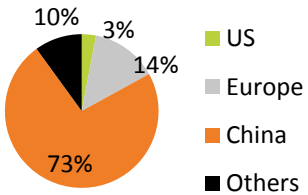
Main Limiters

- 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

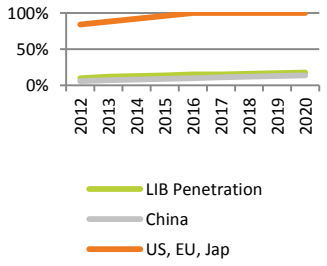
Battery 2013 by Area



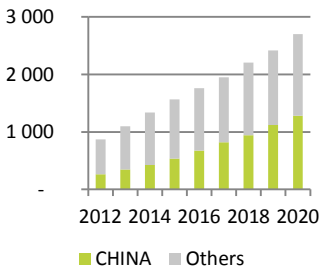
LIB 2020 by Area



LIB Penetration (% device)



LIB market (M$)



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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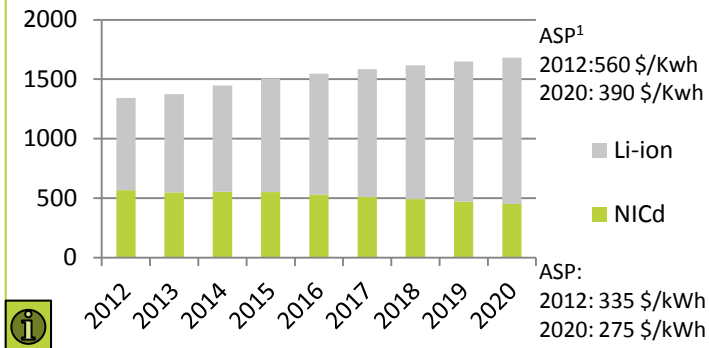
2- POWER TOOLS

LIB: FROM US$ 0,8 BILLION IN 2012 TO 1,2 IN 2020[1] – CAGR: +7%

Market 2013-2020 (US $, Million) – CAGR:+3%



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.

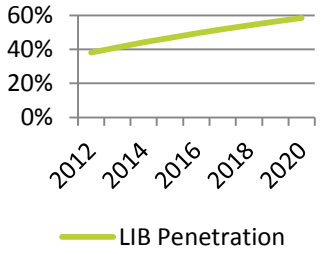
Competitors

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

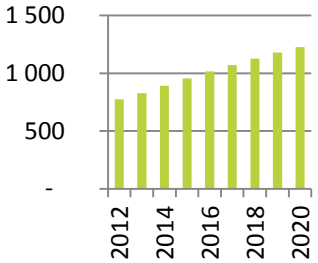
Customers

- 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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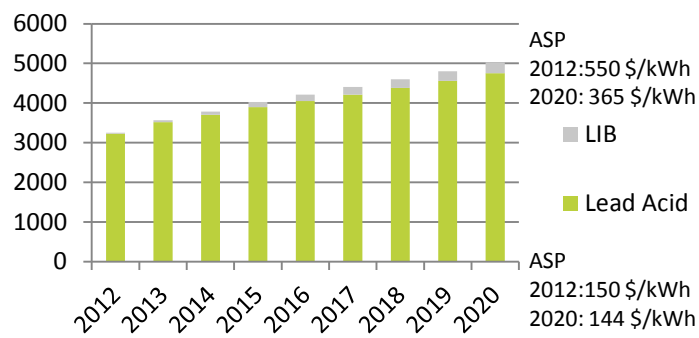
3- MOTIVE INDUSTRIAL: FORKLIFTS[2]

LIB: FROM US$ 60 MILLION IN 2013 TO 375 IN 2020[1] – CAGR: >40%

Market 2013-2020 (US $, Million) – CAGR:7%



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)

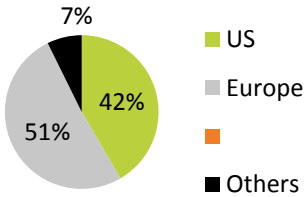
Main Limiters

- 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

Battery 2012 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 2020 by Area



Competitors

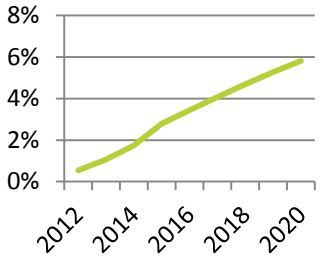
- Lead Acid & LIB: Enersys (35%), Exide (10%), East Penn (10%), Hoppecke (10%), Crown (10%)
- LIB systems: BMZ, Lithium Balance, …

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

LIB Penetration



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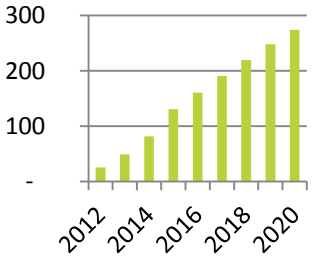

Battery needs

- 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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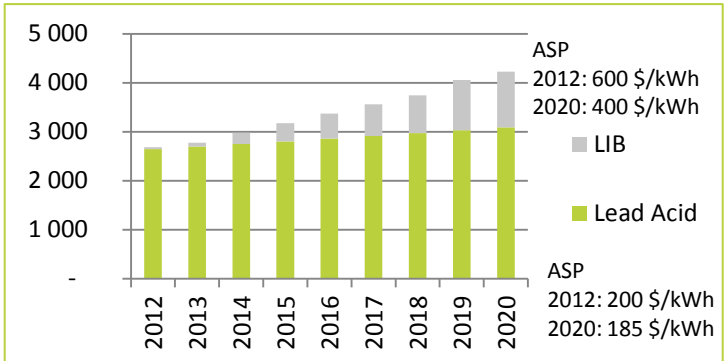
4- STATIONARY: TELECOM MARKET

LIB: FROM US$ 0,2 BILLION IN 2013 TO 1,1 IN 2020[1] – CAGR: >50%

Market 2013-2020 (US $, Million) – CAGR: +7%



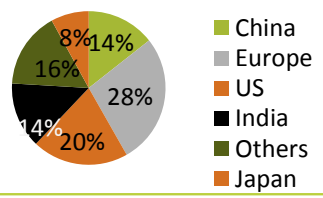
Main drivers

- 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**

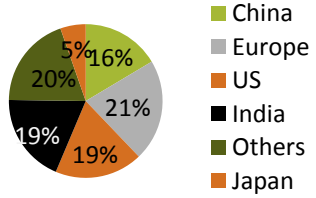
main Limiters

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

Battery 2012 by Area



Battery 2020 by Area



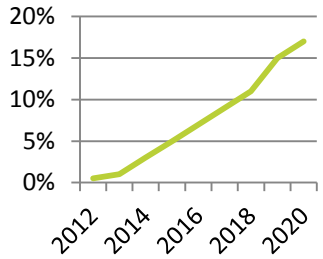
Competitors

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

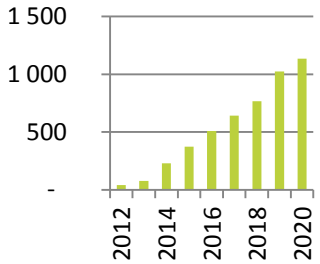
Customers

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

LIB Penetration



LIB market (M$)



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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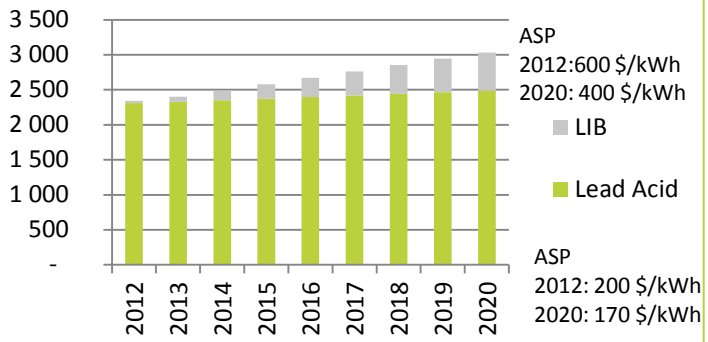
5- STATIONARY: UPS MARKET

LIB: FROM US$ < 0,1 BILLION IN 2013 TO 0,5 IN 2020[1] – CAGR>+40%

Market 2013-2020 (US $, Million) – CAGR: +4%



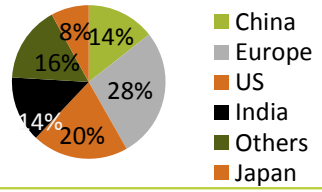
Main drivers

- 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

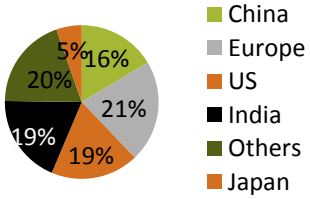
main Limiters

- Safety could be an important issue here

Battery 2012 by Area



Battery 2020 by Area



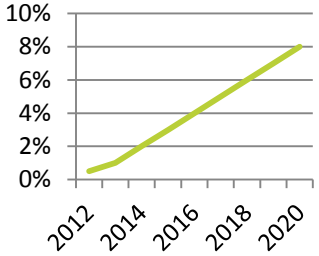
Competitors

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

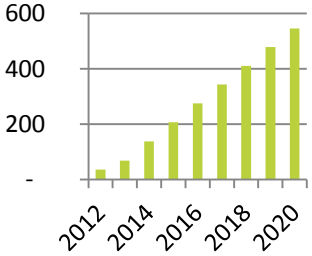
Customers

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

LIB Penetration



LIB market (M$)



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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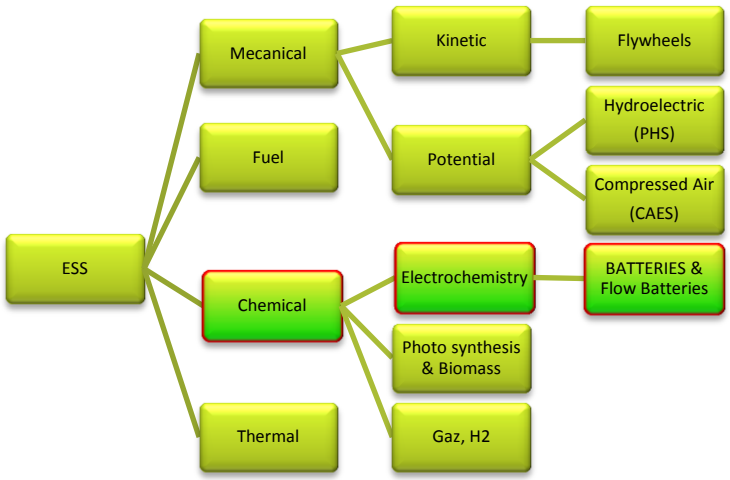
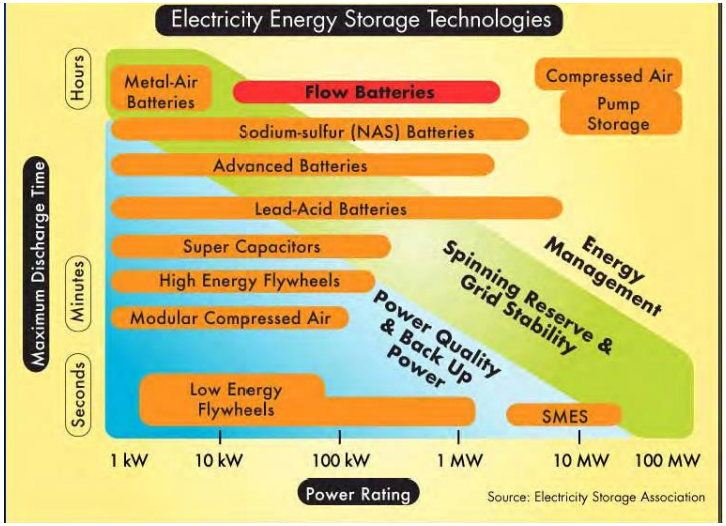
THE BATTERY MARKET FOR ENERGY STORAGE SYSTEM (ESS)

ESS segmentation

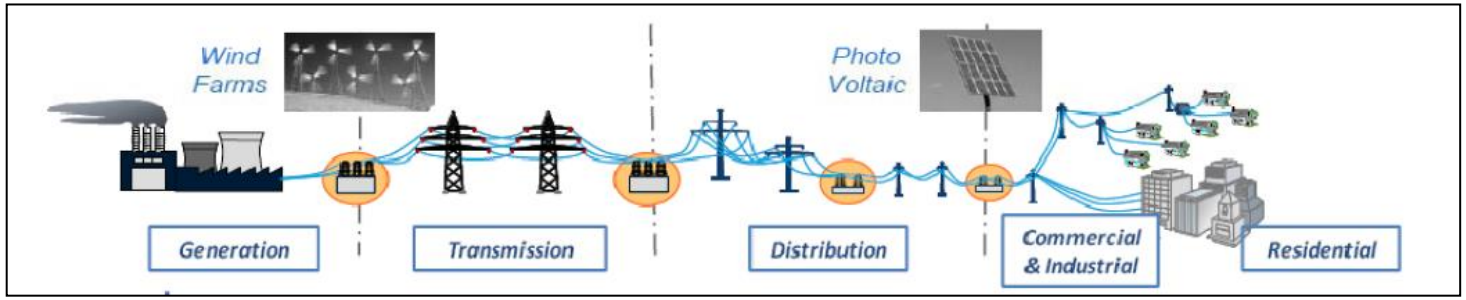


PHS: Pumped Hydroelectric Storage
CAES: Compressed air energy storage

ESS by power rating



Source: Electricity Storage Association



Source: KEMA, Market Evaluation for Energy Storage in the United States, 2012

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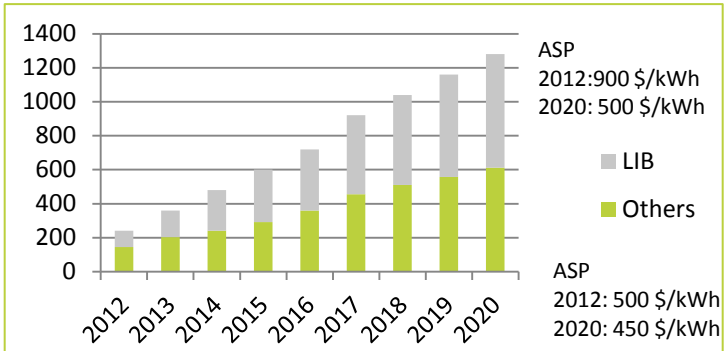
6- ESS (LARGE SYSTEMS[2])

LIB: FROM US$ 0,2 BILLION IN 2013 TO 0,7 IN 2020[1] – CAGR: +30%

Battery Market 2013-2020 (US $, Million) – CAGR: +25%



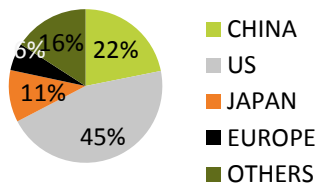
Main drivers

- Integration of Renewable energy
- Poor electricity network
- Gas Turbine Replacement
- Purpose:
  - Frequency Regulation
  - Peak Shifting
  - Load Leveling

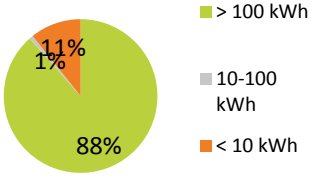
main Limiters

- Not a mature market
- Business model ?
- Regulation?
- Battery capital cost (leasing could be a good solution)

Battery 2012 by Area



Battery 2012 by type



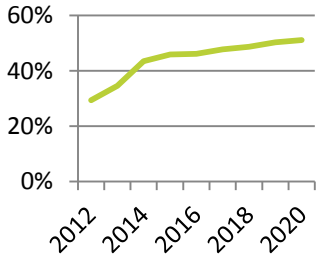
Competitors

- All big LIB suppliers: Panasomic, Samsung, LG, …
- A123,
- Johnson Controls
- Yuasa
- SAFT
- Tesla
- Altairnano
- …

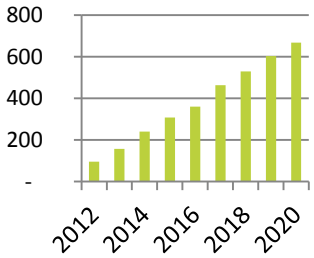
Customers

- Large Electricity providers
- New comers with renewable energy
- Often support by local government

LIB Penetration



LIB market (M$)



Battery needs

- Most important performances characteristic
  1- Life time
  2- Power capabilities
  3- Cost
- Average Capacity: from 10 kWh to MWh

LIB needs

- Most valuable improvements
  1- cost of ownership
- Customized development

Source: AVICENNE ENERGY Analyses

Note: : 1- Pack level – 2- > 10 kWh systems

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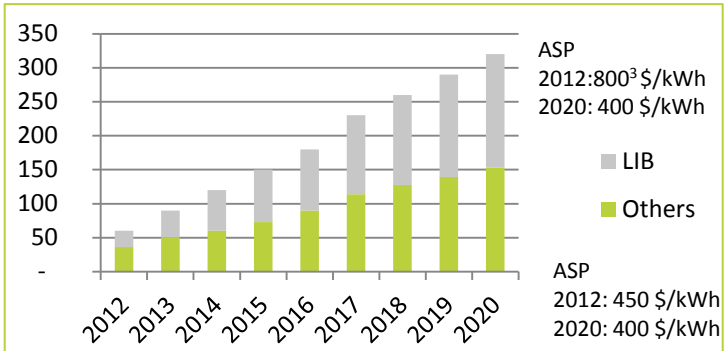
7- ESS (SMALL SYSTEMS)[2]

LIB: FROM US$ 40 MILLION IN 2013 TO 170 IN 2020[1] – CAGR>30%

Battery Market 2013-2020 (US $, Million) – CAGR: +27%



Main drivers

- Residential back-up
- PV Integration
- « Net Zero Energy Home »
- Electricity cost
- Government subsidiaires

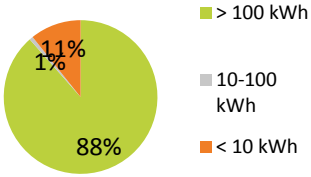
main Limiters

- Not a mature market
- Business model ?
- Regulation?
- Battery capital cost (leasing could be a good solution)

Main countries

- Germany
- France
- US
- Japan

Battery 2012 by type



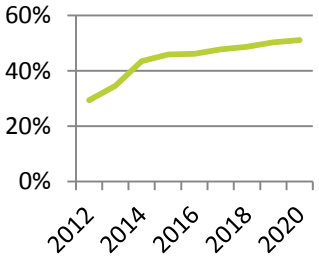
Competitors

- All big LIB suppliers: Panasonic, Samsung, LG, …
- A123,
- Johnson Controls
- Yuasa
- SAFT
- Tesla
- Altairnano
- …

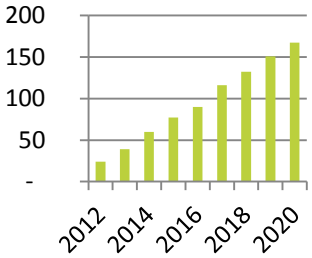
Customers

- Large Electricity suppliers
- Private companies: (Ex: Solarcities, One Energy Corp., SunRun's)
- PV residential solution providers: Panasonic, Kyocera, Sharp, SMA …

LIB Penetration



LIB market (M$)



Battery needs

- Most important performances characteristic
  1- Energy density
  2-Life time
  3- Power capabilities
- Average Capacity: < 10 kWh

LIB needs

- Most valuable improvements
  1- Cost of ownership
  2- Life time
  3- Charge acceptance
- Customized development
- Standardization?

Source: AVICENNE ENERGY Analyses

Note: : 1- Pack level – 2- < 10 kWh systems for home or office
3- Battery pack only, not including the management system, power electronics, installation, …
The total price of a 7 kWh system from SAFT is 10 k€ (1800 $/kWh)

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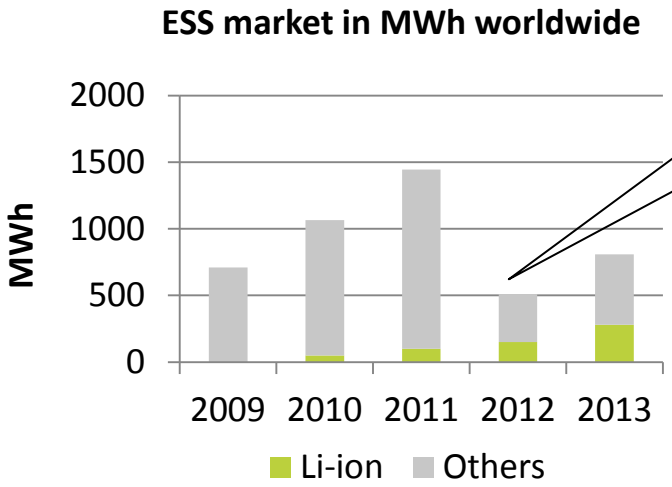
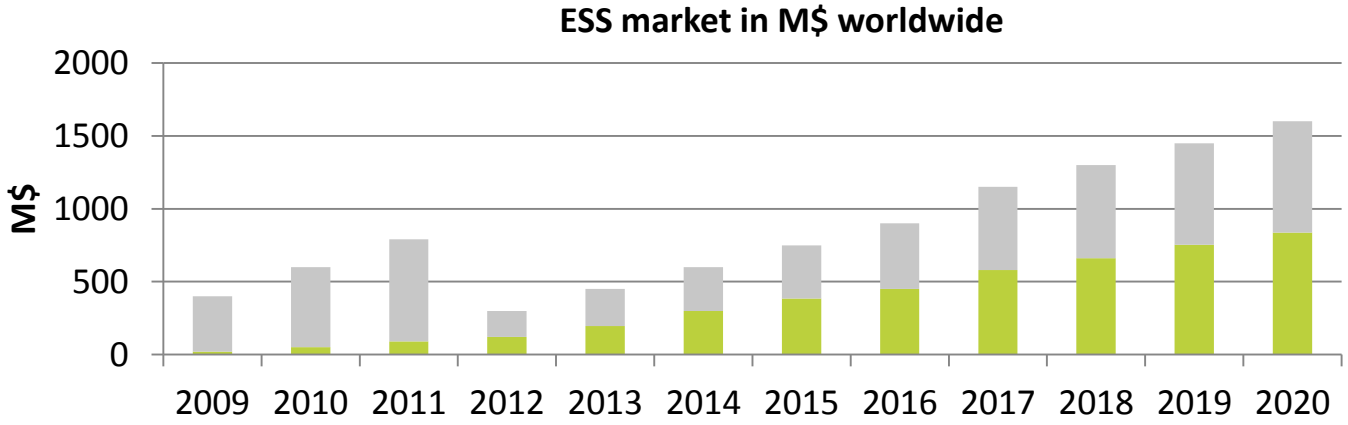
THE BATTERY MARKET FOR ESS IN 2013-2020

AVICENNE ENERGY estimates the ESS market in 2013 < 500 M$

On Sept 2011 NGK-manufactured NaS batteries plant caught fire. Following the incident, NGK temporarily suspended production





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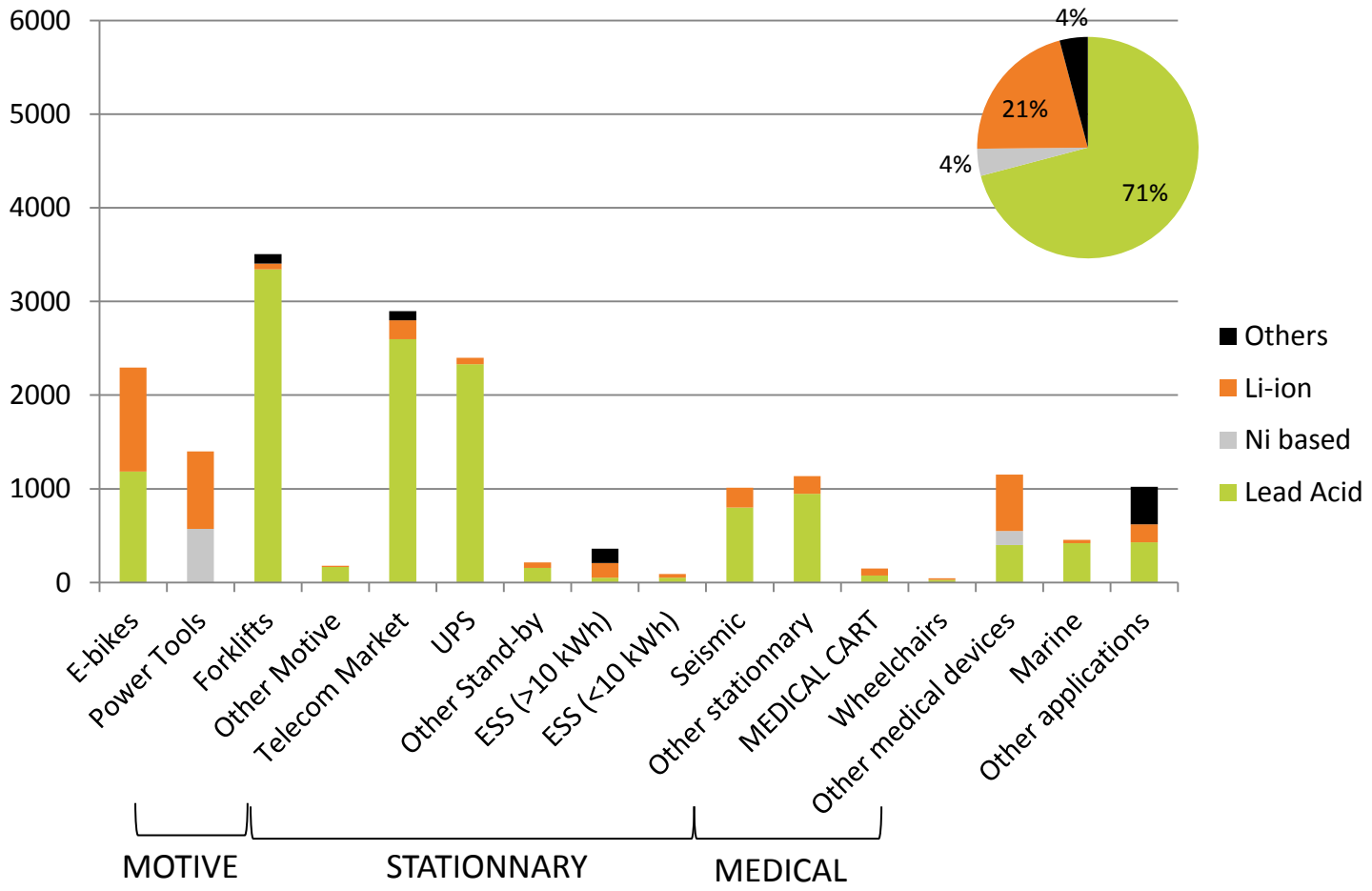
2013 OTHER APPLICATION MARKET US$ MILLION

US $ 18 Billion in 2013



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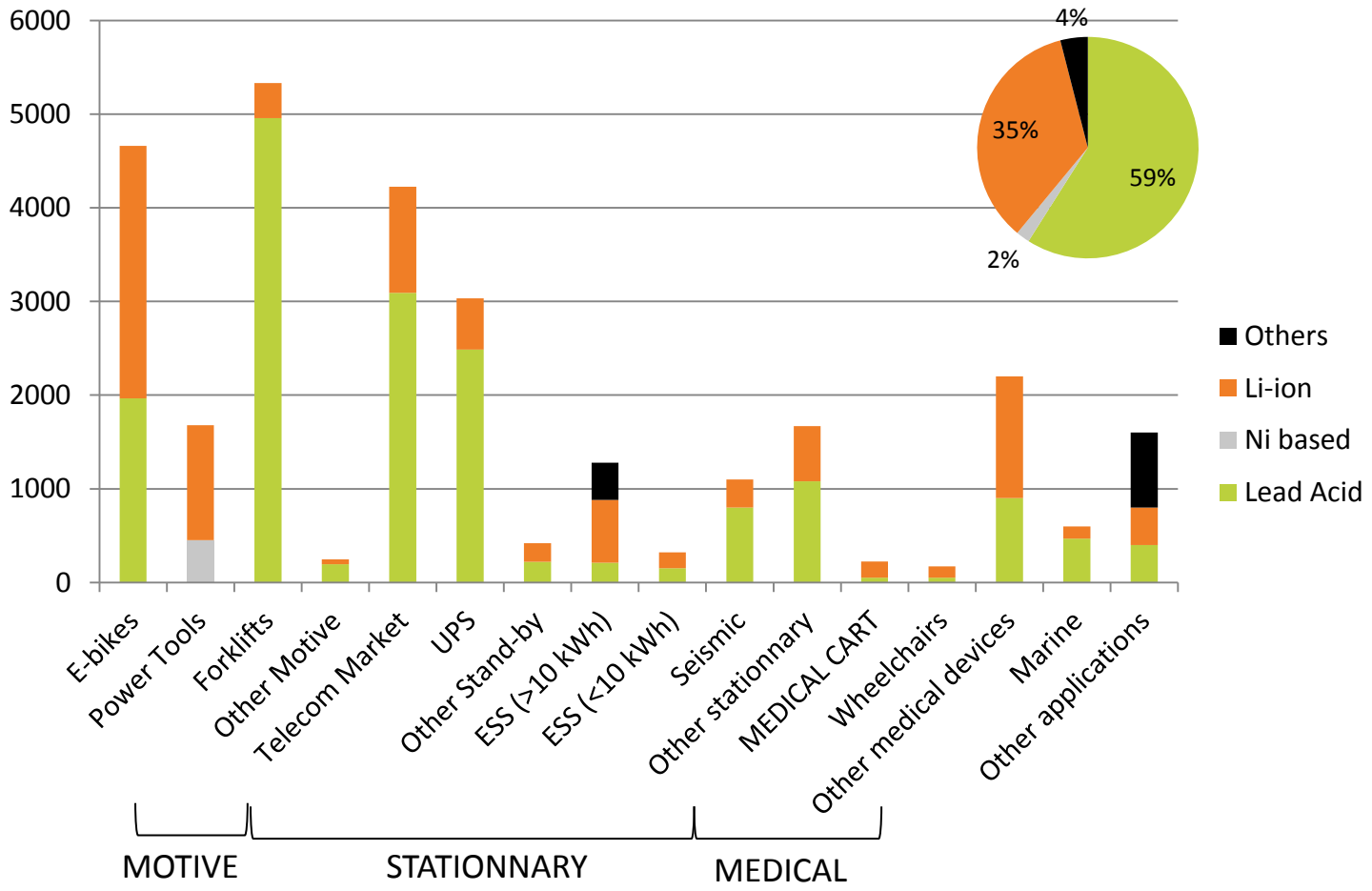
2020 OTHER APPLICATION MARKET US$ MILLION

US $ 28 Billion in 2020 – CAGR 2013/2020: +8%



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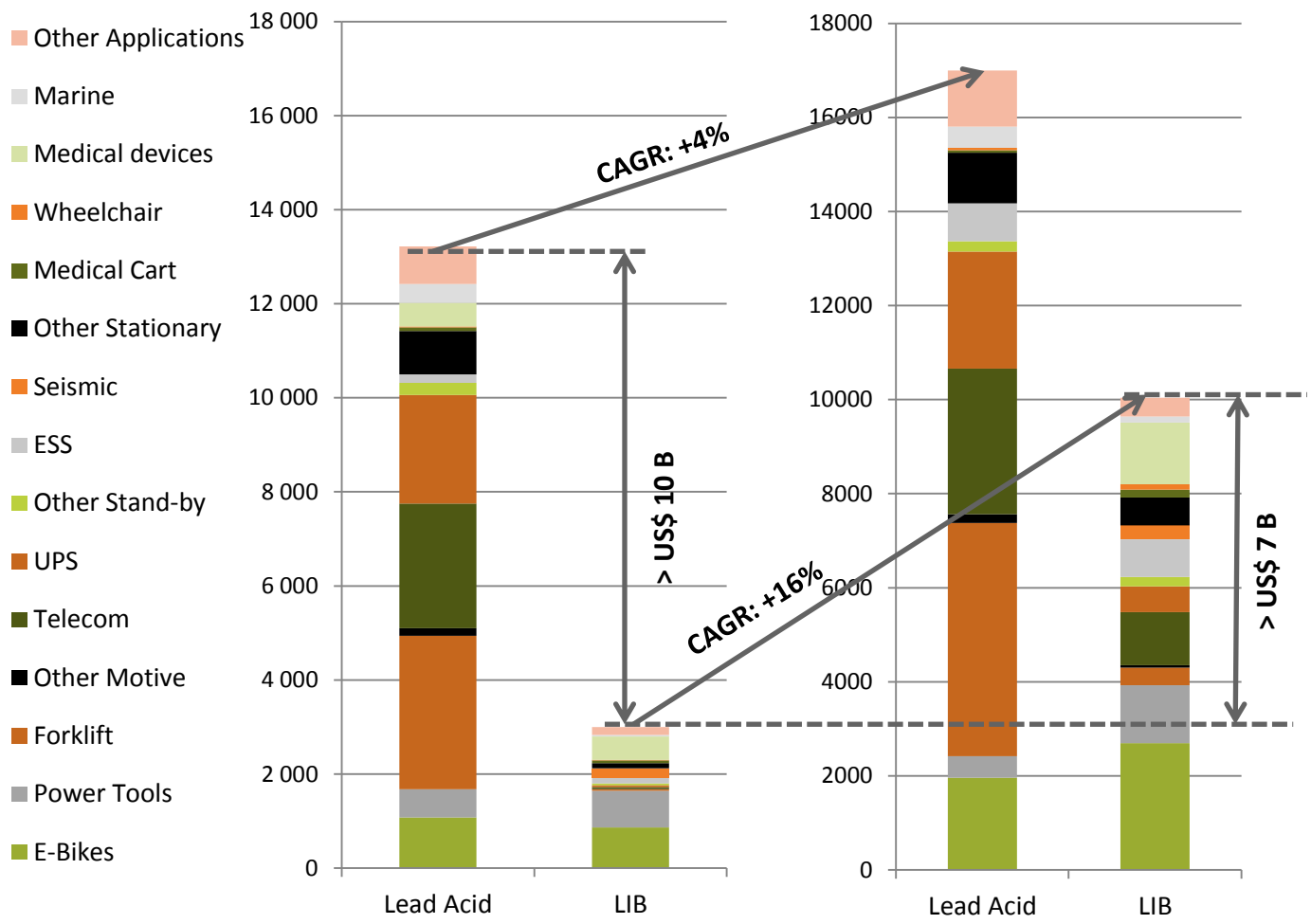
"OTHER APPLICATIONS" 10 B$ POTENTIAL MARKET[1]

Battery market in 2012 (M$) Battery market in 2020 (M$)



Source: AVICENNE ENERGY, 2013

For Power tools, NiCd batteries are used rather than lead acid batteries

1- Pack level

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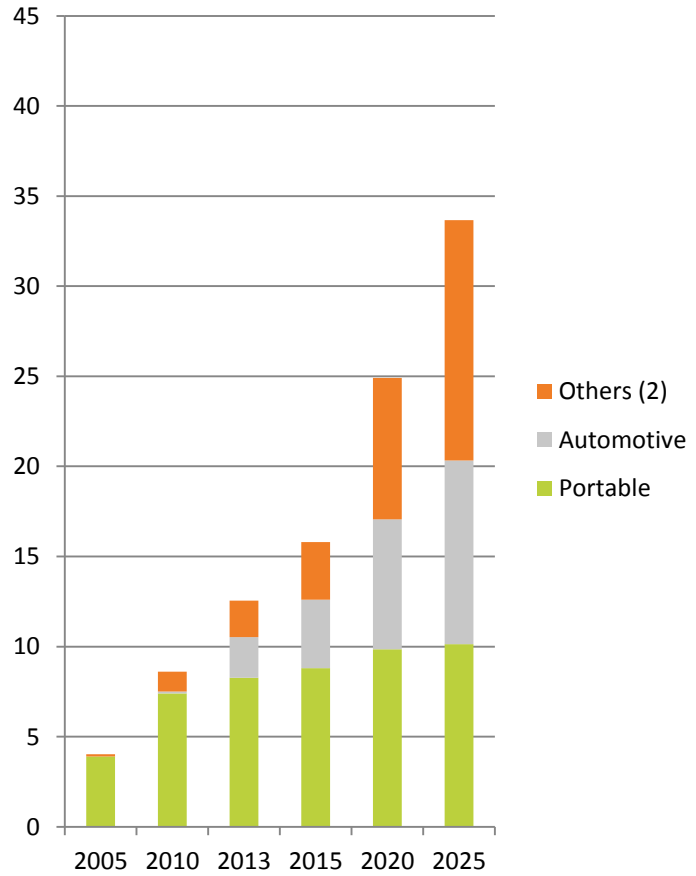
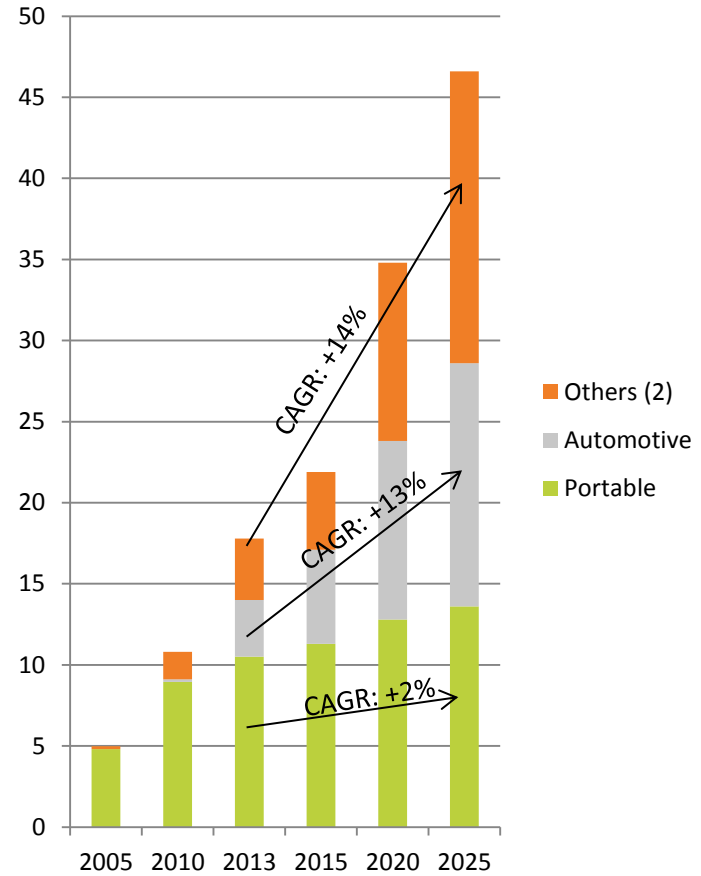
LI-ION CELL & PACK MARKET DETAILS

2013 -2025
- Portable: from 28 to 83 GWh
- Automotive: from 6 to 50 GWh
- « Others »: from 5 to 30 GWh

Li-ion cell market (B$)



Li-ion Pack market[1] (B$)



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

2- Others: Batteries for Power tools, E-bikes, Industrial, medical…

Source: AVICENNE ENERGY Analysis 2014

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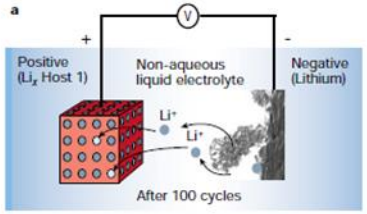
SAFETY ISSUES

Li-ion is 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.

- CONSEQUENCES: 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")
CONSEQUENCES: 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.

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SAFETY IS A SINE-QUA-NON SELECTION CRITERIA FOR BATTERY TECHNOLOGIES

Some technologies are already out of the game due to stability issues

Cathode

	LCO	NMC	LMO	LFP	High V	Sulfur
SAFETY	◕	◑	◔	◔	◕	?
xEV ?	NO	YES	YES	YES	?	?

Anode

	Graphite	Hard Carbon	Soft Carbon	LTO	Si/C	Li Metal
SAFETY	◔	◔	◔	○	◕	◕
xEV ?	YES	YES		No (1)	?	?

Electrolyte

	Liquid	+ Additive	Gel Polymer	5 V	Polymer membrane	Solid
SAFETY	◕	◑	◑	?	◔	○
xEV ?	NO	YES	YES	No	YES	> 2025

Separator

	PE, PP membrane	+ coating	Non woven	Polymer membrane	Solid
SAFETY	◕	◑	◑	◔	○
xEV ?	YES	YES	YES	YES	> 2025

BMS

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

Packaging

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

Thermal

- Thermal management improve both the safety and the life time

○ Very Safe ● Unsafe

(1) Low energy density ; mostly developed for stationary applications, or LV start light & ignition batteries

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

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Lithium-Ion Battery Market: Expansion Beyond Consumer and Automotive

AABC 2015
January 26-29
Mainz, Germany

advanced automotive battery conference
www.advancedautobat.com

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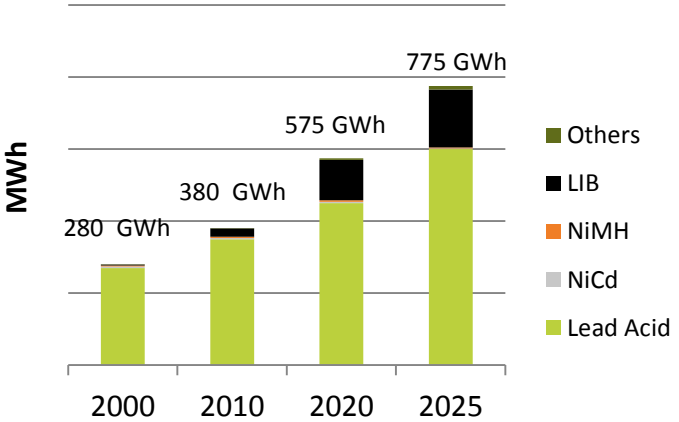
TAKEAWAYS

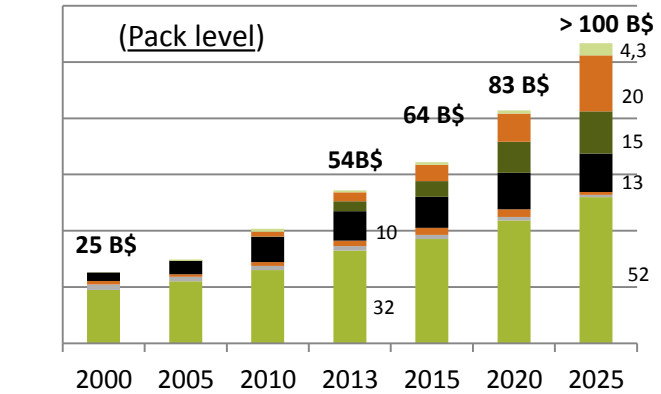
Battery Market 2013-2025

CAGR > +10%

- Li-ion battery is driven today by Portable PCs & electronic devices (smartphones, tablets)
- For HEV, the battery technology is today the NiMH
- In 2012, most of the car makers (except Toyota) switch to Li-ion
- P-HEV & EV will be powered by Li-ion: 6 B$ market in 2015 - 11 B$ in 2020 & 15 B$ in 2025
- EV expectations attract large Chemical companies
- New materials are needed to meet Automotive standards
- HEV will account for less than 5% of the automotive sales in 2020
- P-HEV & EV < 2% by 2020
- Micro-hybrid will achieve >50%
- Lead acid battery will be the first market in 2025 in volume & value
- 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 > 15% in the next 15 years
- In 2020, Energy storage for the grid will represent less than 5% of the total battery market

RECHARGEABLE BATTERY MARKET WORLDWIDE 2000-2025





Lead Acid (+4%)
NiCd (-5%)
NiMH (-4%)
LIB for 3C (+3%)
LIB for xEV (+16%)
LIB for Others* (+16%)
Others

(CAGR 2012-2025)

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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