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INFORMATION FOR GROWTH

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September 28th, 2021

Lyon, France

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BATTERIES
EVENT 2021

The Rechargeable Battery Market and Main Trends 2020-2030

Christophe PILLOT

Director, AVICENNE ENERGY

Presentation Outline

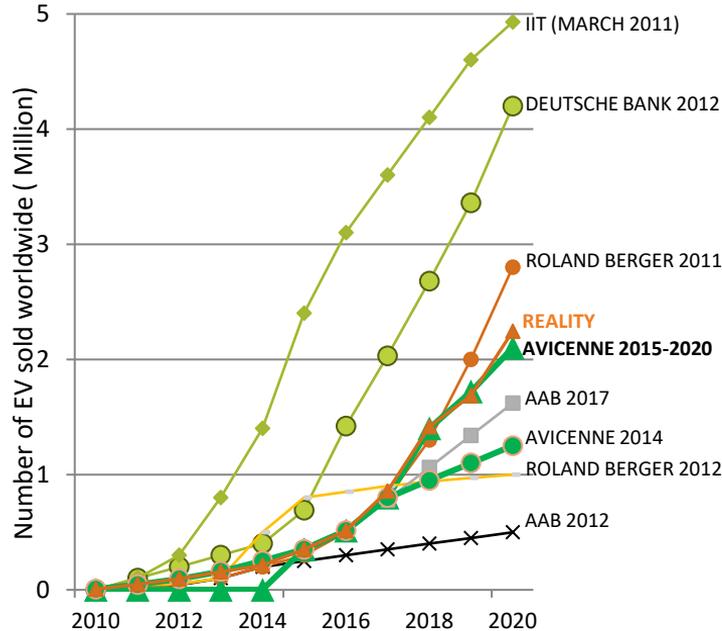
- The rechargeable battery market in 2020
- The Li-ion battery value chain
- Li-ion battery material market
- Focus on xEV batteries
- Forecasts & conclusions

AGENDA

- 🕒 The market in 2020 by technology, applications & battery suppliers
- 🕒 Li-ion components market & value chain
 - 🕒 Raw materials market
 - 🕒 Supplier / customer relationship
 - 🕒 Raw material cost
 - 🕒 New entrants strategy
 - 🕒 Raw material road map 2000-2030
- 🕒 xEV market in 2020
- 🕒 xEV forecasts up to 2030
- 🕒 Industrial, stationary & ESS applications 2020-2030
- 🕒 Rechargeable battery market forecasts up to 2030

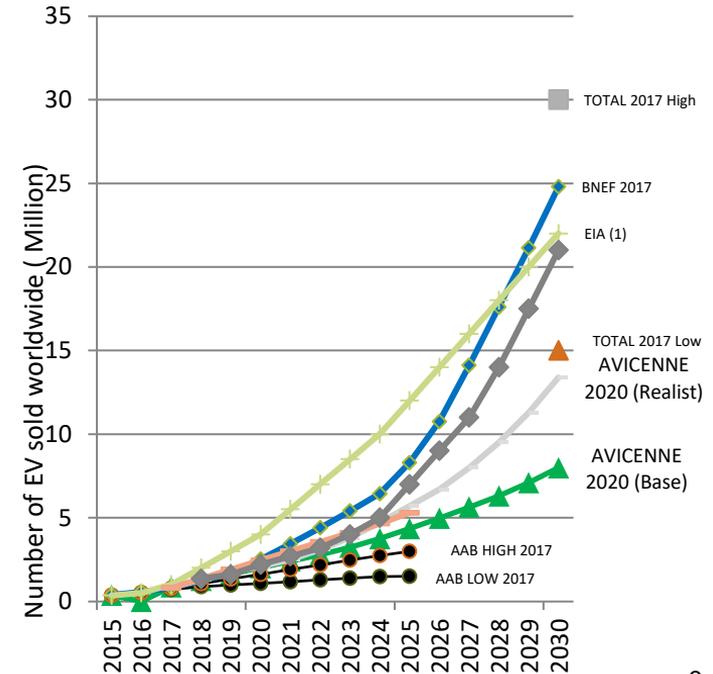
AVICENNE ENERGY: RENOWNED TO HAVE REALISTIC FORECASTS

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



Source : International Battery Conference, Fort Lauderdale 2010-2019

EV sold, in million units, worldwide, 2015 - 2030



IN 2016/2017 SEVERAL ANNOUNCEMENT ACCELERATE THE XEV GROWTH



- 🕒 **Norway**, has set a target of only allowing sales of 100% electric or plug-in hybrid cars by 2025 – Feb 2016
- 🕒 **The Netherlands** voted to ban all new petrol and diesel car sales by 2025 – March 2016
- 🕒 “We would phase out the internal combustion engine in the coming years” – **Volvo**, June 2017
- 🕒 “We are announcing an end to the sale of petrol and diesel cars by 2040” Nicolas Hulot, **French** ecology minister (July 2017)
- 🕒 **Britain** to Ban New Diesel and Gas Cars by 2040 (July 2017)
- 🕒 **Germany**’s Federal Council, which represents the country’s 16 states, had passed a resolution on banning ICEs from 2030 onward
- 🕒 **India** government was planning for India to become a 100 percent electric vehicle nation within 14 years (2030) – March 2016 - Power Minister Piyush Goyal

🕒 **BUT, On the other hand:**

- 🕒 “A complete end of the internal combustion engine from 2030 would be totally unrealistic”
Former German Transport Minister Alexander Dobrindt



OEM INVESTMENT IN VEHICLE ELECTRIFICATION

January 2018 news

Carmakers to invest more than \$90 Billion in EV

- 🔋 **Ford** will invest **\$11 billion** by 2022 to launch 40 new electric cars and hybrids worldwide
- 🔋 **Volkswagen** plan to spend **\$40 Billion** by 2030 to build electrified versions of its 300-plus global models
- 🔋 **Daimler** will spend at least **\$11,7 billion** to introduce 10 pure electric 40 hybrid models
- 🔋 **Nissan** pledged to launch 8 new electric vehicles and hit annual sales of 1 million electrified vehicles by 2022
- 🔋 **Toyota** will launch 10 Evs by the early 2020s and sell 5,5 million electrified vehicles, including hybrids and hydrogen fuel cell vehicles, by 2030
- 🔋 **BMW** will offer 25 electrified (12 fully electric) vehicles by 2025
- 🔋 **GM** pledging to sell 20 all-electric vehicles by 2023
- 🔋 **Honda** says two-thirds of total car sales to be electrified models by 2030
- 🔋 **Chinese automakers**, all have publicized aggressive investment plans



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The Rechargeable Battery
Market and Main Trends
2020 – 2030

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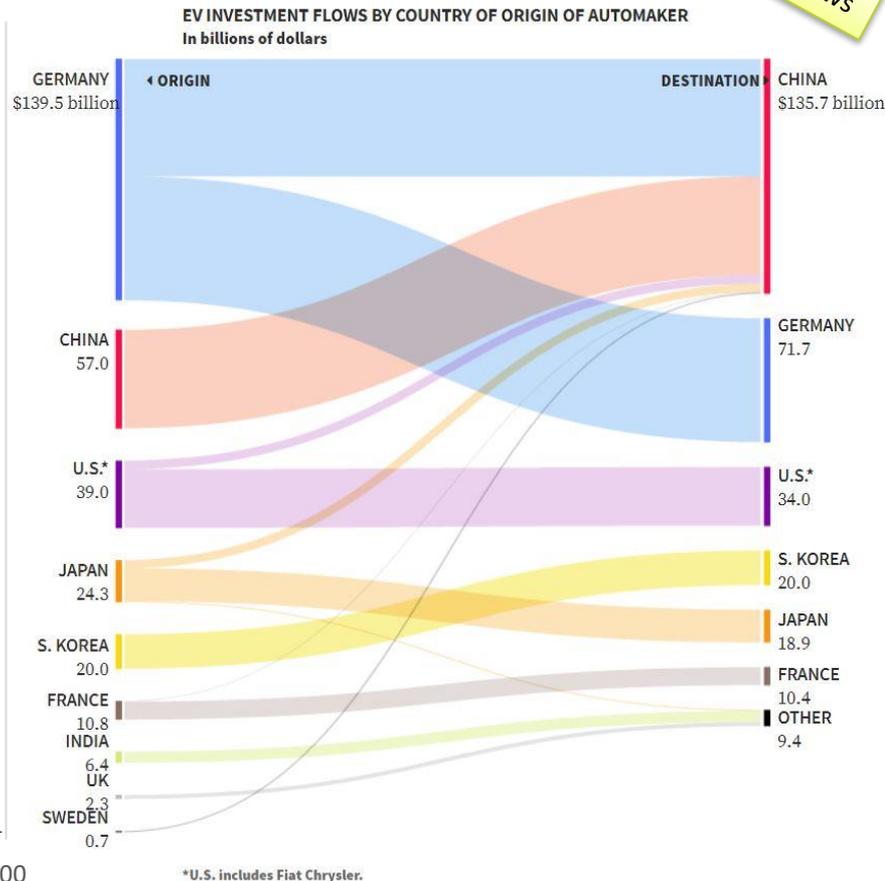
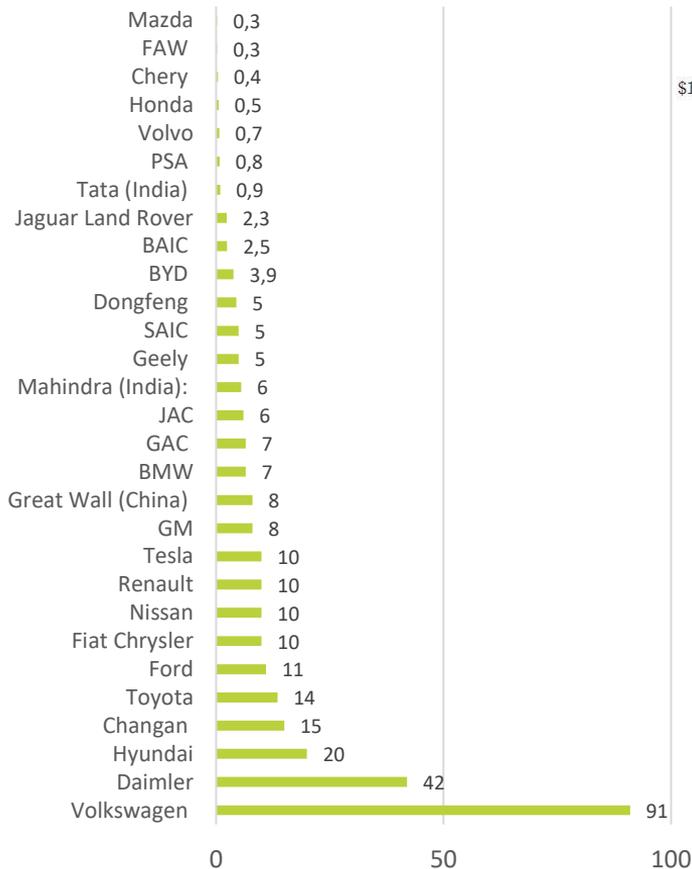
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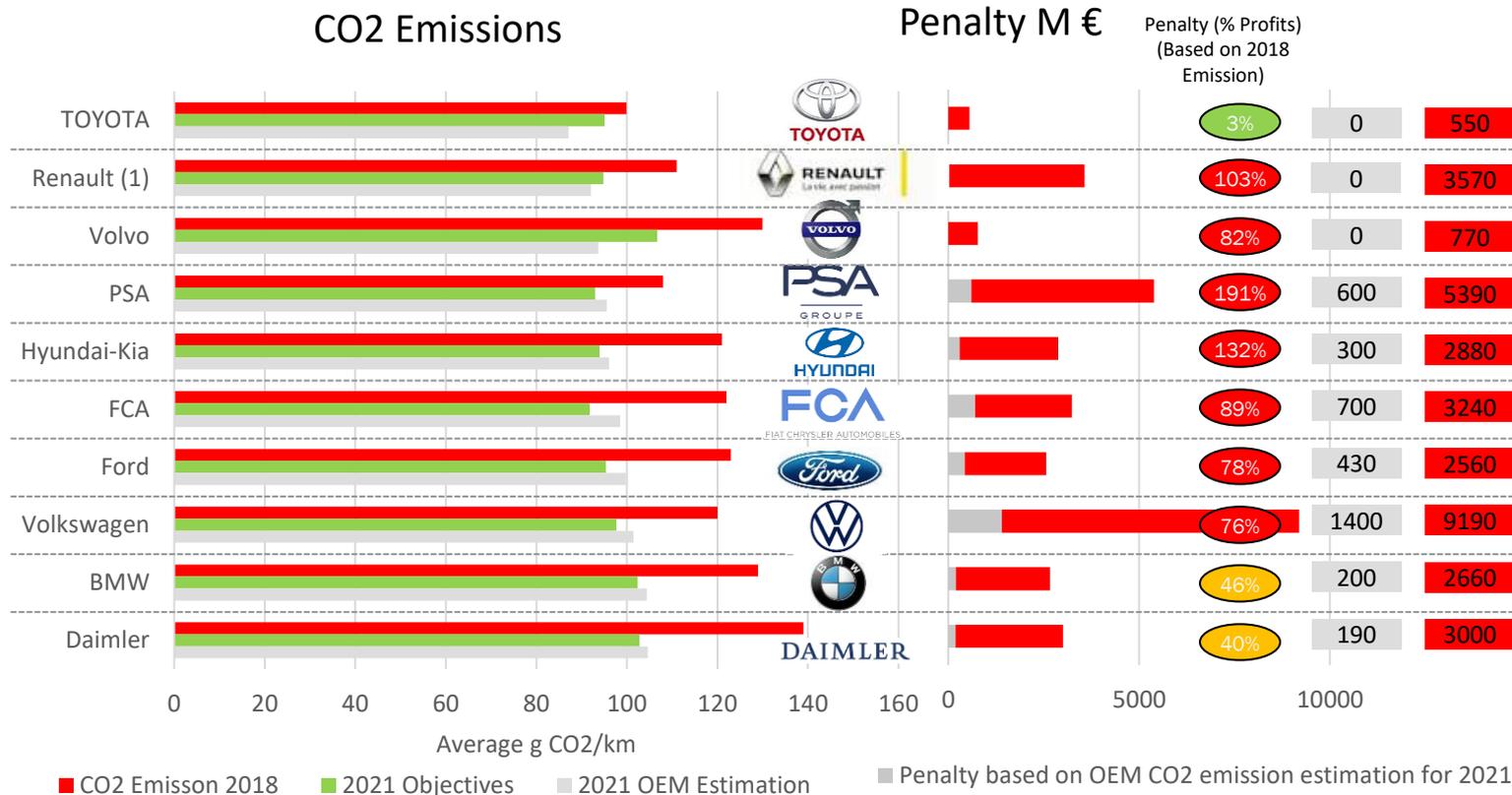
CARMAKERS TO INVEST MORE THAN \$300 BILLION IN EV

January 2019 news



Source: Reuters January 2019, Avicenne Energy

ESTIMATION OF THE FINANCIAL IMPACT OF CO2 EMISSION ON OEM IN 2021



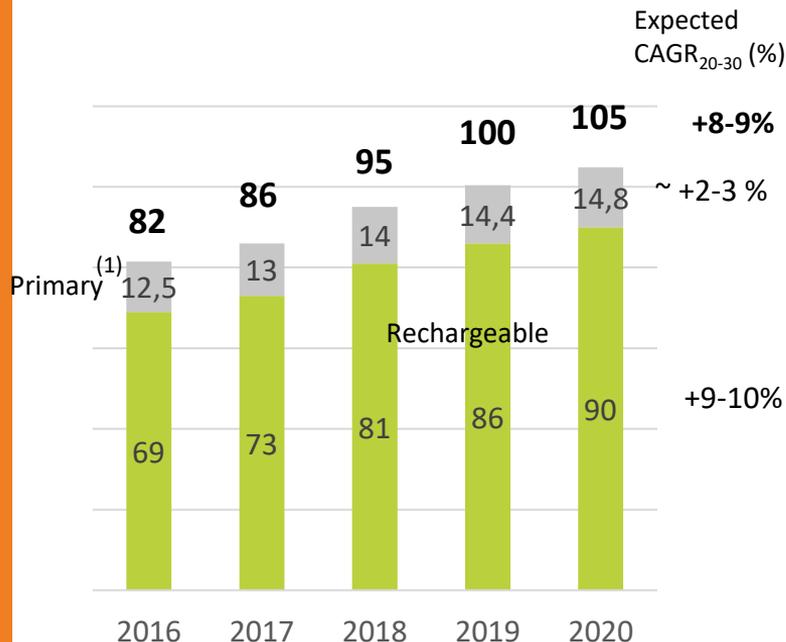
(1) Including Nissan, Mitsubishi

Source : PA Consulting Group, Alix Partner, Avicenne Energy 2021

CONTACT

WORLDWIDE BATTERY MARKET OVERVIEW

Battery market in value (2016-2020, global, \$bn, all market segments, all technologies)



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

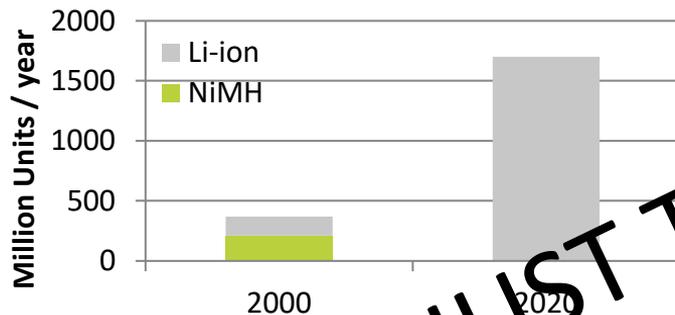
Source: AT Kearney, Duracell, AVICENNE ENERGY 2021

Macro-trends driving the battery market

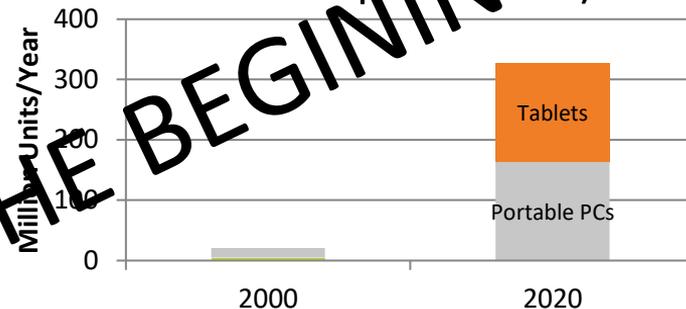
- Battery is a key technology for new concepts of mobility and energy (e.g. electric mobility, stationary storage) supported by the following trends:
 - **Population increase and city growth challenging existing mobility and energy solutions**
 - **Shift in energy production** with an increasing focus 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)

THE BATTERY MARKET IS REALLY DYNAMIC

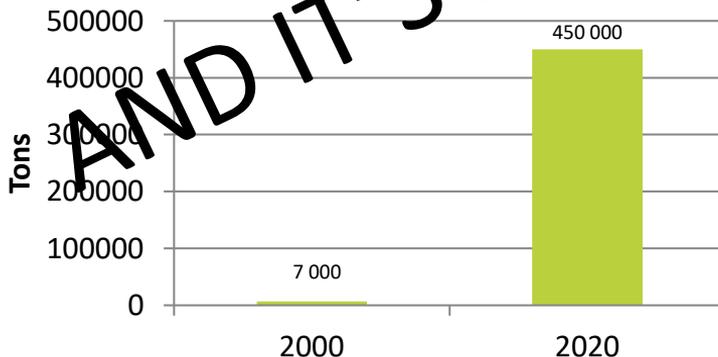
Cellular Phones sold per Year (Million)



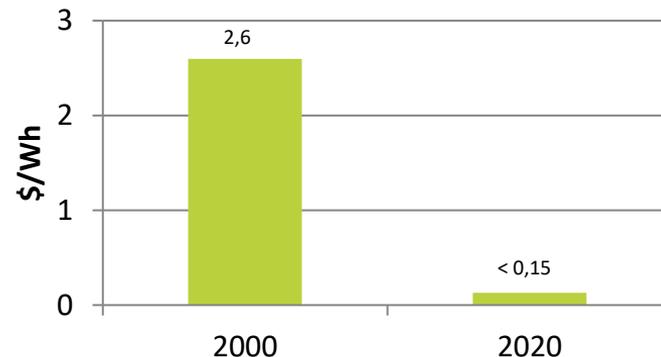
Portable PC sold per Year (Million)



Tons of cathode active materials

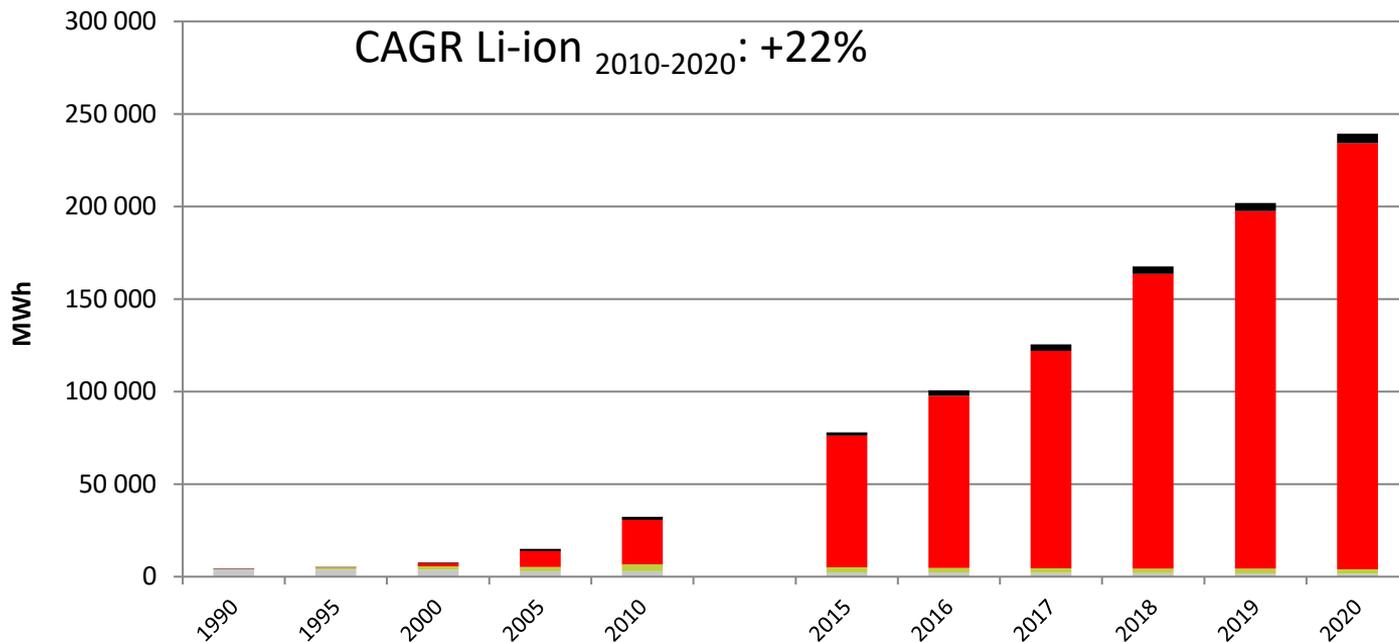


Li-ion 18650 cell price (\$/Wh)



THE WORLDWIDE BATTERY MARKET 1990-2020

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



THE WORLDWIDE BATTERY MARKET 1990-2020

Lithium-Ion Battery: Highest growth & major part of the investments
Lead acid batteries: By far the most important market (~60% market share)

The Rechargeable Battery
Market and Main Trends
2020 – 2030

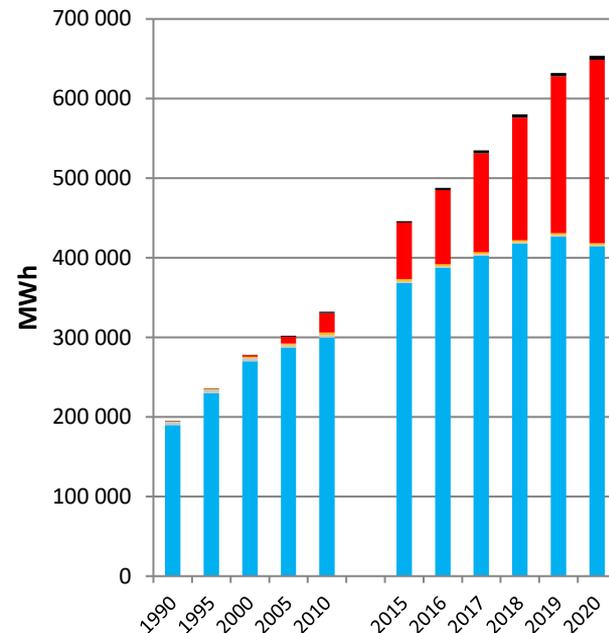
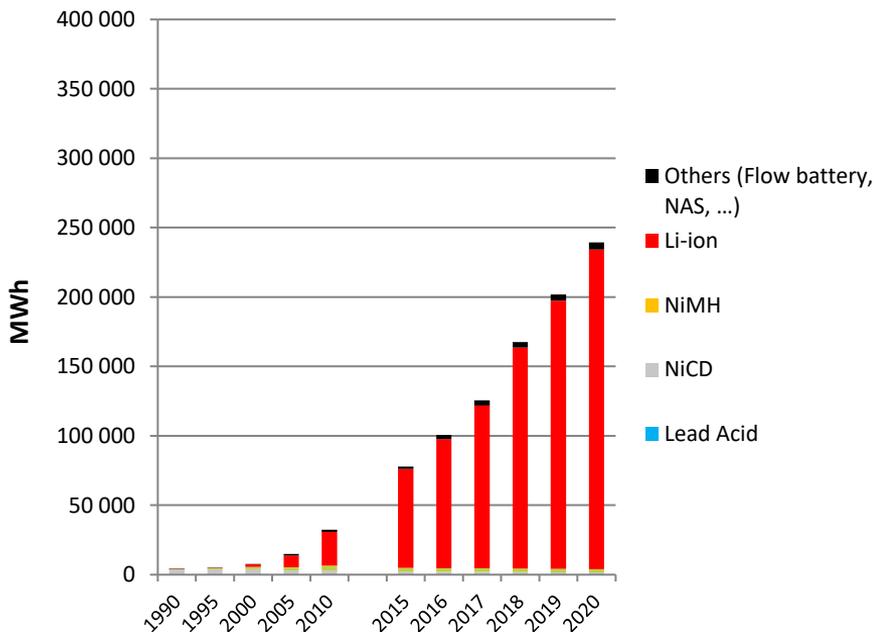


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THE WORLDWIDE BATTERY MARKET 1990-2020

90 BILLION US\$ in 2020 – Pack level¹

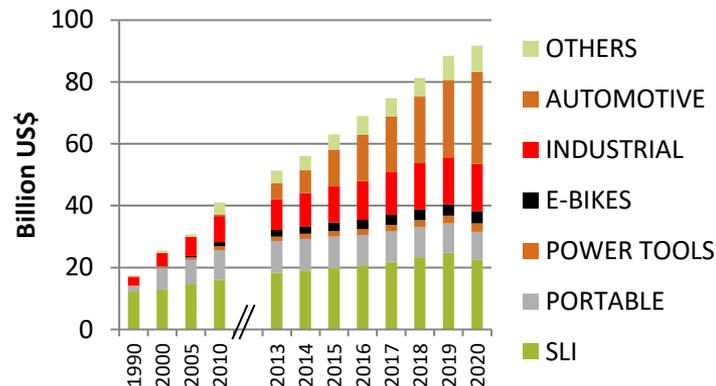
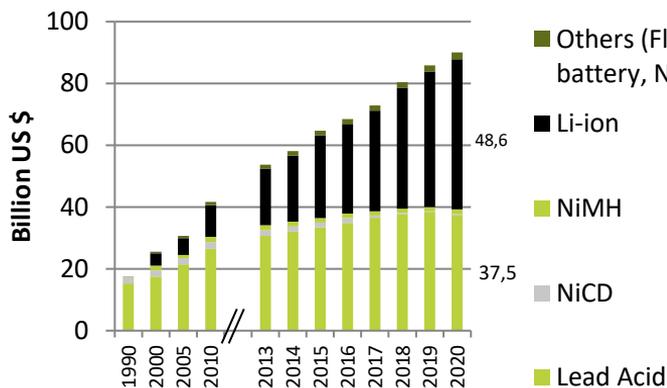
8% AVERAGE GROWTH PER YEAR (2010-2020)

The Rechargeable Battery
Market and Main Trends
2020 – 2030



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

PORTABLE: consumer electronics (cellular, portable PCs, tablets,
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, 2021

INDUSTRIAL

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

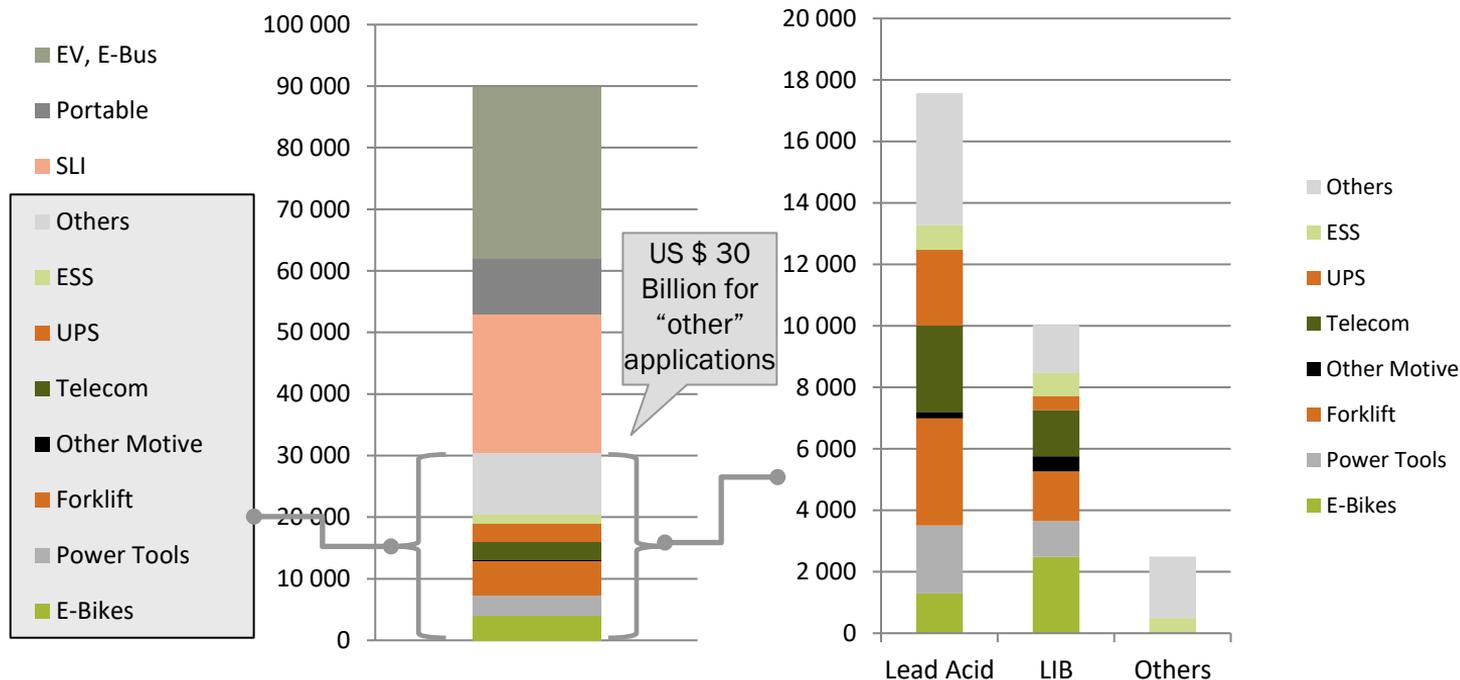
AUTOMOTIVE: HEV, P-HEV, EV

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 2020: US \$ +90 BILLION



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

WORLDWIDE BATTERY SALES BY CHEMISTRY, MWh, 1995-2020

The worldwide rechargeable battery market, in volume, MWh, 1995-2020

The Rechargeable Battery Market and Main Trends
2020 – 2030

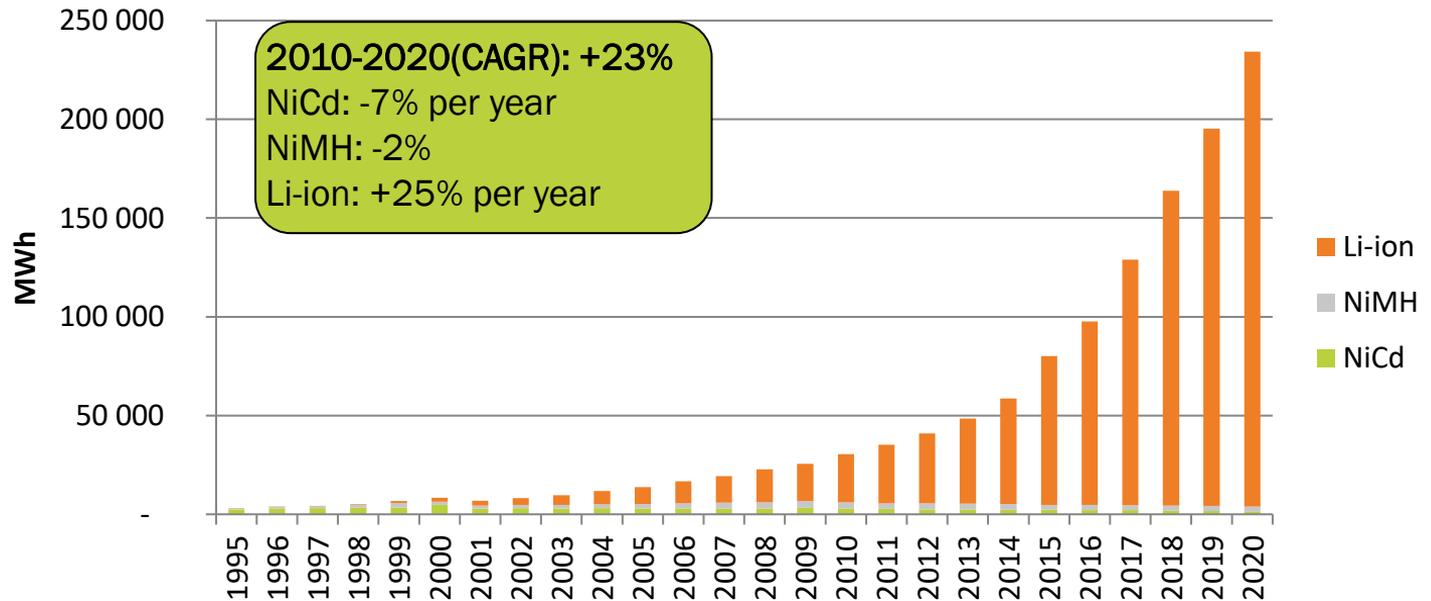


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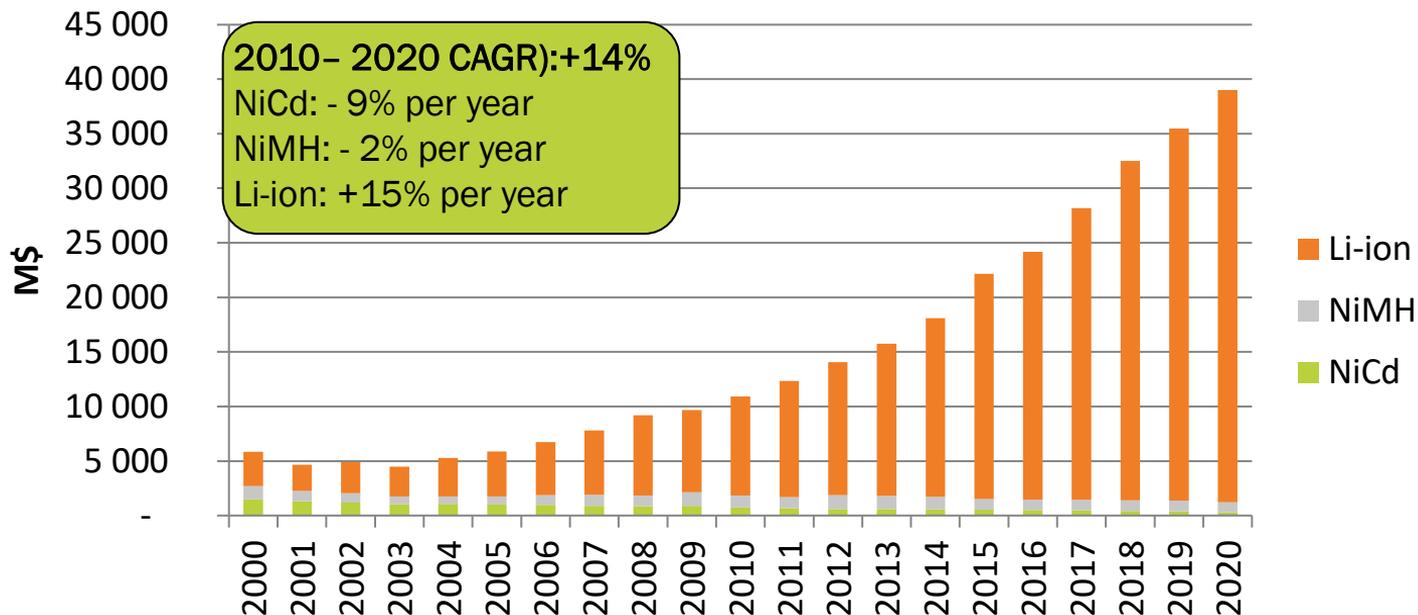
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Source: AVICENNE ENERGY, 2021

WORLDWIDE BATTERY SALES BY CHEMISTRY, M\$, 1995-2019

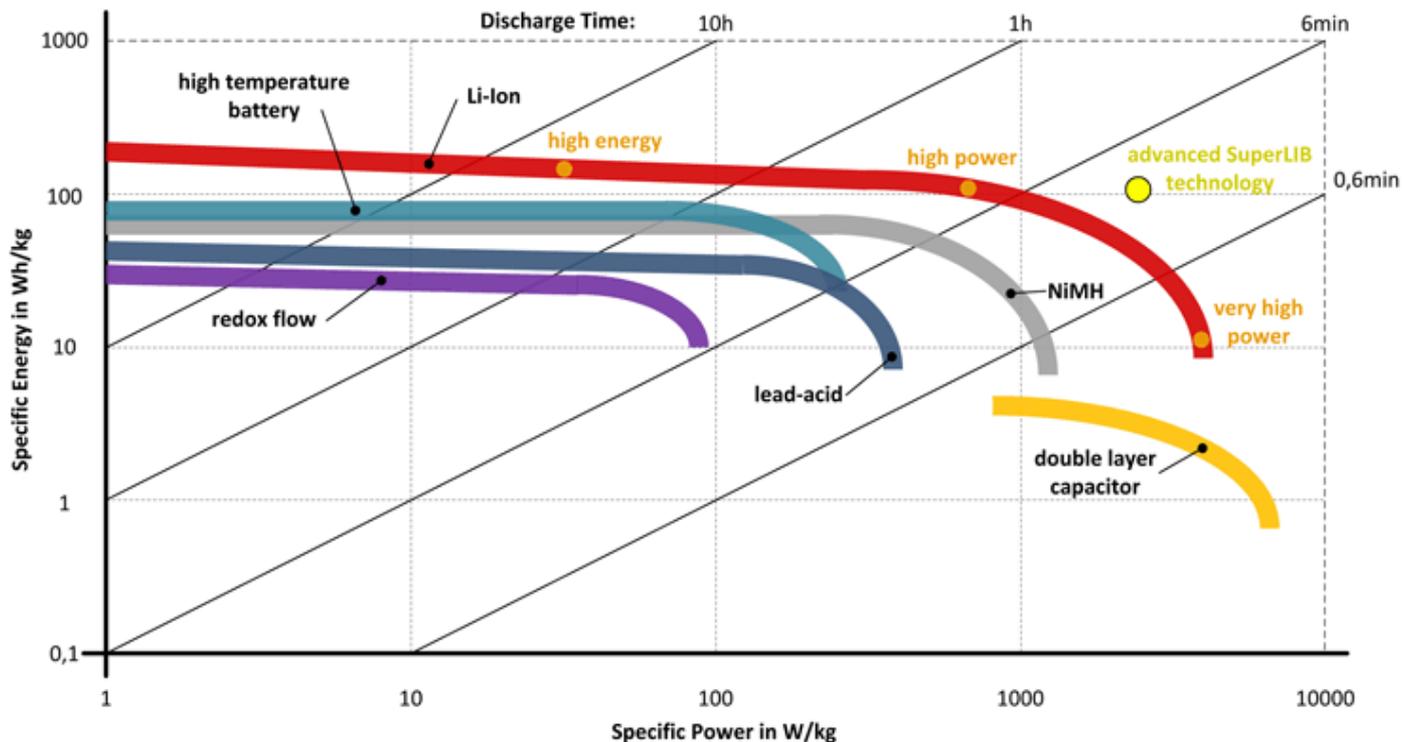
The worldwide rechargeable battery market, in value, M\$(¹), 1995-2020



(1) Cell level

Source: AVICENNE ENERGY, 2021

BATTERY TECHNOLOGY ENERGY & POWER



Source: AVICENNE Analysis 2021

2019-2025 BATTERY TECHNOLOGY AVAILABLE

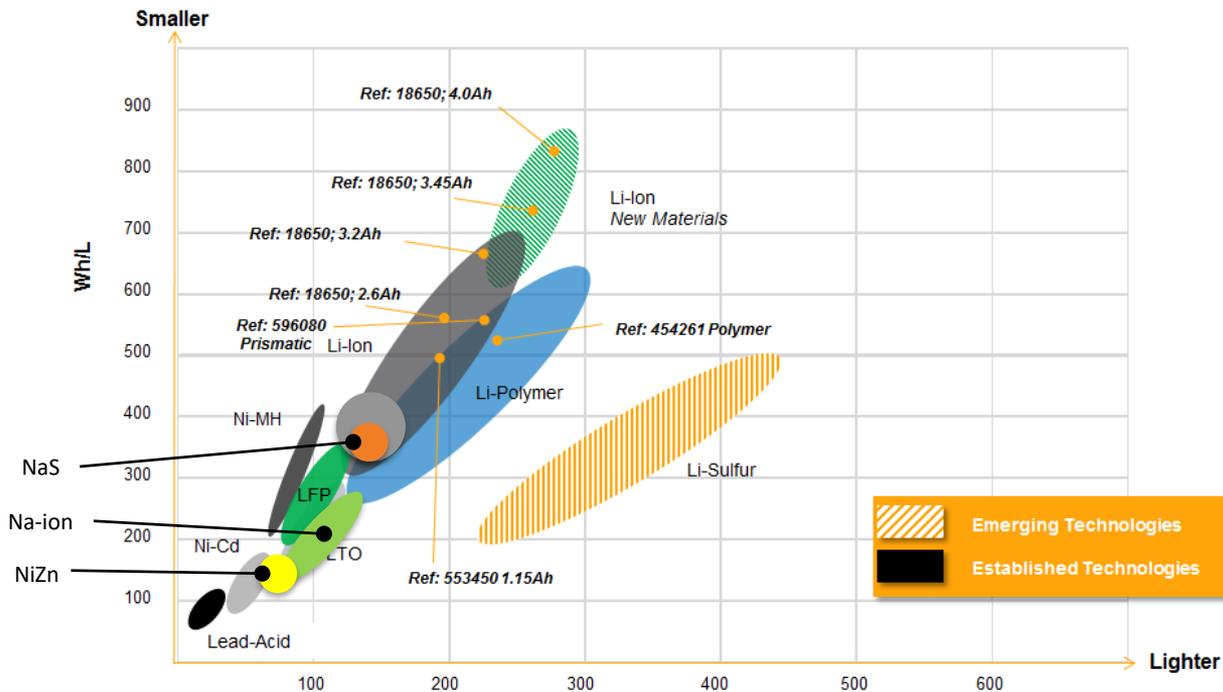
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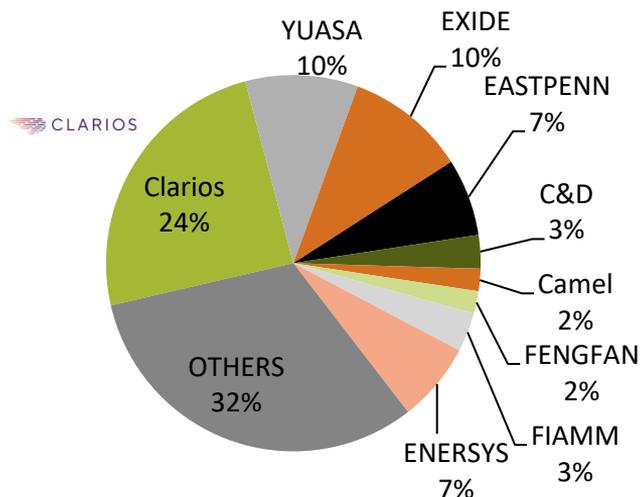
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Source: AVICENNE Analysis 2021, Inventus Power

LEAD ACID BATTERY SUPPLIERS 2020

Global market share on lead acid battery market (B\$ 38)



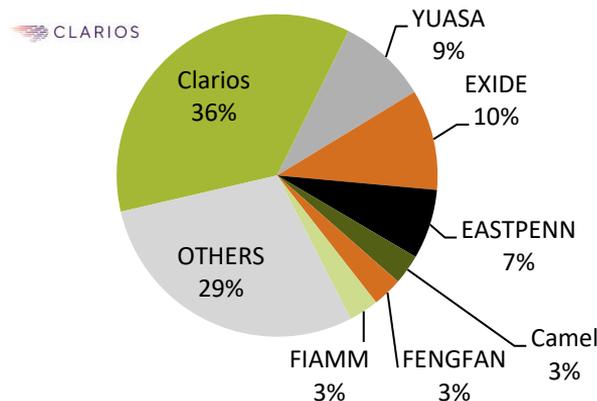
	SLI	Others	TOTAL
Clarios (ex JCI)	36%	4%	24%
YUASA	9%	11%	10%
EXIDE	10%	11%	10%
EASTPENN	7%	6%	7%
C&D		8%	3%
Camel	3%		2%
FENGFAN	3%		2%
FIAMM	3%	4%	3%
ENERSYS		19%	7%
OTHERS	29%	37%	32%

JCI battery business was bought by Brookfield Business Partners L.P., a publicly traded limited partnership, and a group of institutional investors, including Caisse de dépôt et placement du Québec, which manages public pension plans in Quebec

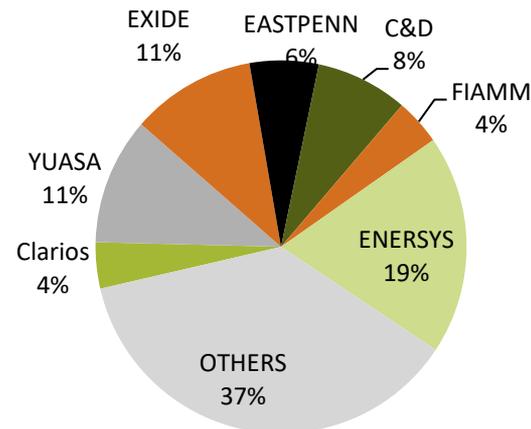
Over the past 15 years, the global lead-acid battery industry has experienced significant consolidation and currently the main international players are EnerSys, Exide Technologies, Clarios, and GS Yuasa Corporation (“GS Yuasa”).

LEAD ACID BATTERY SUPPLIERS 2020

Lead Acid battery Market share : Clarios is leading the SLI market (B\$ 22,5)



Lead Acid battery Market share : EnerSys is leading the Industrial market (B\$ 14,4)



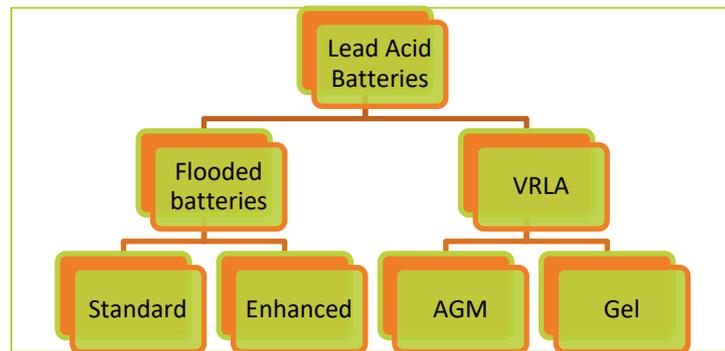
Over the past 15th years, the global lead-acid battery industry has experienced significant consolidation and currently the main international players are EnerSys, Exide Technologies, Clarios, and GS Yuasa Corporation (“GS Yuasa”).

LEAD ACID BATTERY SEGMENTATION

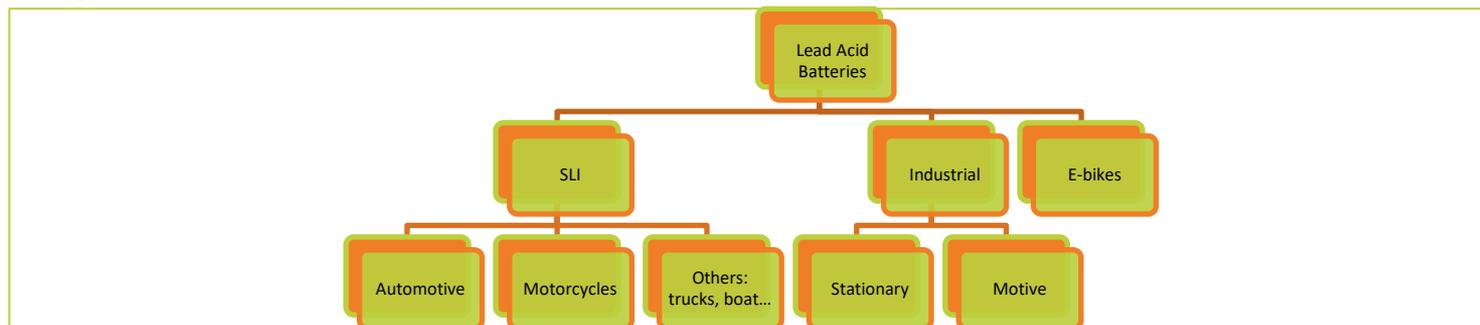
Technology / Application

	Flooded batteries (Wet)		VRLA (Sealed)
Applications	Standard	Enhanced	AGM
Auto standard	√ (100%)		
Moto	√ (80%)		√ (20%)
Micro-hybrid		√ (35%)	√ (65%)
Stationary	√ (25%)		√ (75%)
Motive	√ (90%)		√ (10%)
E-bikes			√ (100%)

Segmentation by technology

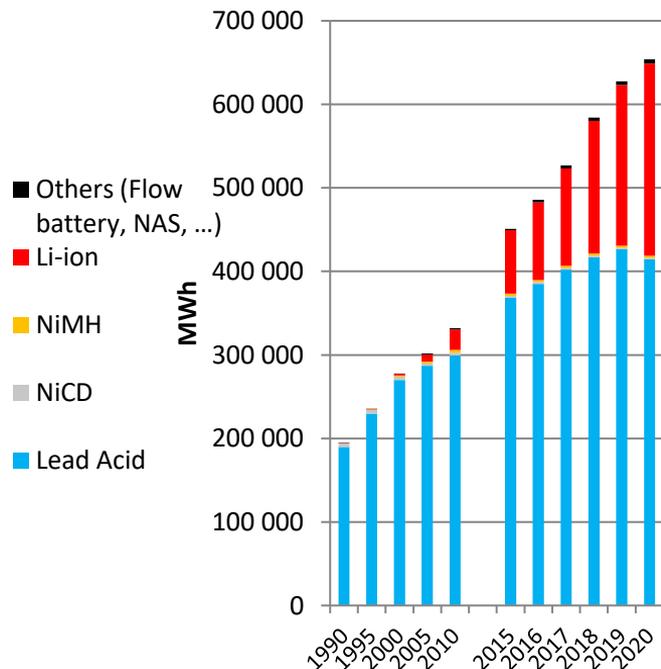


Segmentation by Application



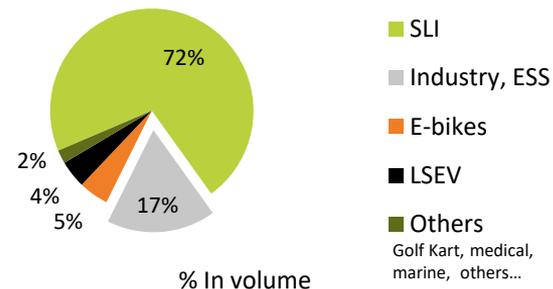
THE WORLDWIDE BATTERY MARKET 1990-2020

In volume (MWh)

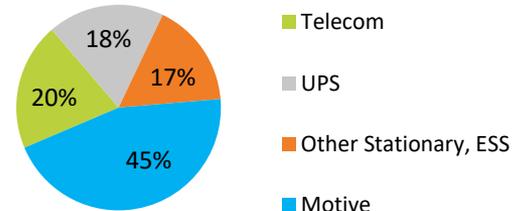


Source: AVICENNE ENERGY, 2021

Lead Acid Batteries 2020
415 GWh for > US \$ 38 Billion



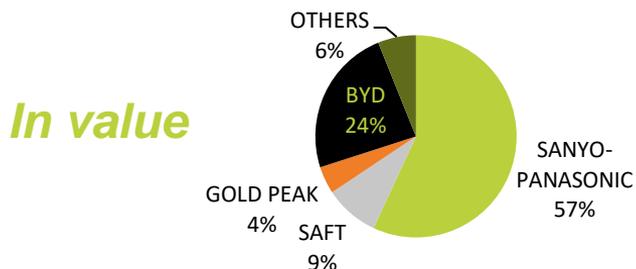
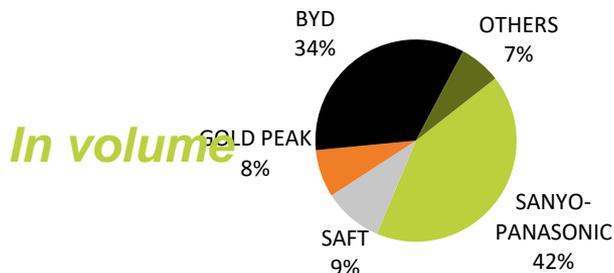
Industrial Batteries – Lead acid batteries
72 GWh for US \$ 10-11 Billion



% In volume

NICD BATTERY: MARKET SHARE IN 2020 IN VOLUME WORLDWIDE

The worldwide NiCd battery market
Company market share in 2020 in
volume – 525 M cells



SANYO-PANASONIC is leading

Companies	Million cells
SANYO-PANASONIC	220
SAFT	50
GOLD PEAK	40
BYD	180
OTHERS	35
TOTAL	525



Fumio Ohtsubo
(Panasonic) &
Seiichiro Sano
(Sanyo)
January 8th,
2012

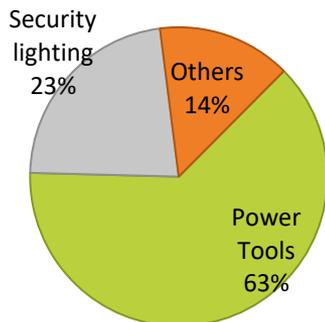
NiCd IN 2020

MAIN APPLICATION: POWER TOOLS

525 M cells – 1500 MWh

310 M\$¹

**NiCd by application worldwide, %
in value, 2020**



Note:

¹ Portable applications, power tools and emergency lighting only:
industrial application as well as energy storage are excluded

Source: AVICENNE ENERGY, 2021

CAGR 2009/2019

-6% per year in volume

-7% per year in value

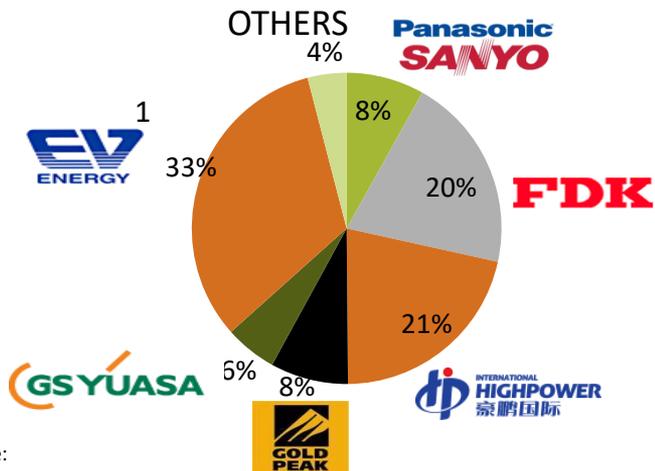
- 🔗 All the applications are decreasing
- 🔗 Competition with NiMH & Li-ion
- 🔗 New application (?)
 - 🔗 Energy storage



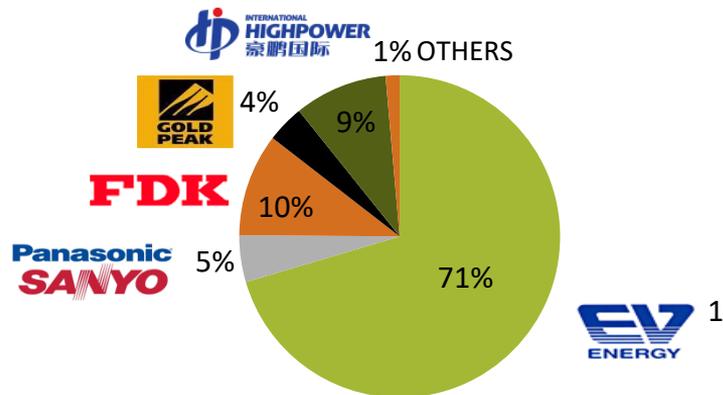
ABB Inc., Fairbanks, Alaska, 27 MW/15 minutes

NIMH BATTERY: MARKET SHARE IN 2020 WORLDWIDE

The worldwide NiMH battery market
Company market share in 2020 in
volume – < 500 M cells



The worldwide NiMH battery market
Company market share in 2020 in
value – 0,9 Bn \$



Note:

¹ PEVE: Primearth EV Energy (PEVE) The company was known as Panasonic EV Energy Co until 2 June 2010. The company was formed in 1996 as a joint venture between Toyota and Panasonic, with Panasonic holding 60% of the capital. Panasonic sold 40.5% of the company to Toyota. PEVE is the supplier of the NiMH battery packs for Toyota's hybrids, as well as for Honda (Civic hybrid and first generation Insight) hybrids. The company also provides the NiMH prismatic battery modules for the General Motors

² Japan's Sanyo Electric Co sold part of its battery operations to FDK Corp a Fujitsu Ltd unit, for 6.4 billion yen (\$70 million) to satisfy antitrust regulators ahead of its planned takeover by Panasonic Corp at the end of 2009.

NIMH IN 2020

MAIN APPLICATION: HYBRID VEHICLES

To be up-date

<500 M cells – 0,9 B\$(1)

CAGR 2010/2020: -2%

The Rechargeable Battery
Market and Main Trends
2020 – 2030

**BATTERIES
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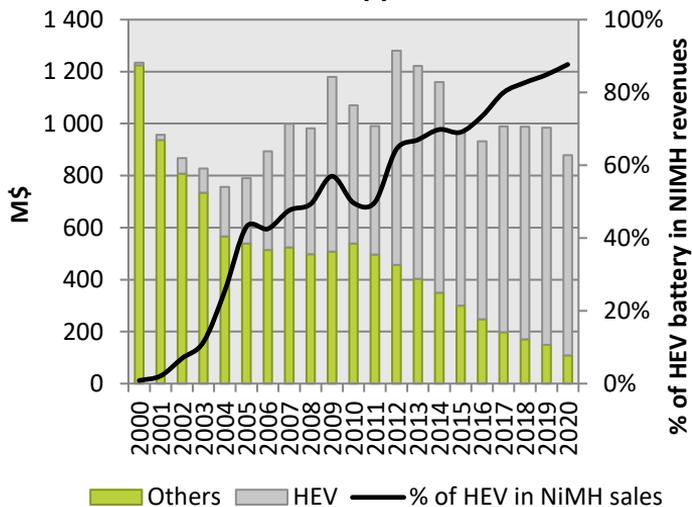
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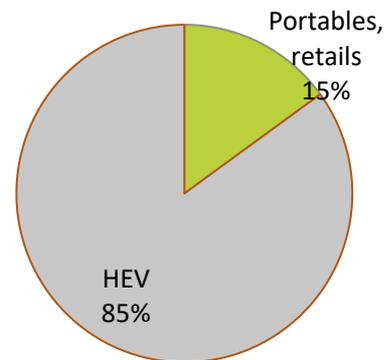
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**NiMH battery market worldwide in value
% for HEV application**



**NiMH battery by applications,
worldwide, % in value, 2019**

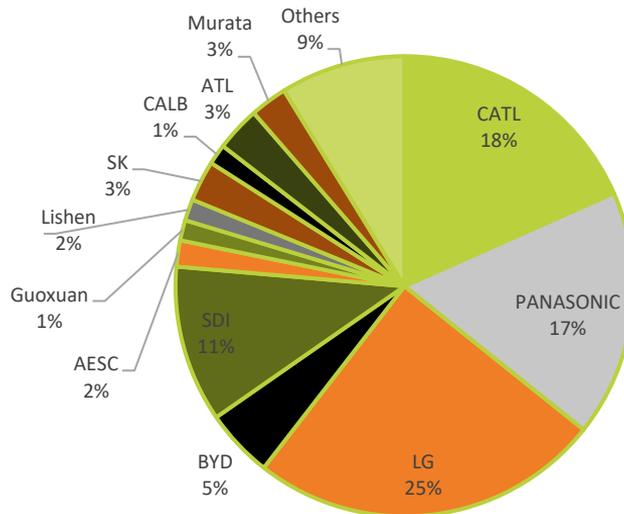


(1) Cell based market – 1,1 B\$ at the pack level

Source: AVICENNE ENERGY, 2021

MAJOR CELL PRODUCERS

Lithium ion battery global market share (245 GWh) - 2020





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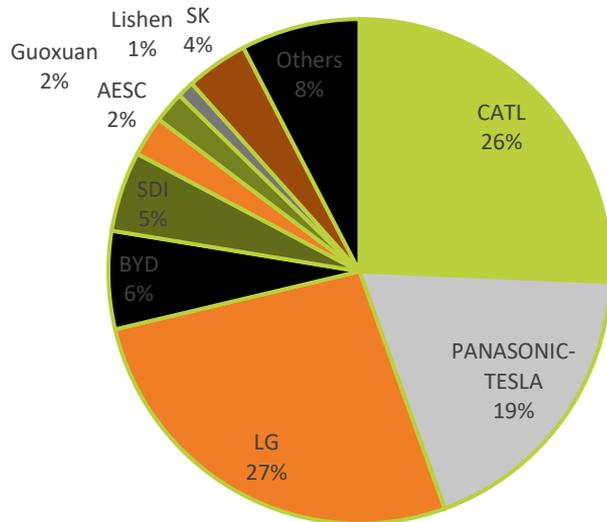
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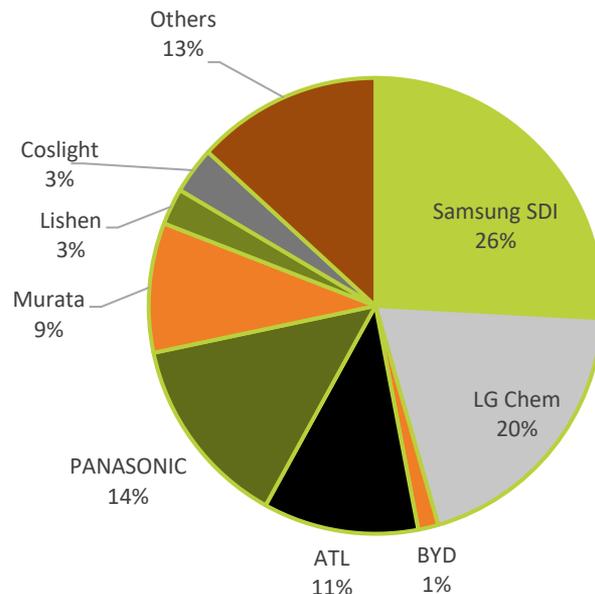
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LITHIUM ION BATTERY MARKET SHARE

xEV Lithium ion batteries Market Share in 2020
(175 GWh)



Lithium ion battery market share (Excluding xEV,
E-buses) – 70 GWh - 2020



Leaders for xEV market are not always the same than historical leaders for Electronic devices



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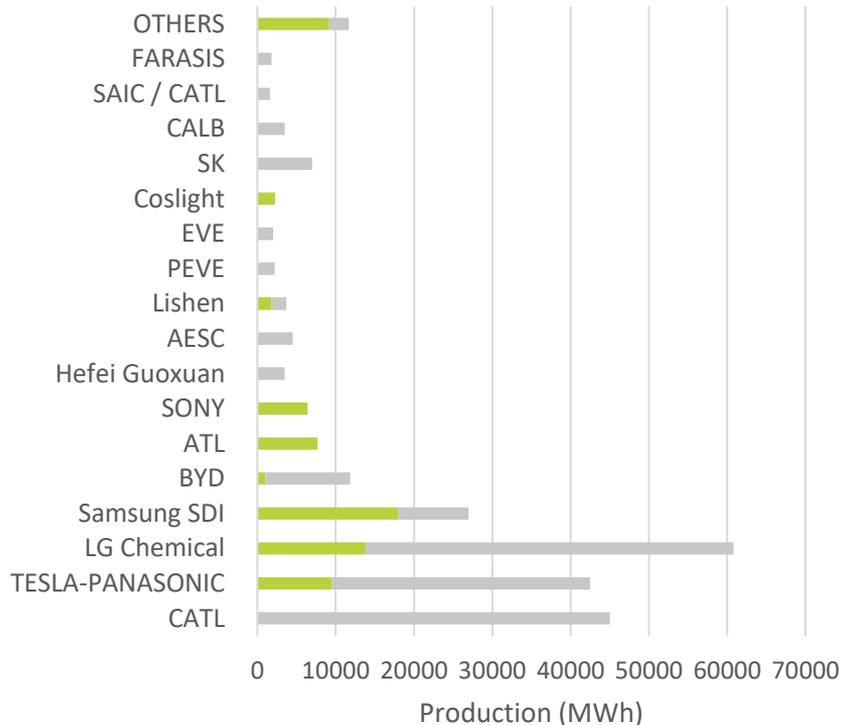
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LITHIUM ION BATTERY PRODUCTION IN 2020

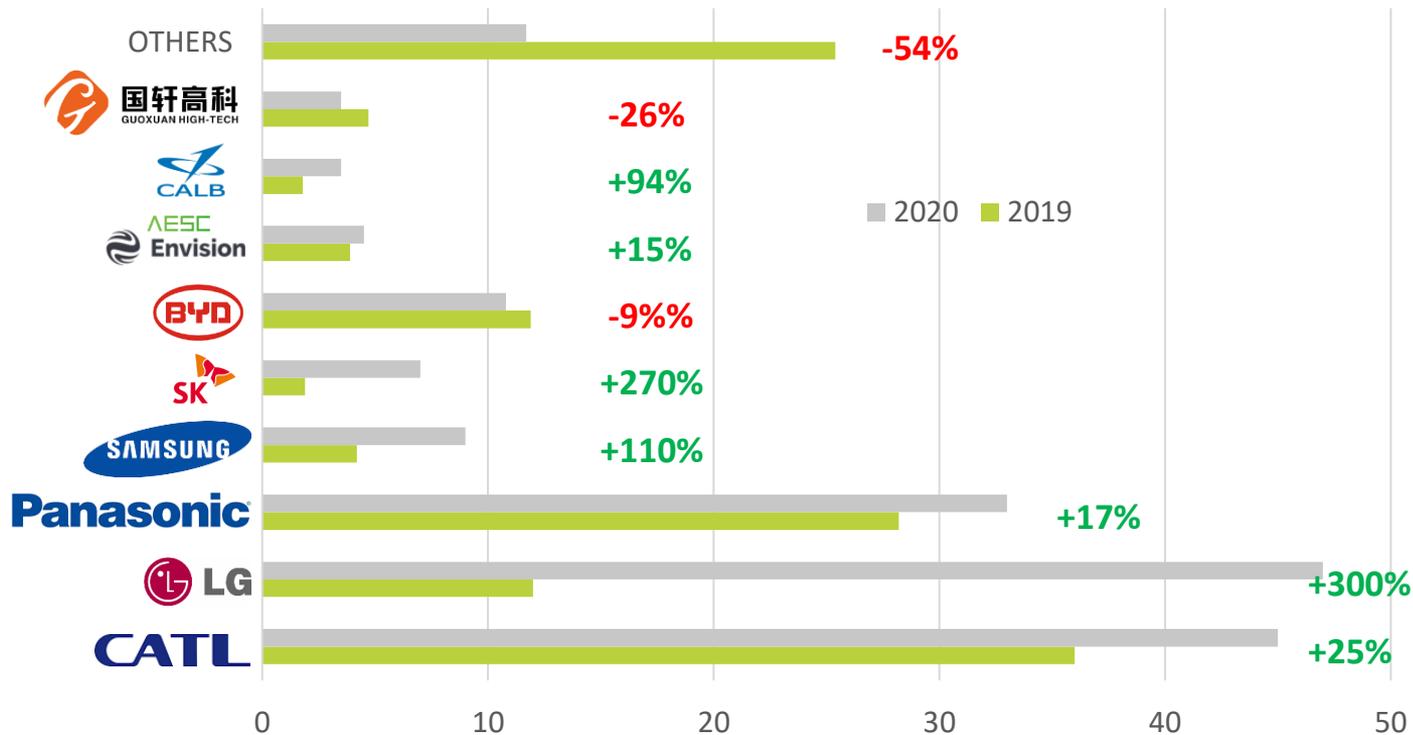


■ Portable & Others ■ xEV

2020	Portable & Others	xEV	TOTAL MWH
	(Avicenne Assumption)		
CATL		45 000	45 000
TESLA-PANASONIC	9487,5	33 000	42 488
LG Chemical	13 791	47 000	60 791
Samsung SDI	17 972	9 000	26 972
BYD	1022,7	10 800	11 823
ATL	7 693		7 693
Murata	6 397		6 397
Hefei Guoxuan		3 500	3 500
AESC		4 500	4 500
Lishen	1 800	1 900	3 700
PEVE		2 200	2 200
EVE		2 000	2 000
Coslight	2 263		2 263
SK		7 000	7 000
CALB		3 500	3 500
SAIC / CATL		1 600	1 600
FARASIS		1 800	1 800
OTHERS	9 176	2 500	11 676
TOTAL	69 601	175 300	244 901

Source: AVICENNE ENERGY 2021

LITHIUM ION BATTERY PRODUCTION FOR XEV IN 2019 & 2020 (GWH)





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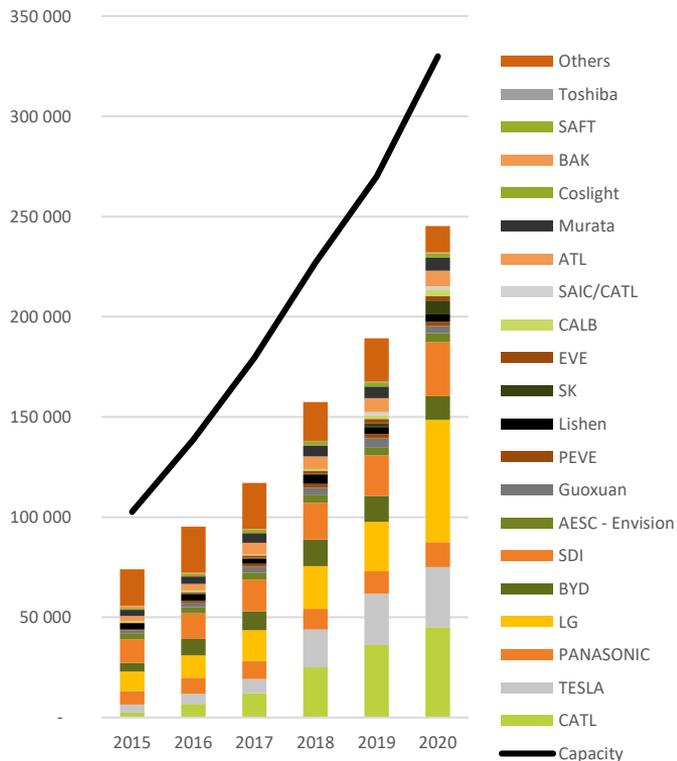
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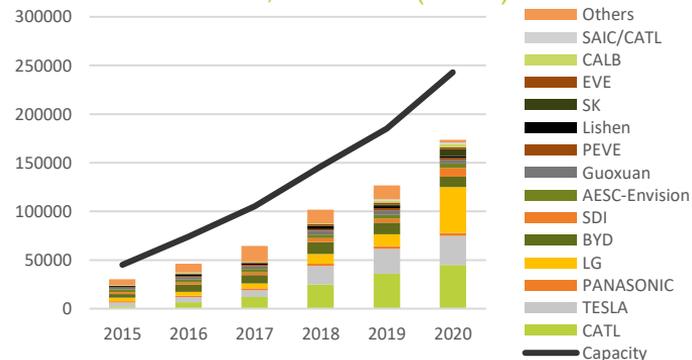
LITHIUM ION PRODUCTION & PRODUCTION CAPACITY (MWH)

Total Production / Production capacity (MWh)

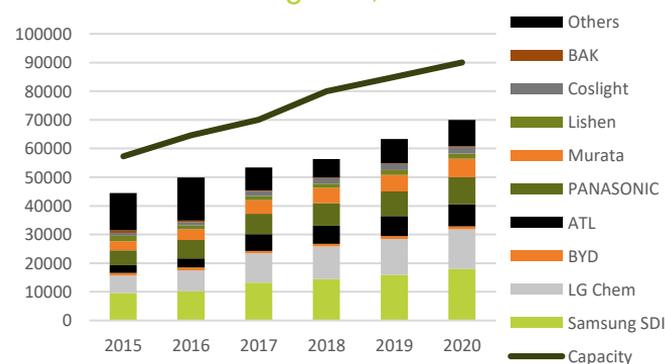


Source: AVICENNE Energy 2021

Production for xEV, E-Buses (MWh)



Production Excluding xEV, E-Buses

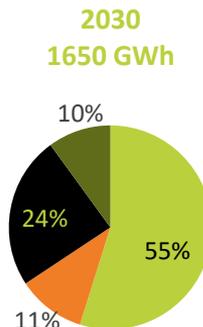
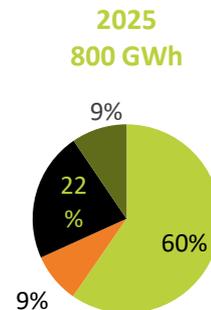
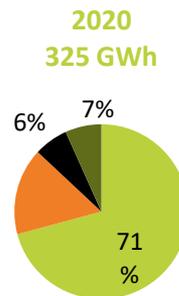
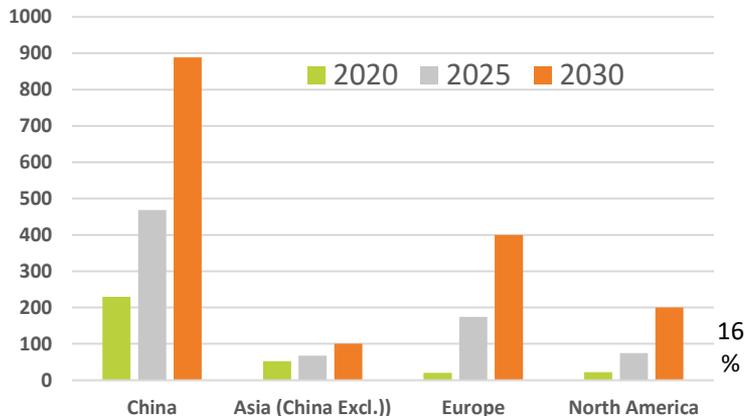


PRODUCTION CAPACITY FORECAST

In Europe, capacity should increase from few GWh before 2020 to 175 GWh in 2025

9 to 11 billion Euros investment required from 2020 to 2025 for cell manufacturing

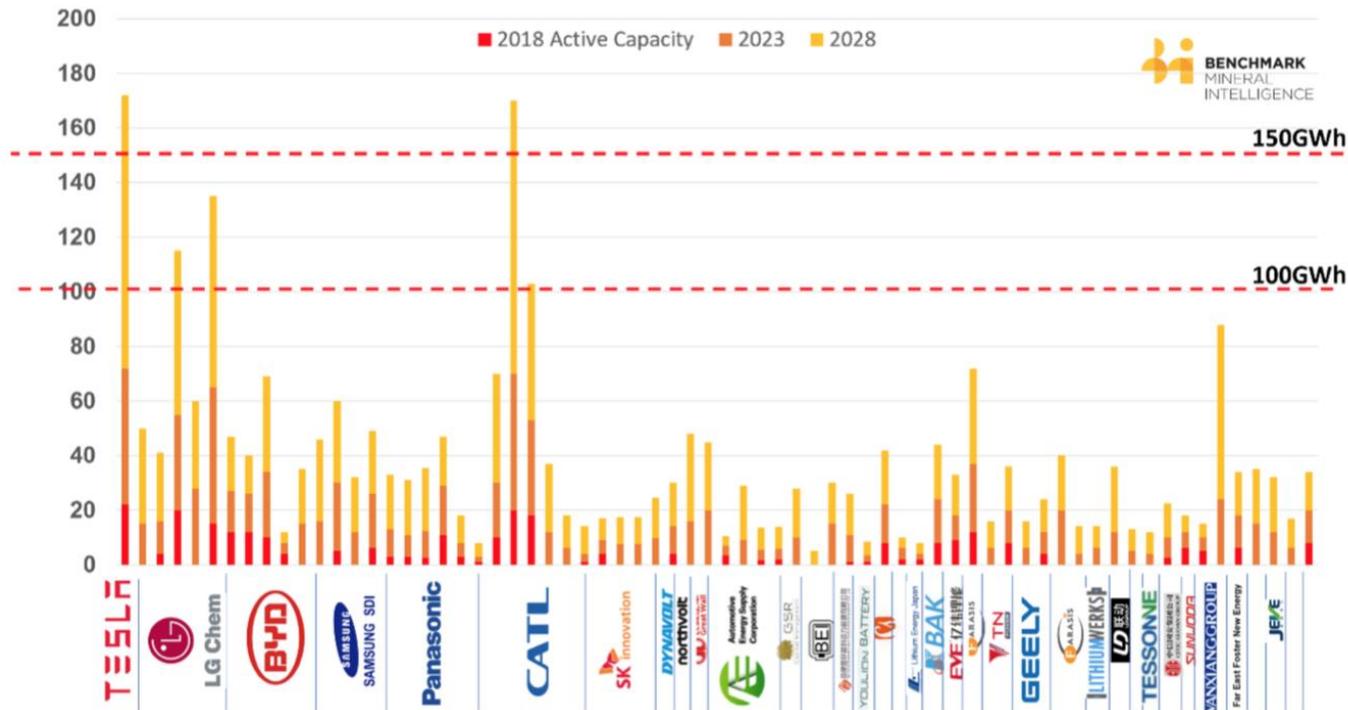
Capacity by region



China Other Asia Europe US

LI-ION PRODUCTION CAPACITY WORLDWIDE

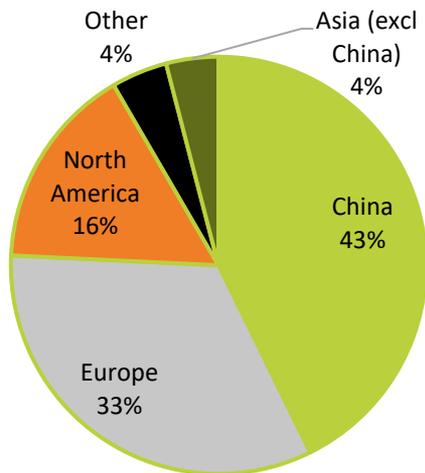
Chart 1: Build out of lithium ion battery capacity from 2018 to 2028



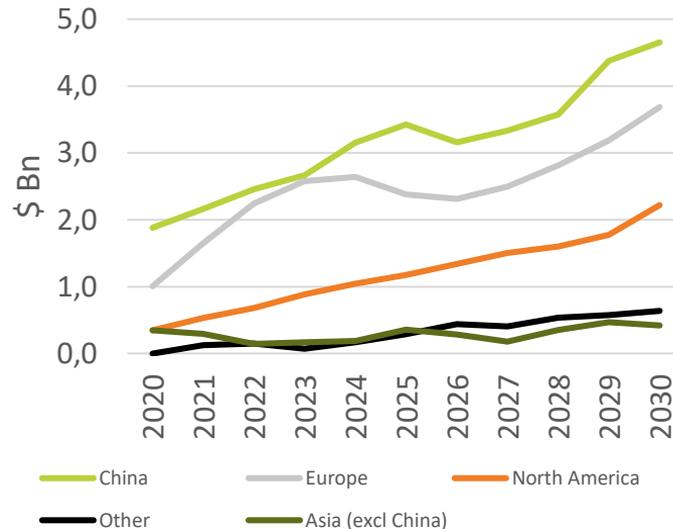
Source: Benchmark Mineral Intelligence

Lithium-Ion Battery – Capex Forecast

82 \$Bn investment over the
period 2020-2030



Annual Capex Evolution by region for
LIB cell manufacturing

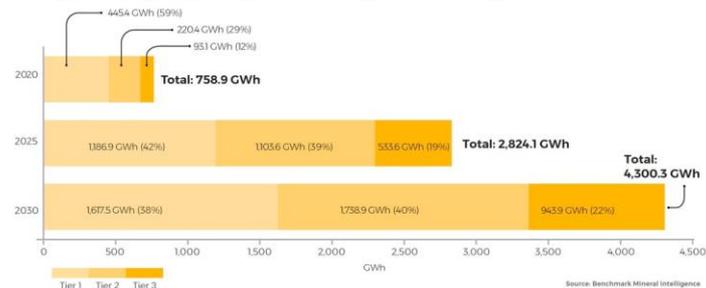


Global Lithium-Ion Battery Capacity Forecast 2020-2030

- Gigafactory tracking** : Benchmark Mineral Intelligence (and Roskill) monitor globally **each announcement** of new battery manufacturing projects on a daily basis; total 2030 'forecast' climb from 2582 GWh recorded in July 2020 to 4300 GWh recorded in August 2021
- Gigafactory announcement** : some of the projects will be implemented at planned capacity, some at reduced capacity, some will be postponed and **a lot will never be built**; for example, in Europe, in addition to the already existing large-scale producers (LG in Poland, Samsung and SKI in Hungary) who are increasing their installed capacity, **the only new players** who are in the process of building their gigafactory today are : CATL in Germany and Nortvolt in Sweden

Source: AVICENNE ENERGY, 2021

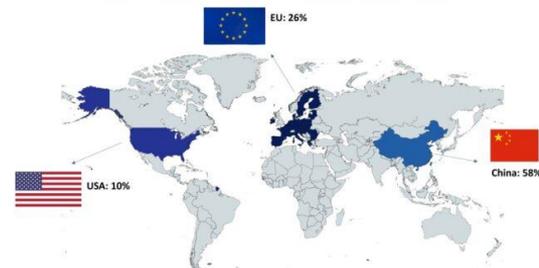
Megafactory capacity forecast by tier ranking



Tier 1 : Qualified for Western Auto Tier 2 : Qualified for Chinese Auto Tier 3 : Not yet qualified for Automotive
Source : Benchmark BMI, August 2021

Roskill

Global Li-ion battery cell capacity planned for 2030



232 Plants for a total of 4000 GWh in 2030

Source : Roskill, August 2021



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The Rechargeable Battery
Market and Main Trends
2020 – 2030

**BATTERIES
EVENT 2021**

September 28th, 2021

Lyon, France

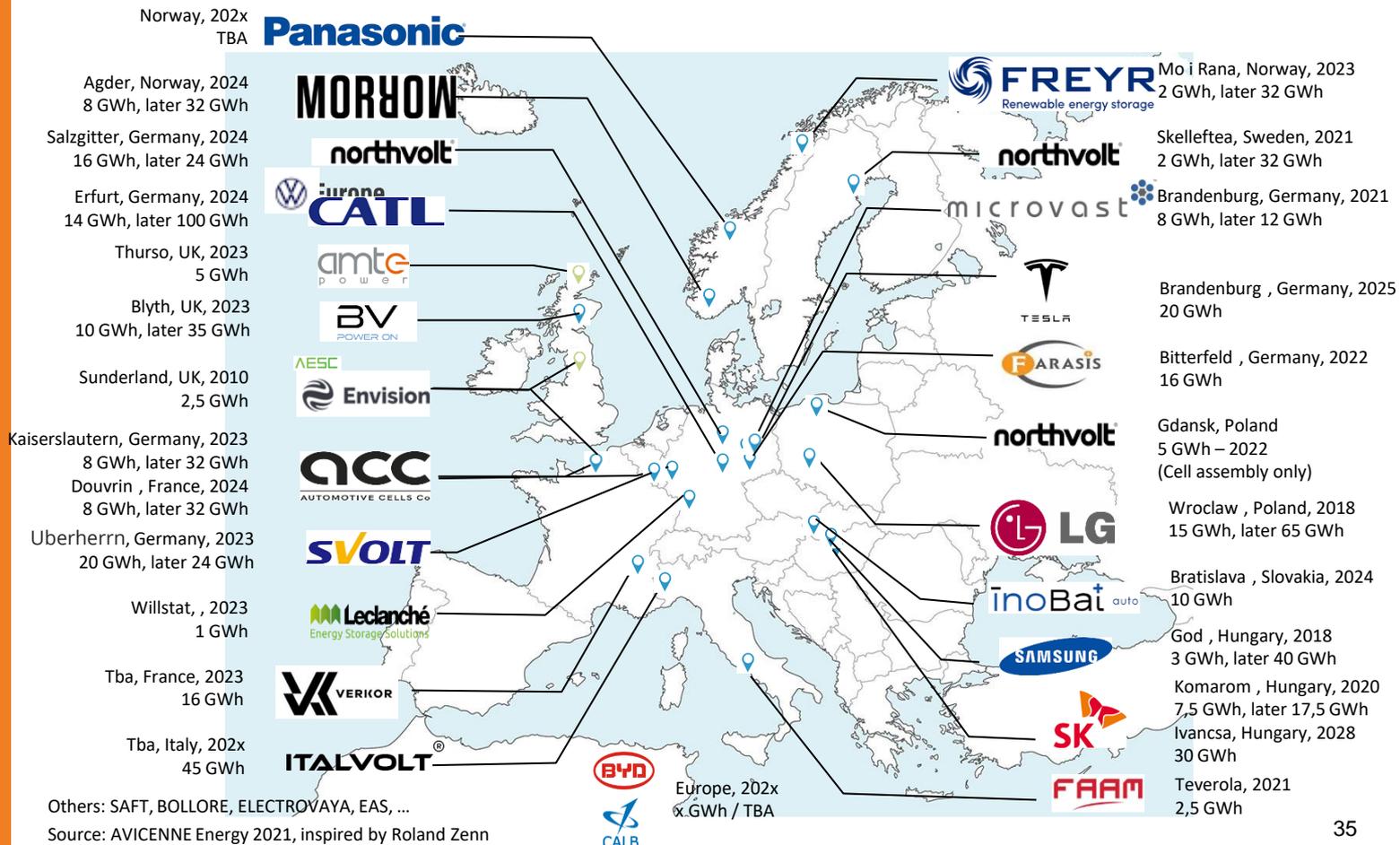
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EUROPE PRODUCTION CAPACITY: FROM SEVERAL GWH IN 2020 TO 100-150 GWH IN 2023 & 500 GWH IN 2028





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2020 – 2030

BATTERIES
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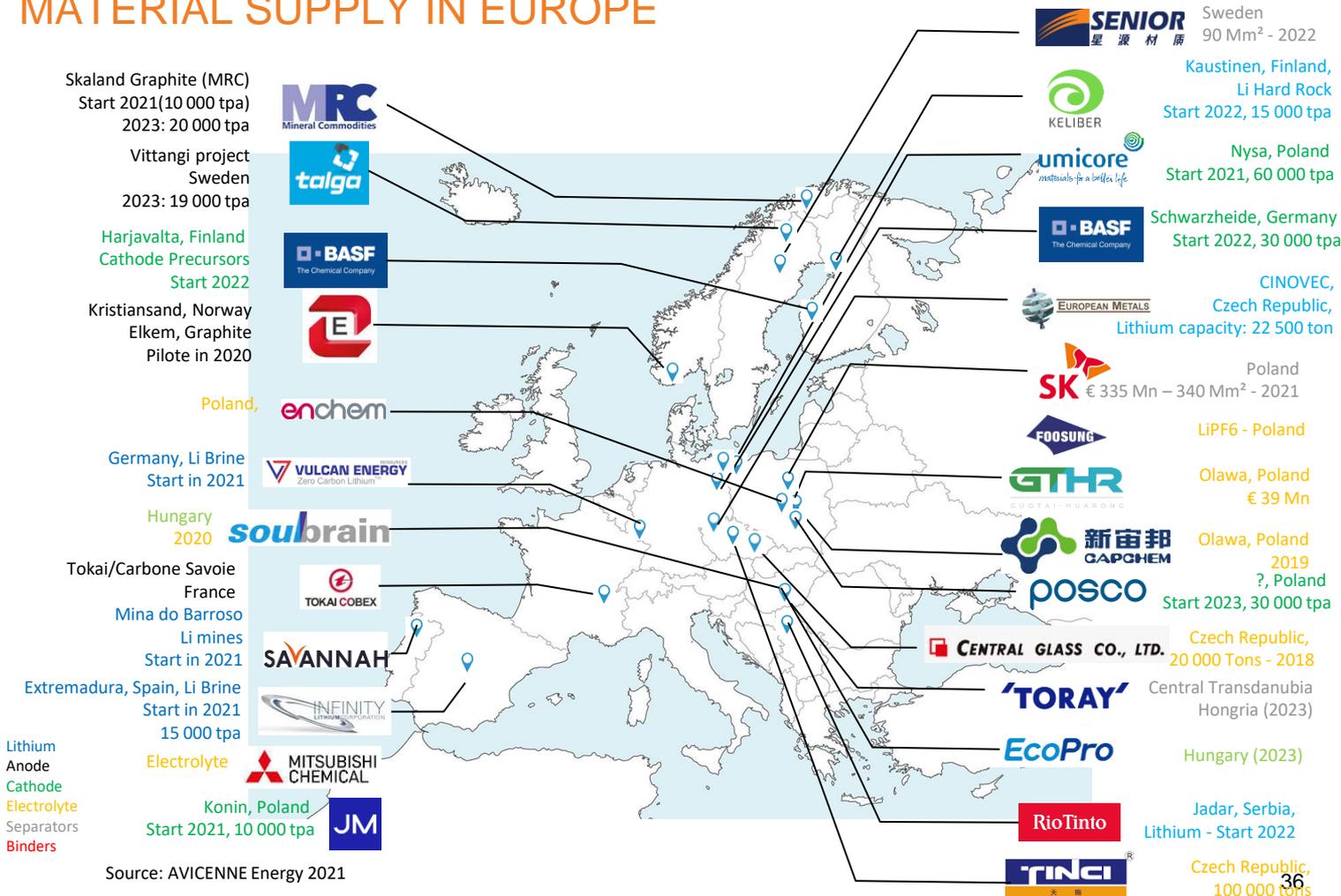
Lyon, France

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MATERIAL SUPPLY IN EUROPE





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Market and Main Trends
2020 – 2030



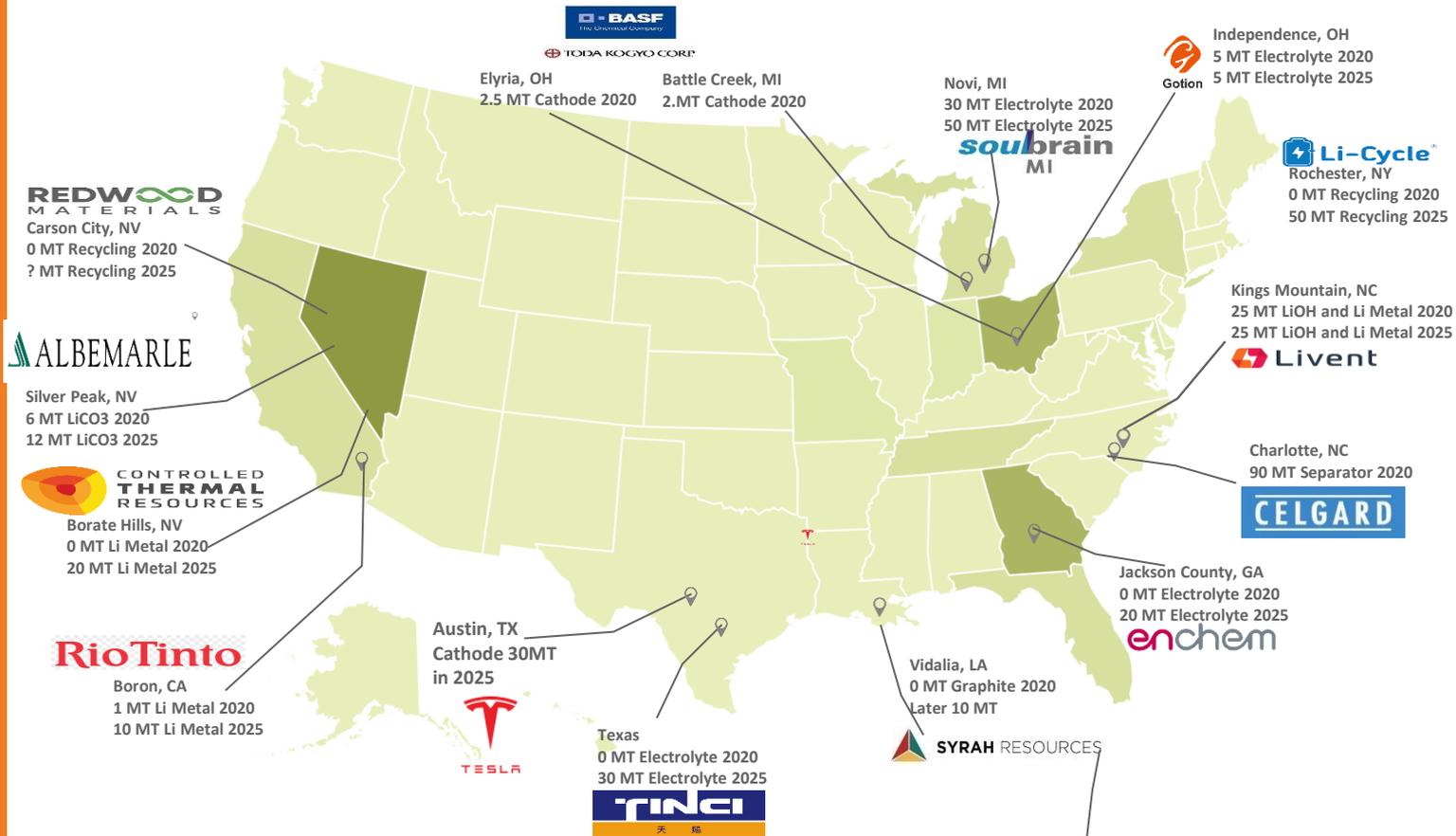
September 28th, 2021

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US BATTERY MATERIALS AND RECYCLING





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BATTERIES
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CONTACT

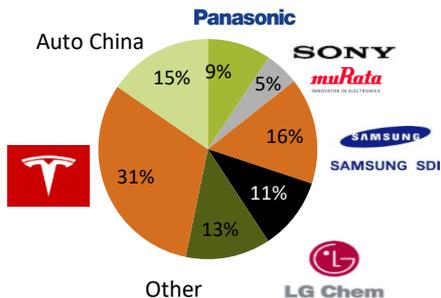
Christophe PILLOT
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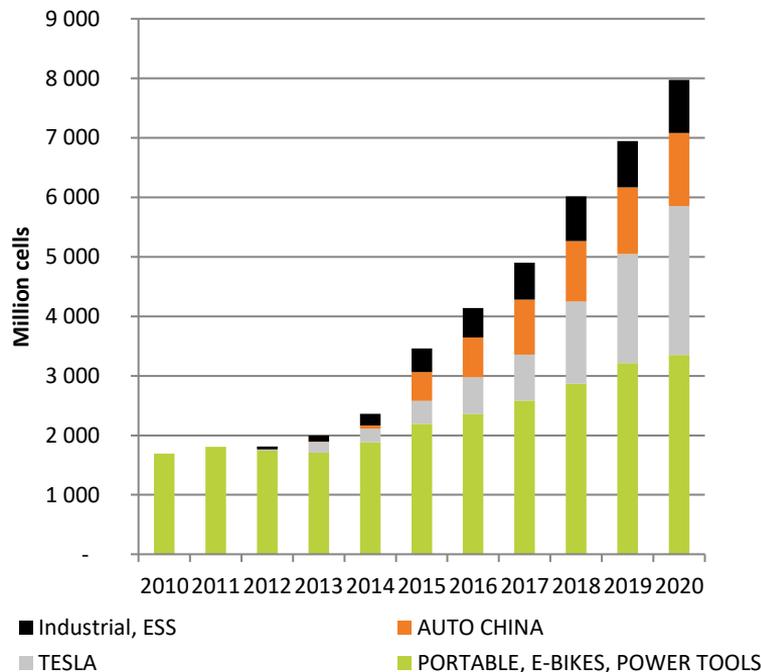
CYLINDRICAL LI-ION BATTERY (SMALL CELLS)

In 2020, AUTO & ESS demand represent almost 60% of the Cylindrical cells demand

Cylindrical LIB market Company market share in 2020 in volume 8000 Million cells (+15%)



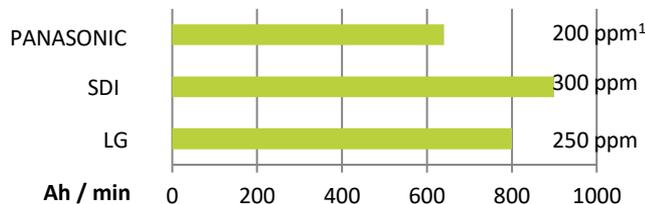
PANASONIC, TESLA, SDI & LG will share the market



Key success factor

- Production speed (-> cost)
- Performances
- Customer access

Production Speed: 18650 – 2,8Ah cells

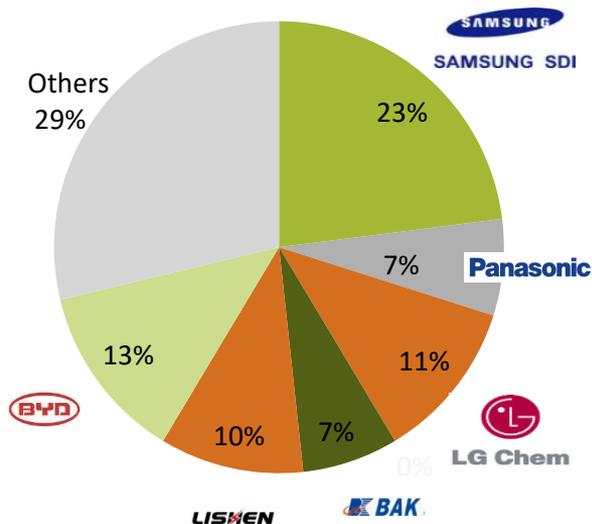


Note: ¹ ppm: piece per minutes

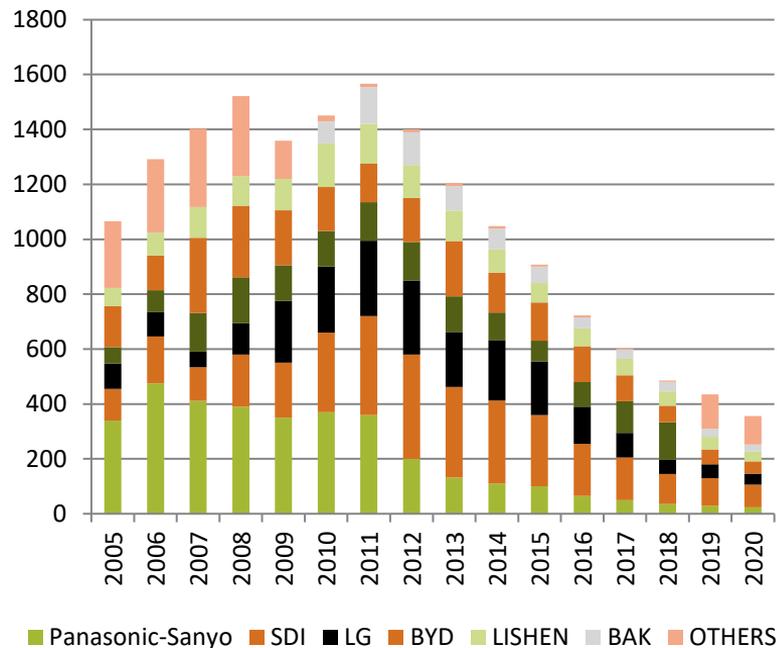
Source: Interviews with LG, SAMSUNG, SANYO-PANASONIC, AVICENNE Energy 2021 39

PRISMATIC LI-ION BATTERY (SMALL CELLS)

Prismatic LIB market Company
market share in 2019 in volume:
~360 Million cells (-15%)



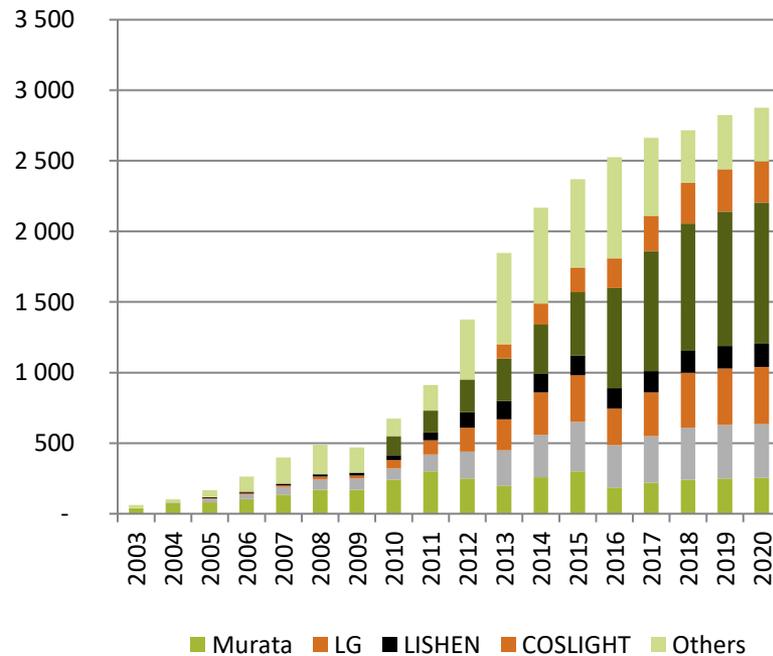
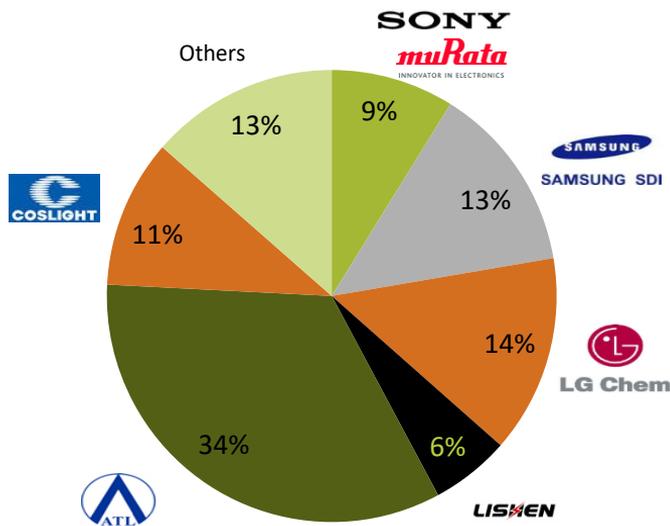
Prismatic cells (M) by Mfg. :
SAMSUNG is leading



LI-ION POUCH BATTERY (SMALL CELLS)

Pouch battery market Company
market share in 2020 in volume:
2,8 Billion cells (stable)

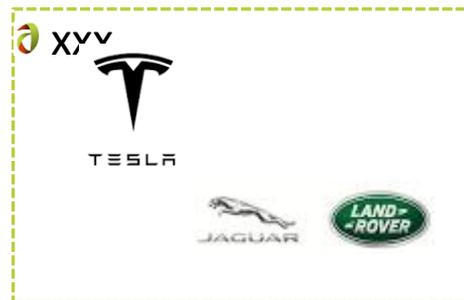
Pouch cells (M) by Mfg. ATL, LG,
SAMSUNG and COSLIGHT are leading
this market



WHICH CELL FORMAT FOR XEV

The cell format depend on the supply

Cylindrical*



Prismatic*



Pouch*



(*) Based on the main production: CATL produce mainly prismatic but they also have cylindrical and pouch cells

Source: AVICENNE Energy 2021

WHICH CELL FORMAT FOR EV?

At the cell level

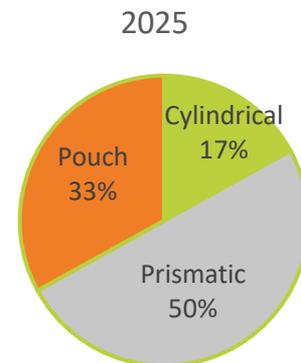
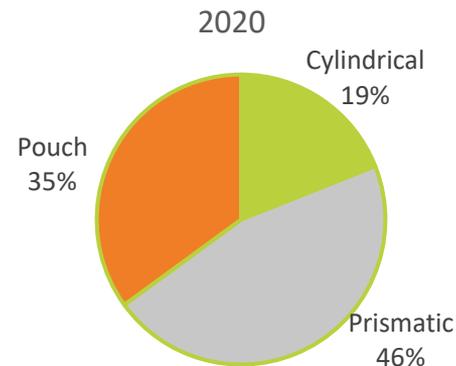
	Cylindrical	Prismatic	Pouch
Weight	+	++	+++
Cost	GOOD	BAD	BETTER
Volume Energy density	+++	++	++
Different Application possible - higher volumes	YES	NO	NO
Safety	YES	YES	LESS

At the pack level

	Cylindrical	Prismatic	Pouch
Weight	+	++	+++
Cooling Efficiency	GOOD	GOOD	BAD
Cost	GOOD	BAD	BETTER
Volume Energy density	BAD	OK	OK
Different Application possible - higher volumes	YES	NO	NO
Safety	YES	YES	LESS

Source: AVICENNE ENERGY 2019

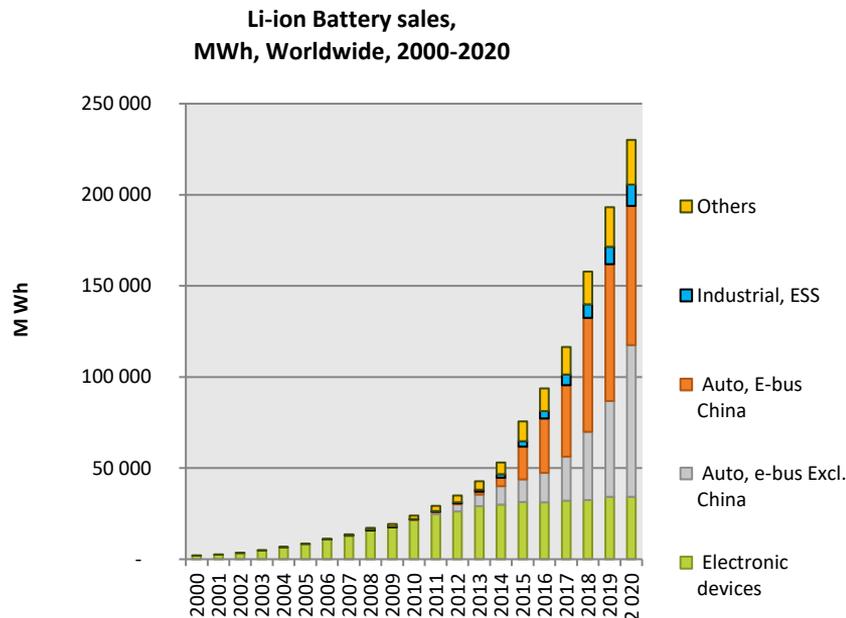
Cell Format % (MWh) for EV



LI-ION IN 2020 - MAIN APPLICATIONS

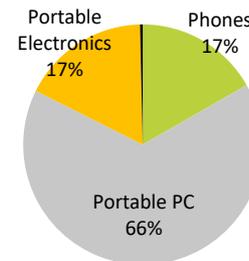
>230 000 MWh - 50 B\$ (1)

CAGR 2010/2020
+25 % per year in Volume

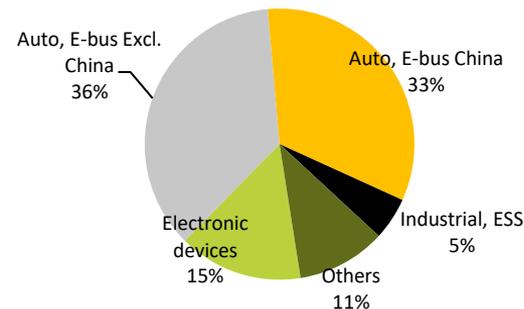


(1) Pack level
Others: medical devices, power tools, gardening tools, e-bikes...
Source: AVICENNE Energy 2021

2000: < 2GWh



2020: >230 GWh



LI-ION IN 2020 - MAIN APPLICATIONS

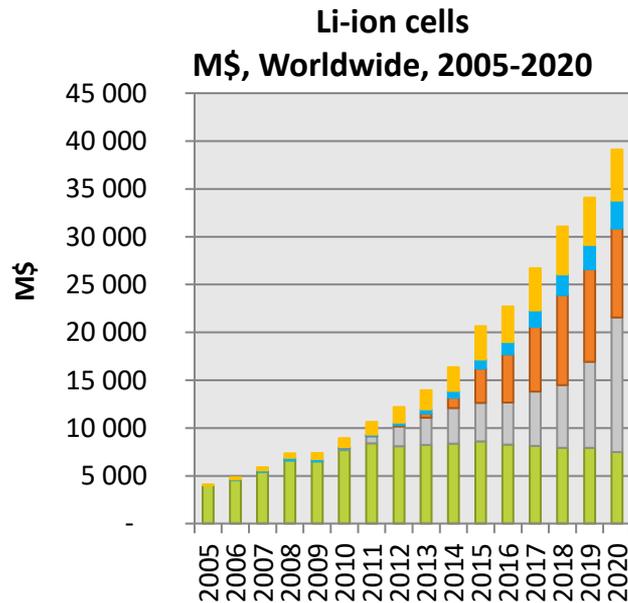
230 000 MWh - 39 B\$ (cell level)

CAGR 2010/2020

+25% per year in Volume

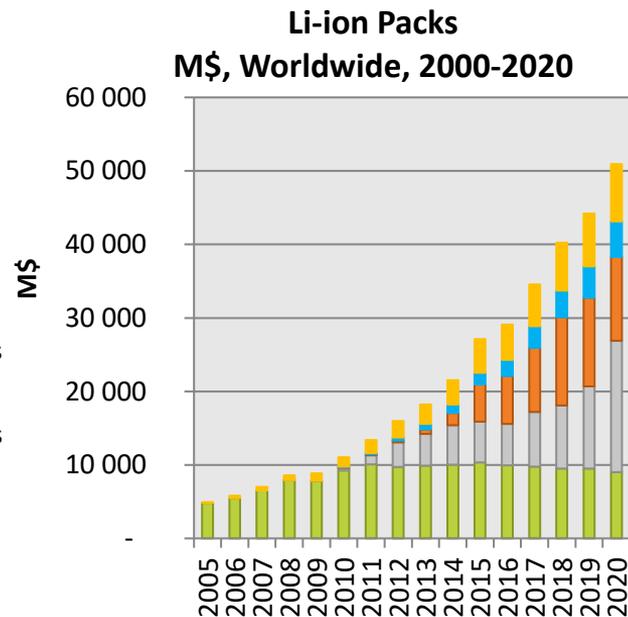
Cell: +16% per year in value

Pack: +17% per year in value



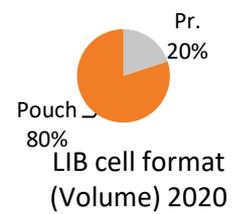
Others: medical devices, power tools, gardening tools, e-bikes...

Source: AVICENNE Energy 2021



CELLULAR PHONES MARKET

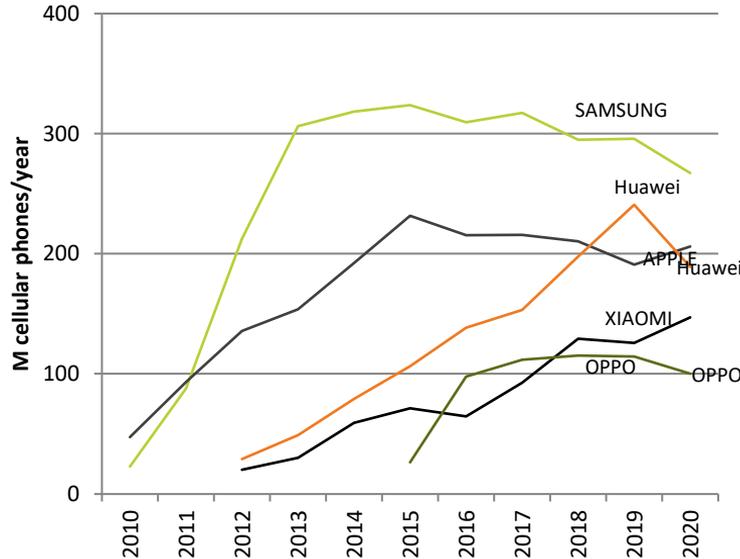
1 600 M LIB CELLS IN 2020



1,6 Billion cell phones sold in 2020 (5% decrease)

Samsung Galaxy & I-phone change the game

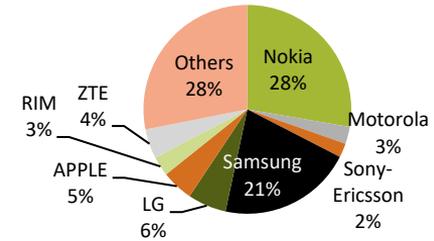
Smartphone Top 5 suppliers



Source: AVICENNE Energy 2021

2012

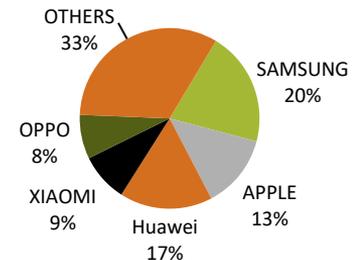
1630 M Phones



2020

1600 M Phones – 1292 Smartphones

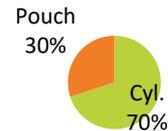
Market share for Smartphones only



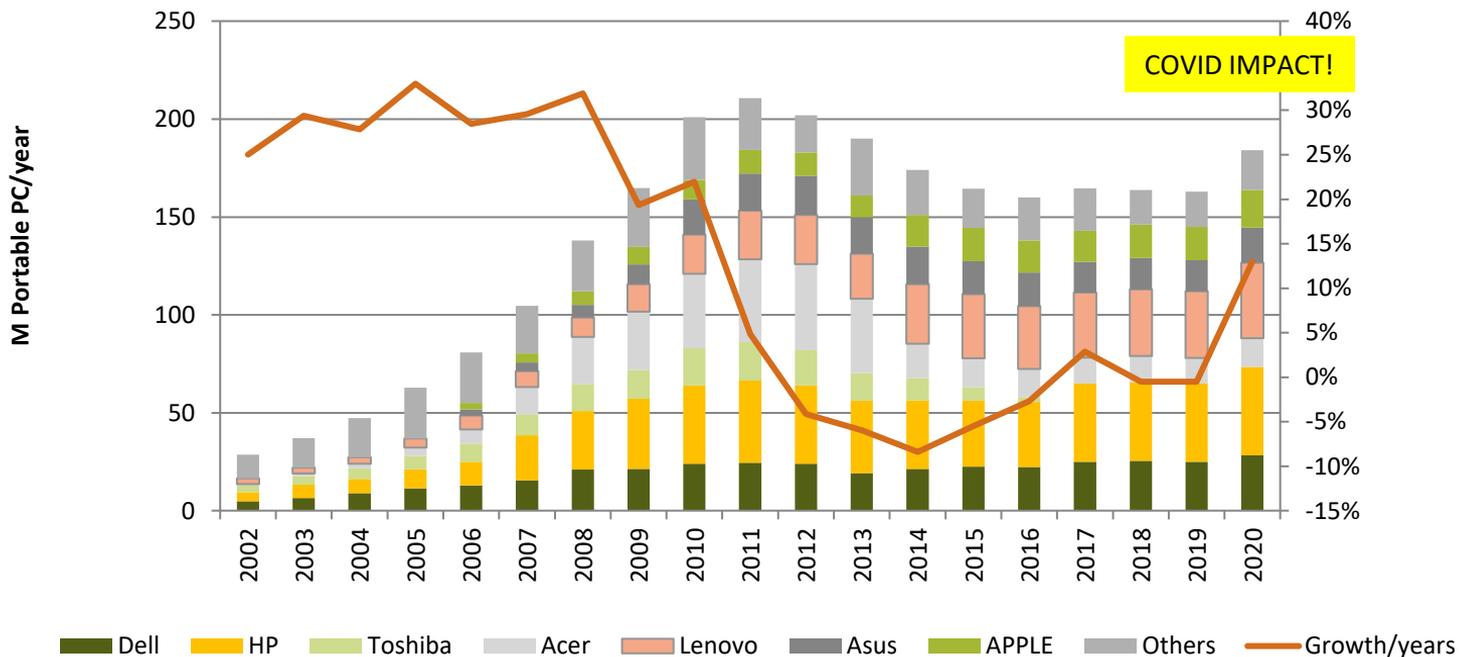
PORTABLE PC MARKET

1 BN LIB CELLS IN 2020 (+12%)

185 M portable PCs sold in 2020: +13%



LIB cell format
(Volume) 2019



Note: Excluding Tablets & convertible or hybrid portable PC + tablets

Source: AVICENNE Energy 2021

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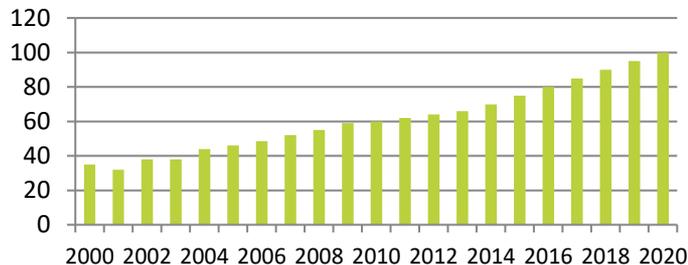
POWER TOOL ⁽¹⁾ MARKET LIB DEMAND IS GROWING

Cyl.
100%

LIB cell format
(Volume) 2020

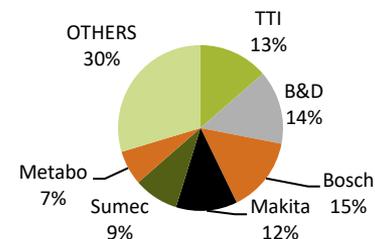
Power tools market is growing

Power Tools (Million/year)



Power tools suppliers

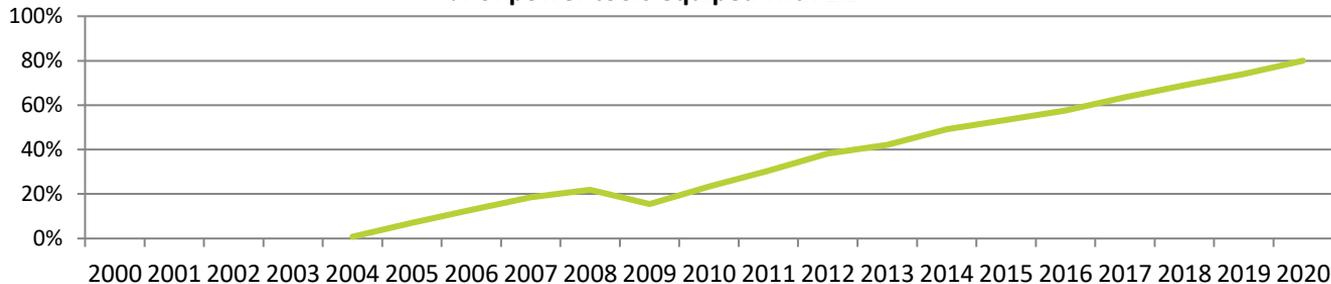
Power tools maker market share (2020)



Others: Jingding, Panasonic, Hitachi, Hilti...

LIB penetration in power tools

% of power tools equipped with LIB



(1) Including gardening tools

Source: AVICENNE Energy 2021



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The Rechargeable Battery
Market and Main Trends
2020 – 2030



September 28th, 2021

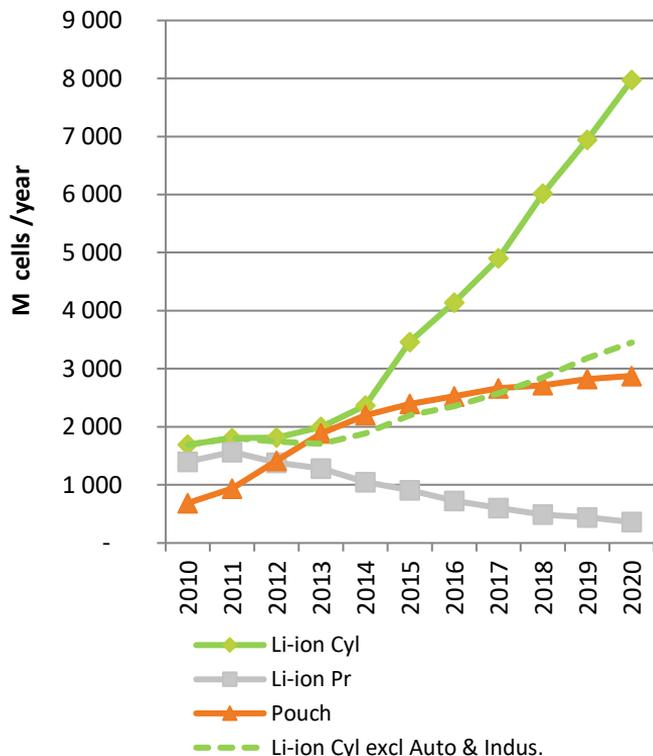
Lyon, France

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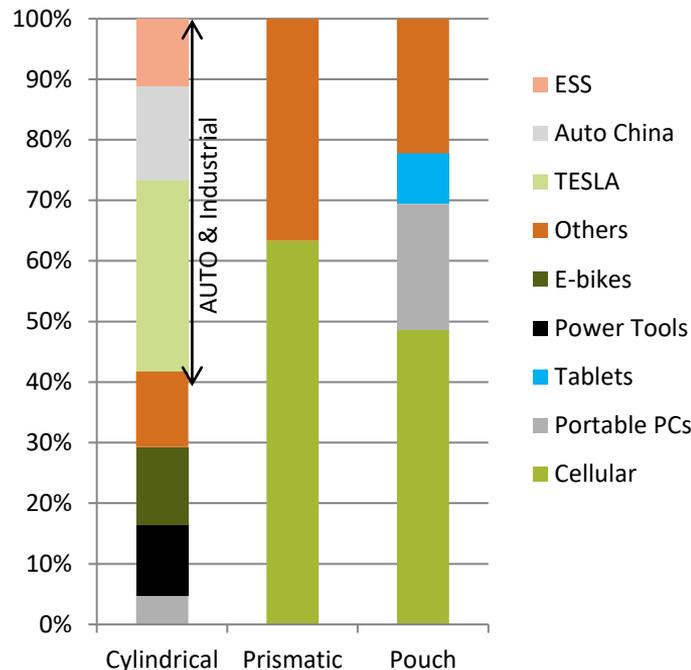
LITHIUM ION SMALL CELL MARKET

Cylindrical/Prismatic/Pouch



Li-ion cylindrical: "Tesla impact": >2500 M cells in 2020 – Auto in China: > 1100 M cells (Avicenne)

Cylindrical/Prismatic/Pouch in 2020



Others:

Cylindrical: hoverboards, medical, power bank

Prismatic: portables

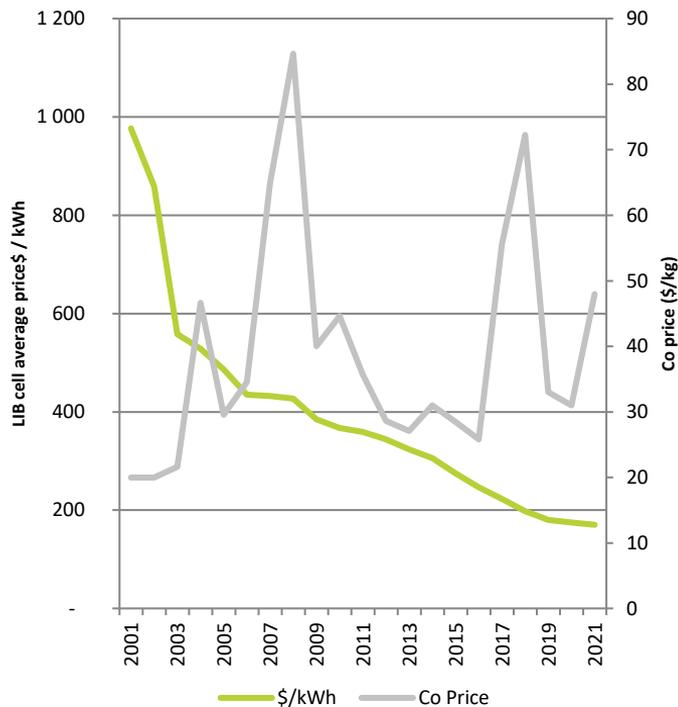
Pouch: drones, BT, wearables, power bank

Source: AVICENNE Energy 2021

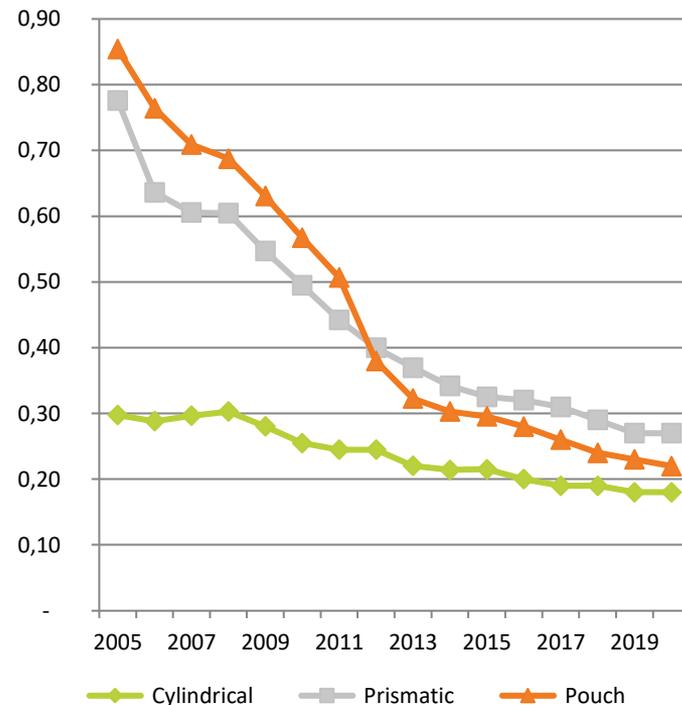
BATTERY PRICE

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)



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 DRASTICALLY ON THE BATTERY MAKERS PROFIT

The Rechargeable Battery
Market and Main Trends
2020 – 2030



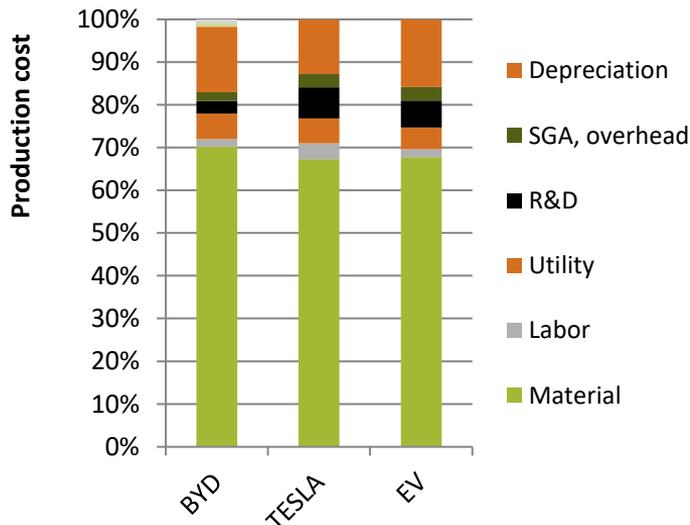
September 28th, 2021

Lyon, France

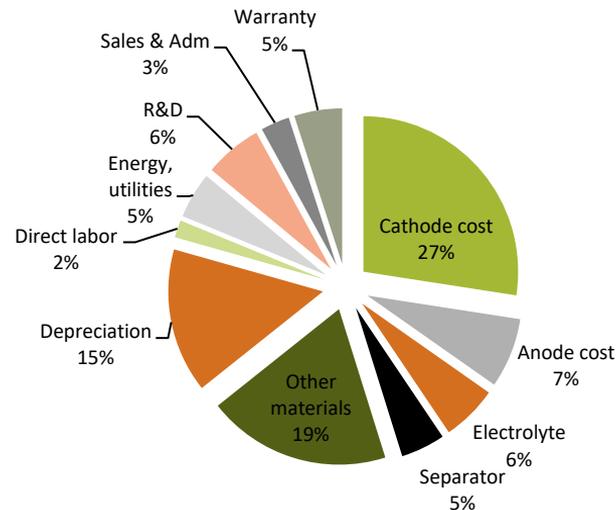
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LIB Cost structure for TESLA & 40 Ah EV pouch cell NMC



Average cost structure of Li-ion cell



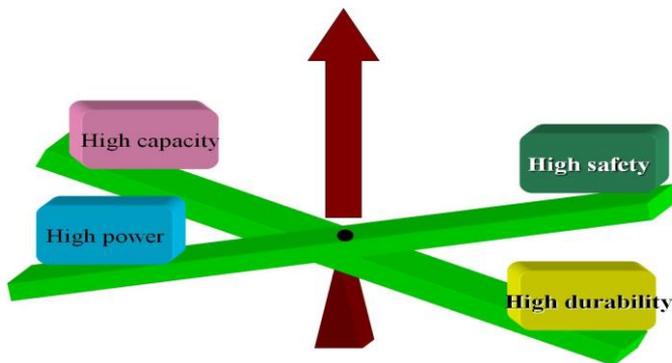
Note: Average mix of cylindrical, prismatic & pouch cells
Sources: AVICENNE ENERGY 2021

LIB CATHODE MATERIAL

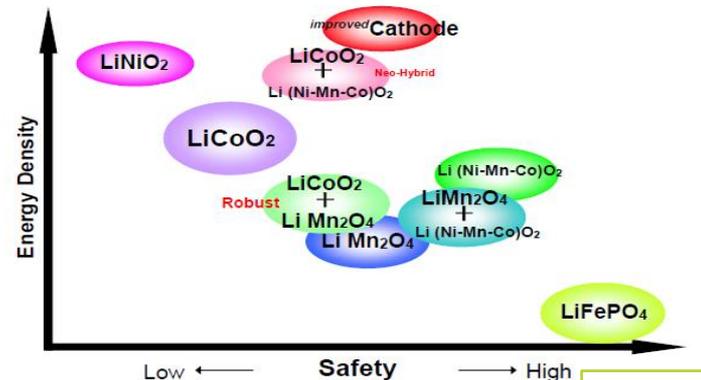
🔋 Cathode raw materials market

- 🔋 LiCoO₂ (LCO)
- 🔋 LiMn₂O₄ (LMO)
- 🔋 LiMPO₄⁽¹⁾ (LFP)
- 🔋 Li[NixMnyCoz]O₂ - NMC
- 🔋 Li[NixCoyAlz]O₂ – NCA

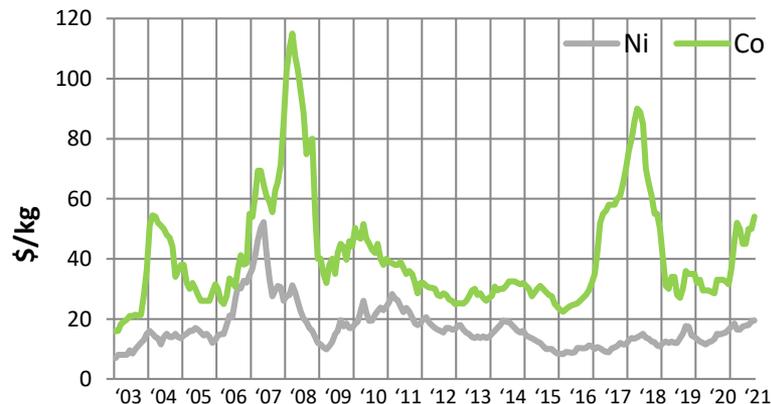
(1) M= Fe or Mn



Source: Mitsubishi, Batteries 2012 – Nice



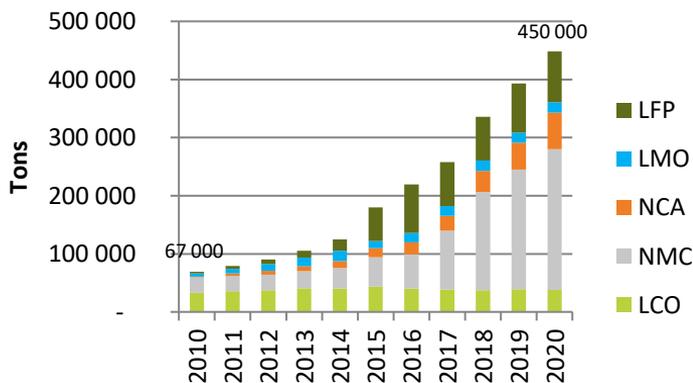
Source: SANYO, March 2011



Source: LME

CATHODE ACTIVE MATERIALS NEEDS

Cathode active materials for LIB in Tons, 2010-2020 (Demand)



LEADERS:



NEW ENTRANTS ON THE FIELD:

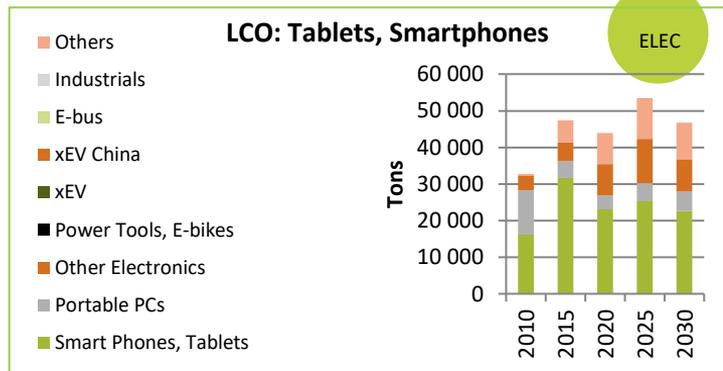


Rationales

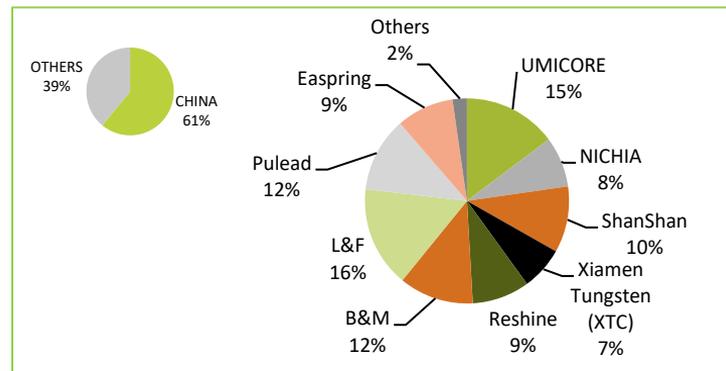
- In 2020, LCO is used in pouch cells for electronic devices: smartphones, tablets, ultra thin portable PCs
- NMC is used in other electronic devices & xEV
- NCA is used by 18650 & 27100 Panasonic cells in Tesla cars and as a blend with LMO in other xEV
- LMO is mostly used as a blend with NMC in xEV
- LFP is used in xEV, e-buses in China and for industrial applications

LCO DEMAND: CAGR₂₀₁₅₋₂₀₃₀: STABLE

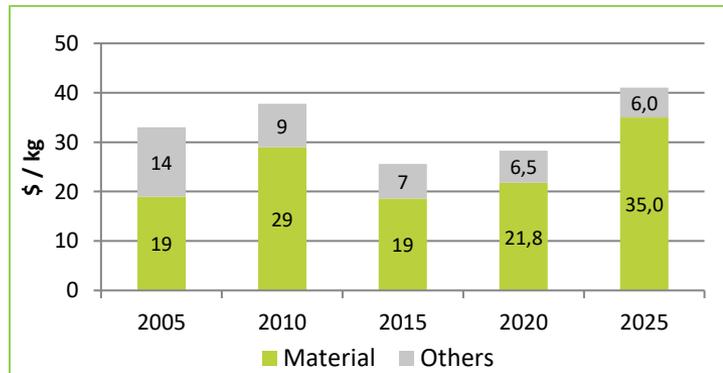
LCO demand details



LCO Offer in 2020



LCO Price forecasts



LCO summary of outlook

🔗 Demand:

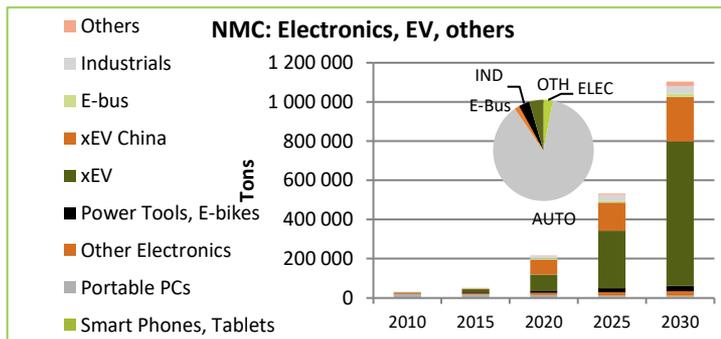
- 🔗 LCO was used in most of the pouch cell lithium ion batteries for electronic devices like smartphones & tablets.
- 🔗 Most OEM (Samsung, Apple, etc..) confirm that LCO will be the first choice for the future.
- 🔗 Then, for portable PCs, penetration of LCO will increase thanks to thinner high end portable PC using pouch cells.
- 🔗 LCO will not be used in large format cells where NMC is preferred.
- 🔗 Price: if the metal price are stable from 2016 to 2025, small cost decrease thanks to scale economy.
- 🔗 Suppliers: Umicore, L&F, and main Chinese (Pulead, ShanShan, Reshine) will keep the lead. Not sure that Nichia will stay at the top.

Assumption: Lithium carbonate price 2020 – 2025 from 8 to 13 \$/kg, Co price in 2020: 31\$/kg, 50\$/kg in 2025

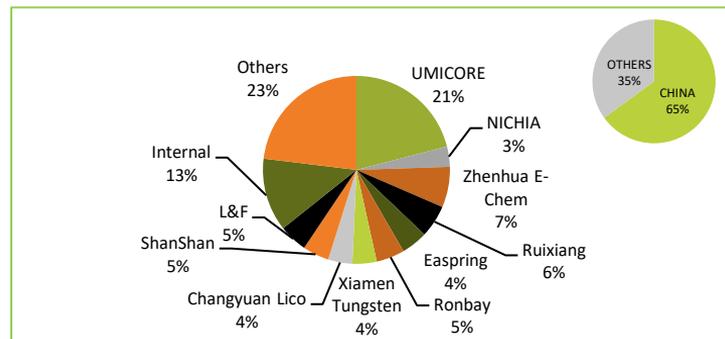
Sources: AVICENNE ENERGY 2021

NMC DEMAND: CAGR₂₀₂₀₋₂₀₃₀: +18%

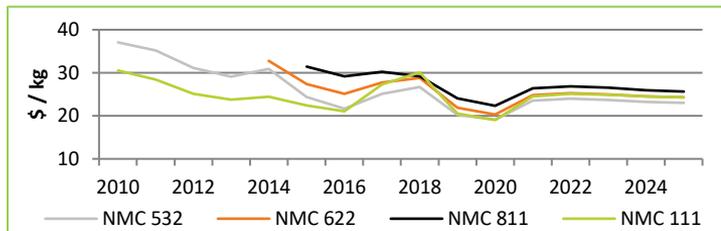
NMC demand details



NMC Offer in 2020

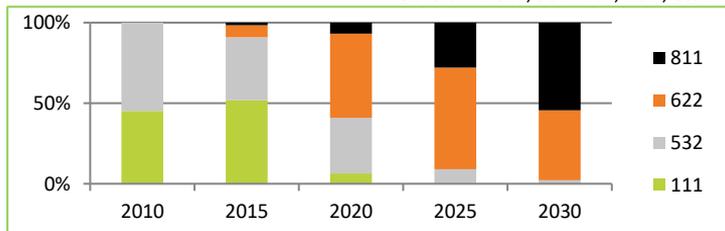


NMC Price forecasts (Metals: 75 to 85% of the price)



Assumption: Lithium carbonate price 2020–2025 from 8 to 13 \$/kg, Lithium hydroxide @ 17 \$/kg in 2025 - Co price 2020 - 2025: 50\$/kg

NMC evolution



Ronbay: Ex. Jinhe, Ruixiang: ex Reshine
Others: Pulead, Soundon, B&K, etc...

NMC summary of outlook

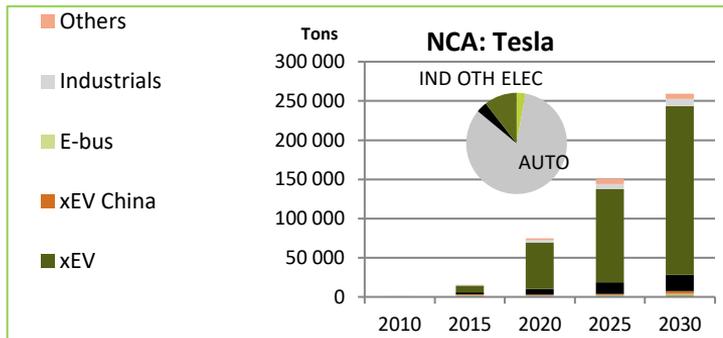
Demand: Except xEV in China, **NMC** is driven by xEV: **Nissan** will switch from NCA-LMO to NMC for example. Then, **Toyota, Mitsubishi, Honda** all choose NMC. From 2012 to 2016 the clear trend was to switch from LMO-NMC 75/25 to LMO-NMC 25/75. **LG, Panasonic and Samsung** agreed that NMC will be the 1st choice for xEV first in Japan, US and Europe, and then, in 2020 in China. **Price** will decrease thanks to process manufacturing improvement. **Suppliers:** Umicore, L&F, and main Chinese (ShanShan) will keep the lead. LG and Samsung will outsource more (Internal part will decrease). As new entrant, BASF try to be on this market since 2011. There market share may increase.

CONTACT

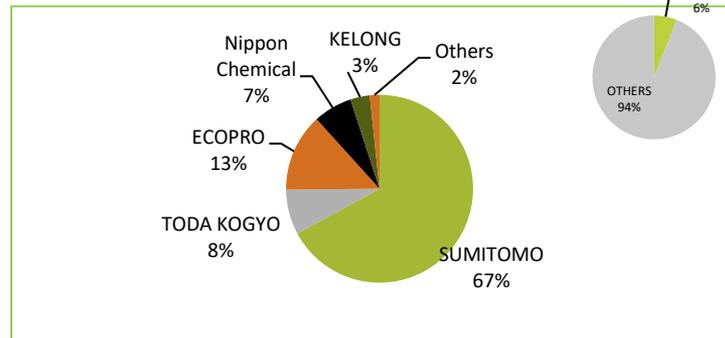
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NCA DEMAND: CAGR 2020-2030: +13%

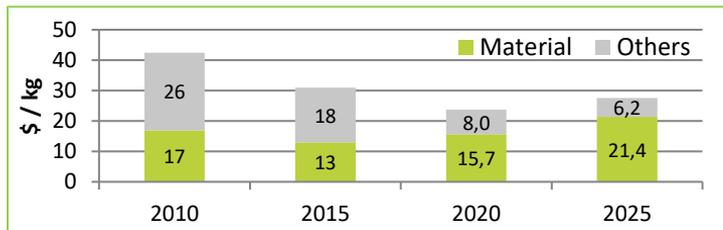
NCA demand details



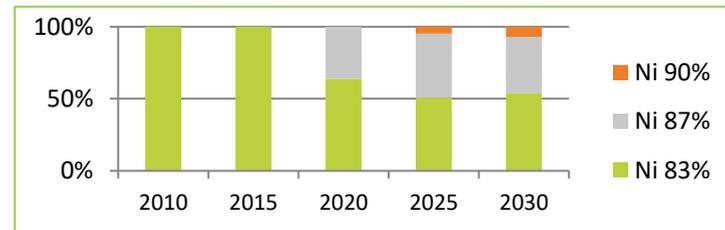
NCA Offer in 2020



NCA Price forecasts



NCA evolution



Assumption: Lithium hydroxide @ 17 \$/kg in 2025- Co price in 2020: 31\$/kg, 50\$/kg in 2025

NCA summary of outlook

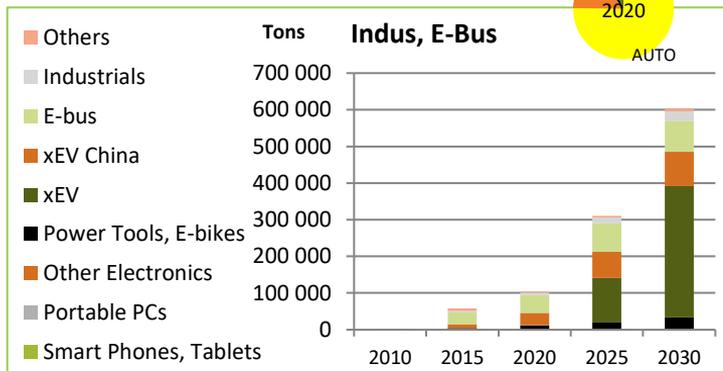
Demand: NCA are also used in electronic devices, in prismatic and cylindrical cells. Main NCA users in electronic devices are [Panasonic](#), [Sony](#) and [Samsung](#). They will keep using NCA but LCO will stay the first choice. [Panasonic](#) and [Samsung](#) confirm that they supply more and more power tools mfg with NCA (from 15% in 2015 to 25% in 2025). Other NCA usage is of course for the [TESLA](#). We do not think [TESLA](#) will switch for another technology in the next years.

Price decrease thanks to better mfg. process

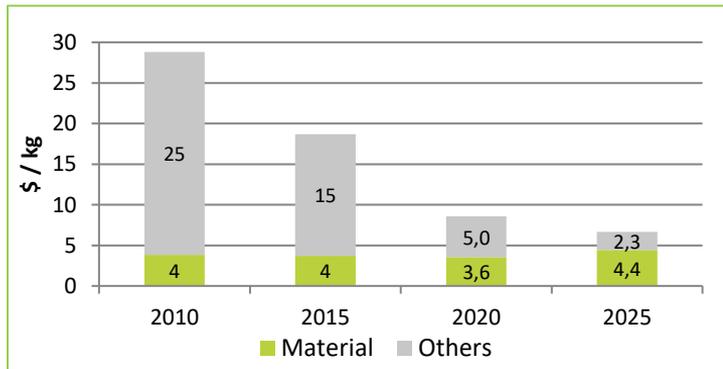
Supplier: Sumitomo will keep the lead thanks to Panasonic / Tesla. Toda Kogyo market share will probably increase thanks to BASF partnership.

LFP DEMAND: CAGR₂₀₂₀₋₂₀₃₀: +19%

LFP demand details

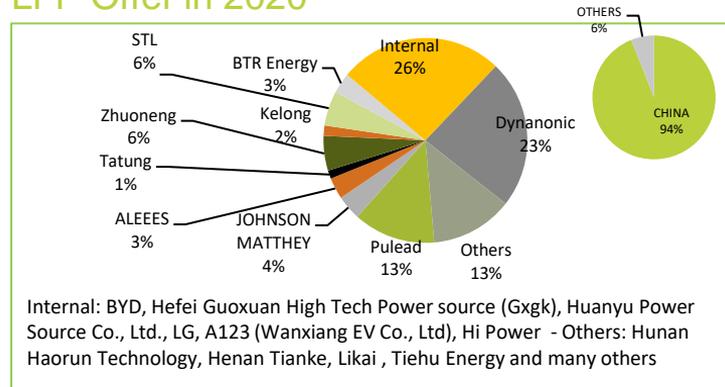


LFP Price forecasts



Assumption: Lithium carbonate price 2025 @ 13 \$/kg

LFP Offer in 2020



LFP summary of outlook

Historically, **LFP demand** is driven by xEV, E-Bus in China, e-bikes and Stationary application. Chinese industrial agreed that E-bikes, e-bus and stationary app will use LFP for the next 10 years. The cost and the life time are the main criteria and Energy density is not so important. Then, Chinese xEV mfg. ([BYD](#), [Kandi](#), [Zotye](#), [Baic](#), [Chery](#)...) told us that they will switch from LFP to **NMC**. In 2021, **TESLA** announced that they will use LFP for some models. Just after, **Ford**, **VW**, **Renault**, (...) announced also the use of LFP for some models.

Price: Process manufacturing cost will decrease. Pulead forecast price @ < 10\$/kg in 2025. In China, some LFP are already sold at 6-7 \$/kg

Suppliers: Pulead will probably increase market share thanks to new contract with BYD and others Chinese battery mfg.

THE LFP RESURGENCE

*Presentation from Joe
Fischer, Lithium Werks, on
Wednesday 29 at 2:50*

LFP-Batteries – The Rediscovery of a battery chemistry



LFP cathode material producer



LFP cell producer



“ Tesla announces \$25,000 electric car enabled by new battery cell

Fred Lambert - Sep. 22nd 2020 8:36 pm PT [@FredericLambert](#)

“ **Ford, VW, Tesla Lean In To LFP Battery Technology For EVs**

AUGUST 3, 2021 BY HARUN ASAD

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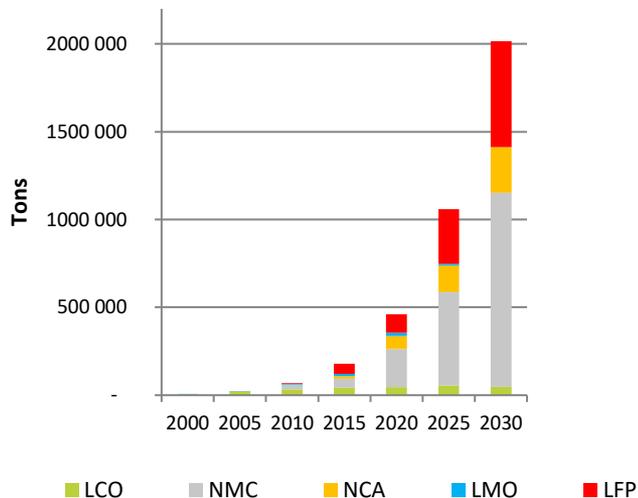
CATHODE ROADMAP

Mooving from NMC 111 to higher Ni content and lower Co content

	2017	2018	2019	2020	2021	2022	2023
 NMC 111			NMC 532		NMC 622		
 NMC 111			NMC 622				
 NMC 111			NMC 622			+LFP	
 NMC 111		NMC 622					NMC 811
 NMC 532			NMC 622				
 NMC 111			NMC 622				
 NMC 111				NMC 622			
 NCA						NCA + LFP	
 NMC 111				NMC 622		+ LFP	
 NMC 111 ?			NMC 622				
 NCA					NCA		
 NMC							
 LFP	LFP	LFP	NMC				
 NMC 111				NMC 622			
 NMC 111						NMC532/622?	

CATHODE ACTIVE MATERIAL FORECASTS 2000-2030

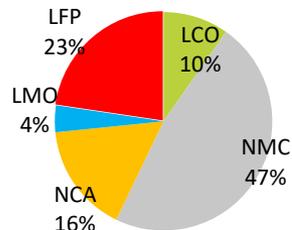
Cathode active materials 2000-2030 - Tons



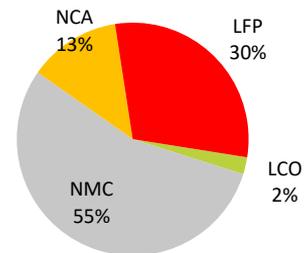
ASSUMPTIONS:

- 🌀 Portable devices: 2019-2030: +4% per year in volume
- 🌀 HEV: 3,1 M HEV/year in 2020, 9,3 M HEV in 2025 & 18,4 M in 2030
- 🌀 P-HEV: 0,9 M P-HEV/year in 2020, 1,8 M in 2025 & 2,8 M in 2030
- 🌀 EV: 2,2 M EV/year in 2020 (1 M in China) / 6,4 M/year in 2025 (2 M in China) 100% LIB, 14,4 M EV in 2030 (3,3 M in China)
- 🌀 Industrial, stationary & other applications 2019-2030: +15% per year in volume

Cathode active materials in 2020 450 000 Tons



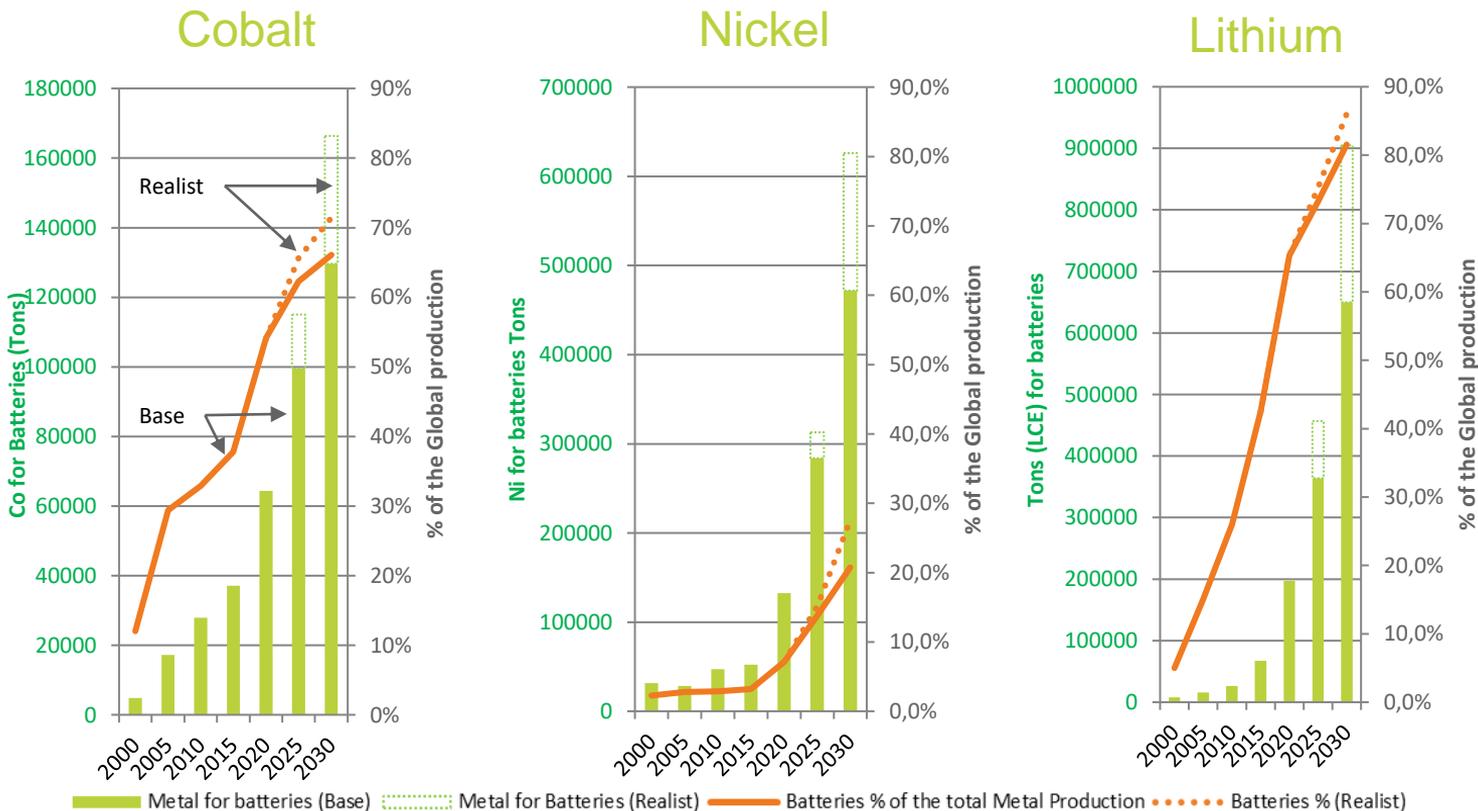
Cathode active materials in 2030 2 100 000 Tons



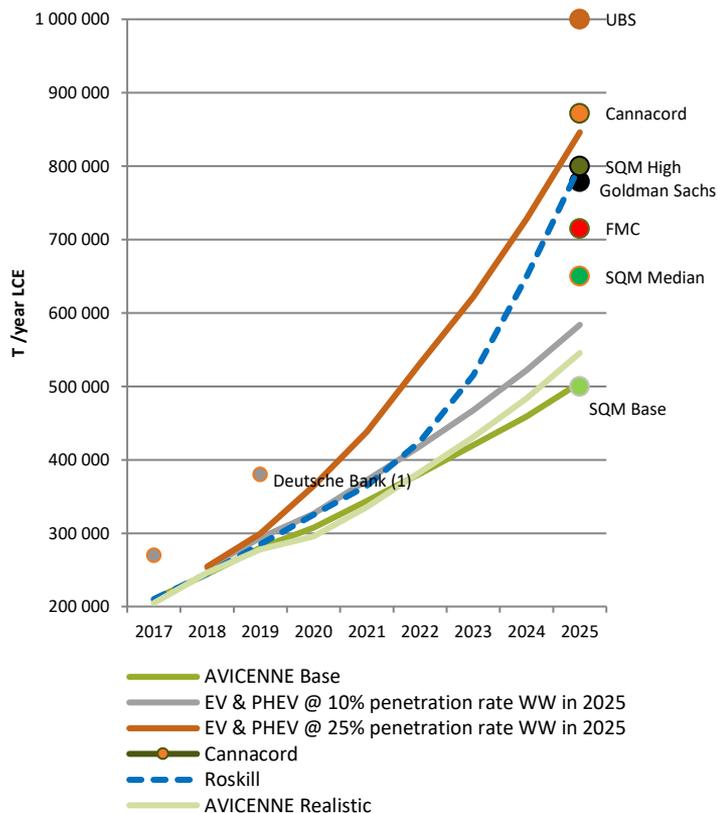
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METAL NEEDS FOR RECHARGEABLE BATTERY WILL INCREASE RAPIDLY



LITHIUM DEMAND – DIFFERENT SCENARIO & SOURCES



(1) Deutsche Bank forecasts March 2017

Rationales

- ⌚ Impact of EV forecast on LCE demand is huge
- ⌚ AVICENNE Assumptions 2025

2025	
Base Scenario	4M EV (58 kWh) & 0,6 M PHEV (12 kWh)
Realistic Scenario	5,2 M EV (58 kWh) & 0,9 M PHEV (12 kWh)
10% EV & PHEV in 2025	6M EV (58 kWh) & 4 M PHEV (12 kWh)
25% EV & PHEV in 2025	14M EV (58 kWh) & 11M PHEV (12 kWh)



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LITHIUM CARBONATE & HYDROXIDE PRICING FORECASTS

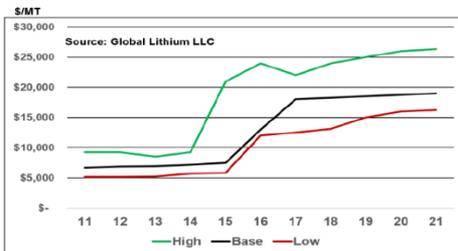
Lithium shortage will keep going on a short term basis. Price of Lithium will stay high

Carbonate Pricing 2011 - 2021



- Price has come off peak levels but remains high for extended period
- High cost capacity additions create "price umbrella"

Hydroxide Pricing 2011 - 2021

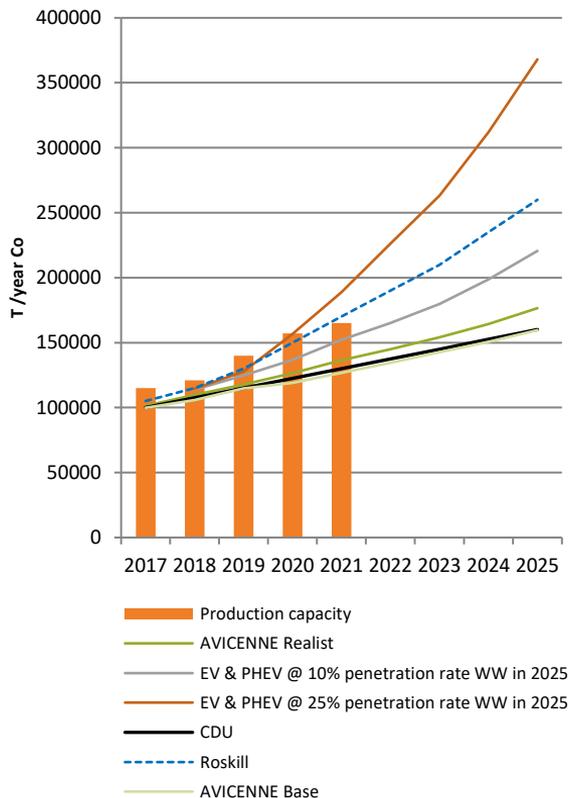


- China's high cost hard rock capacity dominates hydroxide supply
- Majority of the hydroxide market is outside China
- Hydroxide price/margins create attractive opportunity for suppliers

Lithium price will stay high



COBALT DEMAND – DIFFERENT SCENARIO & SOURCES



Rationales

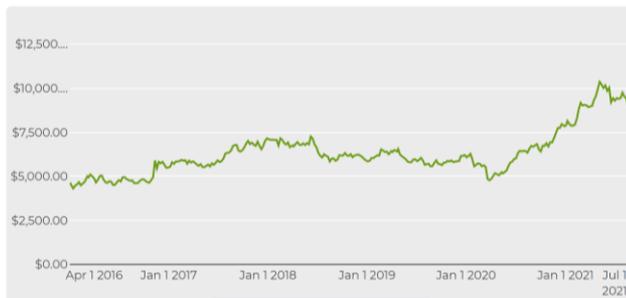
- Impact of EV forecast on LCE demand is huge
- AVICENNE Assumptions 2025

2025	
Base Scenario	4M EV (58 kWh) & 0,6 M PHEV (12 kWh)
Realistic scenario	5,2 M EV (58 kWh) & 0,9 M PHEV (12 kWh)
10% EV & PHEV in 2025	6M EV (58 kWh) & 4 M PHEV (12 kWh)
25% EV & PHEV in 2025	14M EV (58 kWh) & 11M PHEV (12 kWh)

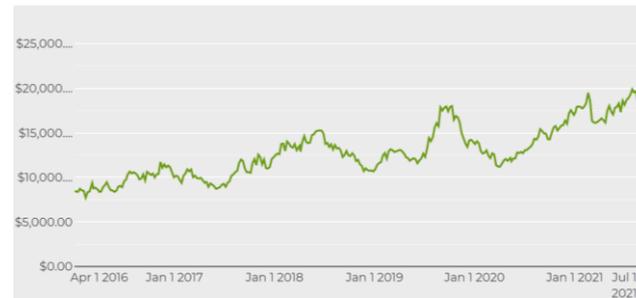
COBALT CAPACITY DEPEND ON NI AND COPPER PRODUCTION

- 🔗 Cobalt is extracted as a by-product of Copper or Nickel BUT....
 - 🔗 Copper and Ni price today are low and investor or producers are reluctant to increase production or develop new sources.
 - 🔗 Ni & Copper demand (CAGR15-25 ~ 3% will grew less than the Cobalt demand CAGR 15-25 ~ 8%

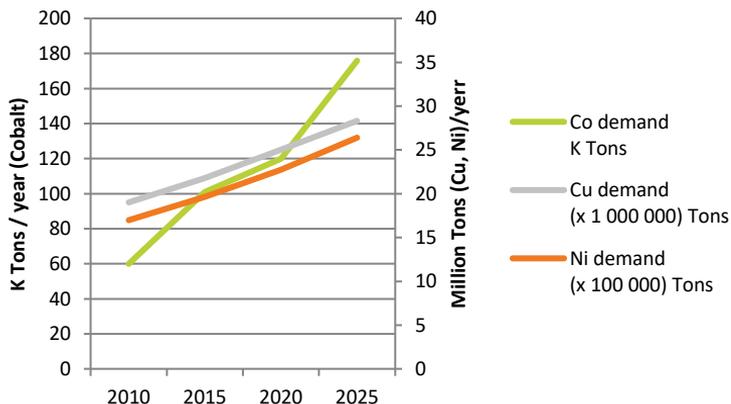
5 Years Copper Price
9,252.00 USD/t



5 Years Nickel Price
19,235.00 USD/t

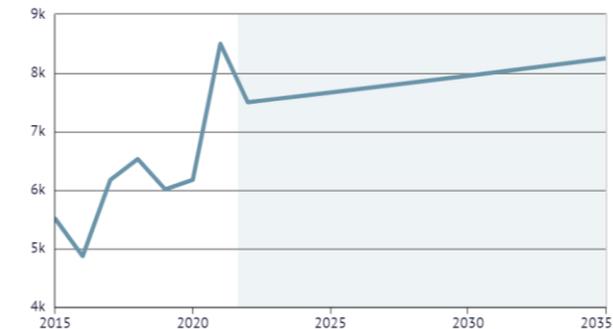


Co Demand increase faster than Cu and Ni demand



World Bank: Copper Price Forecast, 2015-2035

\$/mt, nominal US dollars





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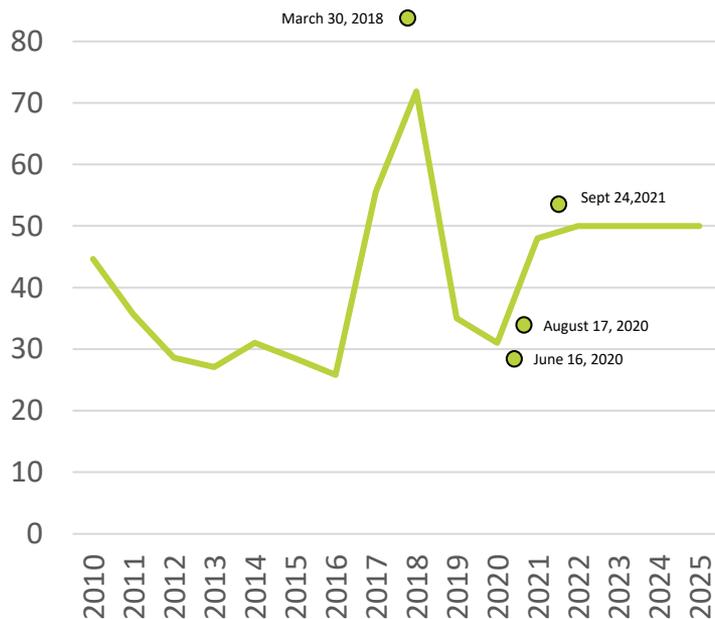
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COBALT PRICE FORECASTS

Prices could increase to >\$80/kg if mined and refined supply fail to keep pace with strong demand growth for Li-ion batteries

Very difficult (Impossible) to forecast Co price



Source: LME, CRU, AVICENNE ENERGY 2020

Rationales

- ⌚ Cobalt price increase from \$/kg 26 in 2016 to \$/kg >80 in march 2018.
- ⌚ Mostly due to financial speculation
- ⌚ Decreasing drastically in 2019
- ⌚ Cobalt sulphate will continue to attract a small premium: 1\$/lb ~ +3-4% compare to LME.
- ⌚ Co Sulfate pricing is very similar in China & outside China
- ⌚ So, our data and forecast for 2020 and following years are presented below:

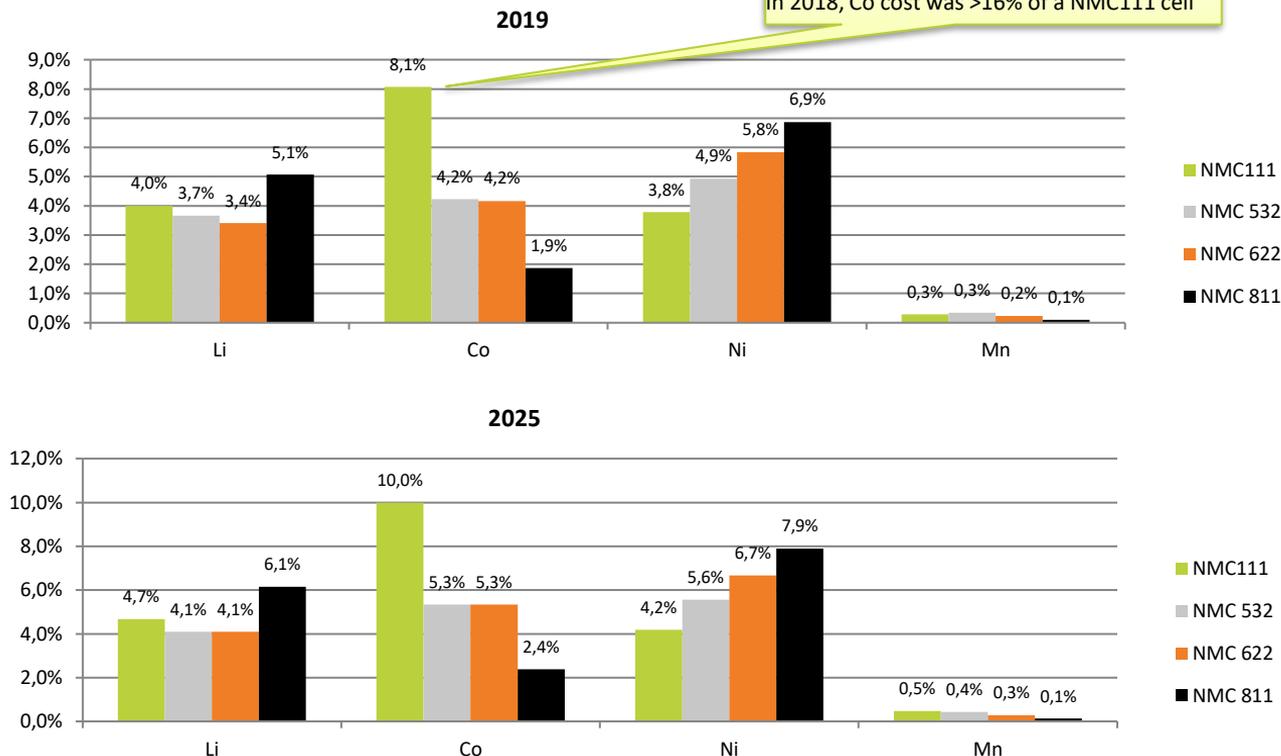
Years	LME	Co Sulfate
2017	56 \$/kg	58 \$/kg
2018	71 \$/kg	73 \$/kg
2019	35 \$/kg	35 \$/kg
2020	31 \$/kg	33 \$/kg
2021	48 \$/kg	50 \$/kg

IMPACT ON CELL FINAL COST

To be up-date

Part of the metal price in the total cell cost

In 2019, Co cost is 8% of a NMC111 cell
In 2018, Co cost was >16% of a NMC111 cell



LITHIUM ION BATTERY RECYCLING

Assumptions

End Of Life battery – Assumptions

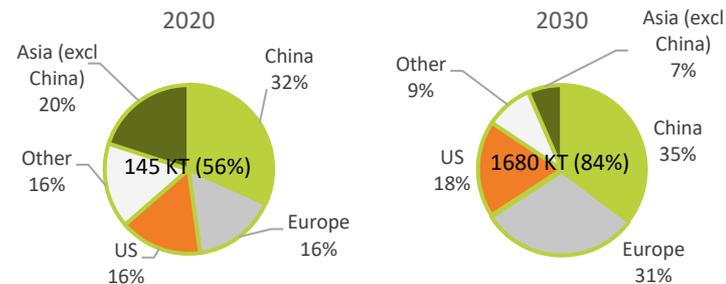
- Warranty/ Recall:** a conservative 2% is considered of battery packs either tested at the manufacturer or placed on the market that may have performance problems and should be recycled
- End of Life:** of batteries put on the market before recycling includes possible second-hand use and the collection process
- Collection rate:** mainly impacted by the regional regulation and the concerned application
- Scrap**
 - Production Scrap:** composed on the one hand of electrode cutting scrap which is incompressible by a few percent and on the other hand of process capability by the various producers
 - Scrap Rate:** in total, the best-in-class could reach 5%, whereas during the start-up phases, the rate can exceed 20 to 30% over a very long period
 - Quality of the scrap:** scrap material has particular characteristics compared to a new or used complete cell or battery pack; it is composed of part of the cell elements, with a well known composition., *In the model, we retain on average a value of 70 % of the weight of the cell (situating itself at electrode level without electrolyte, cell housing...)*

- Energy density at cell level:** average energy density for lithium ion at cell level varies in the model from 100 Wh/kg in 2010 to 320 Wh/kg in 2030

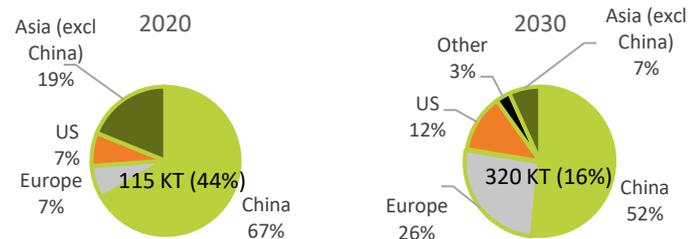
➔ In 2030 metal from recycling could account for 15 to 25% of the metal needs to produce Li-ion batteries

	End of Life in years (including potential second Life and collecting process)	Collection Rate
Electronic devices	3	25%
E-Bikes	4	65%
eEV	10	95%
Industrial, ESS	10	80%
Others	5	25%
Ebus	10	90%
Warranty / Recall (2%)	2	100%

End Of Life 145 KT in 2020 – 1680 kT in 2030



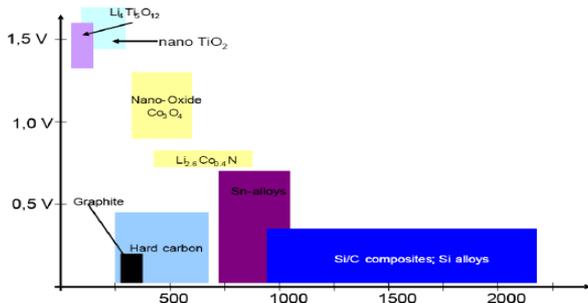
Scrap: 115 KT in 2020 – 320 KT in 2030



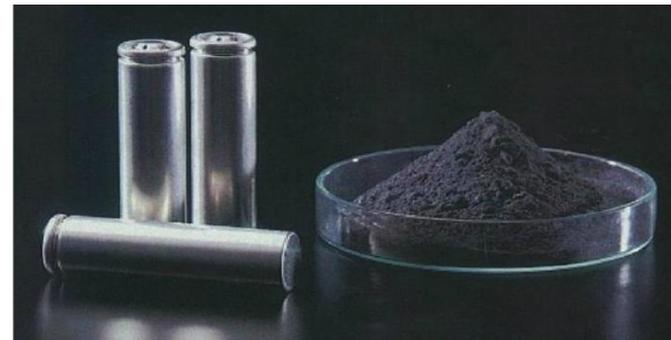
ANODE ACTIVE MATERIALS

235 000 TONS IN 2020

LIB Anode Materials

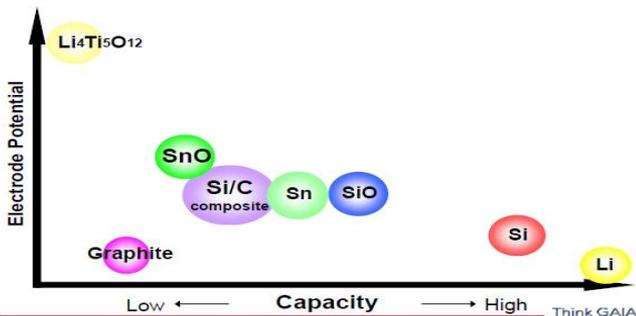


Source: A. Jossen, IRES 2007



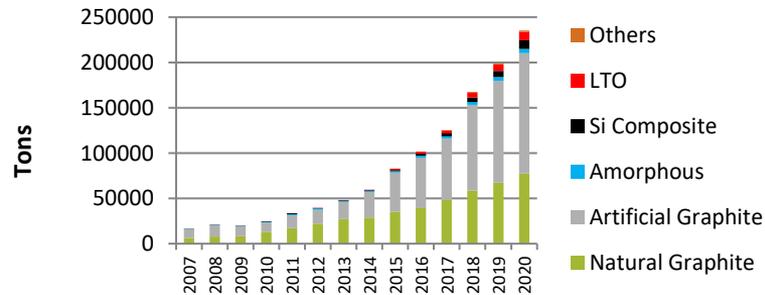
Source: Hitachi Chemical

LIB Anode Materials



Source: Sanyo, March 2013

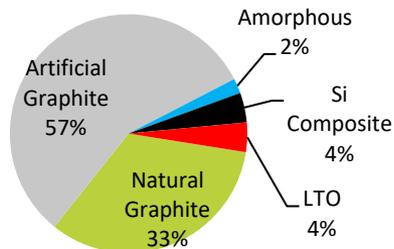
LIB Anode market, (Tons)



Sources: AVICENNE ENERGY 2021 69

ANODE FOR LIB IN 2020

Carbon for LIB anodes by type (2020)



Item	Energy	Life	Power	Safety	Cost	BPEV	HEV
Artificial graphite (MAG)	++	+	-	+	--	☹️	
Artificial Graphite (Low Cost)	+	+	+	+	+	😊	☹️
Natural Graphite (w/ coating)	+	--	+	-	++	😊	☹️
Meso carbon	-	++	++	++	--	☹️	☹️
Hard Carbon (Amorphous)	--	++	++	++	-		😊
Soft Carbon (Amorphous)	--	+	++	++	+		😊

Source Hitachi

	Hard Carbon	Soft Carbon	Graphite
Capacity (/g)	250 mAh/g	300 mAh/g	325-375 mAh/g
Capacity (/cc)	++	0	+
Power	++	+	0
Stability	++	+	0
Cyclability	++	+	0
Precursors	Petroleum Pitch, Resin, cellulose, wood, coconuts...	Petroleum coke	Natural or petroleum coke
COST 2015->2020	25 -> 20 \$/kg	20->15 \$/kg	5-15-> 5-10 \$/kg
SUPPLIERS	KUREHA	HITACHI	HITACHI BTR...
APPLICATIONS	HEV	HEV	EV

Source: Hitachi

LEADERS:



Sources: AVICENNE ENERGY 2021



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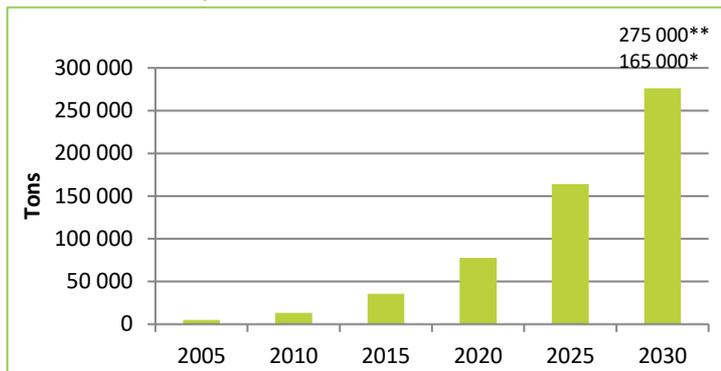
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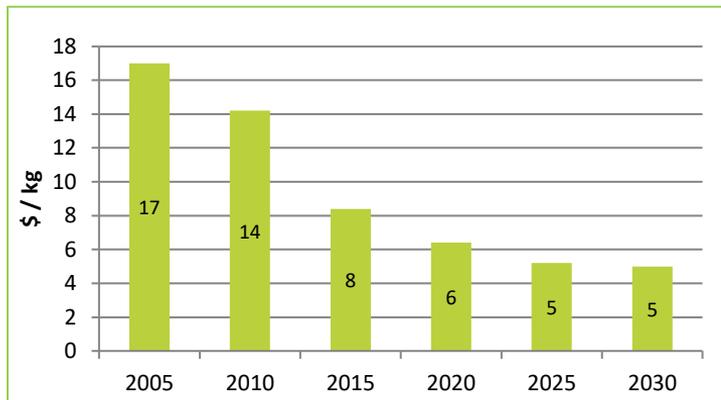
NATURAL GRAPHITE: CAGR₂₀₁₅₋₂₀₃₀: +10% IN VALUE, +14% IN VOLUME

Natural Graphite demand details



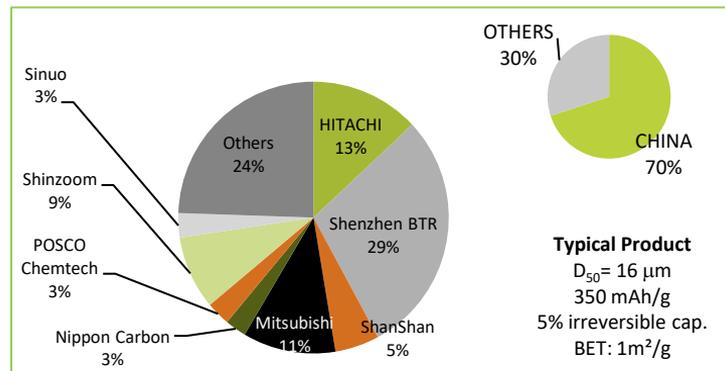
* Base scenario - ** Realistic scenario

NG Price forecasts



Sources: AVICENNE ENERGY 2021

NG Offer in 2020



Typical Product

D_{50} = 16 μ m
350 mAh/g
5% irreversible cap.
BET: 1m²/g

NG summary of outlook

Demand: smaller growth because new app. Need artificial Gr and Chinese LIB choose mostly artificial Gr. This demand may change if the price decrease is more important for NG compare to AG. **Price:** The price will decrease fast because the supply is huge. Already over supply in China (Capacity: BTR 30 000 Tons, Zichen: 10 000 Tons, Shinzom: 10 000 Tons, Sinuo: 8 000 Tons, Qingdao: 8 000 Tons, Jianxi Zhentuo: 7000 Tons, Kimwan: 5 000 Tons...). Then, a lot of new projects in China and Canada: Focus Graphite > 40000 Tons/year (2020*), Northern Graphite > 20 000 Tons/year (after 2018*) Syrah Resources Ltd. > 80 000 Tons (2020*)

Suppliers: BTR and new Chinese (Zichen thanks to ATL, - Shinzom thanks to BYD, CATL – Sinuo etc...). New entrant like Focus Graphite, Northern Graphite, or Syrah Resources Ltd. May change the market share in the future

* Subject to financing



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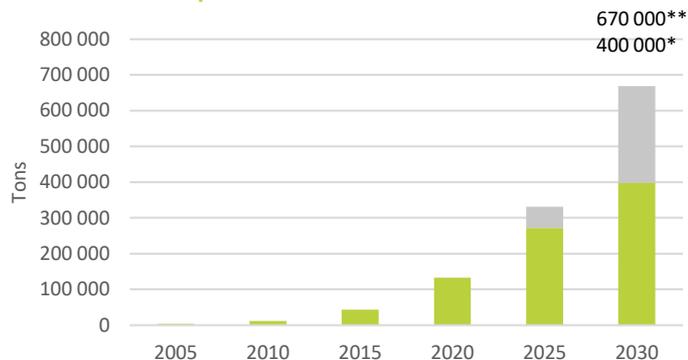
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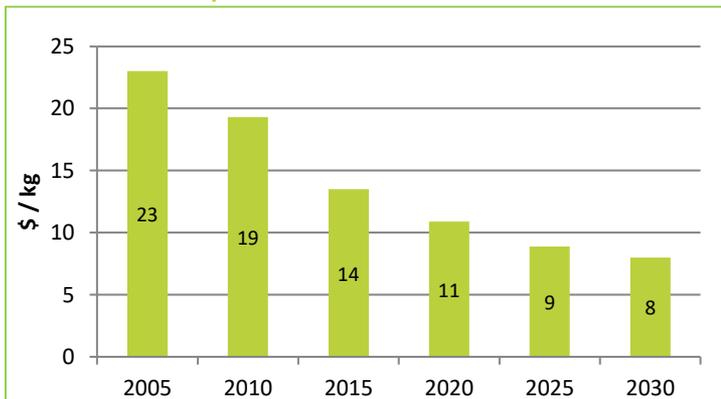
ARTIFICIAL GR.: CAGR₂₀₁₅₋₂₀₃₀: +12% IN VALUE, +16% IN VOLUME

Artificial Graphite demand details



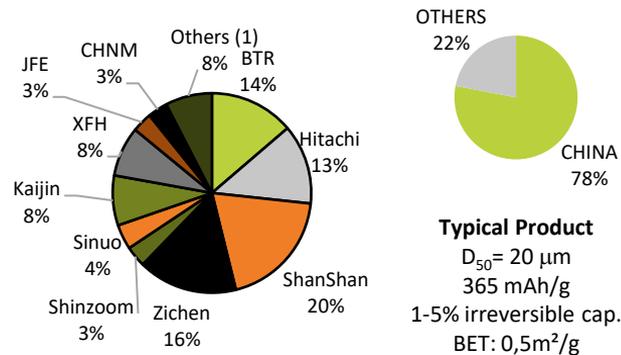
* Base scenario - ** Realistic scenario

Artificial Graphite Price forecasts



Sources: AVICENNE ENERGY 2021

Artificial Graphite Offer in 2020



Typical Product
D₅₀ = 20 μm
365 mAh/g
1-5% irreversible cap.
BET: 0,5m²/g

(1) Kimwan, Colin, Nippon carbon, Hairong

Artificial Graphite summary of outlook

Demand: The demand will increase fast thanks to xEV market and Chinese market. Long life time requirement involve high level of purity and high consistency, difficult to achieve with Natural Graphite.

Price will decrease fast (-3-4%/year) thanks to better process efficiency, new process

Supply: Thanks to the best quality, Hitachi will keep the lead but Chinese main suppliers market share will increase (ShanShan mostly).

Production Capacity: BTR: 50 000 Tons, Hitachi: 20 000 Tons, ShanShan: >42 000 Tons, Zichen: 35 000 tons, Sinuo: 24 000 tons, XFH 22 000 Tons, Kaijin 15 000 Tons, JFE: 8000 Tons, Showa Denko: 3000 Tons, CHNM: 20 000 tons, ...



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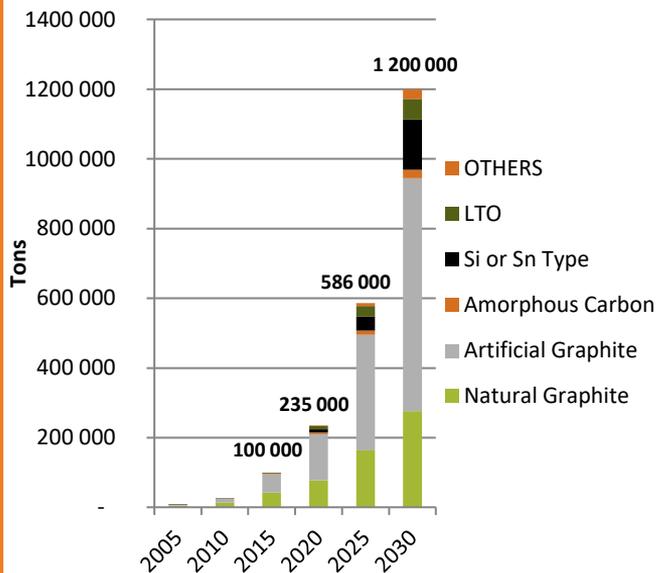
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ANODE ACTIVE MATERIAL FORECASTS

Anode active materials 2005-2030



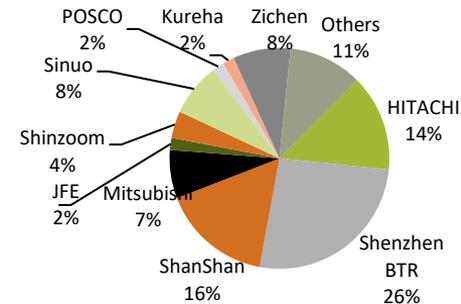
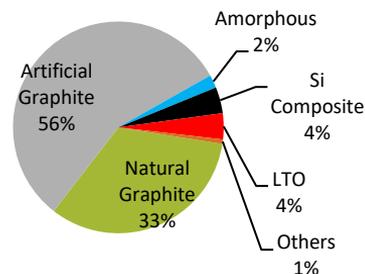
Natural Graphite

- Low price (from 4 to 13 \$/kg – average: 7 \$/kg in 2019)
- Environmental impact concerns

Artificial Graphite

- More expensive (from 10 to 20 \$/kg – Average: 12 \$/kg in 2019)
- Higher purity
- Lower electrical resistance
- Higher safety
- Better life time

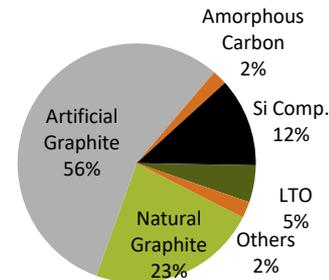
Anode active materials in 2020: 235 000 Tons



Others: Toda Kogyo, Nippon Carbon, Titan, Ishihara, Toho Titanium...

Anode active materials in 2030:

> 850 KTONs (Base) – 1,2 M Metric Tons (Realistic)



Source: AVICENNE ENERGY Analyses 2021



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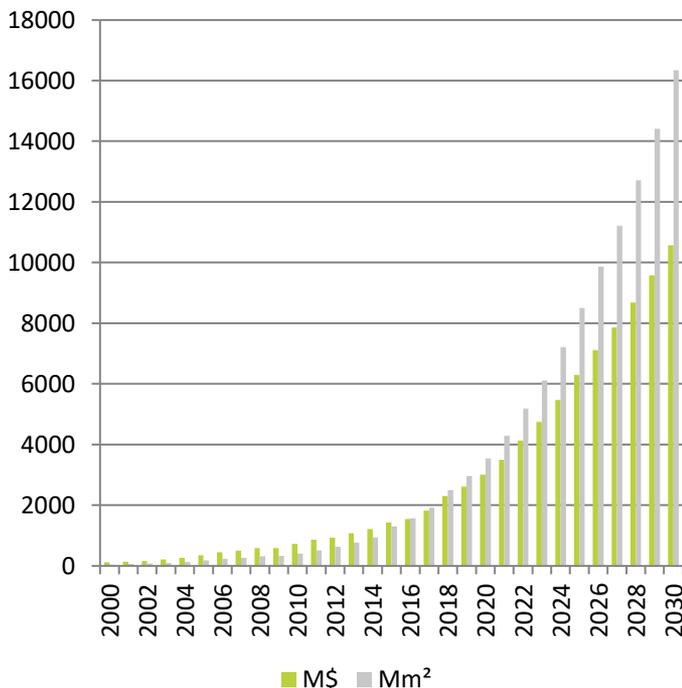
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LIB SEPARATOR MARKET 2000-2030

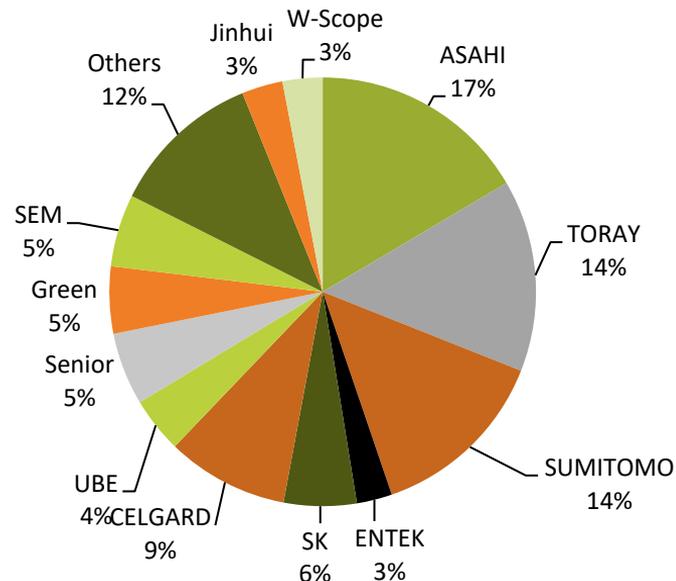
In February 2015, ASAHI announced that they will acquire all Polypore shares in the Energy Storage segment: Asahi Kasei to pay around \$2.2billion to purchase Polypore's battery separator business

LIB separator market, M\$ - CAGR 2020/2030 :+13%

CAGR 2020-2030 in Volume: 17%



Supplier, market share in 2020

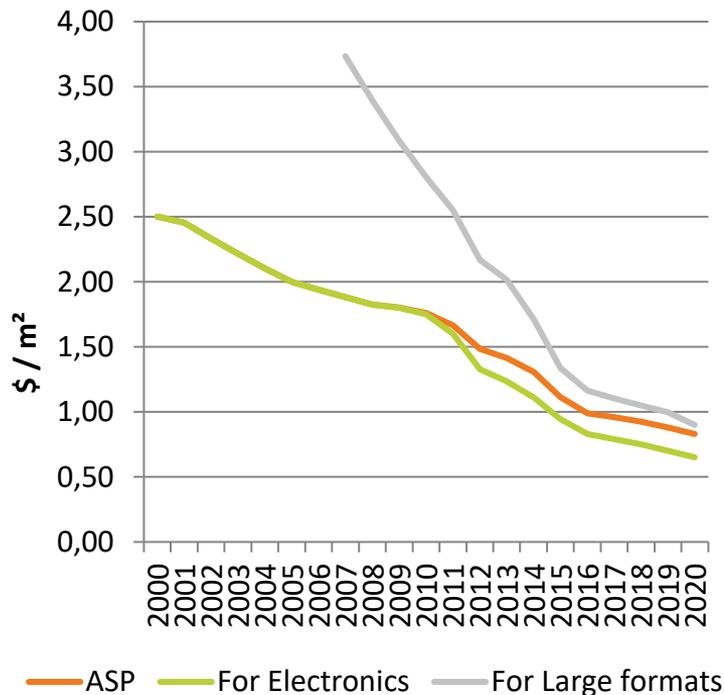


Others: Newmi, JGP, TDK, In house (BYD), Mingzhu, Tianfeng, Yiteng, BNE...

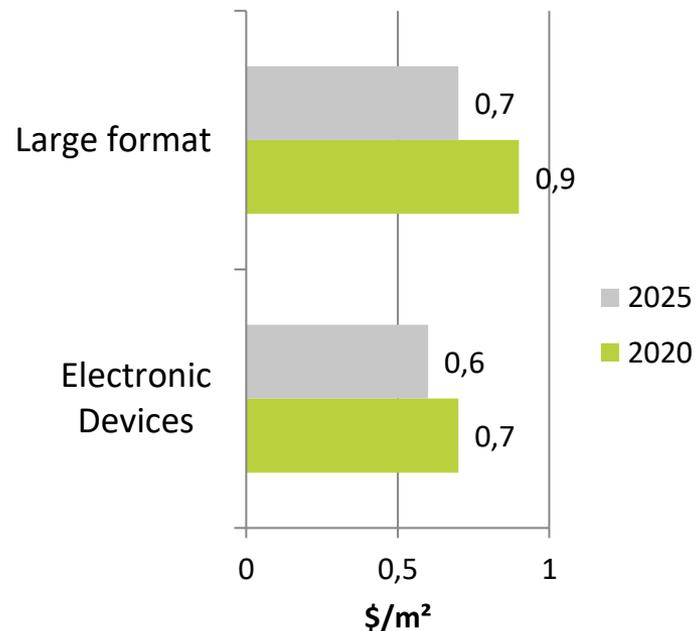
Sources: AVICENNE ENERGY 2021

SEPARATOR AVERAGE PRICE

Separator Average price (\$/m²)
2000-2019



Separator average price by
application



ELECTROLYTE SUPPLIERS/CUSTOMERS

175 000 TONS IN 2020 – US\$ 1,8 BN

LIB electrolyte market, Tons,
CAGR 2010/2020 (Volume): +25%
CAGR 2009/2020 (Value): +17%

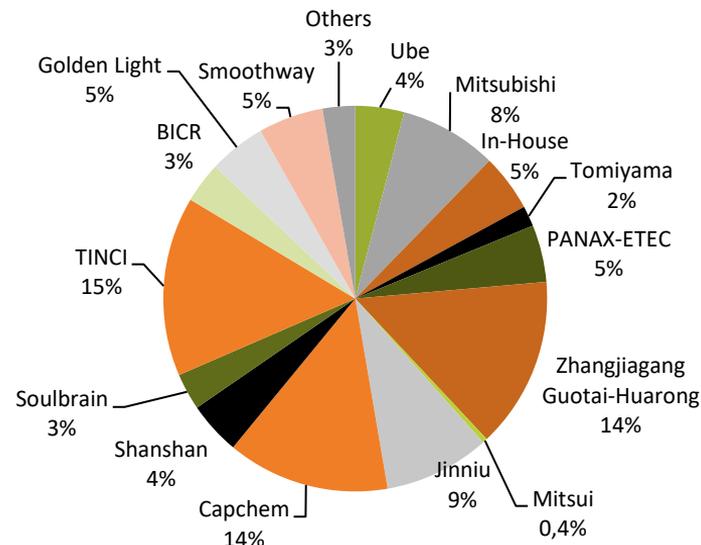
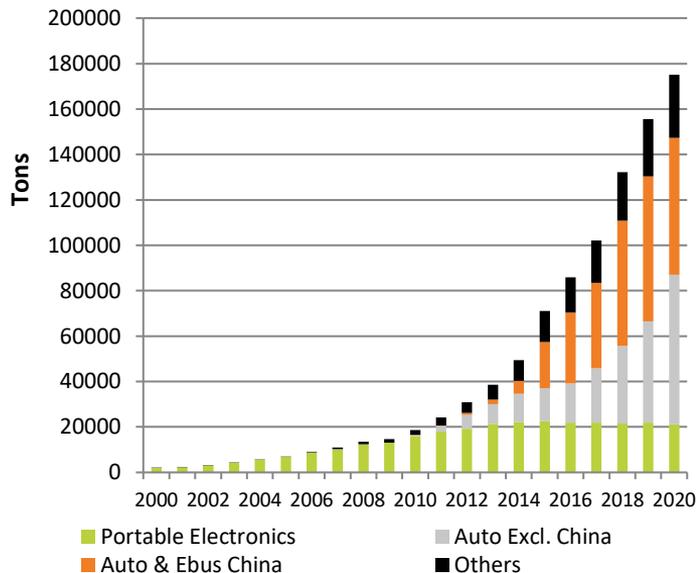
LIB electrolyte supplier, market share in 2020

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ELECTROLYTE DEVELOPMENTS

For the future, the main development are

- ① to replace the expensive Lithium salt,
- ① to find the new 5 volts electrolyte : Fluoro chemicals: company like Solvay, Arkema, Daikin, 3M, Mitsui and so on, are all searching for new fluorinated solvents and additives.
- ① Then, for the long term, lot of developments are on the way to find the future solid electrolyte, with a good conductivity, even at ambient temperature.

AUTOMOTIVE SOLID STATE BATTERIES

Early Technology Leaders and Developers

- 🕒 All the major cell manufacturers are working on solid state (LG, Samsung, Panasonic)
- 🕒 Some OEM also ;
 - 🕒 most advanced is TOYOTA (aims to commercialize the technology by the early 2020s – Very Challenging !)
 - 🕒 BMW (investment in Solid Power)
- 🕒 In Japan, Toyota, Nissan, Honda and Panasonic are just four of the heavyweight Japanese companies that have reportedly teamed up for a new research and development program to develop solid-state batteries (May 2018). The Consortium for Lithium Ion Battery Technology and Evaluation Center, or "Libtec," is being supported by a \$14 million support grant from Japan's Ministry of Economy, Trade and Industry
- 🕒 Lot of start-up like Seo (Bosch stop its investment in those company), Satki3 (Dyson has acquired 100% in 2015 but stop the investment in Sept. 2018), Solid Power (BMW investment) ...

AUTOMOTIVE SOLID STATE BATTERIES

Significant Issues Remain Unsolved

Not expected to be resolved until late 2020s or 2030s

- ⌚ **Conductivity** – Conductivity of polymeric and inorganic solid state remain significant hurdles. Ionic Materials has made claims and has attracted significant investments with industry leading data, however these are still an order of magnitude lower than current LIB. Much research has focused on this issue with technical approaches ranging from heating the battery, to adding liquids to move to semi-solid state and more exotic approaches. With automotive use cycle requirements this is likely to be the most difficult challenge to overcome
- ⌚ **Electrode/Electrolyte Interface management**
- ⌚ **High Temperature Operation** – the only demonstrated technology for solid state for auto is the niche applications by Bollore in the Blue Car demo program, however costs and high temperature requirements of the battery have prevented this from becoming mainstream
- ⌚ **Durability** – most of the developers have focused on non-automotive applications to demonstrate technology and have commercial production at very small scale, this is based on only having limited cycle life unless being charged at very low C-rates and often at different charge/discharge cycles. Current leaders are achieving a few hundred cycles max, most at just room temperature.

AUTOMOTIVE SOLID STATE BATTERIES

Significant Issues Remain Unsolved

Current Major Issues (Cont'd):

- ① **Processing costs** – Many of the battery developers lack significant scale to understand coating and laminating process in enough detail to move the next level of pilot production. Technology pivots have also compounded this issue as there have been significant changes in the materials needed and the process for coating and assembling the battery
- ① **Lithium Requirements and Costs** – Lithium anode costs are being underestimated according to major lithium producers, ideal foil thicknesses required by developer is about 6 micron, commercial production is being challenged with achieving 20 micron and costs are 3-4x Li requirements for LIB. Deposition of Lithium on copper is the alternative option, this would lower Li costs, but high capital costs for larger deposition equipment and low throughput for thicker Li layers remain a very significant cost hurdle

So, Solid State batteries could be the first disruptive technology to the market. They will not be on the mass market before 2025 for sure but they may penetrate slowly the market after 2025. Solid state technology will provide better safety for sure, but not convince that solid state will provide longer life, smaller battery, lighter battery, cheaper battery.

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...

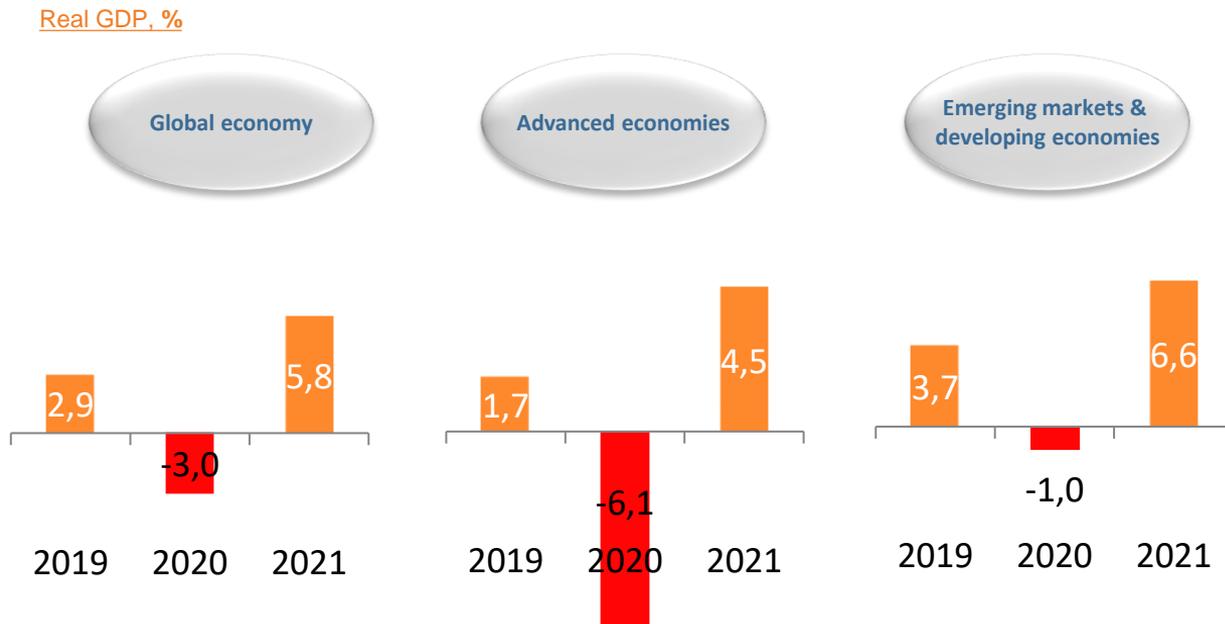
Parameters analysis

- 🔋 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

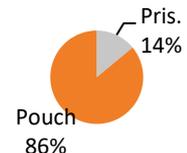
+ Impact of COVID 19

GROWTH PROJECTIONS

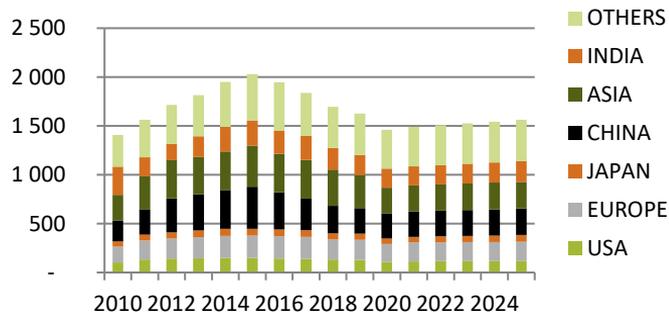
The COVID-19 health crisis had a severe impact on economic activity in 2020 ; But, it was positive for the battery industries: EV, E-bikes, video games, portable devices...



PORTABLE ELECTRONIC DEVICES FORECASTS 2010-2025

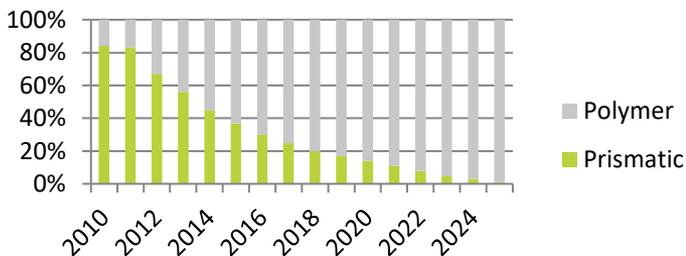


Cellular phones demand (M Units) CAGR 2020-2025: stable



LIB cells demand 2010-2025

Pouch cell penetration: 20% -> 99%



Cellular Phones market Drivers

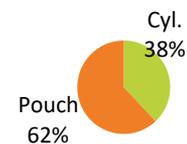
- Emergent market
- Renewal ratio increase
- Smartphone penetration increase



LIB cells for cellular phones trends

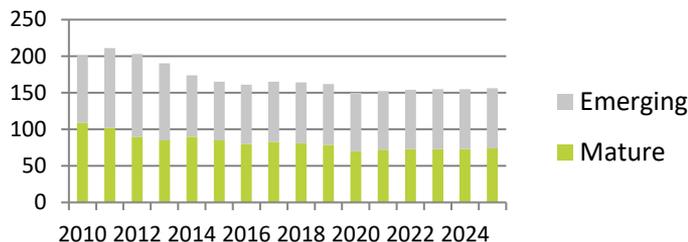
- Pouch cell ratio increase
- Decrease of Thickness
- Increase of the capacity

PORTABLE ELECTRONIC DEVICES FORECASTS 2010-2025



Portable PCs demand (M Units)

2020-2025 – Almost stable

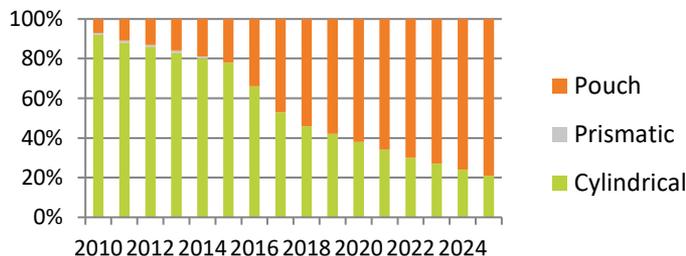


Excluding Tablets and convertibles (Tablets + PC)

Source: IDC, Gartner, AVICENNE Energy

LIB cells demand 2020-2025

Pouch penetration: 62% -> 80%



Source: AVICENNE ENERGY Analyses

Portable PCs market trends

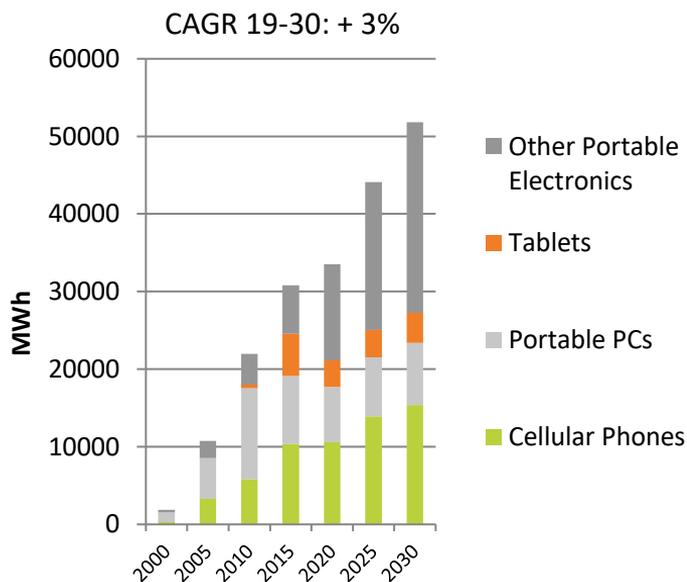
- 🔗 Mature market stable or decreasing
- 🔗 Growth driven by Emerging market
- 🔗 Ultrabook is increasing
- 🔗 ASP decreasing (<499\$ Portable PCs increase from 25% in 2010 to 40% in 2015)

LIB cells for portable PCs trends

- 🔗 Thinner cells
- 🔗 Pouch cells penetration increasing from 7% in 2010 to 40% in 2025
- 🔗 > 3000 mAh for Premium/corporate
- 🔗 2.2 Ah for consumer, emerging market

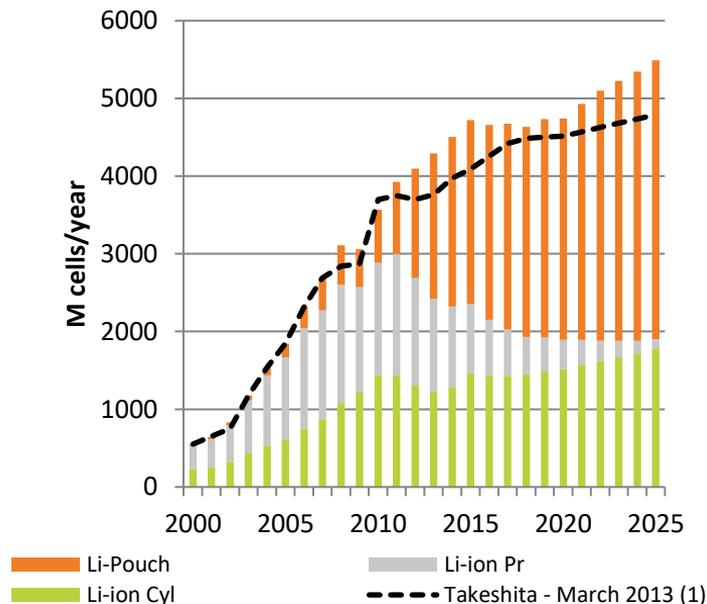
2030 LIB FORECASTS FOR PORTABLE ELECTRONIC DEVICES

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



Source: AVICENNE ENERGY 2020

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



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

X-EV MARKET

X-EV worldwide in 2020

- > 175 GWh
- CAGR₂₀₁₉₋₂₀₂₀ : 25%
- Main cell suppliers: CATL, LG,
- Chemistries: NMC hi Ni, NCA, LFP

X-EV forecasts

- Realistic scenario: ~20% EV and PHEV sold per year in 2030
- > 400 GWh in 2025 & 1,1 TWh in 2030
- CAGR₂₀₂₀₋₂₀₃₀ : > 20%
- Battery cost forecasts: from 150 \$/kWh to ~110 \$/kWh in 2025

xEV sales 2020-2030

Base S.

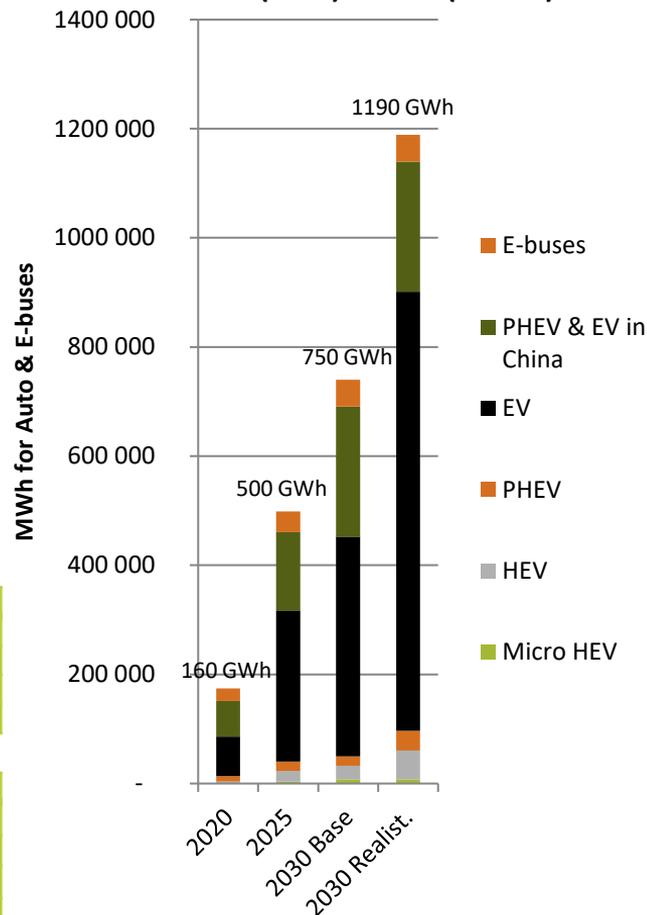
M of cars	China			EU, US, Others			World		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
HEV				3,1	5,8	8,7	3,1	5,8	8,7
P-HEV	0,2	0,3	0,3	0,7	0,9	1,2	0,9	1,2	1,5
EV	1,1	2	3,3	1,2	2,8	5,6	2,2	4,8	8,8

Realist. S.

M of cars	China			EU, US, Others			World		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
HEV				3,1	9,3	18,4	3,1	9,3	18,4
P-HEV	0,2	0,3	0,3	0,7	1,5	2,5	0,9	1,8	2,8
EV	1,1	2	3,3	1,2	4,5	11,2	2,2	6,4	14,4

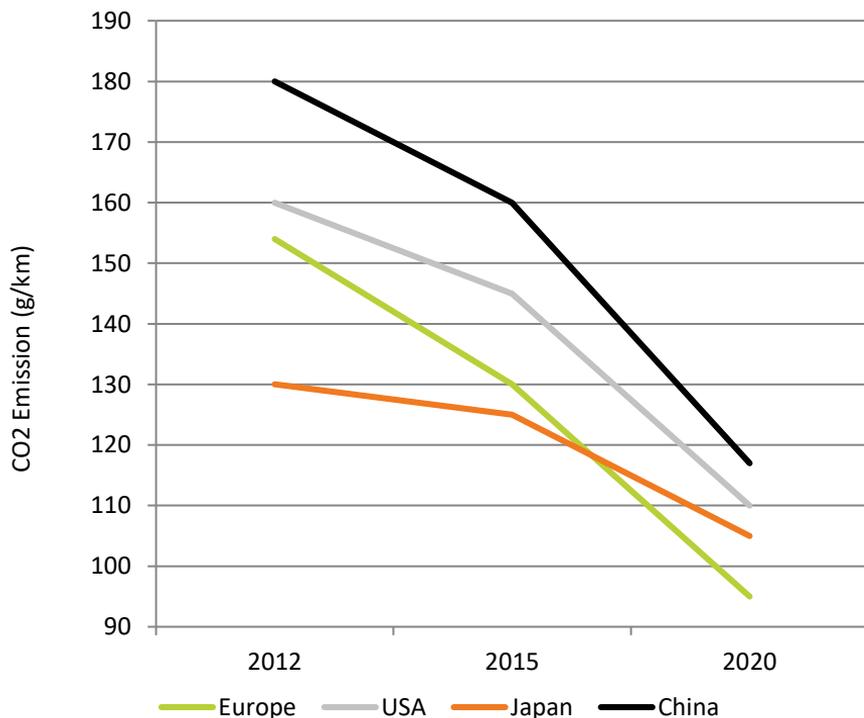
Source: AVICENNE ENERGY Analyses 2021

CAGR 2020-2030: + 16% (Base) - +21% (Realist)

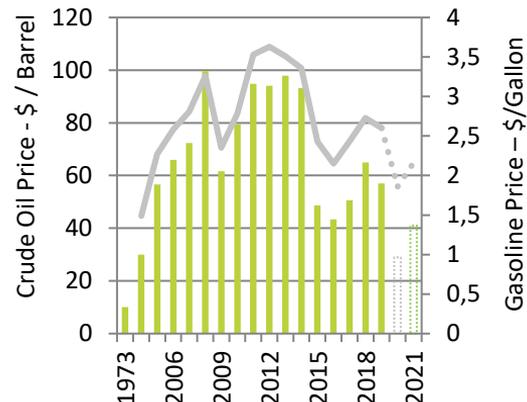


WHY X-EV ?

MAJOR DRIVER: CO₂ regulation worldwide: From 2013 to 2014 Oil price decrease but HEV sales increase by 5%, P-HEV by 30% and EV by 60%

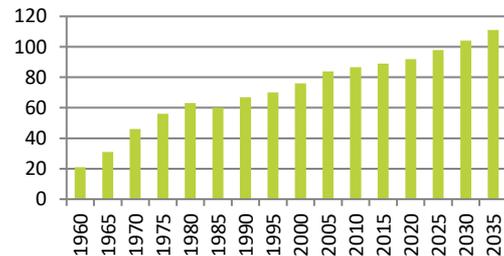


Price of the WTI¹ barrel of oil, US \$



Source: <http://www.eia.doe.gov/emeu/steo/pub/contents.html>

Petroleum consumption worldwide
Million barrel per day



Source: Energy Information Administration, US Government

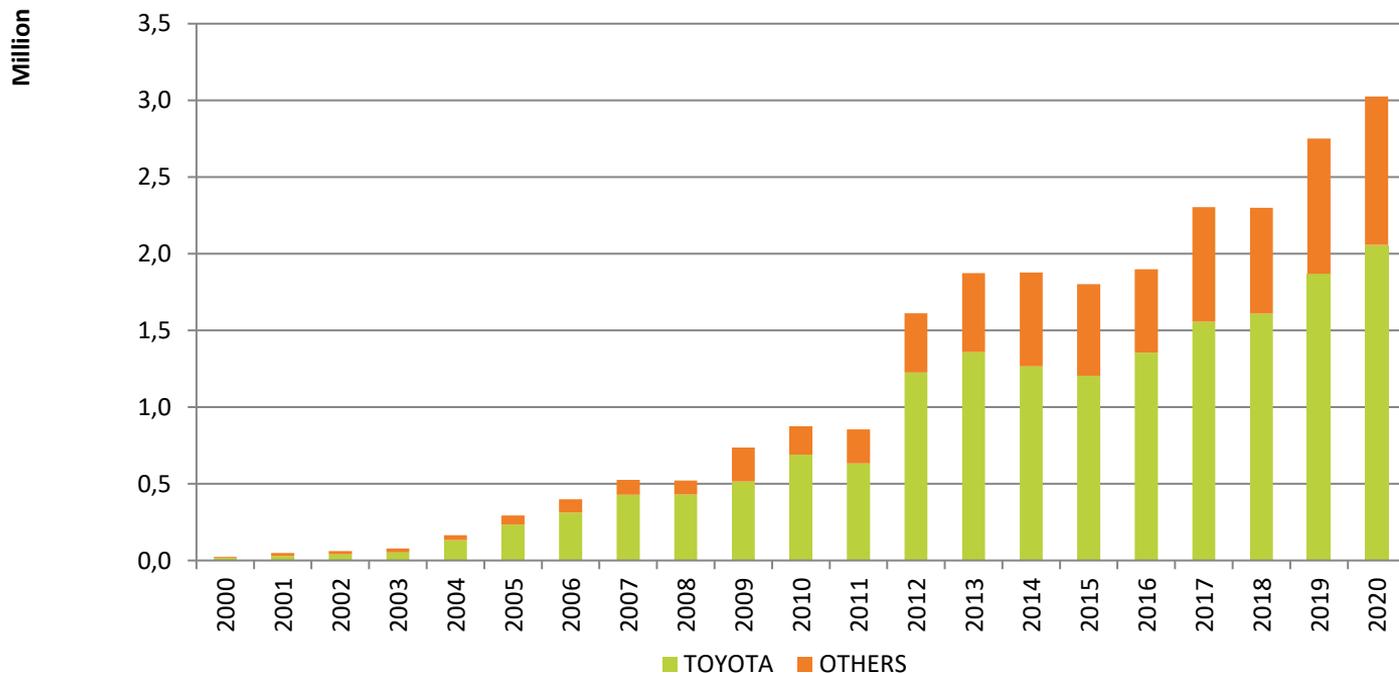
Note

¹ WTI: West Texas Intermediate

HEV WORLDWIDE IN 2020

3,1 M HEV

HEV sold per year, M units, worldwide, 2000 - 2020

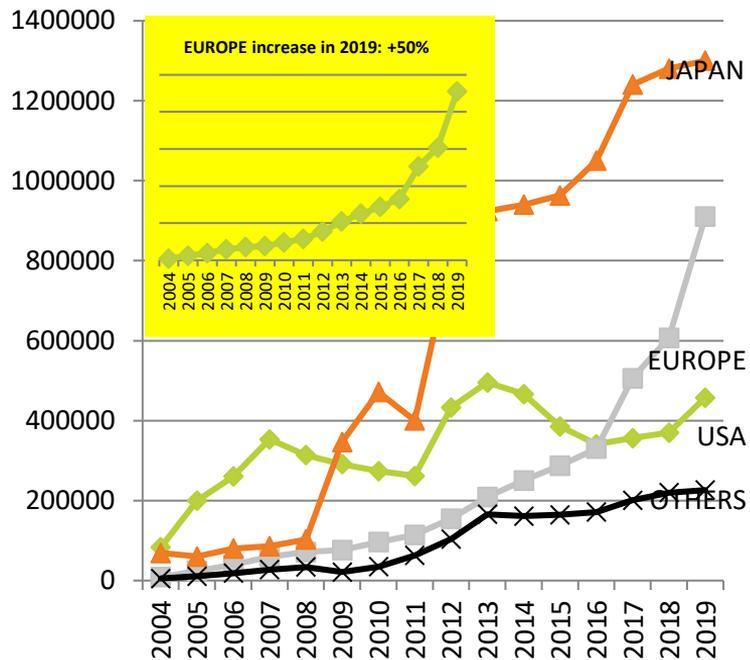
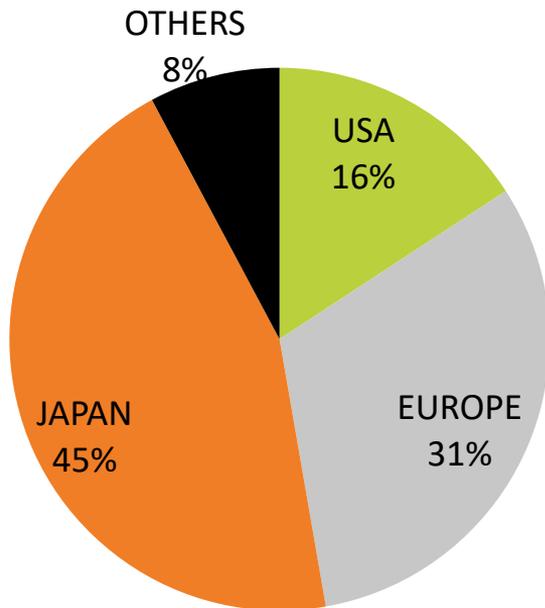


Source: TOYOTA, HONDA, NISSAN, FORD, GM, HYUNDAI, MERCEDES, GM, BMW, VW, PORSCHE... Compilation AVICENNE ENERGY
Micro hybrid not included

HEV WORLDWIDE IN 2019 BY COUNTRY

Total HEV Vehicles
2,9 M in 2019

HEV sold per year, M units per
country, 2004-2019





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The Rechargeable Battery
Market and Main Trends
2020 – 2030



September 28th, 2021

Lyon, France

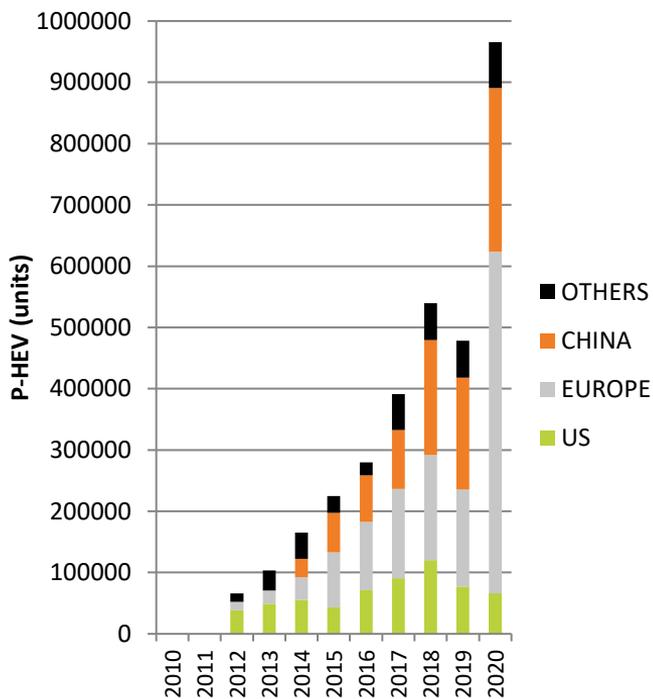
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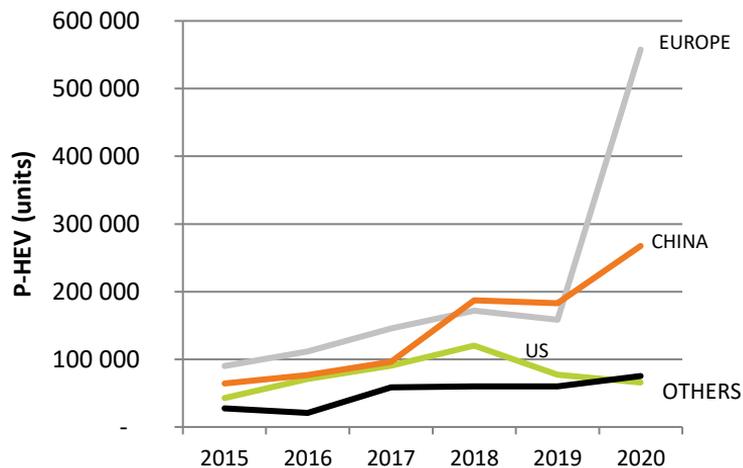
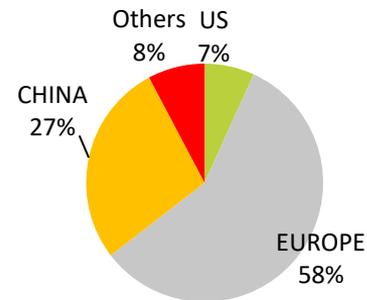
PHEV SOLD WORLDWIDE

>900 000 IN 2020 – CAGR₂₀₁₉₋₂₀₂₀: +100%

Positive impact of the COVID



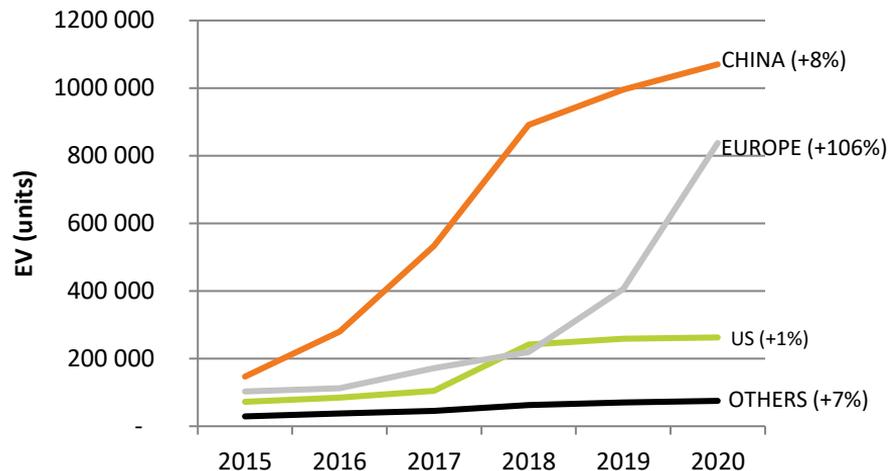
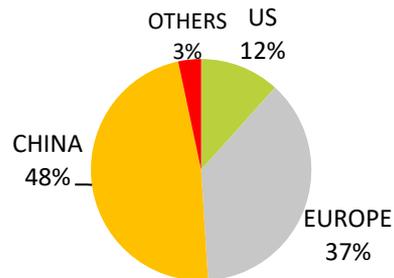
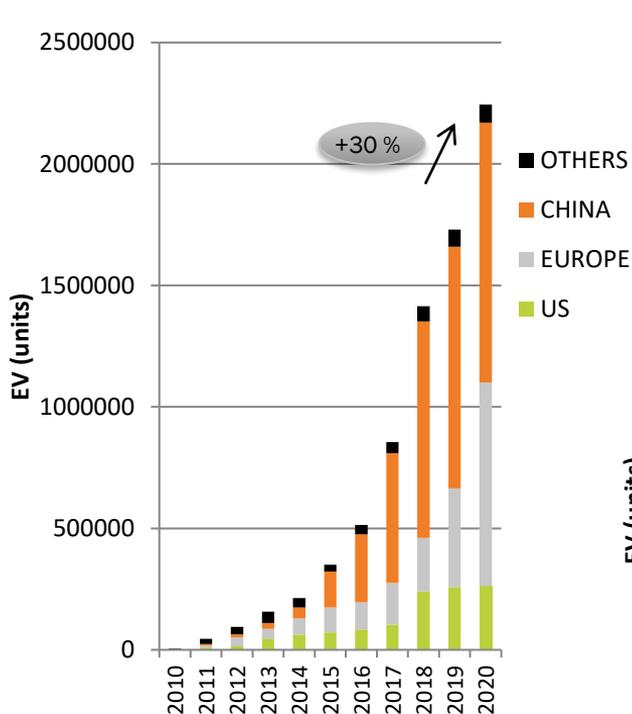
Source: AVICENNE ENERGY Analysis, 2021



EV SOLD WORLDWIDE > 2,2 M IN 2020

2019/2020 growth: +30%

China is leading the EV market but
market share decrease





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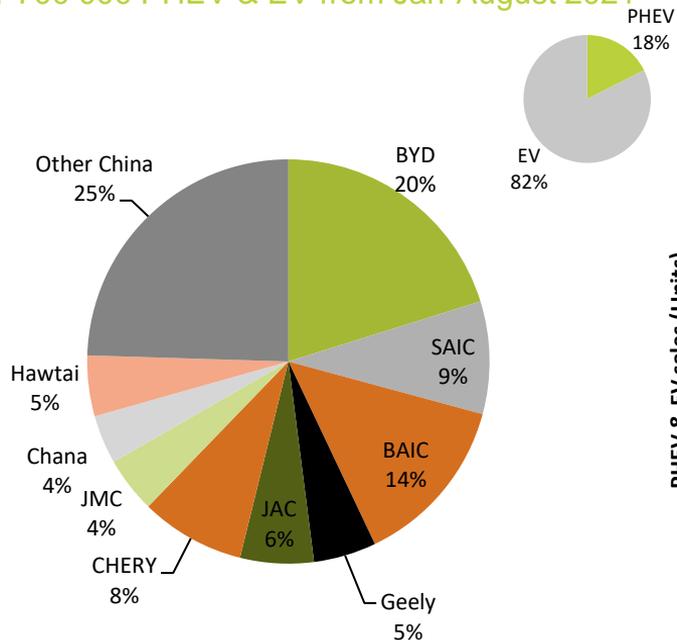
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NEV* DEVELOPMENT IN CHINA

> 1 100 000 PHEV & EV sold in China in 2020

> 1 700 000 PHEV & EV from Jan-August 2021

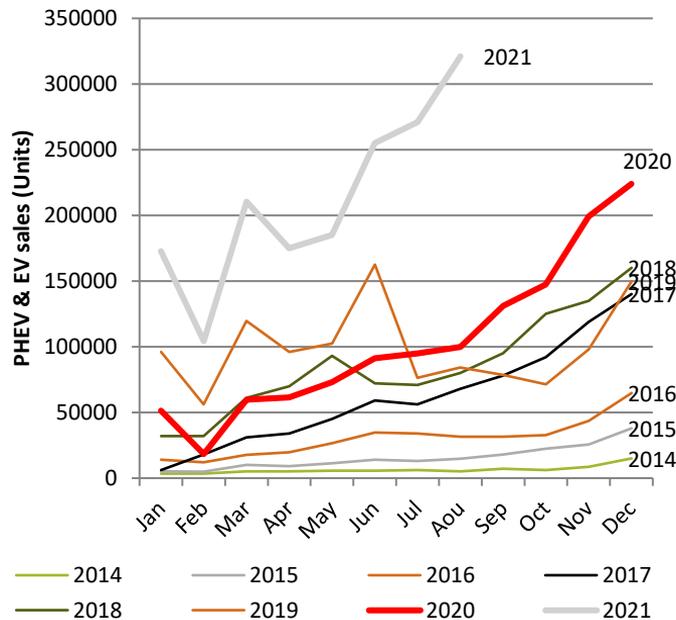


Others: Tesla, BMW, VW, Greatwall, Changan...

*NEV=PHEV+EV (New Energy Vehicles)

PHEV & EV evolution

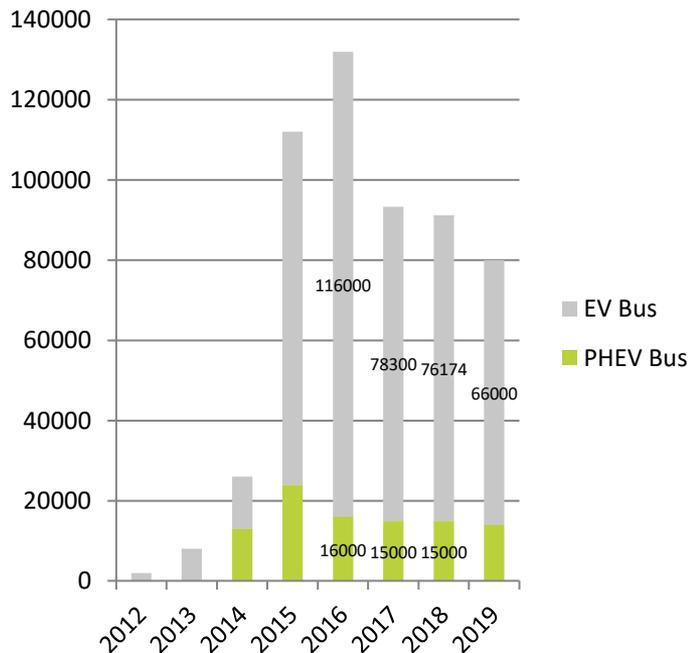
PHEV & EV evolution
Impact of the regulation



XEV BUSES MARKET IN CHINA

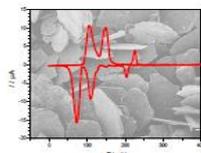
xEV buses market in China:
+75 000 xEV Buses sold in 2018
< 70 000 in 2019 (-11%)

Rationales



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

TIME TO MARKET FOR NEW MATERIALS IN LIB INDUSTRY



1970ies



1980ies



1991



2004



2010

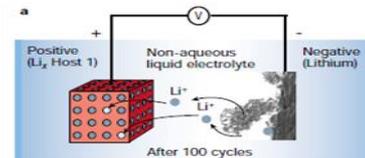
- ⌚ The research and development in this industry is very long and time consuming.
- ⌚ Time to market to commercialize a new material is long. Remember that the first Li-ion battery was launched by Sony in 1991 with LCO cathode, graphite, LiPF_6 electrolyte & polyolefin membrane. It was 27 years ago.
- ⌚ LTO was invented by Matsushita in 1993 (25 years ago)
- ⌚ Lithium iron phosphate was invented in 1995 (23 years ago).
- ⌚ So, it takes between 10 & 20 years to commercialize a new material in the battery industry.

SAFETY ISSUES

Li-ion and LMP are 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. 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"). In 2006, SONY had to recall millions of portable PCs for total costs of 400 million USD, more than their profit-to-date. More recently, in 2016, SAMSUNG had to recall about 2.5 million phones after complaints of overheating and exploding batteries. In Oct 2016, Samsung permanently stops production of the Note 7



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

Boeing 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 Boeing.



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

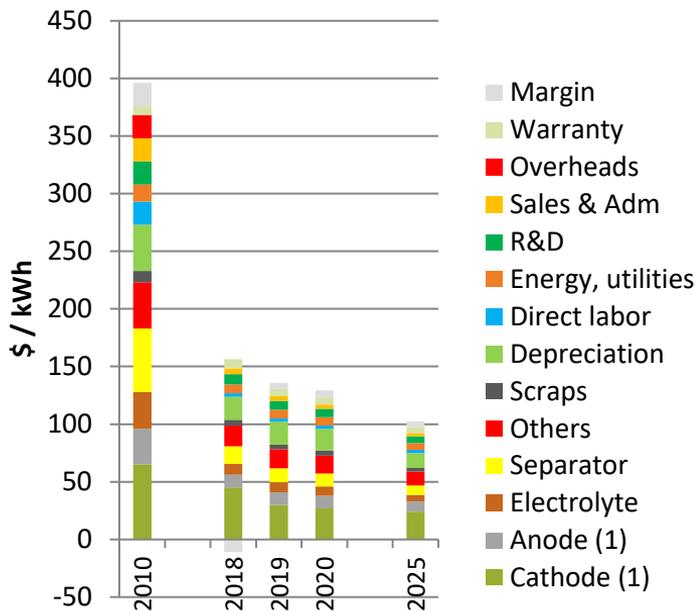
(1) Low energy density ; mostly developed for stationary applications, or LV start light & ignition batteries

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

Source: AVICENNE ENERGY

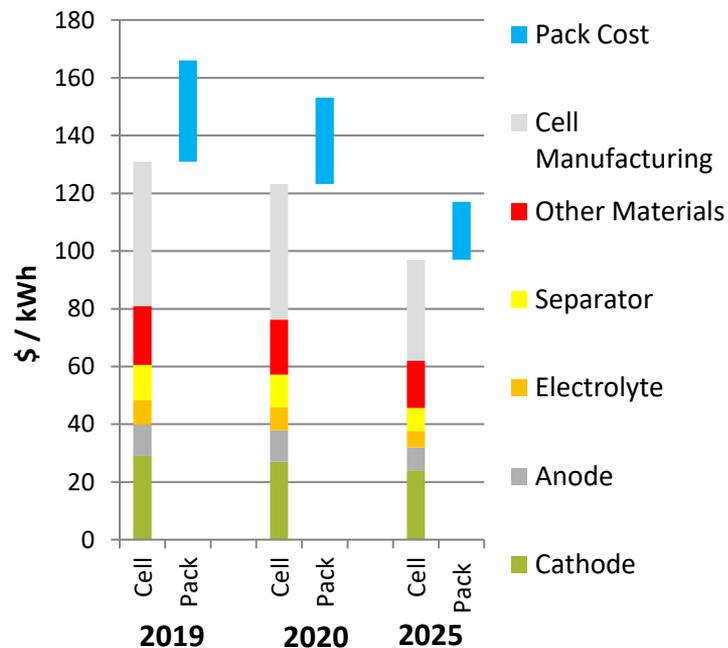
LI-ION BATTERY COST 2019-2025

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



(1) Active materials only
Source: AVICENNE ENERGY 2021

LI-ION BATTERY PACK COST FOR
EV



* For Production > 100 000 packs/year



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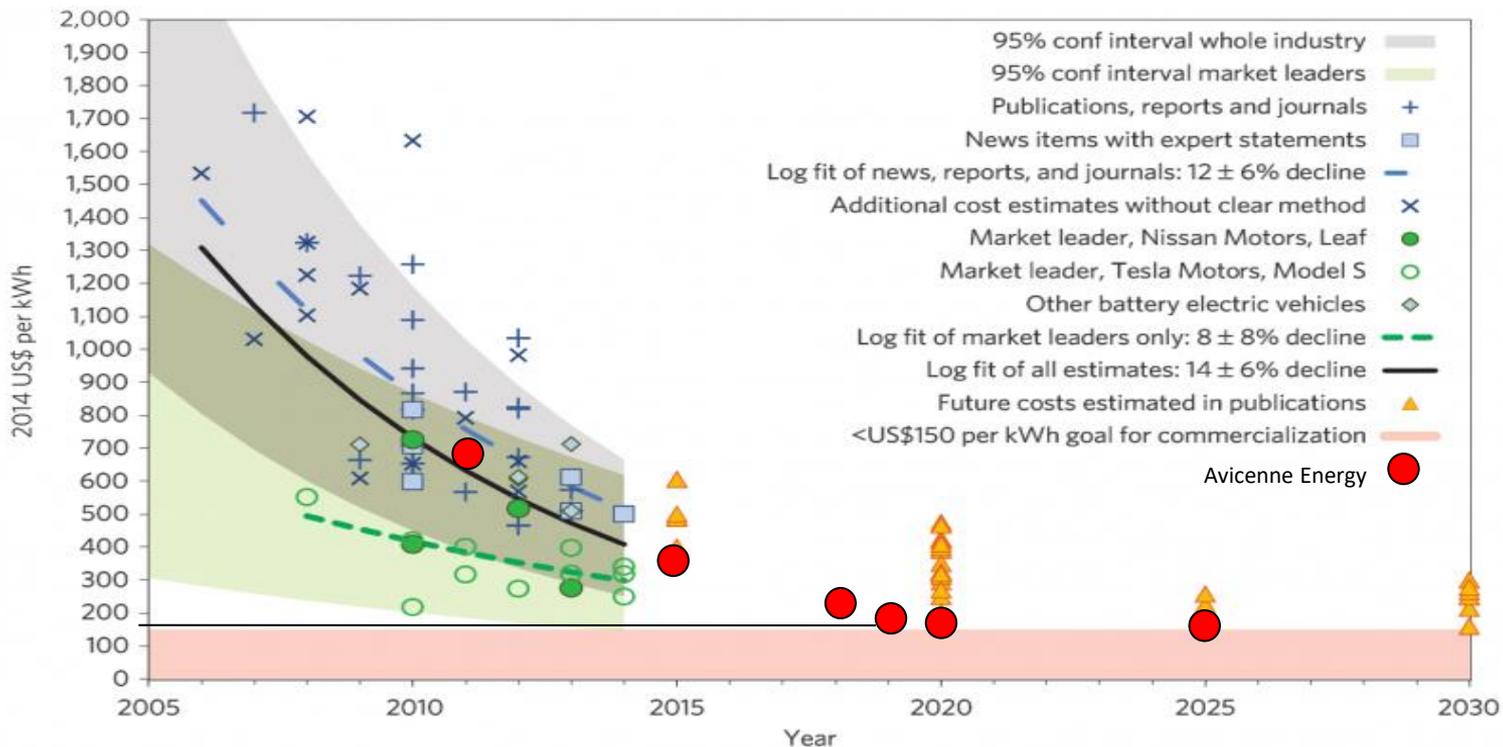
September 28th, 2021

Lyon, France

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LIB COST FORECASTS



Source: Rapidly falling costs of battery packs for electric vehicles, Nature Climate Change , March 2015



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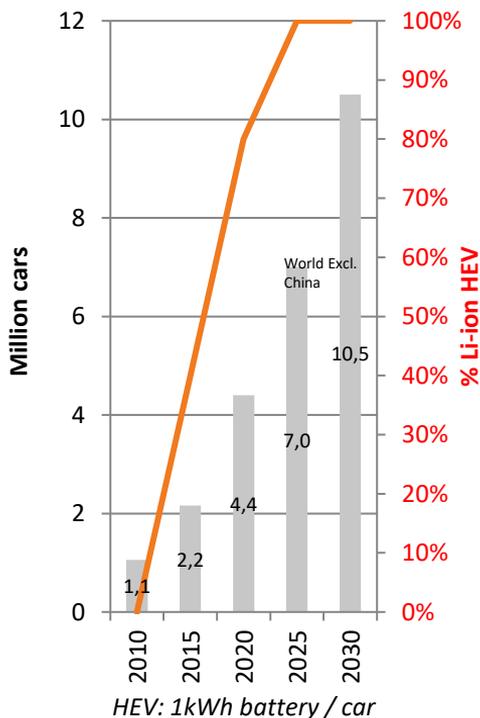
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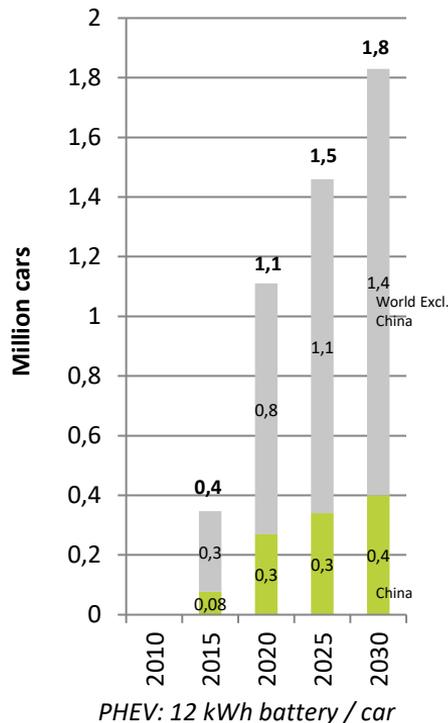
HEV, P-HEV, EV 2030 FORECAST Supprimer ?

Base Scenario

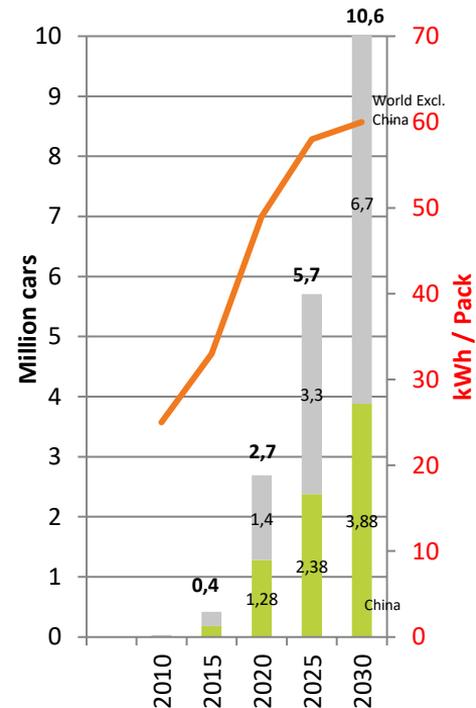
HEV manufactured



PHEV manufactured



EV manufactured





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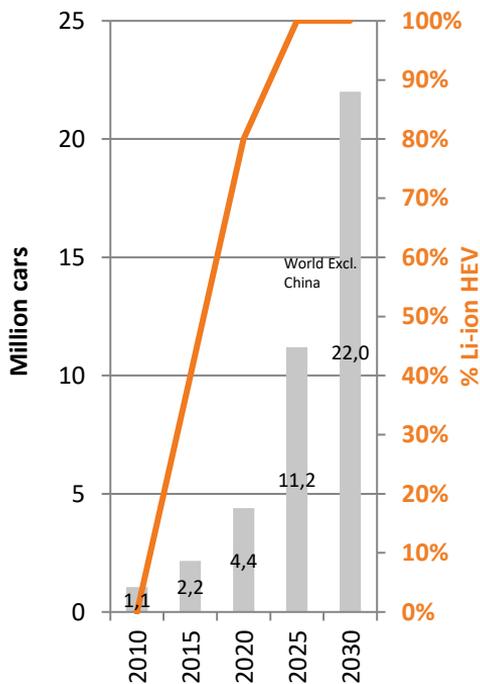
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HEV, P-HEV, EV 2030 FORECASTS

Realistic Scenario

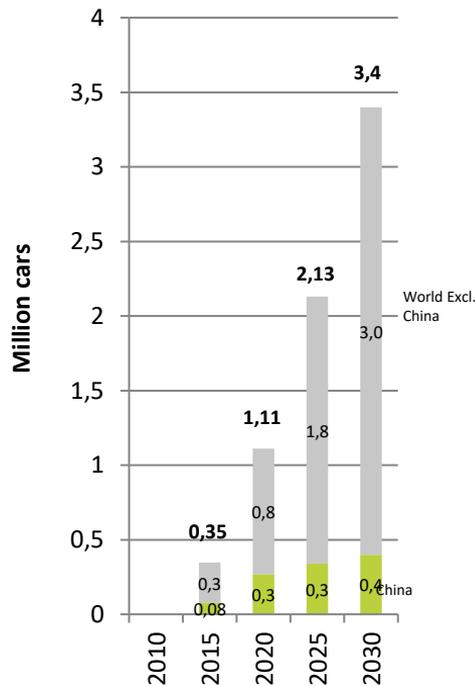
HEV manufactured



HEV: 1kWh battery / car

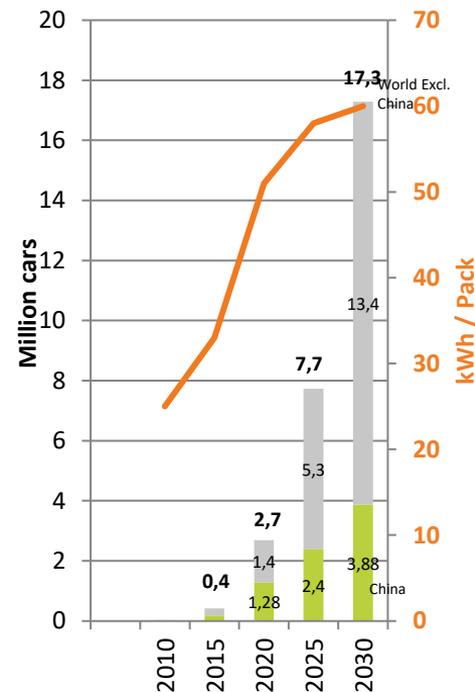
Source: AVICENNE ENERGY 2021

PHEV manufactured



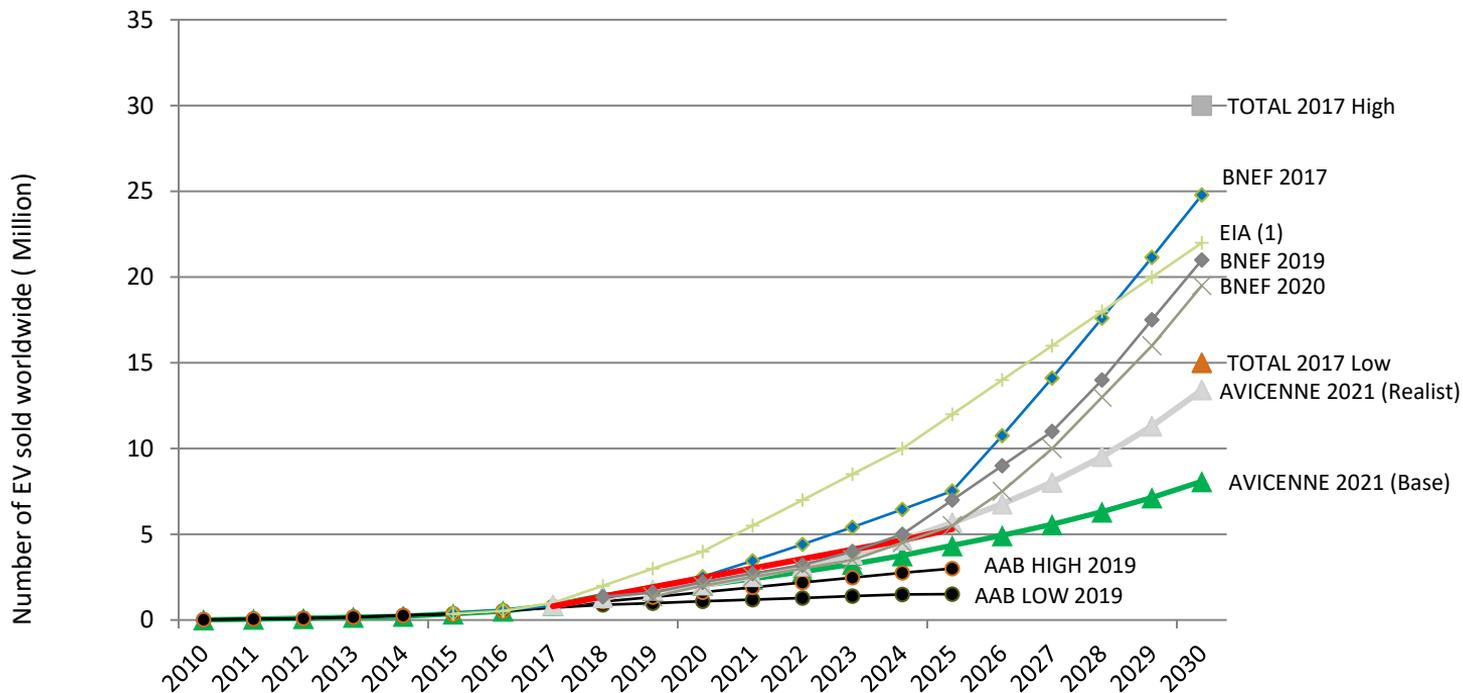
PHEV: 12 kWh battery / car

EV manufactured



LONG TERM EV FORECAST

EV sold, in million units, worldwide, 2010 – 2030



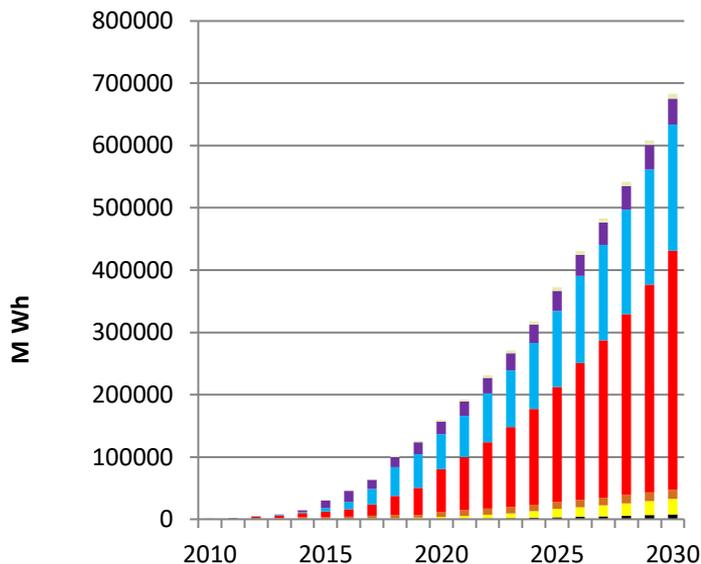
AAB, AABC US, June 2017, 2018, 2019
BNEF, BATTERIES 2017, October 2017
AVICENNE Analysis 2020
COVID 19 impact partially implemented as the crisis is not over - Impact could be worst

(1) EIA – Avicenne estimation based on “Stock” numbers

TOTAL BATTERY DEMAND FOR XEV 2030 FORECASTS (BASE SCENARIO)

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

CAGR 2020-2030: +16%

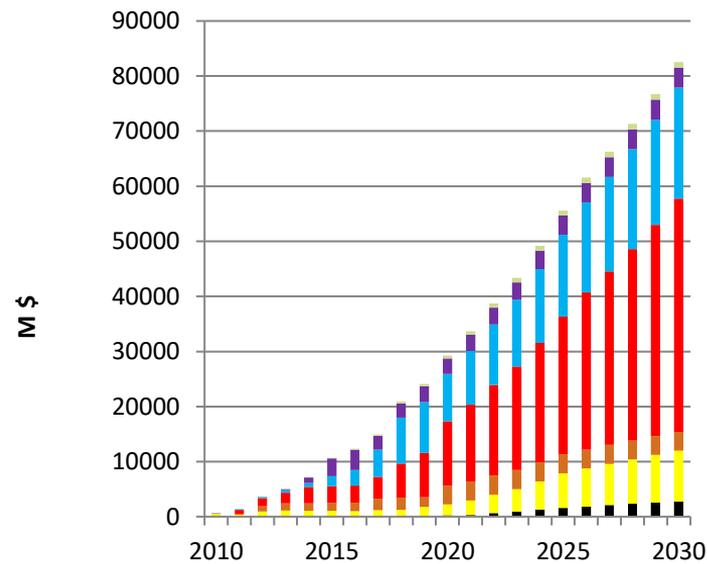


12-48 volts SLI
 EV
 HEV
 EV & PHEV China
 PHEV
 E-bus China
 E-bus excl. China

Source: AVICENNE ENERGY Analysis, 2021

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

CAGR 2020-2030: +11%

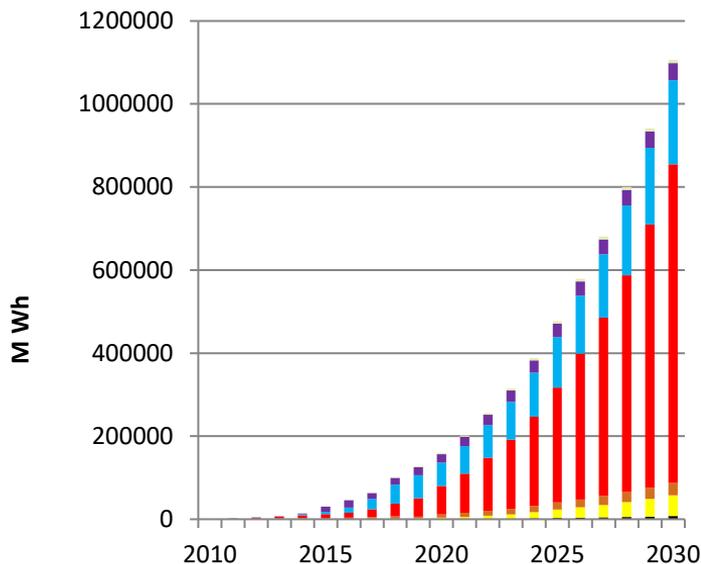


12-48 volts SLI
 EV
 HEV
 EV & PHEV China
 PHEV
 E-bus China
 E-Bus excl. China

TOTAL BATTERY DEMAND FOR XEV 2030 FORECASTS (REALISTIC SCENARIO)

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

CAGR 2015-2030: +27%

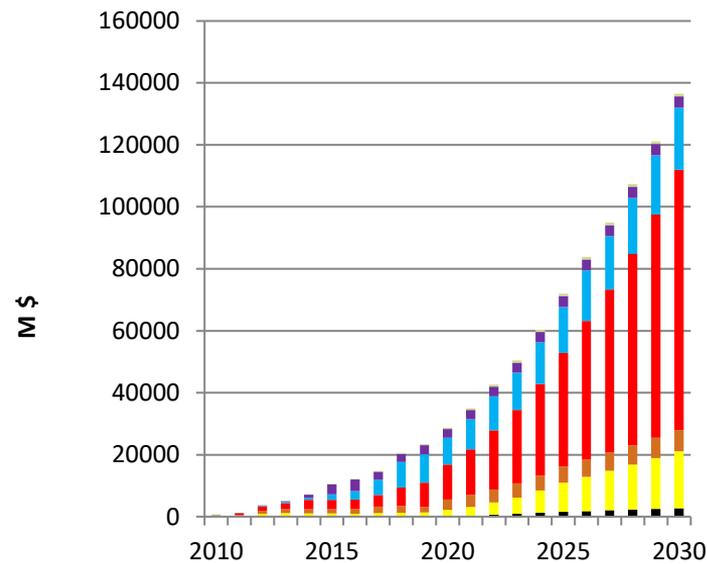


■ 12-48 volts SLI ■ HEV ■ PHEV
 ■ EV ■ EV & PHEV China ■ E-bus
 ■ E-bus excl. China

Source: AVICENNE ENERGY Analysis, 2021

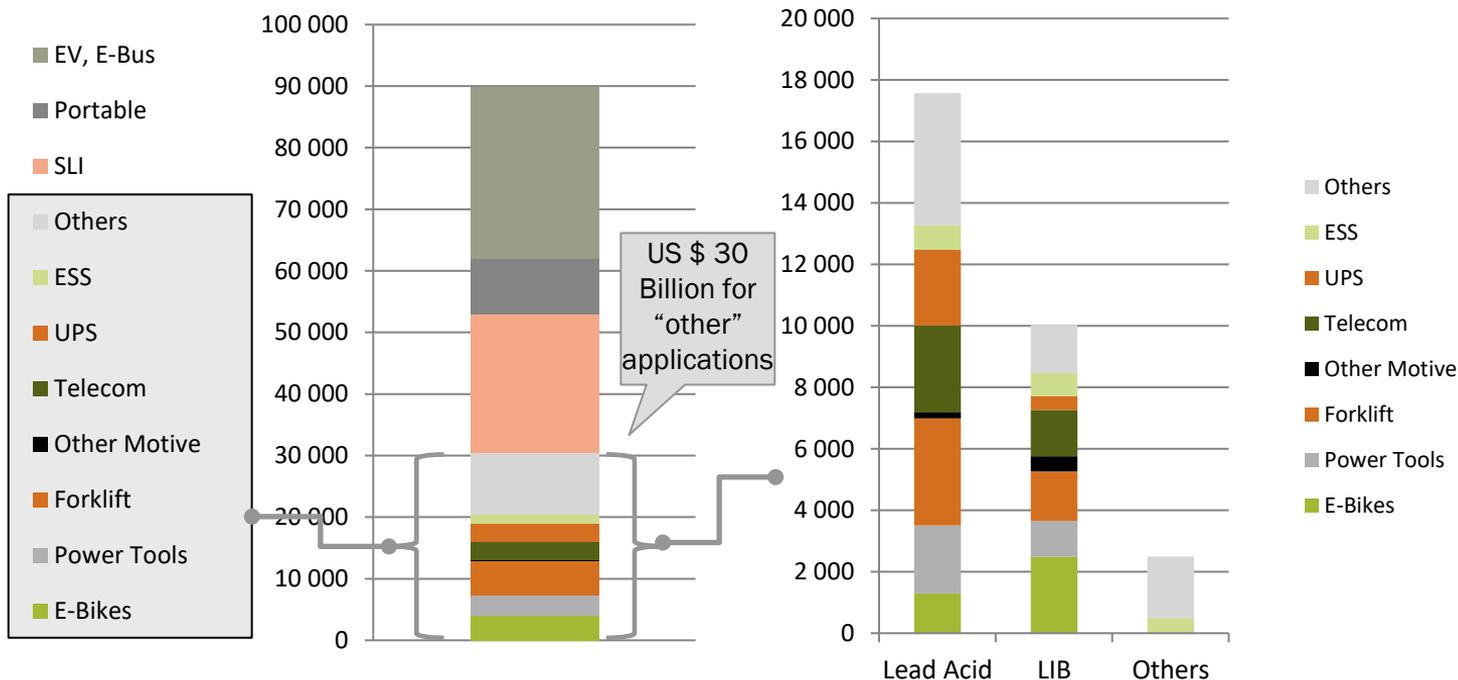
Li-ion for EV, HEV & P-HEV Battery
needs (M\$)

CAGR 2015-2030: +19%



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

THE WORLDWIDE BATTERY MARKET IN 2020: US \$ +90 BILLION

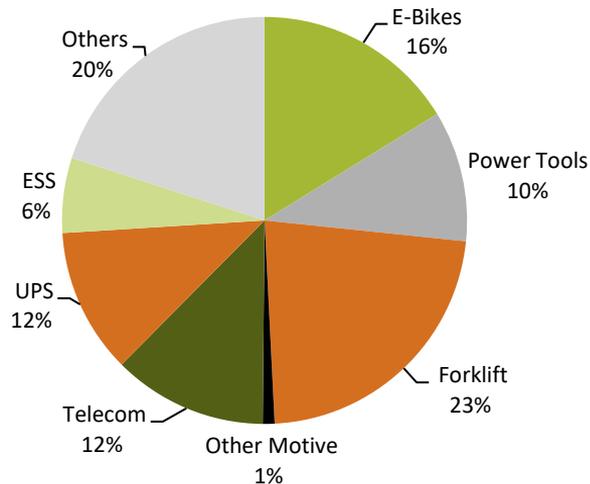


1- Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC DC converters, invertors...) not included

TOTAL POTENTIAL MARKET (M\$, PACK LEVEL¹)

Application details

US\$ 25 Billion in 2020 (1)



Source: AVICENNE ENERGY 2019



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,...

The Rechargeable Battery
Market and Main Trends
2020 – 2030

BATTERIES
EVENT 2021

September 28th, 2021

Lyon, France

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LI-ION BATTERY MARKET FORECAST

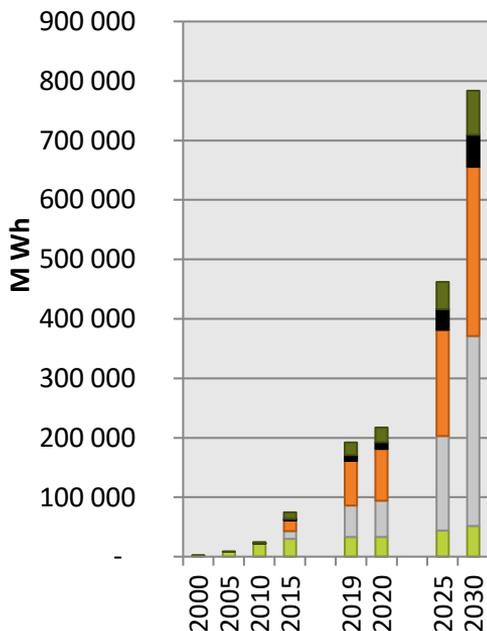
Base scenario

From 190 GWh in 2019 to 880 GWh

CAGR 2015/2030

18 % per year in Volume

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



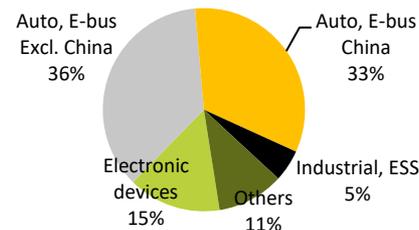
Others: medical devices, power tools, gardening tools, e-bikes...

Source: AVICENNE Energy 2020 - COVID 19 impact partially implemented as the crisis is not over - Impact could be worst

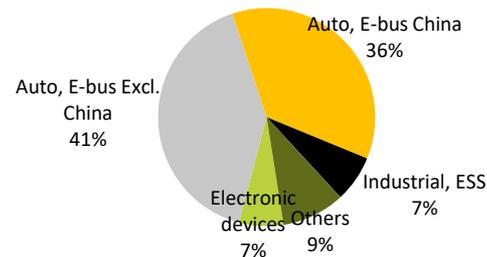
CAGR 15/30
(Base scenario)

- Others 14%
- Industrial, ESS 21%
- Auto, E-bus China 20%
- Auto, e-bus Excl. China 24%
- Electronic devices 4%

2020: >230 GWh



2030: >780 GWh



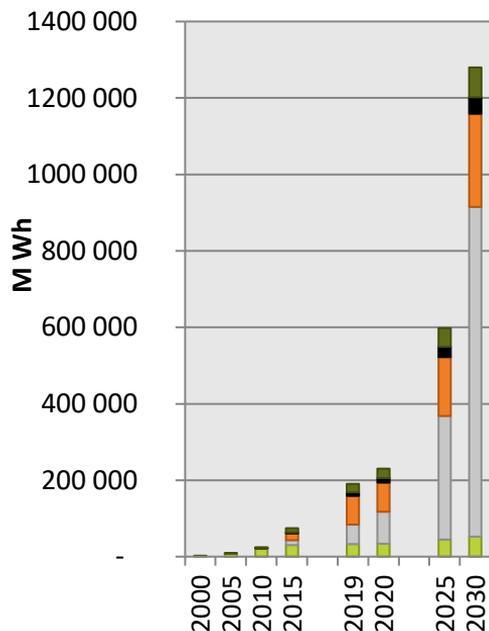
LI-ION BATTERY MARKET FORECAST

realistic scenario

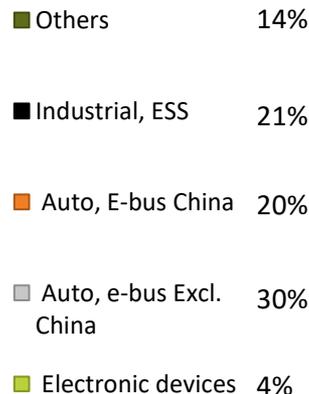
From 230 GWh in 2020 to 1,3 TWh

CAGR 2020/2030
+20 % per year in Volume

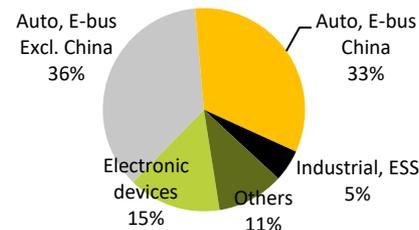
Li-ion Battery sales,
MWh, Worldwide, 2000-2030



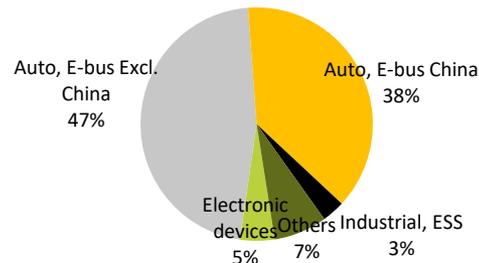
CAGR 15/30
(Optimistic)



2020: >230 GWh



2030: 1300 GWh



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

Source: AVICENNE Energy 2020 - COVID 19 impact partially implemented as the crisis is not over - Impact could be worst



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The Rechargeable Battery
Market and Main Trends
2020 – 2030

BATTERIES
EVENT 2021

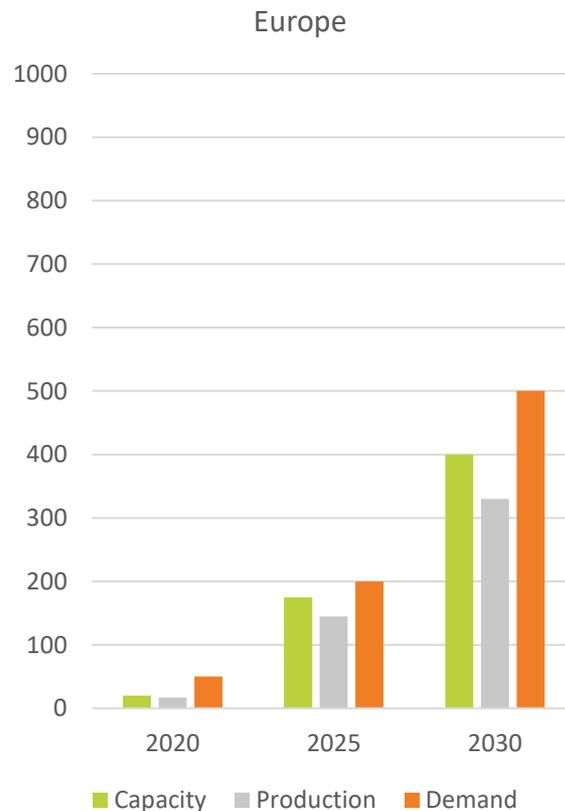
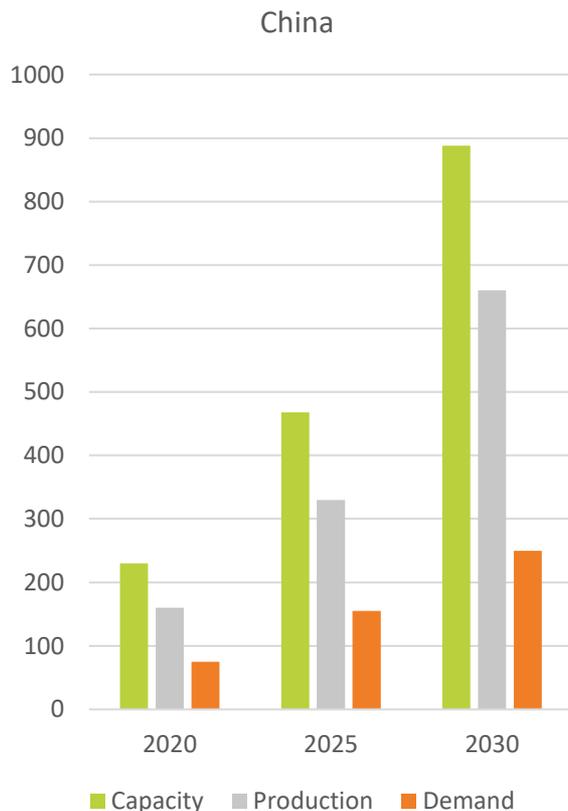
September 28th, 2021

Lyon, France

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LIB Demand & supply 2020-2030 (GWh)



Source: AVICENNE ENERGY, 2021

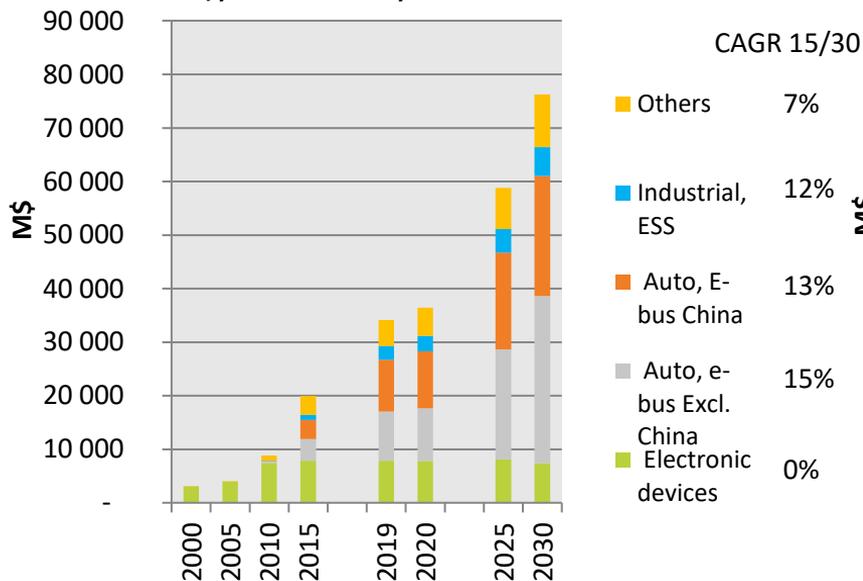
LI-ION BATTERY MARKET FORECAST

Base scenario

CAGR 2015/2030: +18 % per year in Volume

Pack: +10% per year in value

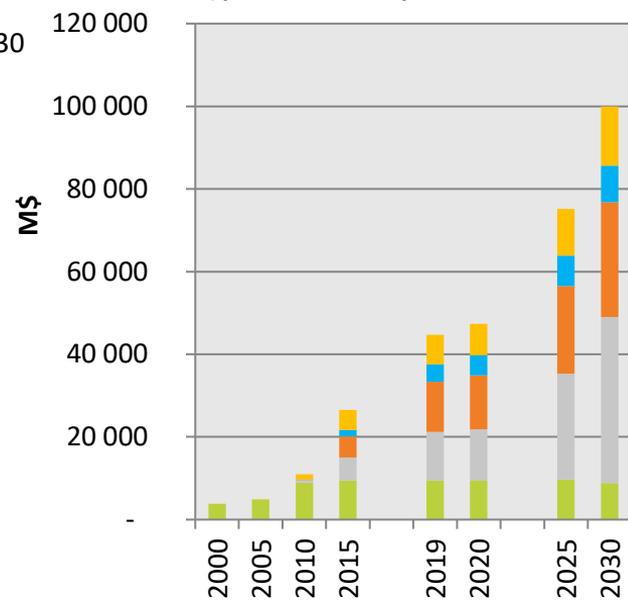
Li-ion cells
M\$, Worldwide, 2000-2025



CAGR 15/30

- Others 7%
- Industrial, ESS 12%
- Auto, E-bus China 13%
- Auto, e-bus Excl. China 15%
- Electronic devices 0%

Li-ion Packs
M\$, Worldwide, 2000-2030



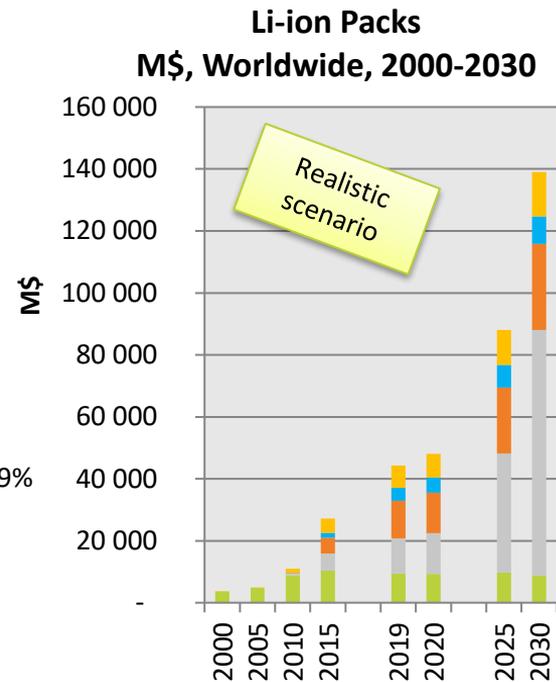
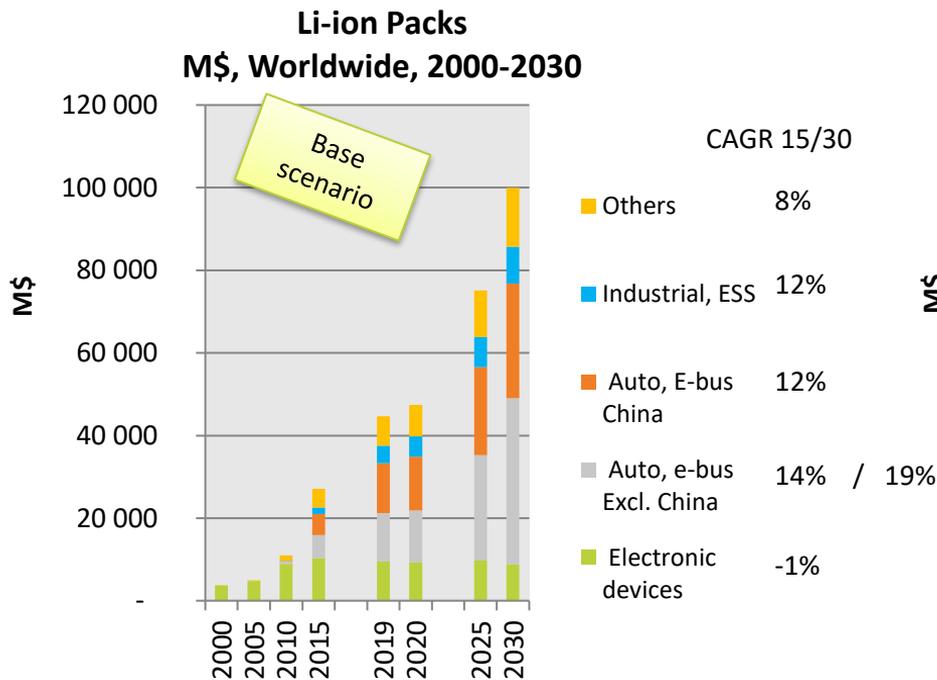
Others: medical devices, power tools, gardening tools, e-bikes...

Source: AVICENNE Energy 2020 - COVID 19 impact partially implemented as the crisis is not over - Impact could be worst

LI-ION BATTERY MARKET FORECASTS

CAGR 2015/2030: +18/20 % per year in Volume

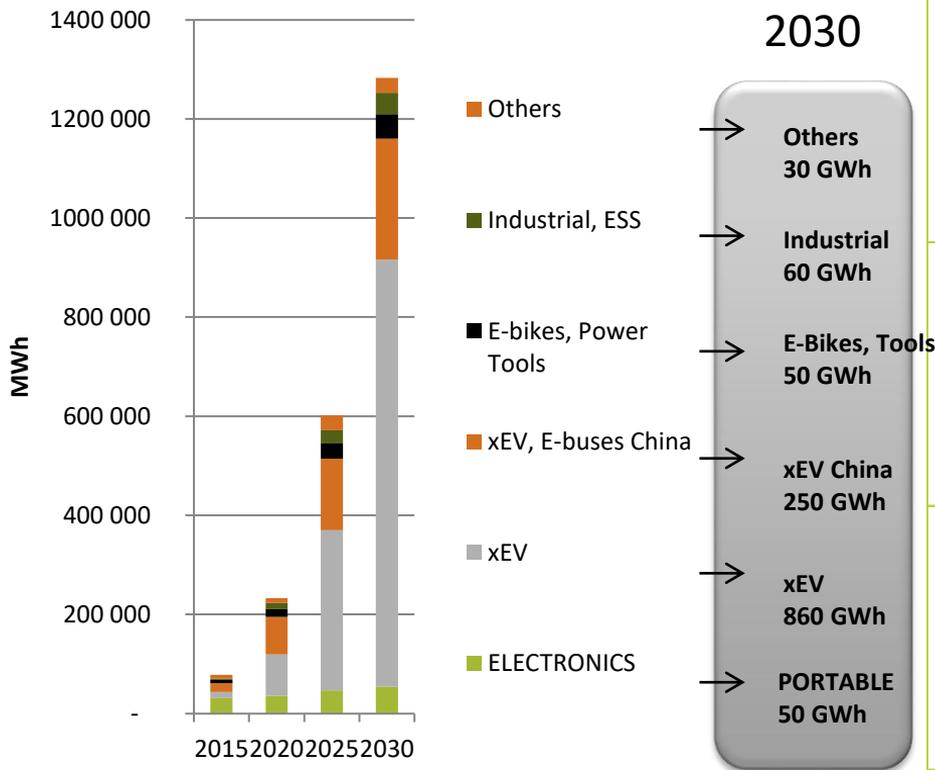
Pack: +10/13% per year in value



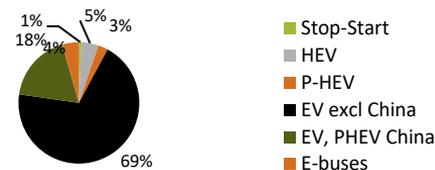
Others: medical devices, power tools, gardening tools, e-bikes...

Source: AVICENNE Energy 2020 - COVID 19 impact partially implemented as the crisis is not over - Impact could be worst

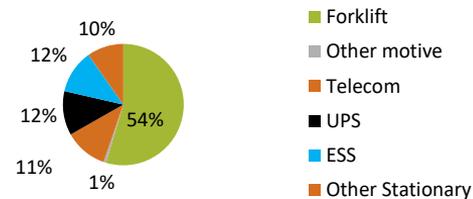
THE LITHIUM ION BATTERY MARKET WORLDWIDE 2015 - 2030



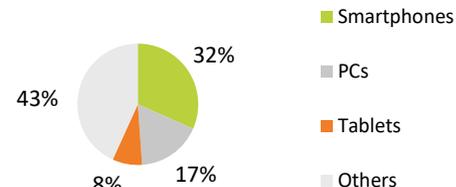
xEV, E-buses: 1100 GWh in 2030



Industrial: 60 GWh in 2030

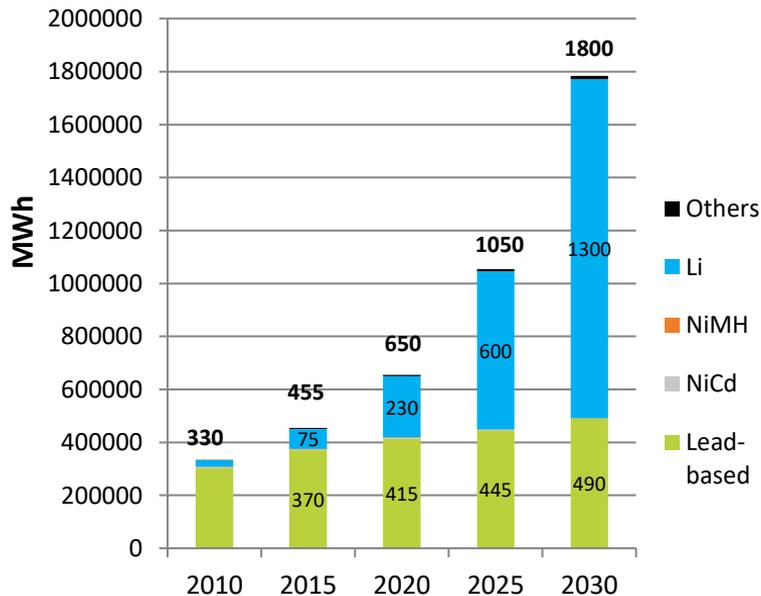


Portables: 50 GWh in 2030



BATTERY MARKET 2010-2030

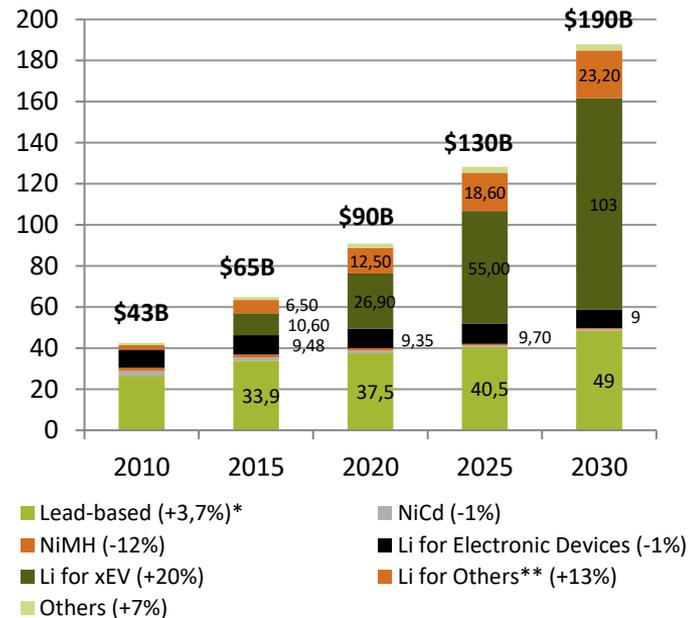
Lead-based and Li-ion batteries will remain the most important markets



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

Source: AVICENNE Energy 2021

Market value will reach \$190b in 2030 – Pack level⁽¹⁾



* CAGR 2015-2030

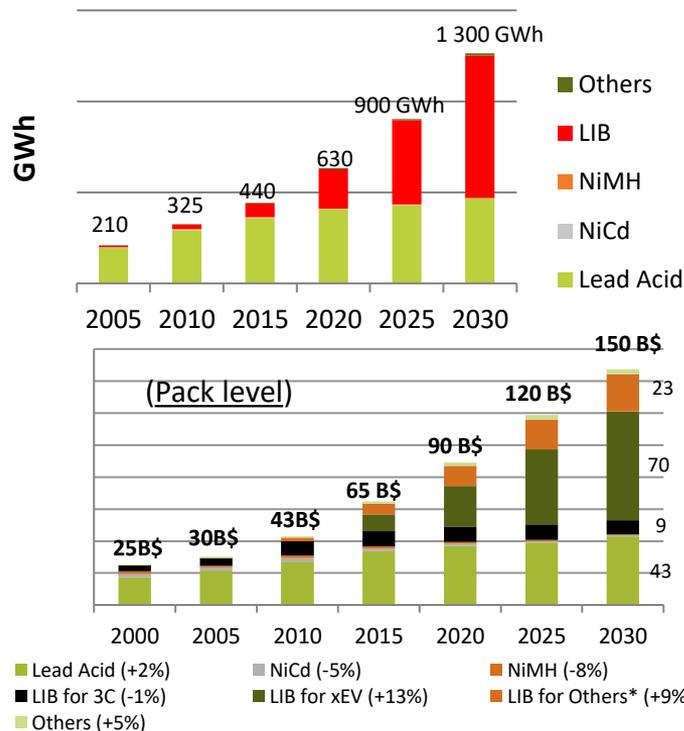
**Others: automatic handling equipment, robots, forklifts, UPS, telecom, medical devices, residential ESS, grid ESS, drones, hoverboards, etc.

TAKEAWAYS

Battery Market 2015-2030 - CAGR = +7% / Li-ion > +11%

- 🕒 Li-ion battery is driven today by Automotive: few% of the automotive market consume ~70% 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: 25 B\$ market in 2020 - 50 B\$ in 2025 & 70 B\$ in 2030 with high numbers in China
- 🕒 EV expectations attract large Chemical companies
- 🕒 New materials are needed to meet Automotive standards
- 🕒 P-HEV & EV will account for 10% by 2025 / 20% by 2030
- 🕒 Micro-hybrid will achieve >50% in 2025
- 🕒 Lead acid battery will be the first market in 2025 in volume, but Li-ion market (US\$ 45 Bn) is higher than Lead acid in value in 2020 (US\$ 37 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 > 10-15% 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 2005-2030 (base scenario)



(CAGR 2015-2030)

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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