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INFORMATION FOR GROWTH

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July 11th, 2019

London

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Current Status and Future Trends for the Lithium-ion Battery Market

Focus on Power Tools, Robotics and Cordless Devices

Christophe PILLOT

AVICENNE ENERGY

Presentation Outline

- The rechargeable battery market in 2019
- The Li-ion battery market – Focus on power tools
- Li-ion Battery market Forecasts

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools



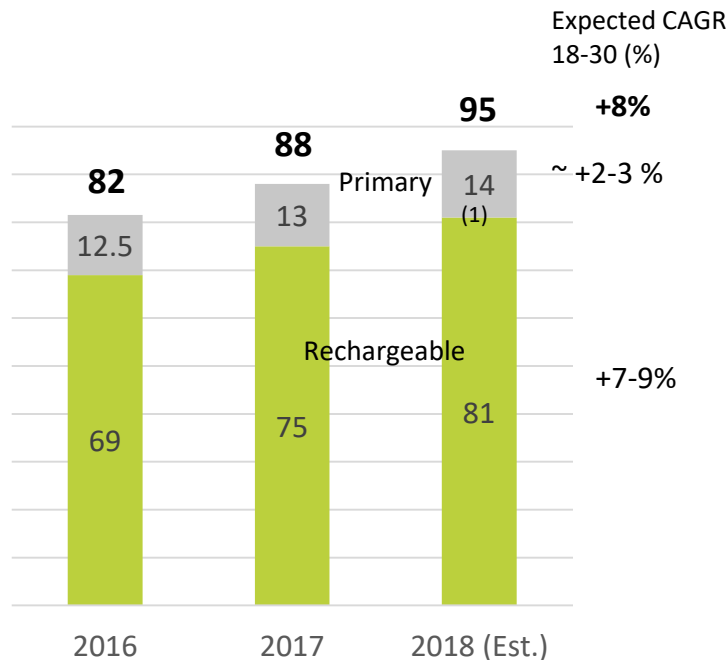
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WORLDWIDE BATTERY MARKET OVERVIEW

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



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

Source: AT Kearney, Duracell, AVICENNE ENERGY 2019

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 CO₂ emissions reduction, government regulations and incentives, social pressure for environmental-friendly solutions)

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools

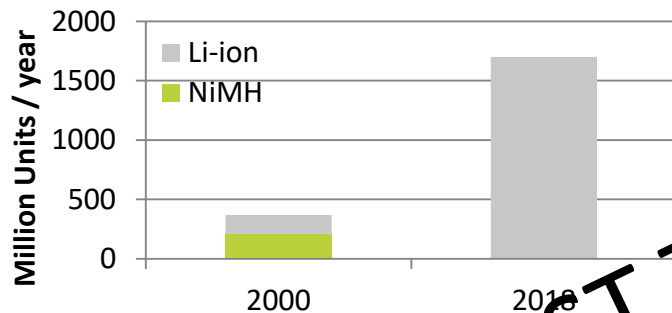


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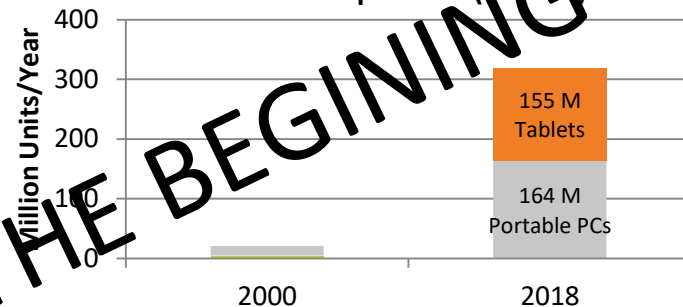
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THE BATTERY MARKET IS REALLY DYNAMIC

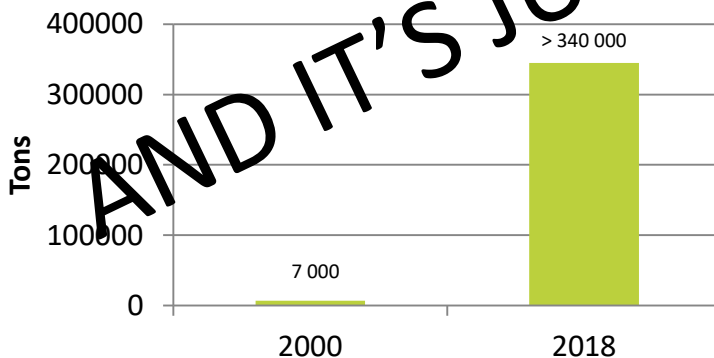
Cellular Phones sold per Year (Million)



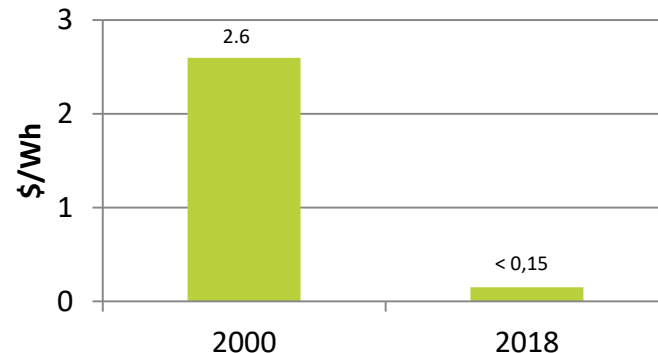
Portable PC sold per Year (Million)



Tons of cathode active materials



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



Source: AVICENNE ENERGY, 2019

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools



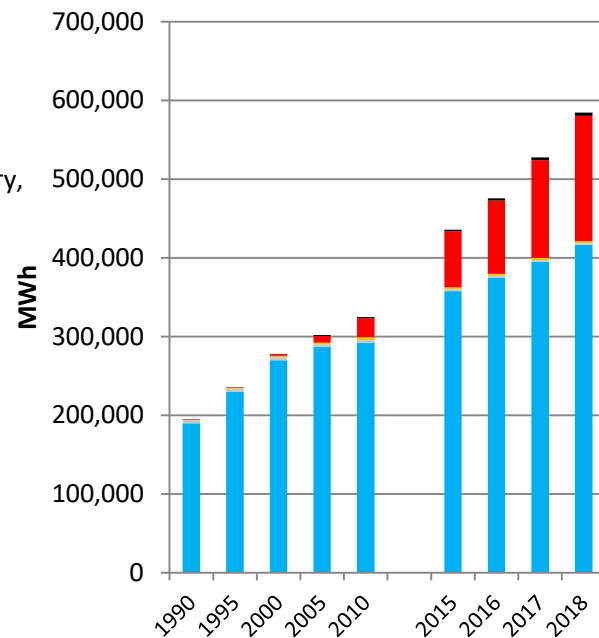
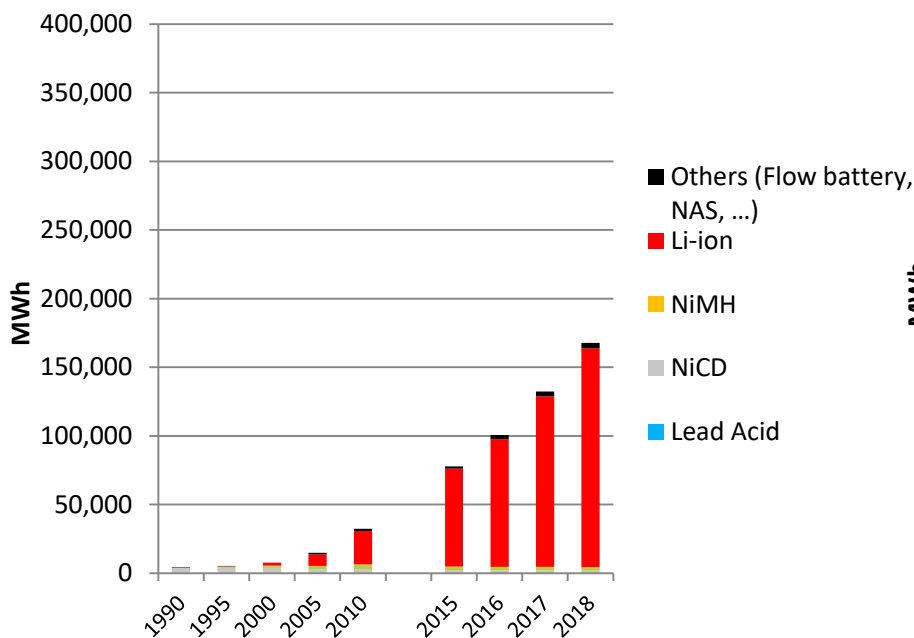
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THE WORLDWIDE BATTERY MARKET 1990-2018

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



Source: AVICENNE ENERGY, 2019

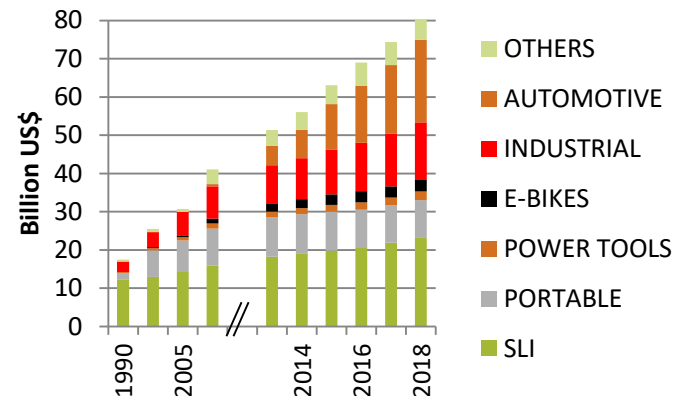
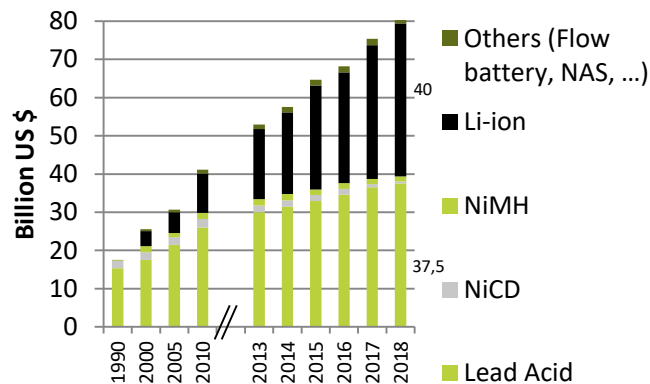
THE WORLDWIDE BATTERY MARKET 1990-2018

80 BILLION US\$ in 2018 – Pack level¹
9% AVERAGE GROWTH PER YEAR (2010-2018)

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools



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

PORTABLE: consumer electronics (cellular, portable PCs, tablests, Camera, ...), data collection & handy terminals,

POWER Tools: power tools but also gardening tools

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

Source: AVICENNE ENERGY, 2019

INDUSTRIAL

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

AUTOMOTIVE: HEV, P-HEV, EV

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

LI-ION IN 2018 - MAIN APPLICATIONS

>160 000 MWh - 31 B\$ (1)

CAGR 2008/2018
+24 % per year in Volume

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools

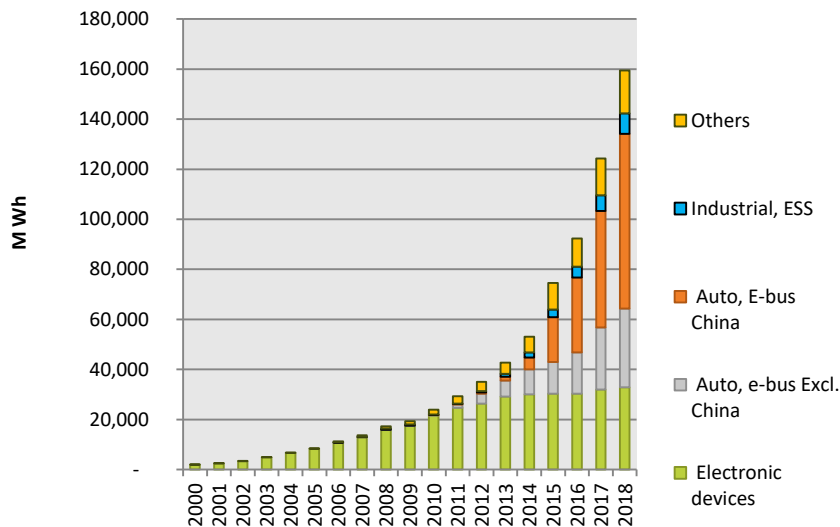


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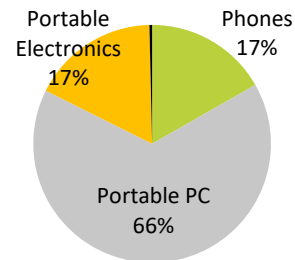
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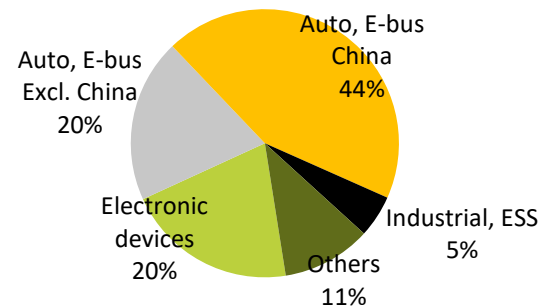
Li-ion Battery sales,
MWh, Worldwide, 2000-2018



2000: < 2GWh



2018: 160 GWh



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

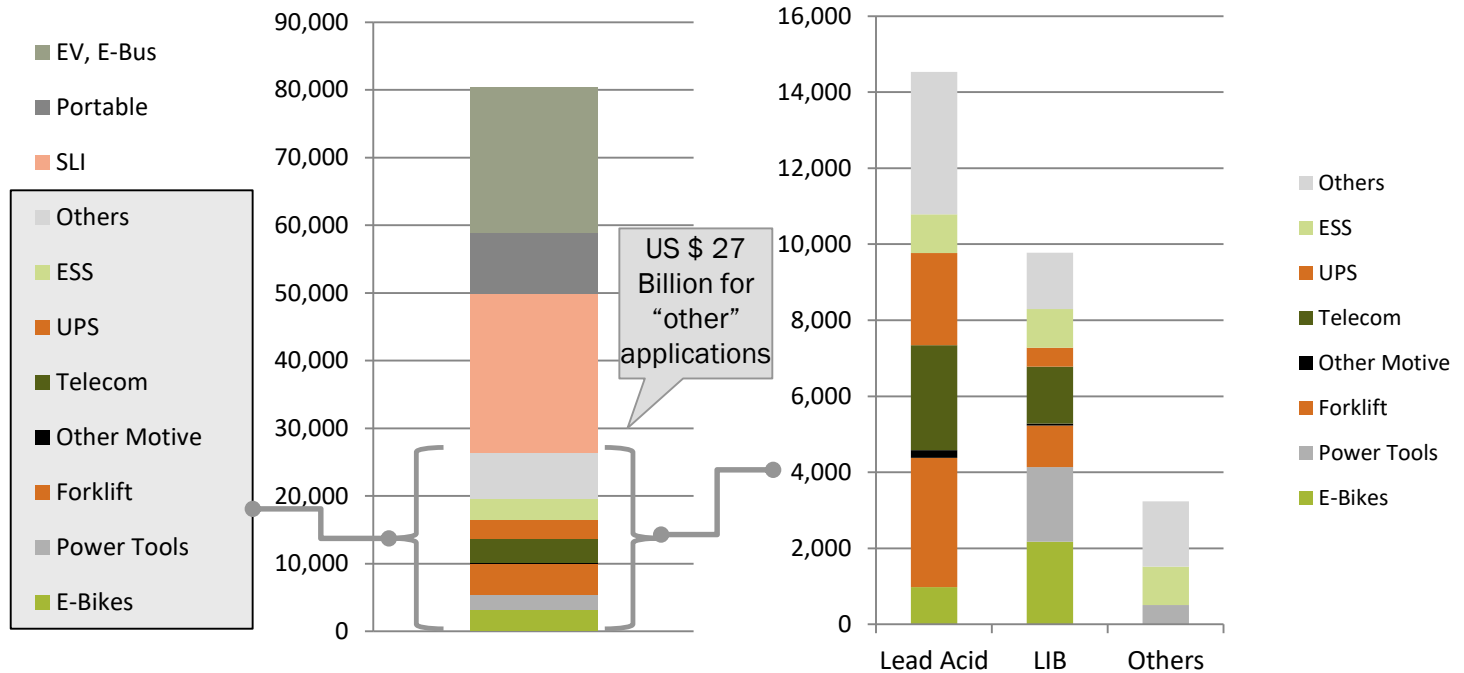


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THE WORLDWIDE BATTERY MARKET IN 2018: US \$ +80 BILLION



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

Source: AVICENNE ENERGY, 2019

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BATTERY MARKET FORECASTS 2018-2030

Applications covered

- 🔋 Portable PCs, net-book, Ultra-book
- 🔋 Cellular Phones, Smart-phones
- 🔋 Tablets
- 🔋 Power Bank
- 🔋 Camcorders
- 🔋 **Cordless Tools, Gardening tools**
- 🔋 Digital Camera
- 🔋 Games, MP3
- 🔋 Cordless Phones
- 🔋 Shavers, Toothbrush,
- 🔋 RC Cars, Toys
- 🔋 Drones
- 🔋 Hoverboard
- 🔋 E-bikes
- 🔋 **Power tools**
- 🔋 Security lighting
- 🔋 Vehicles: HEV, P-HEV, **EV, E-buses, Tram,**
- 🔋 Industrial motive (forklift)
- 🔋 Industrial stationary (UPS, Telecom)
- 🔋 **Medical**
- 🔋 Energy Storage (Small / large)



Parameters analysis

- 🔋 Main segment trends
- 🔋 Power need trends (volume, weight, capacity, running time)
- 🔋 Penetration rate for each Chemistry, each form factor,
- 🔋 2018 -2030 Forecasts
- 🔋 OEM strategies and positions
- 🔋 Main drivers & limiters

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools

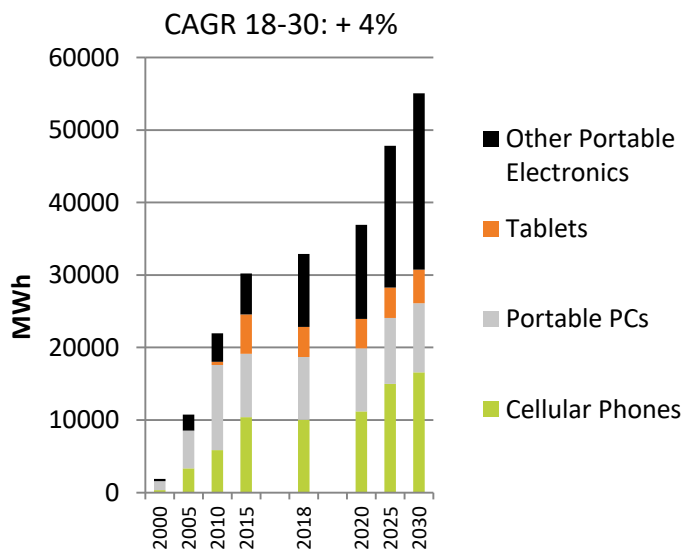


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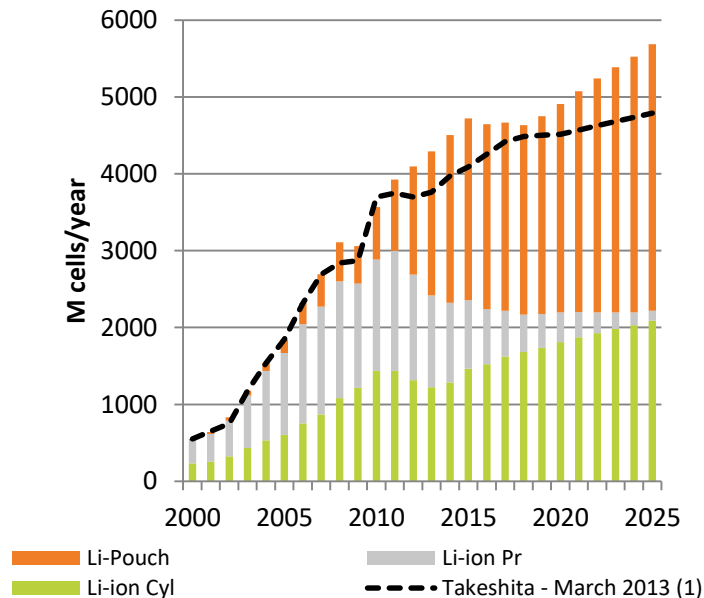
2030 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

2000-2030 LIB market, MWh, by application (3C)



Source: AVICENNE ENERGY Analyses

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



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

HEV, P-HEV, EV 2030 FORECASTS

Realistic Scenario

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools

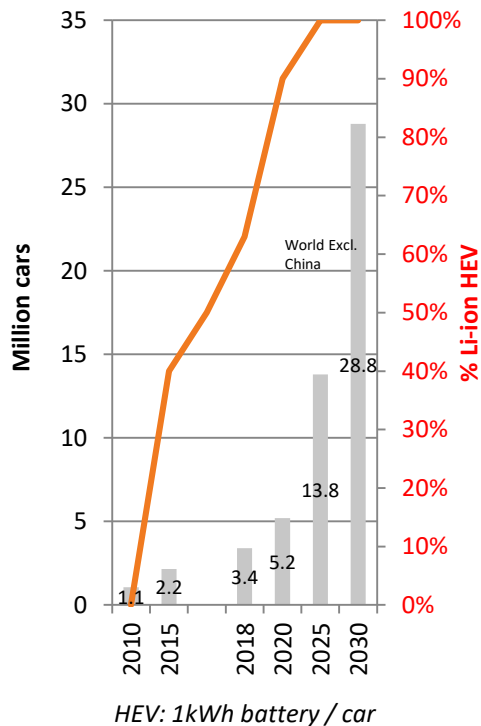


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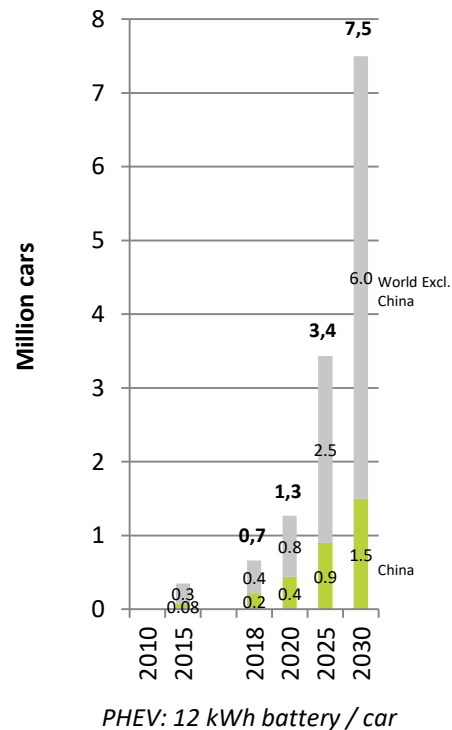
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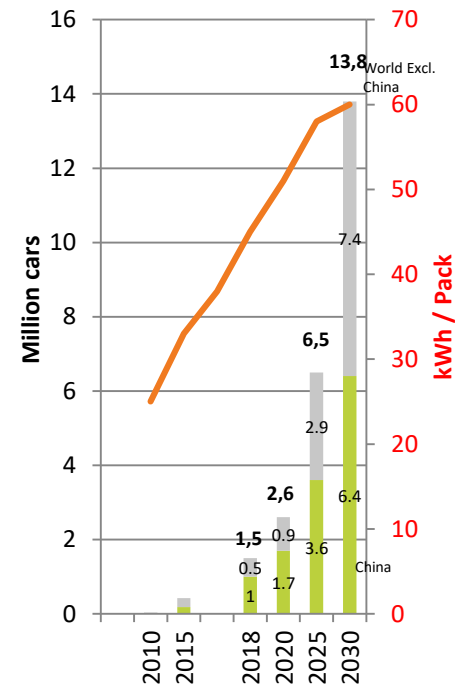
HEV manufactured



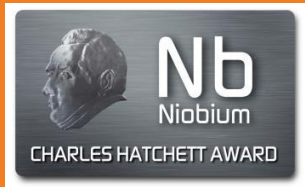
PHEV manufactured



EV manufactured



Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools



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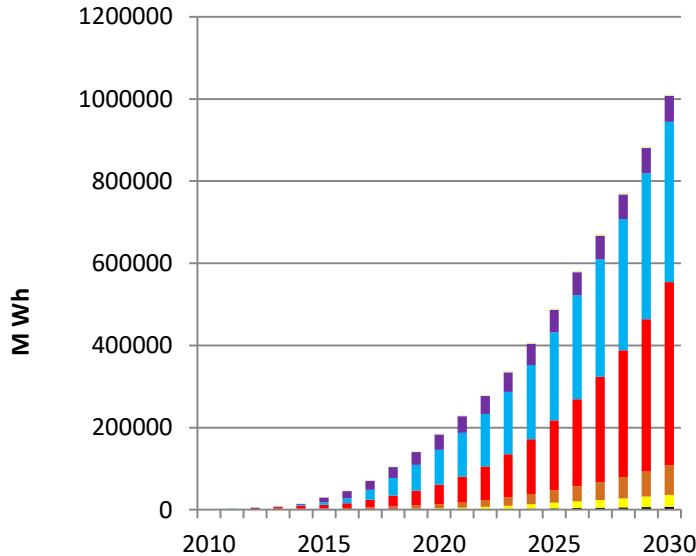
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TOTAL BATTERY DEMAND FOR XEV 2030 FORECASTS (REALISTIC SCENARIO)

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

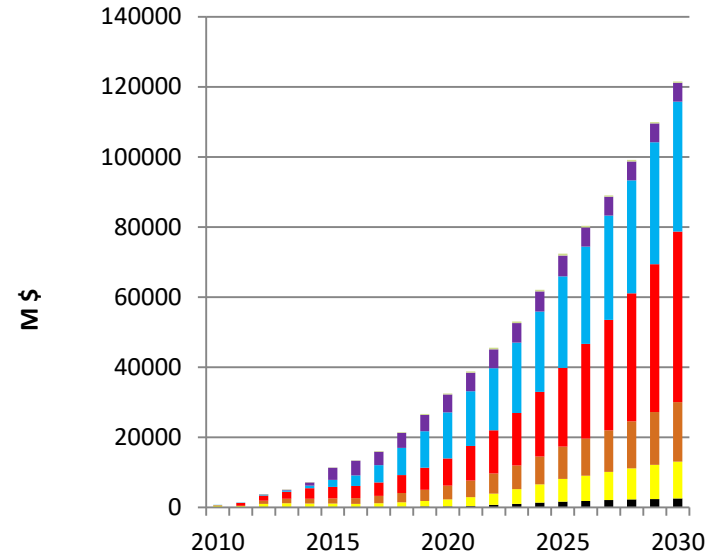
CAGR 2015-2030: +26%



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

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

CAGR 2015-2030: +18%



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



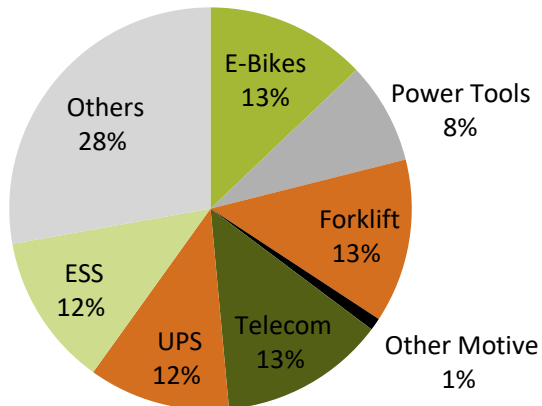
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TOTAL POTENTIAL MARKET (M\$, PACK LEVEL¹)

Application details

US\$ 25 Billion in 2017 (1)



Source: AVICENNE ENERGY 2017



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,...



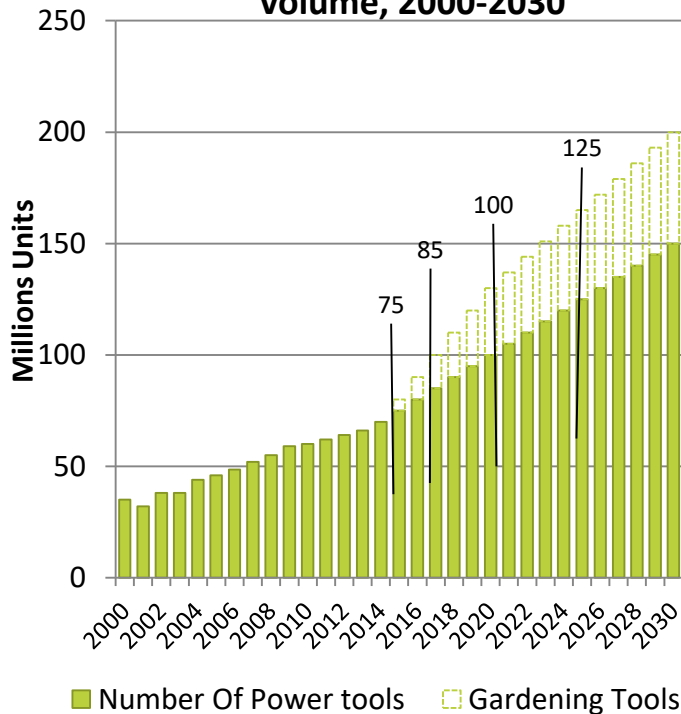
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POWER TOOLS MARKET 2000-2030

Power Tools market worldwide, in volume, 2000-2030



| In Million units | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|------------------|-------------|-------------|-------------|-----------|-----------|-------------|-----------|-----------|
| Bosch | 8,8 | 9,2 | 9,5 | 10 | 10 | 10,7 | 11 | 10,5 |
| B&D | 9,5 | 9 | 9,5 | 9,75 | 10 | 11,3 | 12,5 | 14,5 |
| TTI | 8 | 8,5 | 9 | 9,75 | 12 | 14,5 | 17 | 19,5 |
| Makita | 7 | 7,5 | 8 | 8 | 8,5 | 7,8 | 7 | 6,1 |
| Metabo | 4,2 | 4,2 | 4 | 4 | 4 | 4,3 | 5 | 5 |
| HITACHI | 2,5 | 2,4 | 2,2 | 2 | 2 | 2 | 1,5 | 0,8 |
| HILTI | 2 | 2 | 2 | 2 | 2 | 2,2 | 2,5 | 3 |
| PANASONIC | 0,6 | 0,5 | 0,5 | 0,5 | 0,5 | 0,6 | 0,5 | 0,4 |
| OTHERS | 18 | 19 | 20 | 20 | 21 | 21,2 | 23 | 25,2 |
| TOTAL | 60,6 | 62,3 | 64,7 | 66 | 70 | 74,6 | 80 | 85 |



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POWER TOOLS

LIB: FROM US\$ 2 BILLION IN 2018 TO 3,5 B IN 2030¹ – CAGR₁₅₋₃₀: +7%

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools

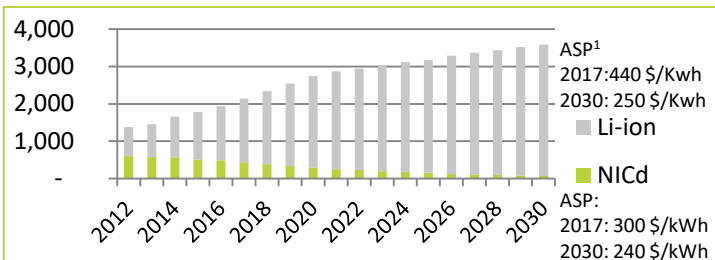


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Market 2017-2025 (US \$, Million) – CAGR:+5%



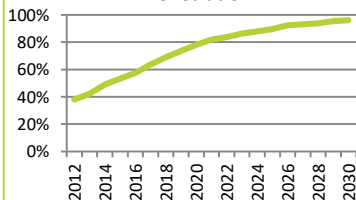
Battery 2013 by Area

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

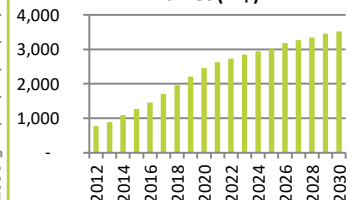
LIB 2020 by Area

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

LIB Penetration



LIB market (M\$)



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

Competitors

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

Customers

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

Battery needs

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

LIB needs

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

Source: AVICENNE ENERGY Analyses

Note: : 1- Pack level



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POWER TOOLS

| | |
|-------------------------|---|
| Major criteria required | Energy density – One day working without recharge Specific project: handy screwdriver with a contactless dock for quick charging High power |
| Actual technology | NMC 622 & NMC 811 for the major part of the market ; LTO for special project like Hilti handy screwdriver with a contactless dock for quick charging (LTO) |
| Unmet needs if any | One day work without recharge – Fast charge |
| Market potential | 18650 cells for power tools in 2018: >500 Millions US\$ 2 Billion market in 2018, will double in 2025 + Gardening Tools potential |
| Entry barriers | Market acceptance Convince battery mfg as well as power tools mfg. |



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MEDICAL TOOLS



Potential application for small medical tools

| | |
|-------------------------|--|
| Major criteria required | Energy density Fast charge High power Heat resistance (for better sterilization) |
| Actual technology | Li-ion LFP, NMC, NCA Li-ion LTO can support high temperature (sterilization process) – LFP (Stryker) |
| Unmet needs if any | High T°C resistance for steam sterilization, like the tools rather than using Gama sterilization. |
| Market potential | In the range of Million battery pack/ year (50 MWh / USD 50 Mn) – Small series for special product High T° resistant for sterilization (To design battery integrated in the device), High cycle life and life time High T° resistant for sterilization the device and the battery together (Depuy-J&J) To replace the LTO in high temperature during the sterilization process (EasyLi) |
| Entry barriers | Time to market 5 years (Stryker) FDA regulation Need long term customer partnership - |

Sources: Stryker, De Soutter, Depuy-J&J, EasyLi, AVICENNE ENERGY Analysis



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E-BUSES (FAST CHARGE E-BUSES, E-TRAM)



Power batteries using Niobium could be very well adapted for very fast charge e-buses (fast charged at each station)

| | |
|-------------------------|---|
| Major criteria required | High power (very fast charge) High cycle life (100s cycles per day) 10 to 15 years calendar life – 600 000 km - > 500 000 cycles ¹ |
| Actual technology | Diesel – Most of European cities have plan to switch to full Electric For Electric buses: Li-ion (LFP in China), NMC outside China. (Exemple of contracts: Volvo-Saft (LFP, NCA) / Daimler-Bolllore (LMP), Super Cap (PVI supply Watt system to Aéroport de Nice Shuttle). PVI was bought by RENAULT in Feb 2017 |
| Unmet needs if any | Green Transportation Life cycle, life time Energy density for standard E-bus – Very fast charge for Fast charge e-buses |
| Market potential | RATP only (Paris) : 2/3 E-Buses in 2025 (> 3000 Bus) >10 000 e-buses in Europe – 3 GWh – US\$ 0,5 Bn City E-bused to be charged at each stations |
| Entry barriers | Long Time to market Prove that the TCO is lower thanks to higher life time |

AUTOBUS DATA:
40 000 km/year
France: 25 000
Bus – 65 000
autocars
Average age: 8
years
Life time: 10 to
15 years
>600 000 km

1- 15 stations x 15 times/day x 300 days x 10years = 675 000

Sources: Daimler, Bolllore, EasyLi, Hilti, PSA, AVICENNE ENERGY Analysis

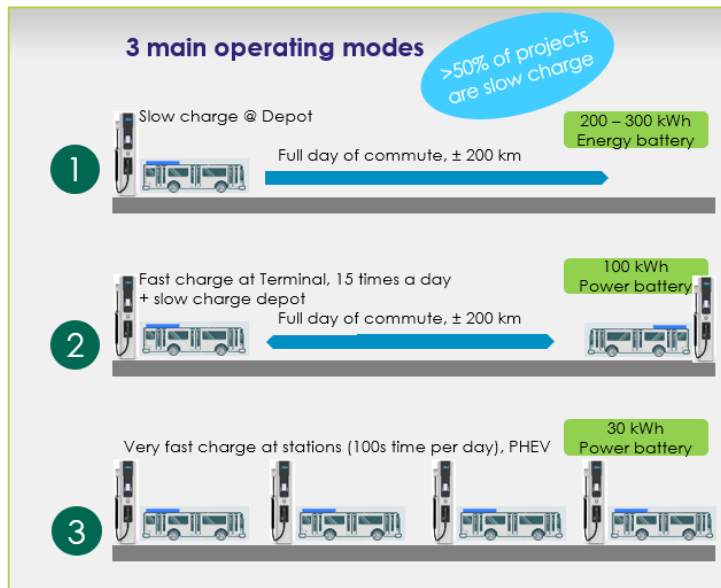


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E-BUSES

3 main operating modes



Source: SAFT 2018

1- New rules for charging buses in depot have huge cost impact
http://www.aveve-france.org/Site/Article/?article_id=7407

Major criteria required

Energy density
Life time
Charge Regulation¹



Energy density
Life time, cycle life



Life time, cycle life
Power, fast charge





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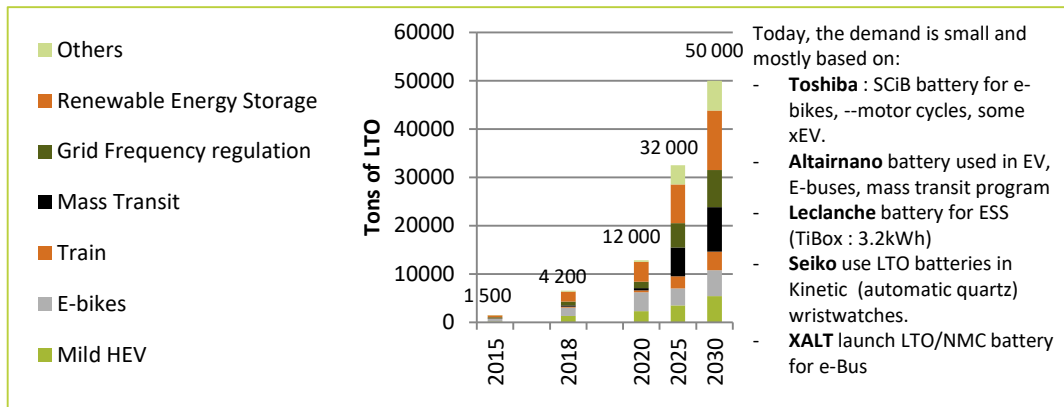
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LTO ($Li_4Ti_5O_{12}$) DEMAND: CAGR₂₀₁₅₋₂₀₃₀: +20% IN VALUE, +25% IN VOLUME

LTO demand details

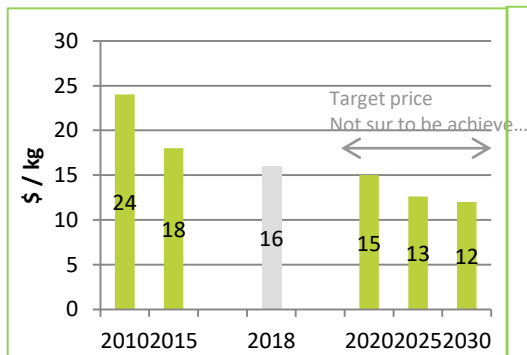


LTO suppliers

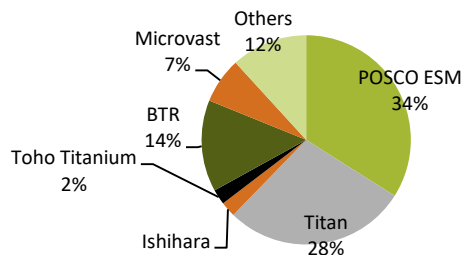
- POSCO ESM (Korea)
- Titan (Japan)
- BTR (China)
- Ishihara (Japan)
- Toho Titanium (Japan)
- Liniy Gelon (China) (1)
- NEI Corp. (US)
- UBE (Japan)
- Altairnano (US)
- Sinuo (China)
- Shanshan (China)
- Umicore (Belgium)
- Zhuhai Ying Tong Group
- Sichuan Xingneng New Materials
- Tianjiao

(2) 1 000 Tons production capacity / year

LTO Price forecasts



LTO market share



Summary of outlook

- 🔗 **Demand**: thanks to high power and long life time application, the LTO market will grow rapidly (+30% per year).
- 🔗 **Price**: to be competitive, LTO cost have to decrease in the range of 12 to 15 \$/kg. Challenging but seems to be possible thanks to scale economy.
- 🔗 **Suppliers**: POSCO is leading the market and should increase production capacity. Historical competitors are Japanese (Toho Titanium, Ishihara, Titan). Lot of new comers from China (BTR, Liniy Gelong, Sinuo, Shanshan...)

Assumption: Lithium carbonate stable @ 10 \$/kg

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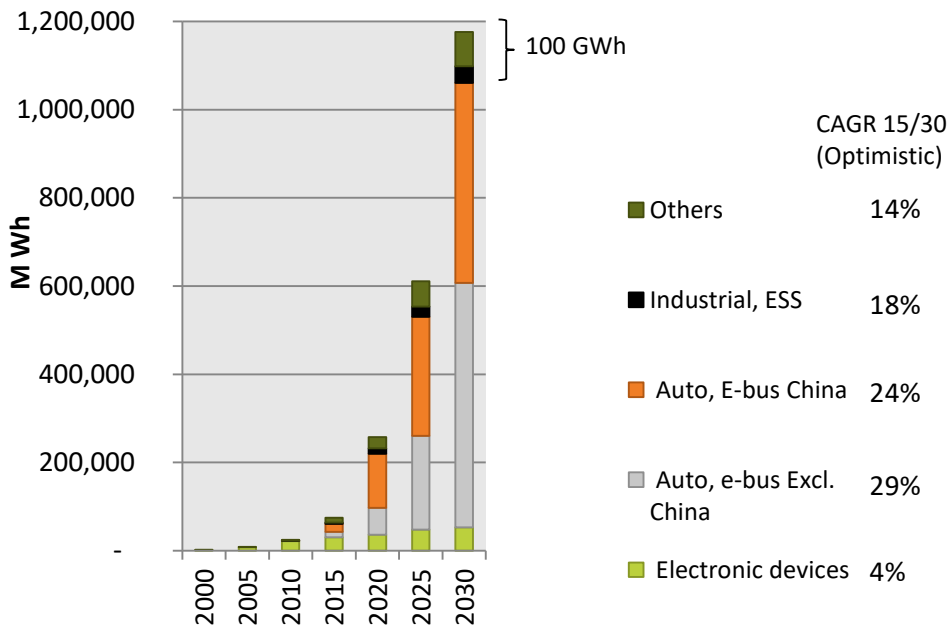
LI-ION BATTERY MARKET FORECAST

realistic scenario

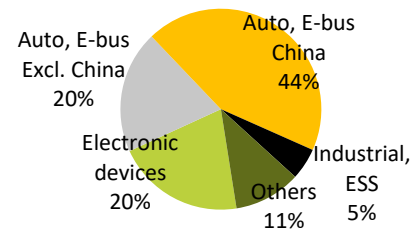
From 160 GWh in 2018 to >1,2 TWh

CAGR 2015/2030
+20 % per year in Volume

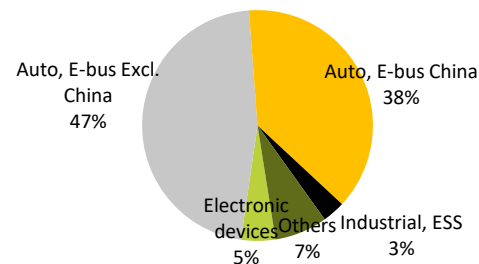
**Li-ion Battery sales,
MWh, Worldwide, 2000-2030**



2018: >160 GWh



2030: 1200 GWh



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

Source: AVICENNE Energy 2019

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools



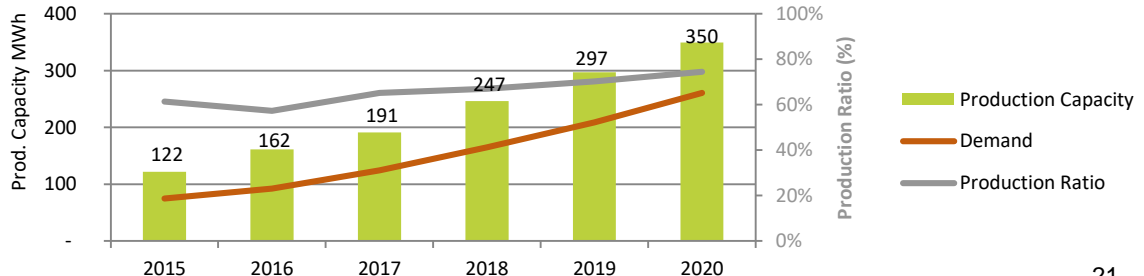
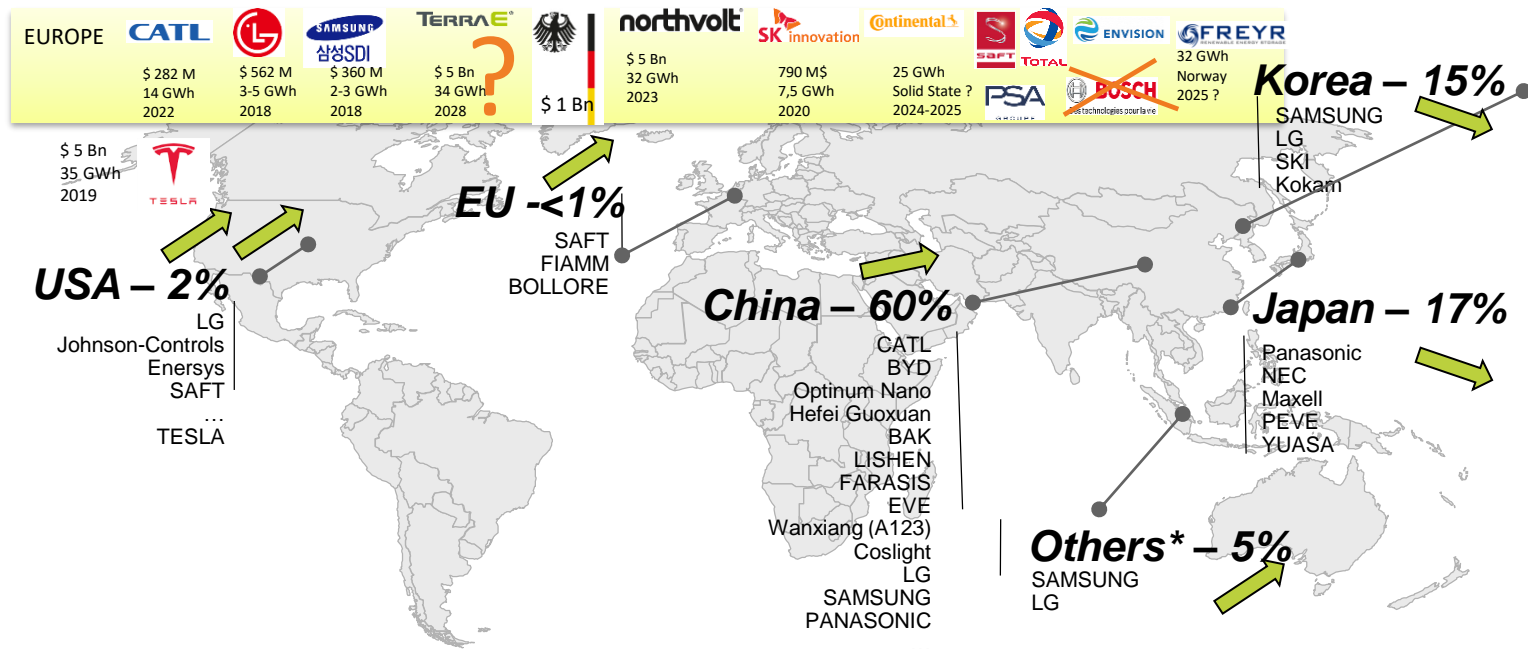
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LITHIUM ION CELL PRODUCTION

European market demand
~100 GWh in 2025



Source: AVICENNE 2019

* OTHERS: Malaysia mostly

PRODUCTION CAPACITY IN EUROPE

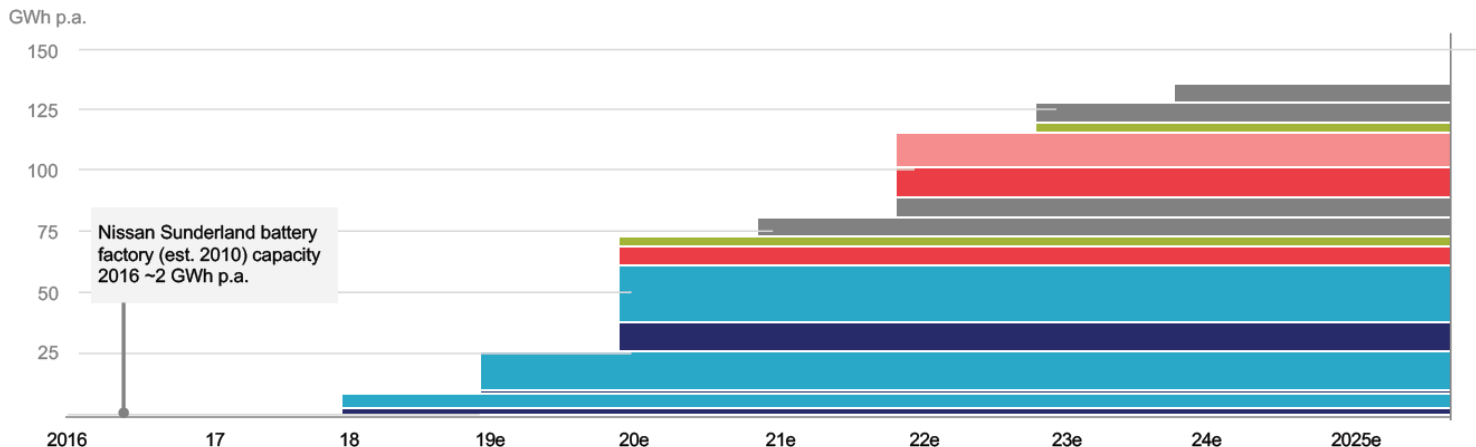
> 125 GWh in 2023

Current Status and Future Trends of the Global Li-ion Battery Market – Focus on Power Tools



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European lithium-ion battery capacity ramp-up until 2025

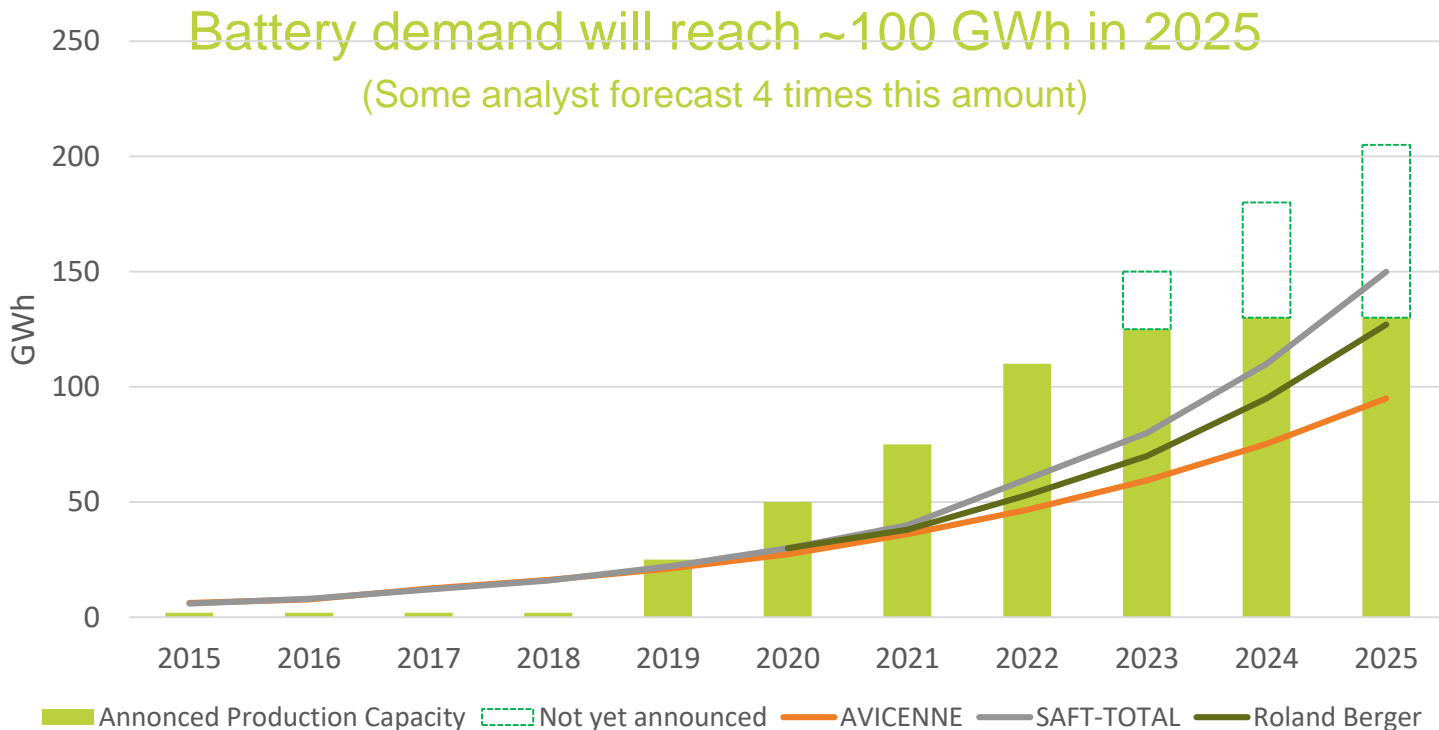


Source: BNEF, Roland Berger, Battery manufacturer announcements, Avicenne 2019



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BATTERY DEMAND/BATTERY CAPACITY IN EUROPE IN 2025





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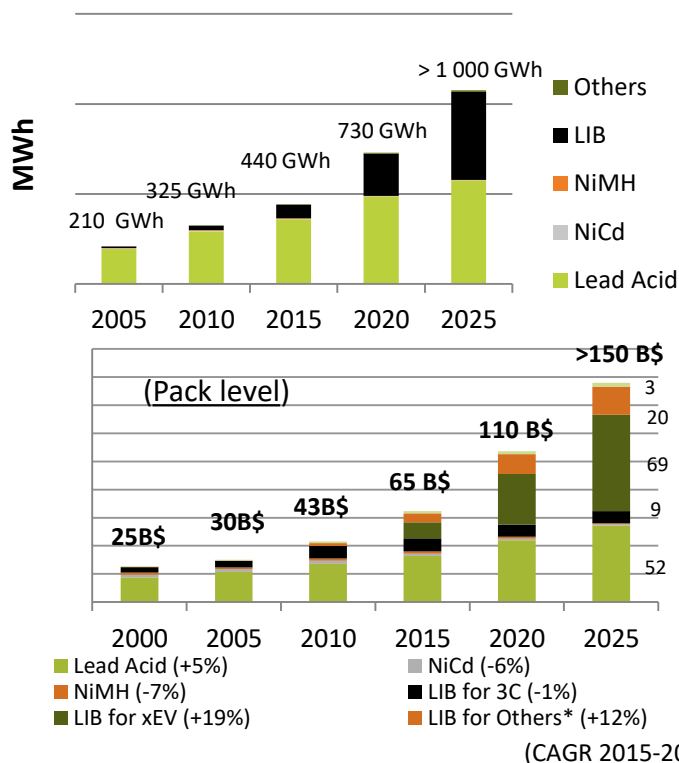
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TAKEAWAYS

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

- ① Li-ion battery is driven today by Automotive & Industrial applications
- ① In 2012, most of the car makers (except Toyota) switch to Li-ion for HEV
- ① P-HEV, EV and E-buses will be powered by Li-ion: 19 B\$ market in 2017 - 36 B\$ in 2020 & 69 B\$ in 2025 with high numbers in China (2017: US\$6 Billion for xEV and US\$ 5 Billion for xE-Buses)
- ① EV expectations attract large Chemical companies
- ① New materials are needed to meet Automotive standards
- ① HEV will account for 3% of the auto sales in 2020
- ① P-HEV & EV for 2% to 3% by 2020
- ① Micro-hybrid will achieve >50% in 2020/25
- ① Lead acid battery will be the first market in 2025 in volume, but Li-ion market will be higher than Lead acid in value from 2018.
- ① A very small EV market in the automotive world will represent a huge market for batteries
- ① New LIB applications: UPS, Telecom, Forklift, Medical, Residential ESS, Grid ESS, hoverboard, drones: CAGR > 10% in the next 15 years
- ① Lithium battery for other application (ESS, stationary, industrial...) will reach 10 Billion \$ market at the pack level in the next 5 years
- ① ESS market could be much more important if the price of LIB at the system level is under 150 \$/kWh

RECHARGEABLE BATTERY MARKET WORLDWIDE 2000-2025



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

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THANK YOU



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