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Market Report: Cell, Pack and Electrode Manufacturing in North America

Michael SANDERS

Senior Advisor, AVICENNE ENERGY

Presentation Outline

- Market Landscape – EV and Industrial
- Pack Implications
- Electrode Manufacturing

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AGENDA

- Market Landscape
- xEV forecasts up to 2030
- Cell Capacity Changes
- Industrial, Stationary & ESS applications 2020-2030
- Electrode Developments and Manufacturing
- Rechargeable battery market forecasts up to 2030

RECHARGEABLE BATTERY REPORT

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BATTERY MARKET FORECASTS 2020-2030

Applications covered

- Vehicles: HEV, P-HEV, EV, Start stop, 48v
- Low Speed EV
- Electronic devices
  - Portable PCs, net-book
  - Cellular Phones, Smartphones
  - Tablets
  - Camcorders
  - Digital Camera
  - Games, MP3
  - Cordless Phones
  - Shavers, Toothbrush,
  - RC Cars
- Drones
- Cordless Tools, Gardening tools
- E-bikes
- Hoverboard
- Security lighting
- Energy Storage Systems
- Other Non Portable applications
  - Motive (forklift)
  - Stationary (ESS, UPS, Telecom, medical…

Parameters analysis

- Main segment trends
- Power need trends (volume, weight, capacity, running time)
- Penetration rate for each Chemistry, each form factor,
- 2020-2030 Forecasts
- OEM strategies and positions
- Main drivers & limiters

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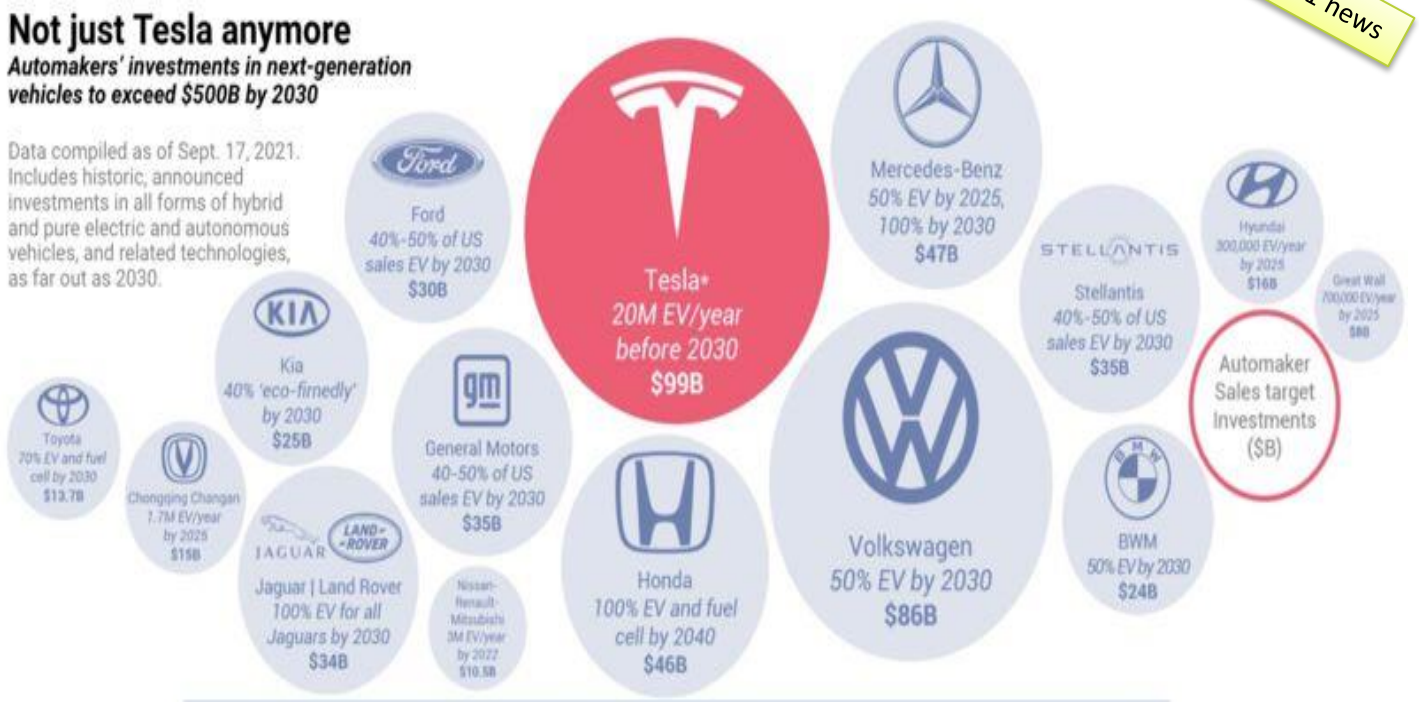
CARMAKERS TO INVEST MORE THAN $500 BILLION IN EV

September 2021 news



Source: Reuters 2021, Avicenne Energy 2021

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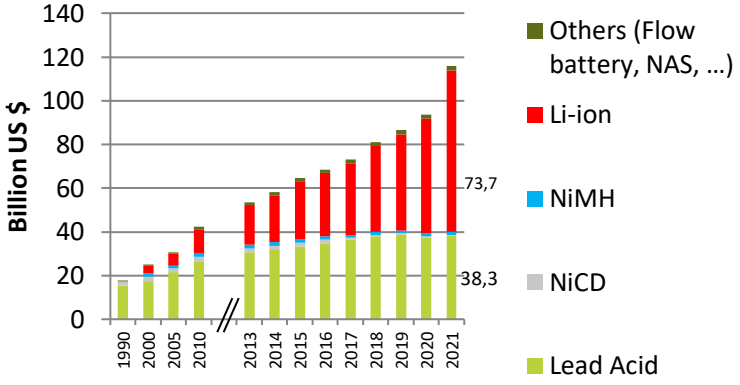
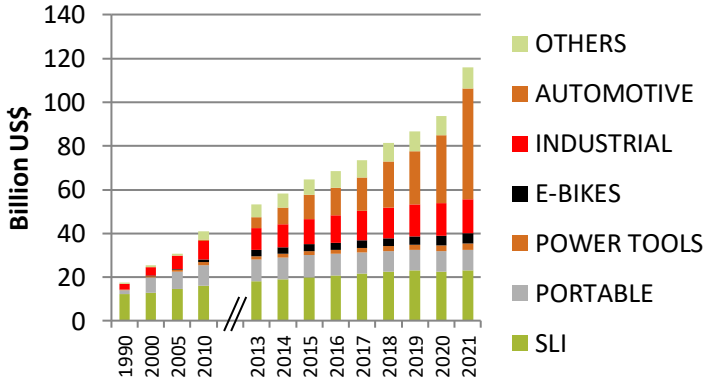
THE WORLDWIDE BATTERY MARKET 1990-2021

116 BILLION US$ in 2021 – Pack level[1]
10% AVERAGE GROWTH PER YEAR (2010-2021)





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, 2022

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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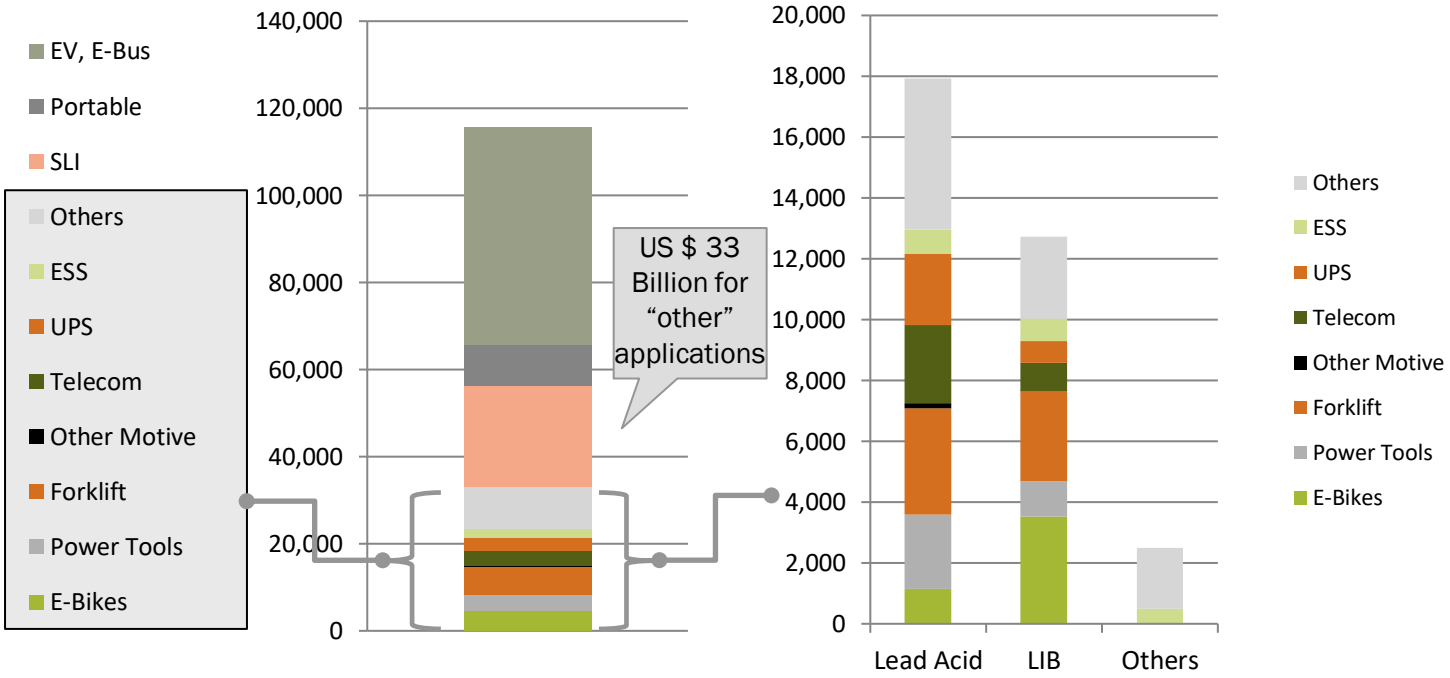
THE WORLDWIDE BATTERY MARKET IN 2021: US $ +116 BILLION



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

Source: AVICENNE ENERGY, 2022

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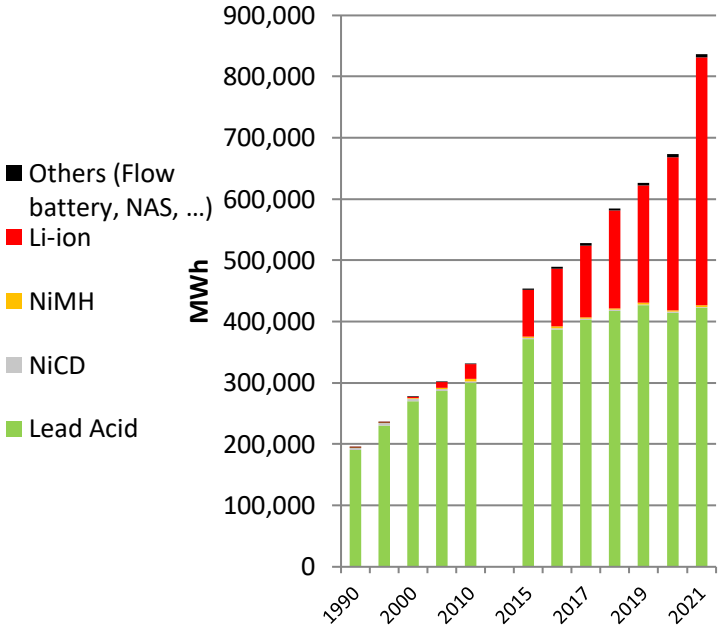
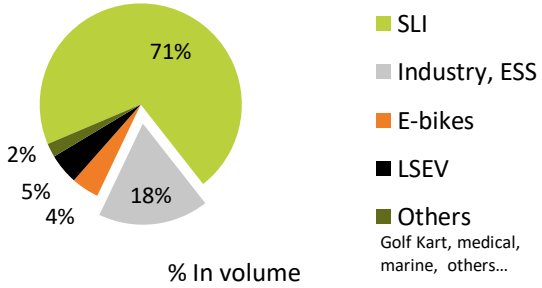
THE WORLDWIDE BATTERY MARKET 1990-2021

In volume (MWh)



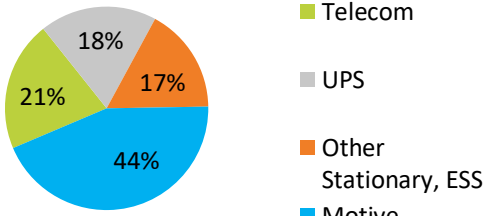
Source: AVICENNE ENERGY, 2022

Lead Acid Batteries 2021
423 GWh for > US $ 38 Billion



% In volume

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



% In volume

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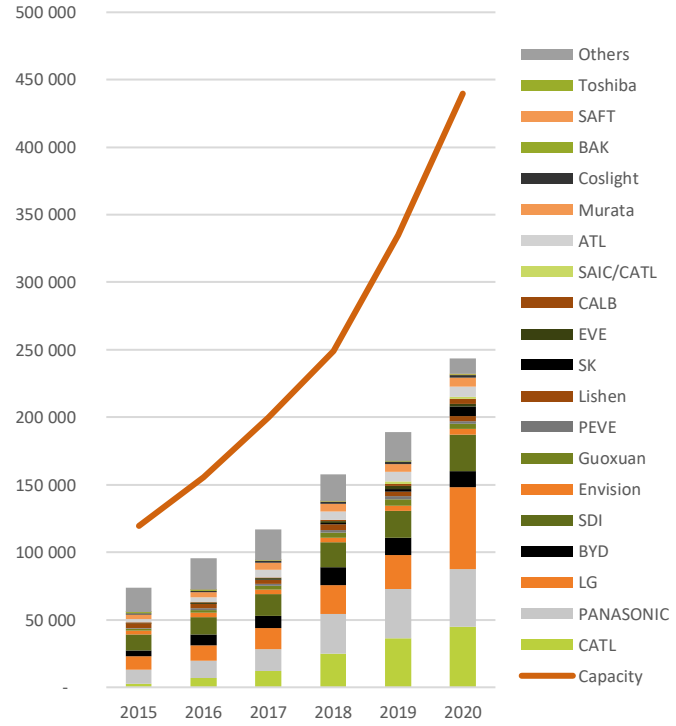
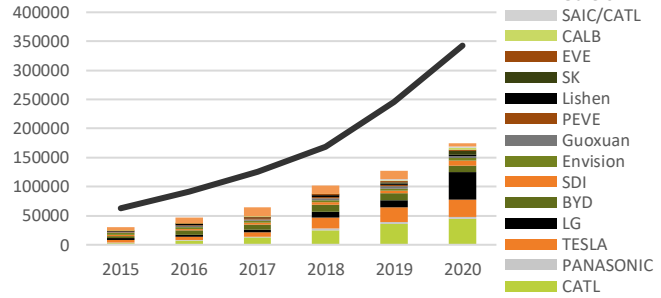
LITHIUM ION PRODUCTION & PRODUCTION CAPACITY (MWH)

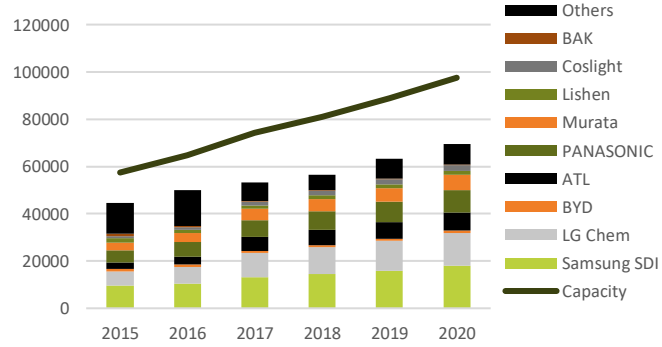
Total Production / Production capacity (MWh)



Production for xEV, E-Buses (MWh)



Production Excluding xEV, E-Buses



Source: AVICENNE Energy 2021

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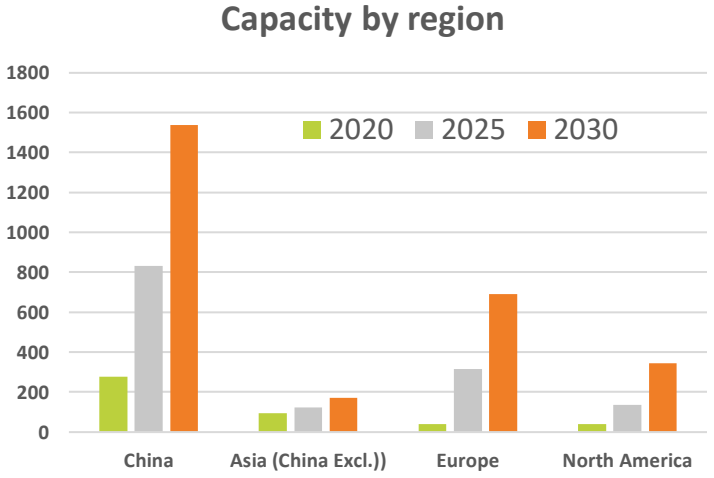
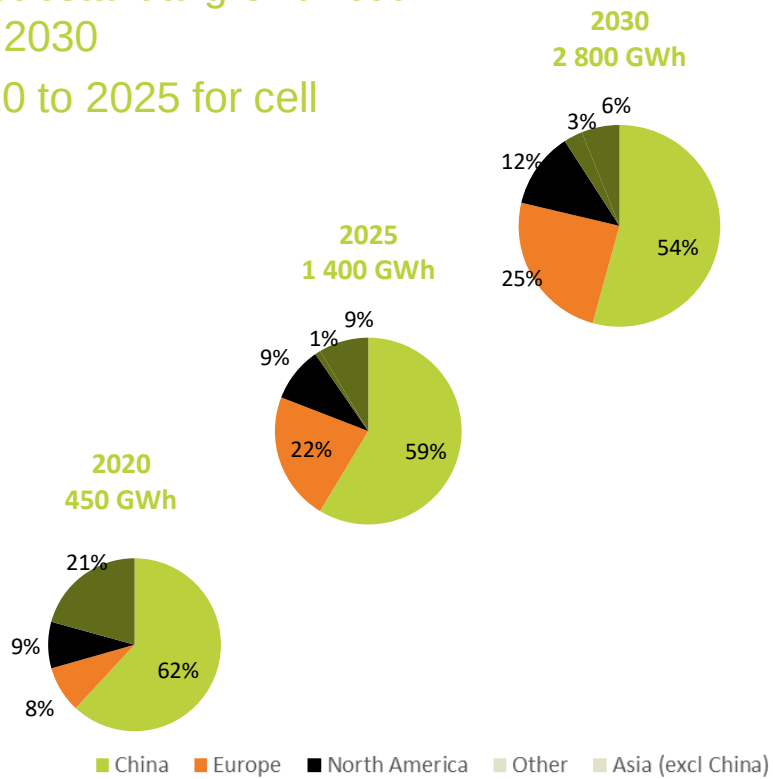
PRODUCTION CAPACITY FORECAST

Europe and North America will have substantial growth but remain net importers of cells through 2030

~ $50B investment required from 2020 to 2025 for cell manufacturing globally





Source: AVICENNE ENERGY, 2022

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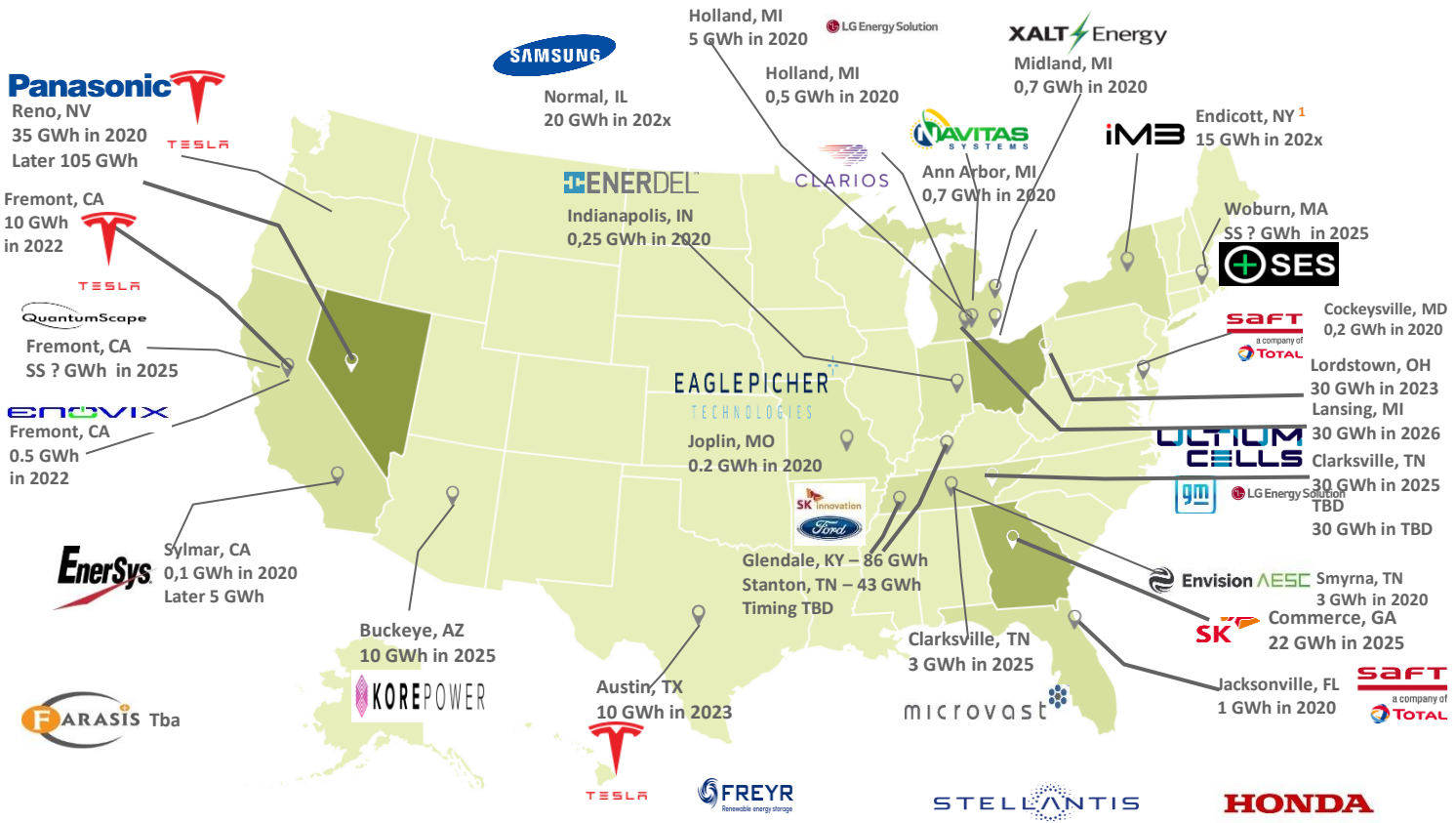
US PRODUCTION CAPACITY: FROM ~45 GWH IN 2020 TO 100 TO 150 GWH IN 2025



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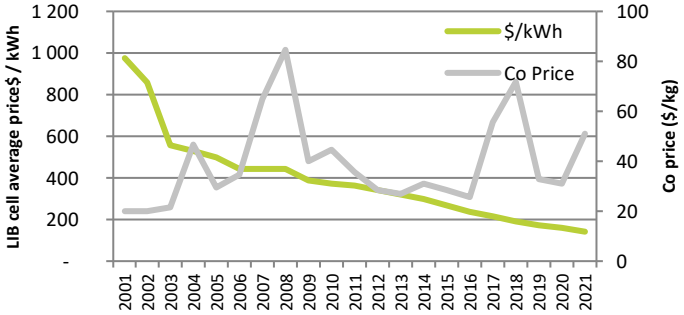
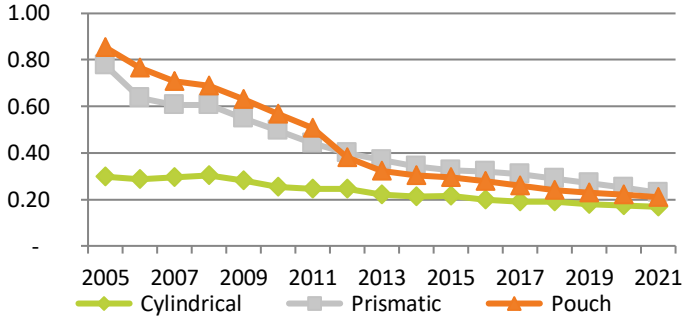
BATTERY PRICE

On average and in $/kWh battery price is decreasing thanks to huge price decrease in EV and increase of battery performances. BUT for smaller niche application we saw some increase and longer delivery time due to shortage

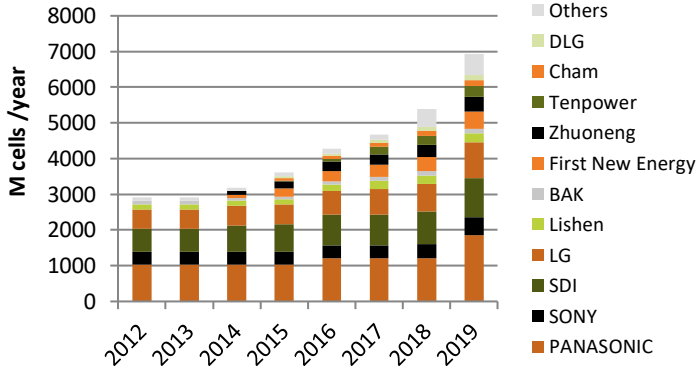
In 10 Years price divided by 2 despite a fluctuating Co price



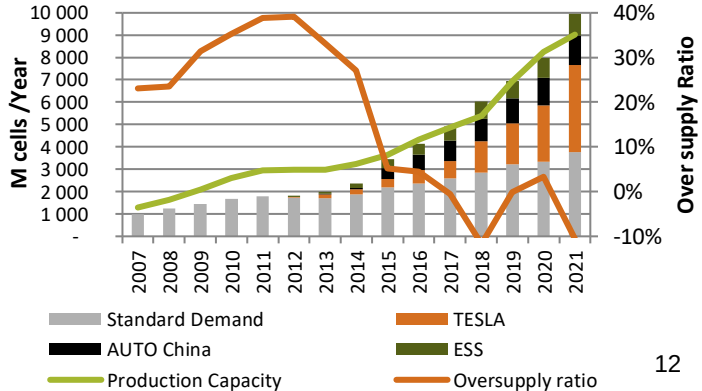
Average LIB cell price ($/Wh)



Cylindrical Production capacity



Cylindrical oversupply ratio is decreasing thanks to TESLA and EV in China



Source: AVICENNE Energy 2022

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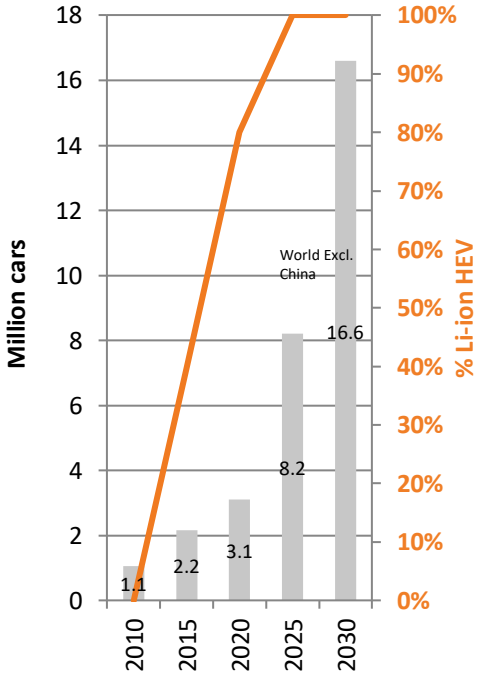
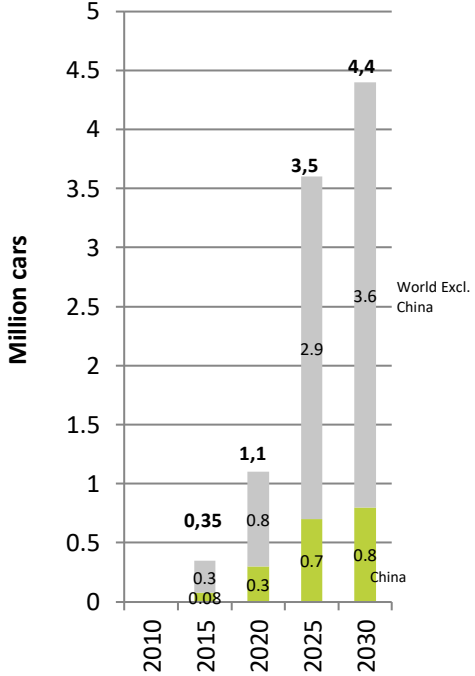
HEV, P-HEV, EV 2030 FORECASTS

HEV Sold



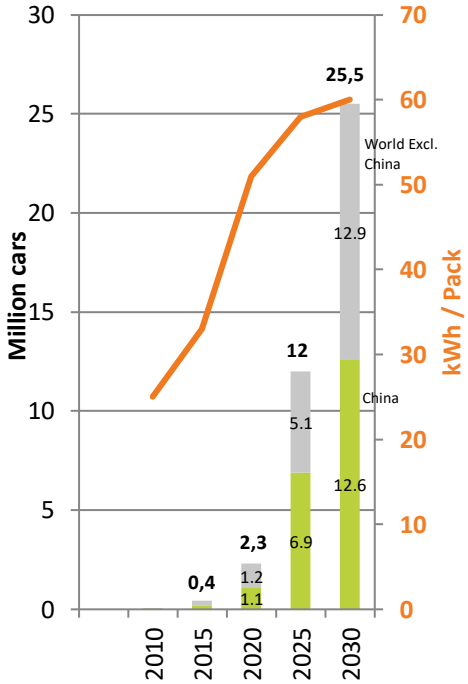
HEV: 1kWh battery / car

PHEV sold



PHEV: 12 kWh battery / car

EV sold



Source: AVICENNE ENERGY 2022

CATHODE ACTIVE MATERIAL FORECASTS 2000-2030

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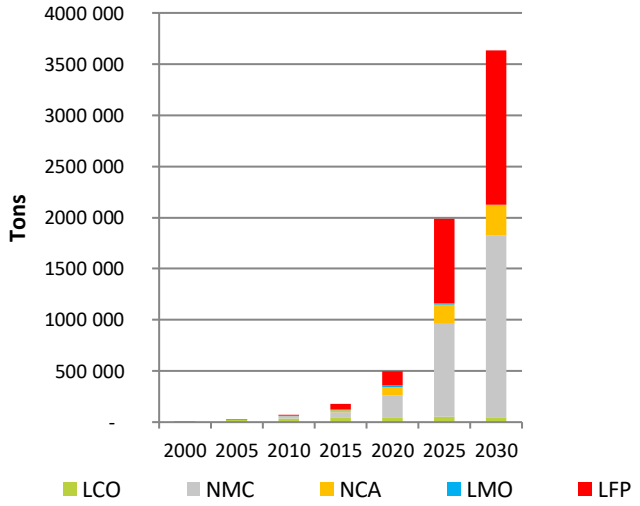
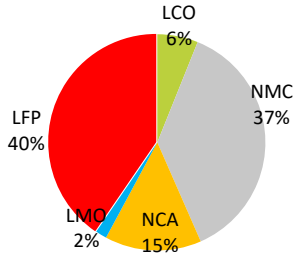
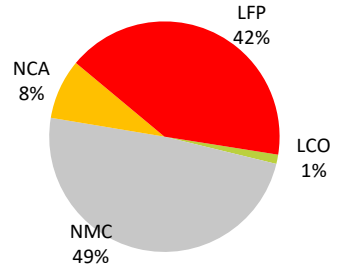
Cathode active materials 2000-2030 - Tons



Cathode active materials in 2021 > 800 000 Tons



Cathode active materials in 2030 3 600 000 Tons



ASSUMPTIONS:

- Portable devices: 2020-2030: +3% per year in volume
- HEV: 3,1 M HEV/year in 2020, 8,2 M HEV in 2025 & 16,6 M in 2030
- P-HEV: 1 M P-HEV/year in 2020, 3,5 M in 2025 & 4,4 M in 2030
- EV: 2,3 M EV/year in 2020 (1,1 M in China) / 12 M/year in 2025 (7 M in China) 100% LIB, 25 M EV in 2030 (13 M in China)
- Industrial, stationary & other applications 2020-2030: +15% per year in volume

Sources: AVICENNE ENERGY 2022

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PACK IMPLICATIONS

Pack building will mirror cell growth by region

- Automotive OEMs are mostly building their own packs
  - New EVs, New Pack Plants, Structural Pack Designs, New People
- Pack costs for all lower volume applications will be significantly higher than high volume auto
- HD and MD Truck & Bus are likely to be a mix of in-house and outside system suppliers
- System Integrators and Pack Builders will be serving the very diverse applications that are growing in all regions
- Stationery systems, larger tools and industrial applications are likely to move to regions
- Many new applications for packs are developing as electrification continues to expand rapidly

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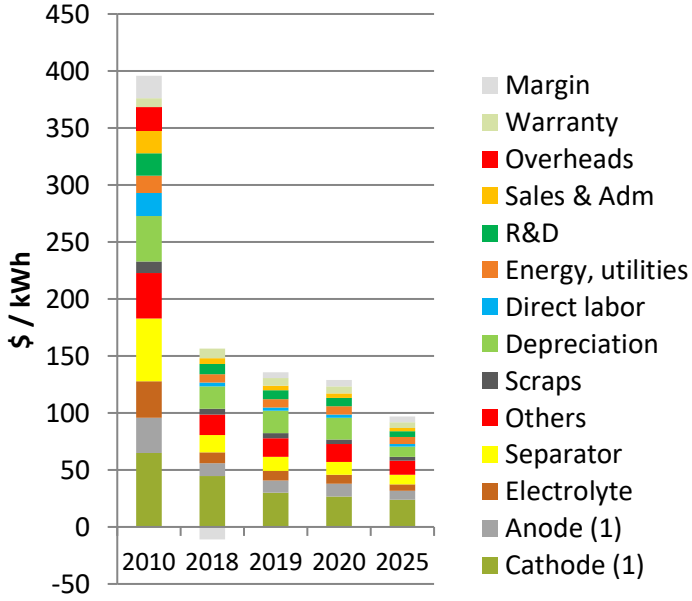
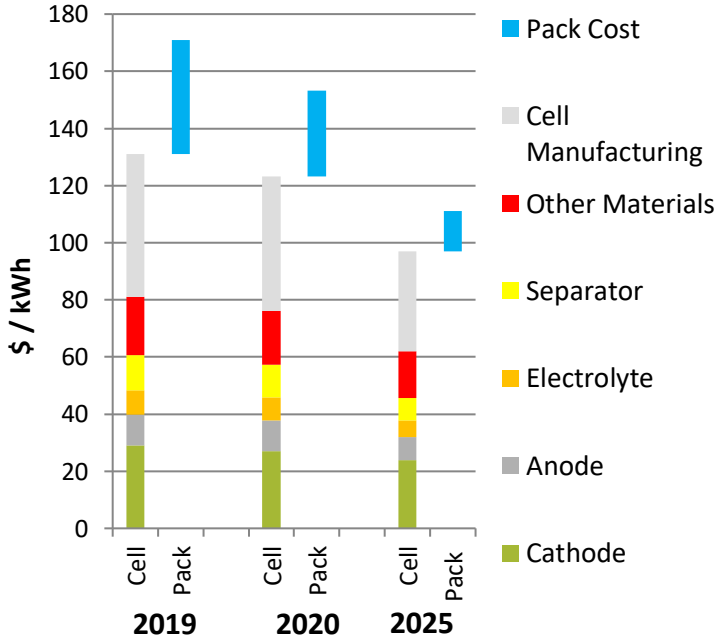
LI-ION BATTERY COST 2019-2025

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



LI-ION BATTERY PACK PRICE FOR EV



(1) Active materials only
Source: AVICENNE ENERGY 2022

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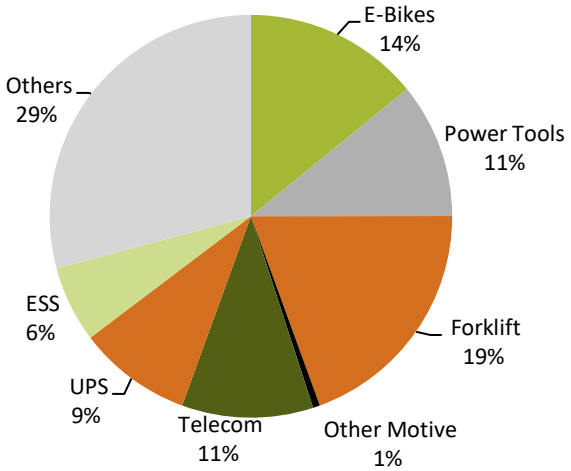
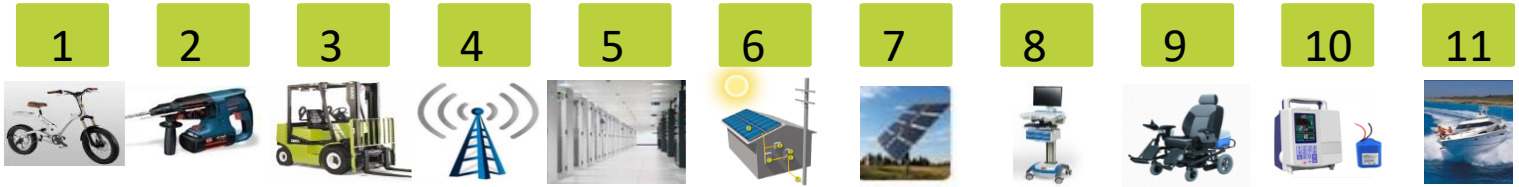
TOTAL POTENTIAL MARKET (M$, PACK LEVEL[1])

Application details

US$ 33 Billion in 2021 (1)



Source: AVICENNE ENERGY 2022



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,…

Source: AVICENNE ENERGY Analysis 2022

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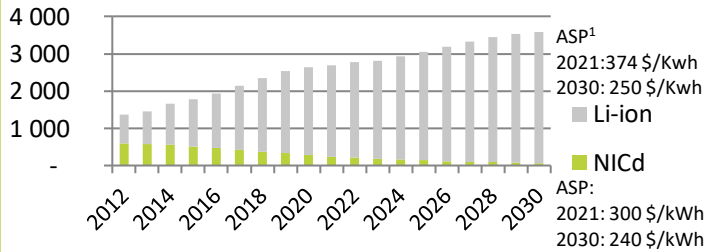
POWER TOOLS

LIB: FROM US$ 2,5 BILLION IN 2021 TO 3,5 B IN 2030[1] – $CAGR_{15-30}$: +7%

Market 2021-2030 (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 2021 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 2021 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.

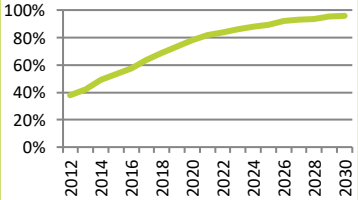
Competitors

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

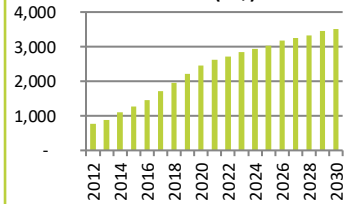
Customers

- 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 Analysis 2022

Note: 1- Pack level

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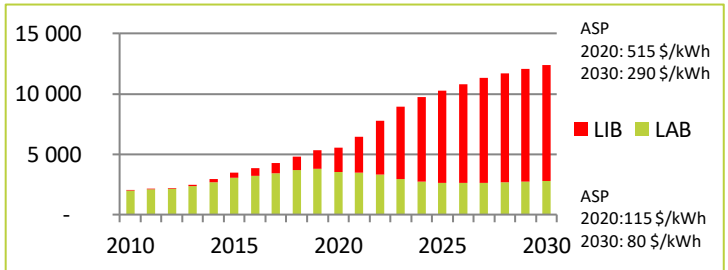
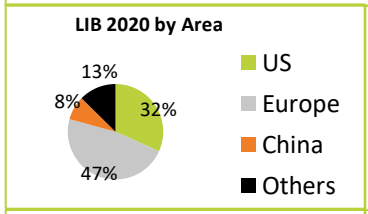
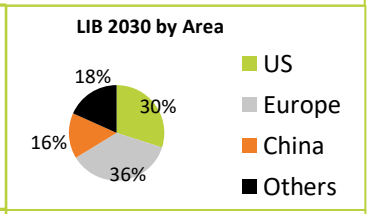
MOTIVE INDUSTRIAL: FORKLIFTS[1]

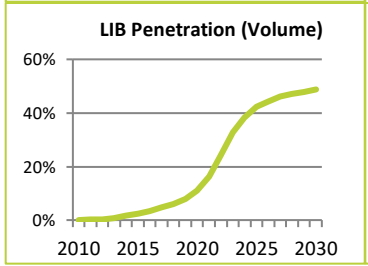
LIB: FROM US$2 BN IN 2020 TO $10 BN IN 2030 - $CAGR_{20-30}$: +15%
LAB: FROM US$3.5BN IN 2020 TO $2,8 BN IN 2030 - $CAGR_{20-30}$: -2%

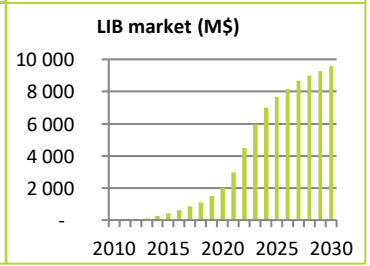
Market 2010-2030 (US $, Million) – $CAGR_{20-30}$:8%











Main drivers for LIB

- Where economies are healthy, they reflect strong motive power production
- Europe and US have 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 restrictions for LIB

- 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 (>25%), Sunlight (n°2), Exide (10%), East Penn (10%), Hoppecke (10%), Crown (10%)
- LIB systems: BMZ, Triathlon, Lithium Balance, …

Customers

For lead-acid, aftermarket represents 40% of the market: lot of different customers (industrials)

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

Battery needs

- Important characteristics
  1-High charge/discharge rates and capacity
  2-Long 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 Analysis 2021

Note: 1- Including all kind of materials handling equipment

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BATTERIES FOR DRONE

Depending on the segment number of battery / device is very different

Consumer Drone <250g	Consumer Drone >250g	Commercial Drone	Military Drone
Life time: 1 year	Life time: 2 years	Life time: 3 years	Life time: 5 years
Average: 2 battery/set	Average: 3,5 battery/set	Average: 12 battery/set	Average: 12 battery/set
2019:	2019:	2019:	2019:
25 M packs market	24,6 M packs market	9,1 M packs market	0,09 M packs market
no after market	18,7 M pack After M.	10,9 M pack After M.	0,18 M pack After M.
68 MWh	815 MWh	955 MWh	28 MWh
2020: 90 MWh	2020: 1 100 MWh	2020: 1 500 MWh	2020: 36 MWh
2030: 230 MWh	2030: 6 300 MWh	2030: 9 800 MWh	2025: 270 MWh
			

Source: AVICENNE Energy 2020

2020 Estimations - COVID 19 impact partially implemented as the crisis is not over - Impact could be worst

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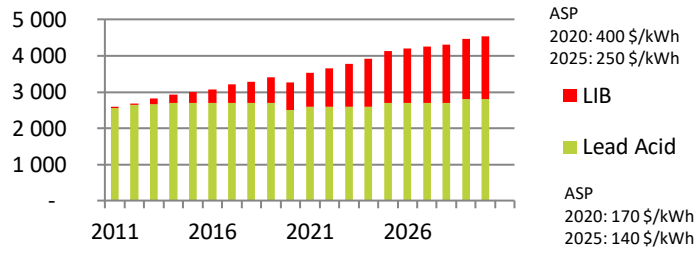
STATIONARY: TELECOM MARKET

LAB: FROM US$ 2,5 BILLION IN 2020 TO 2,8 IN 2030 – CAGR20-30: 0,5%
LIB: FROM US$ 0,8 BILLION IN 2020 TO 1,7 IN 2030(1) – CAGR20-30: 8,5%

Market 2010-2030 (US $, Million) – $CAGR_{20-30}$:+2,7%



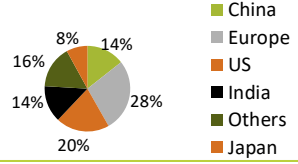
Main drivers for LIB

- LIB developed for new equipment
- Increased bandwidth requirements
- Wireless market driving growth
- Strong network growth in China, India, E. Europe & S. America
- 3G-> 4G -> 5G … need new equipment
- LIB: **Especially in hot climates**

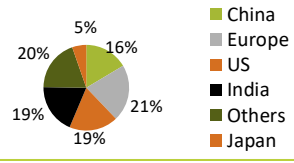
Main restrictions for LIB

- Lead-acid vs Li-ion…
- Lead-acid capital cost 2-3 times cheaper
- Total cost of ownership could be compared with lead-acid

Battery 2020 by Area



Battery 2030 by Area



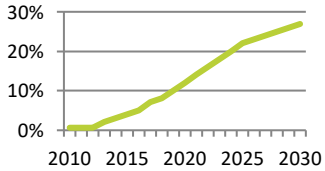
Competitors

- Lead-acid and LIB: Enersys (35%), Exide (10%) and local suppliers in each country
- LIB systems: 'large companies': SAFT, others

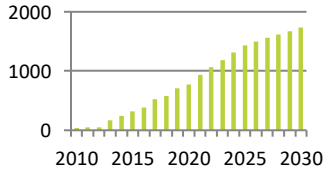
Customers

- Few customers: large telecom carriers in each country

LIB Penetration



LIB market (M$)



Battery needs

- Most important performances characteristic
  1- High temperature performance
  2- Customized for the new equipment network
- Average capacity: 5-10 kWh modules (100Ah)
- Frequency of use: Good network <15 cycles/year / bad network: 300 cycles/year (2)

LIB needs

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

Source: AVICENNE ENERGY Analysis 2021

Note: : (1) Pack level – (2) All the battery details in the Excel file

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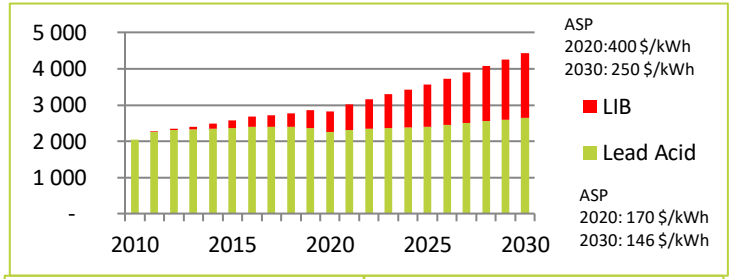
STATIONARY: UPS MARKET

LIB: FROM US$0,6BN IN 2020 TO $1,8BN IN 2030 – $CAGR_{20-30}$: +12%

LAB: FROM US$2.3BN IN 2020 TO $2,7BN IN 2030 – $CAGR_{20-30}$: : +1,6%

Market 2010-2030 (US $, Million) – $CAGR_{20-30}$:+4,6%

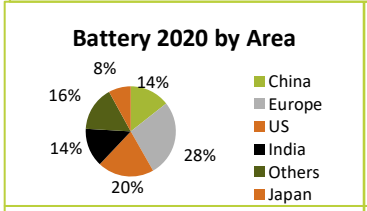


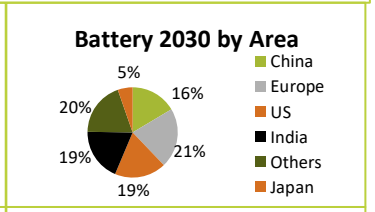
Main drivers for LIB

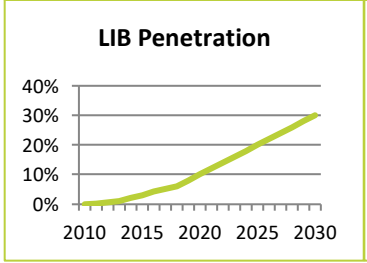
- UPS Drivers:
  - New data storage centres
  - Mobile Society
- LIB drivers:
  - Less volume, less place
  - > Life time
- LIB is needed more where data are sensitive
- Li-ion battery could also help to save electricity during peak time

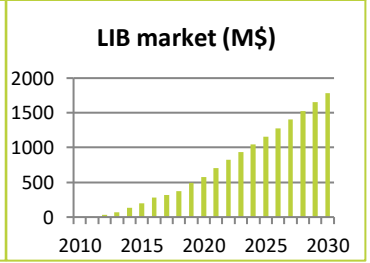
Main restrictions for LIB

- Safety could be an important issue here
- CAPEX 2-3 times higher than lead acid









Competitors

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

Customers

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

Battery needs

- Most important performance characteristic
  1- Back-up at high current
  2- Weight, volume
  3- Life time
- Average Capacity: 3-5 kWh modules
- Frequency of use: <15 cycles/year
- Discharge duration <30 minutes

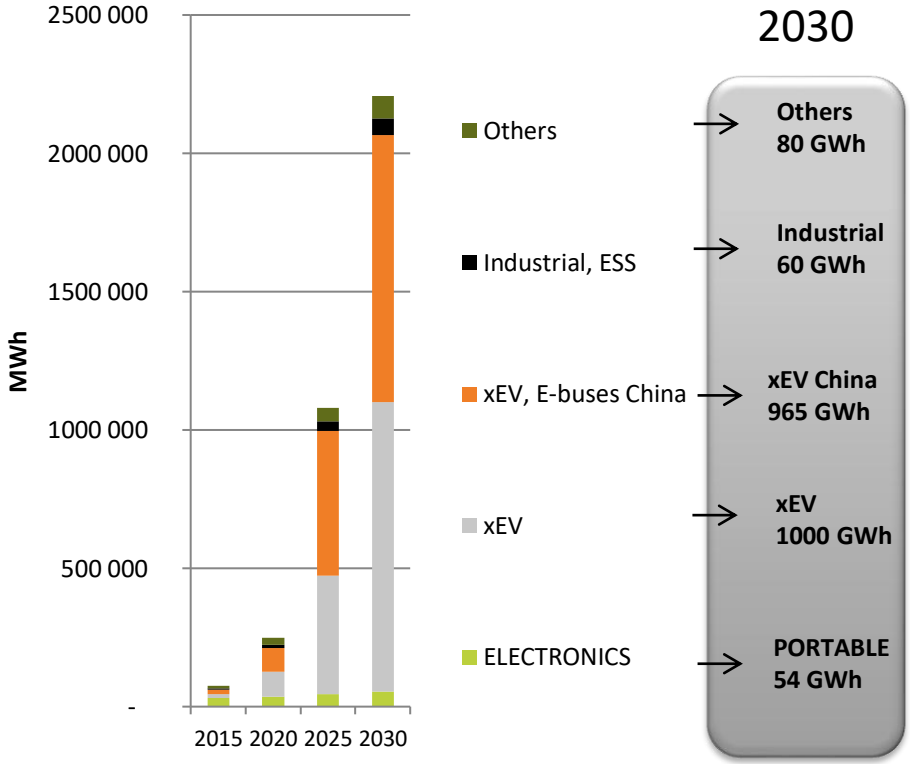
LIB needs

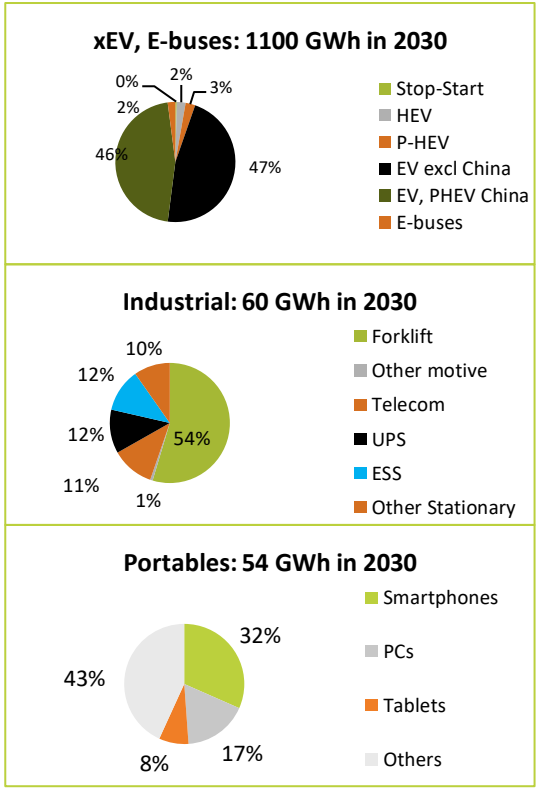
- Most valuable improvements
  1- Convince on safety
  2- Capital Cost
  3- Reliability
- Form factor: Cylindrical
- New development for new equipment

Source: AVICENNE ENERGY Analysis 2021

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

THE LITHIUM ION BATTERY MARKET WORLDWIDE 2015 - 2030





Source: Avicenne Energy Analysis 2022

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ELECTRODE MANUFACTURING

Electrode Manufacturing mostly by cell manufacturers

- Cell manufacturing will dominate electrode manufacturing
- Coating width, speed, and complexity continues to increase and one or two side coatings
- Dry process experimentation happening at a few cell builders
- Alternative electrode manufacturing methods of printing or deposition remain early experimental
- Potential exists for contract supply for either primed electrodes or specialty electrodes but his has remained very limited
- New processes for electrode production are being established for the emerging solid-state technology

Source: Avicenne Energy Analysis 2022

TOTAL BATTERY DEMAND FOR XEV 2030 FORECASTS

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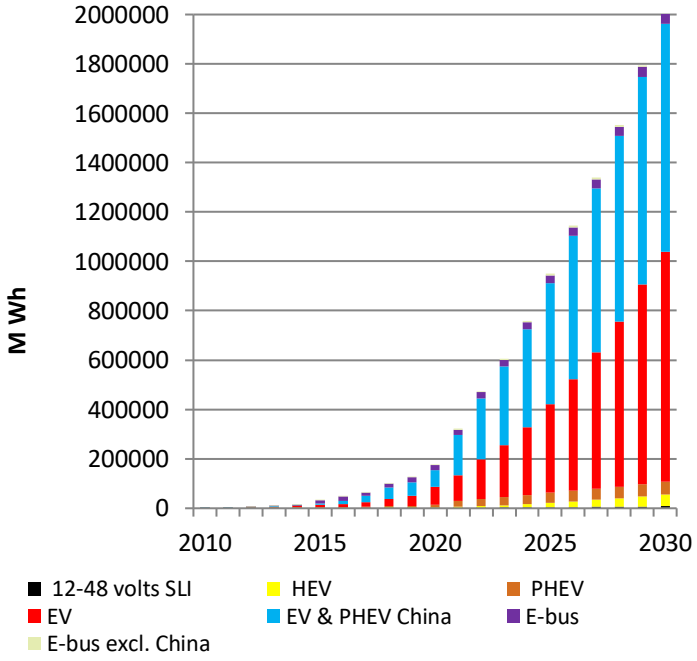
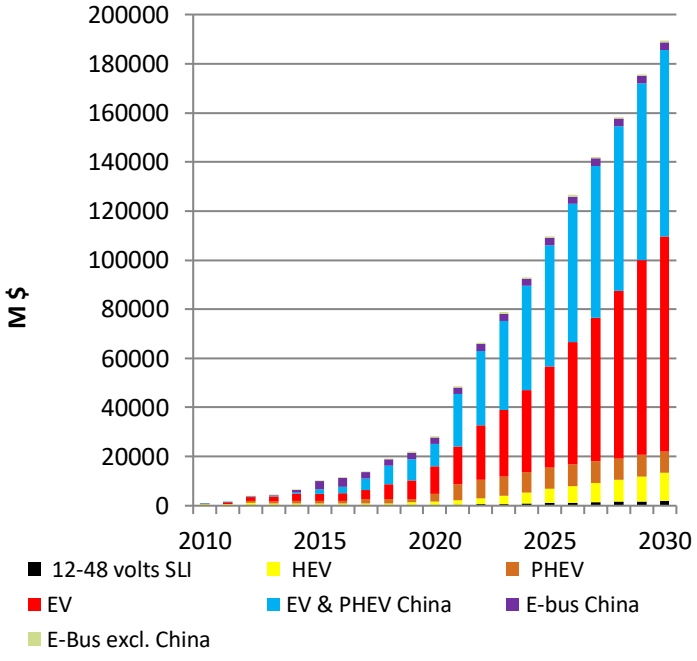
Li-ion for EV, HEV & P-HEV Battery needs (MWh)

CAGR 2020-2030: +28%



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

CAGR 2020-2030: +21%



Source: AVICENNE ENERGY Analysis, 2022

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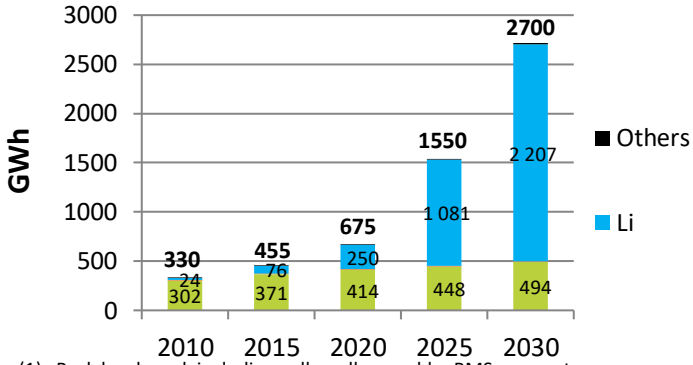
TAKEAWAYS

Market value will reach $275b in 2030 – Pack level(1) - $CAGR_{20-30}$: +12%

- Li-ion battery is driven today by Automotive: It will double in next 5 years and another 50% growth by 2030
- North America will grow to 12% of the LIB cell manufacturing capacity by 2030 or 345 GWhr
- Pack building for EV will be mostly done in region and it is expected to also grow in larger applications
- Electrode manufacturing will remain dominated by cell builders
- EV will become larger than HEV and P-HEV by 2027
- Lead acid battery will be the first market in 2022 in volume, but Li-ion market (US$ 74 Bn) is higher than Lead acid in value in 2021 (US$ 38 Bn)
- New LIB applications: UPS, Telecom, Forklift, Medical, Residential ESS, Grid ESS, hoverboard, drones: CAGR > 15% in the next 10 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

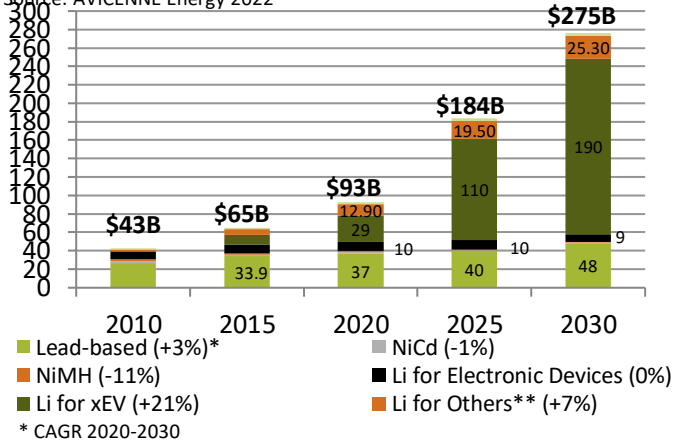
Source: Avicenne Energy Analysis 2022

Lead-based and Li-ion batteries will remain the most important markets



(1) Pack level: pack including cells, cell assembly, BMS, connectors – power electronics (DC DC converters, invertors, etc.) not included

Source: AVICENNE Energy 2022



* CAGR 2020-2030

**Others: automatic handling equipment, robots, forklifts, UPS, telecom, medical devices, residential ESS, grid ESS, drones, hoverboards, etc.

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