MARKET REPORT: THE MARKET FOR LITHIUM-ION BATTERY CELLS AND COMPONENTS MAIN TRENDS 2023-2030

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avicenne ENERGY

NAATBATT 2025
EXTENDING RANGE

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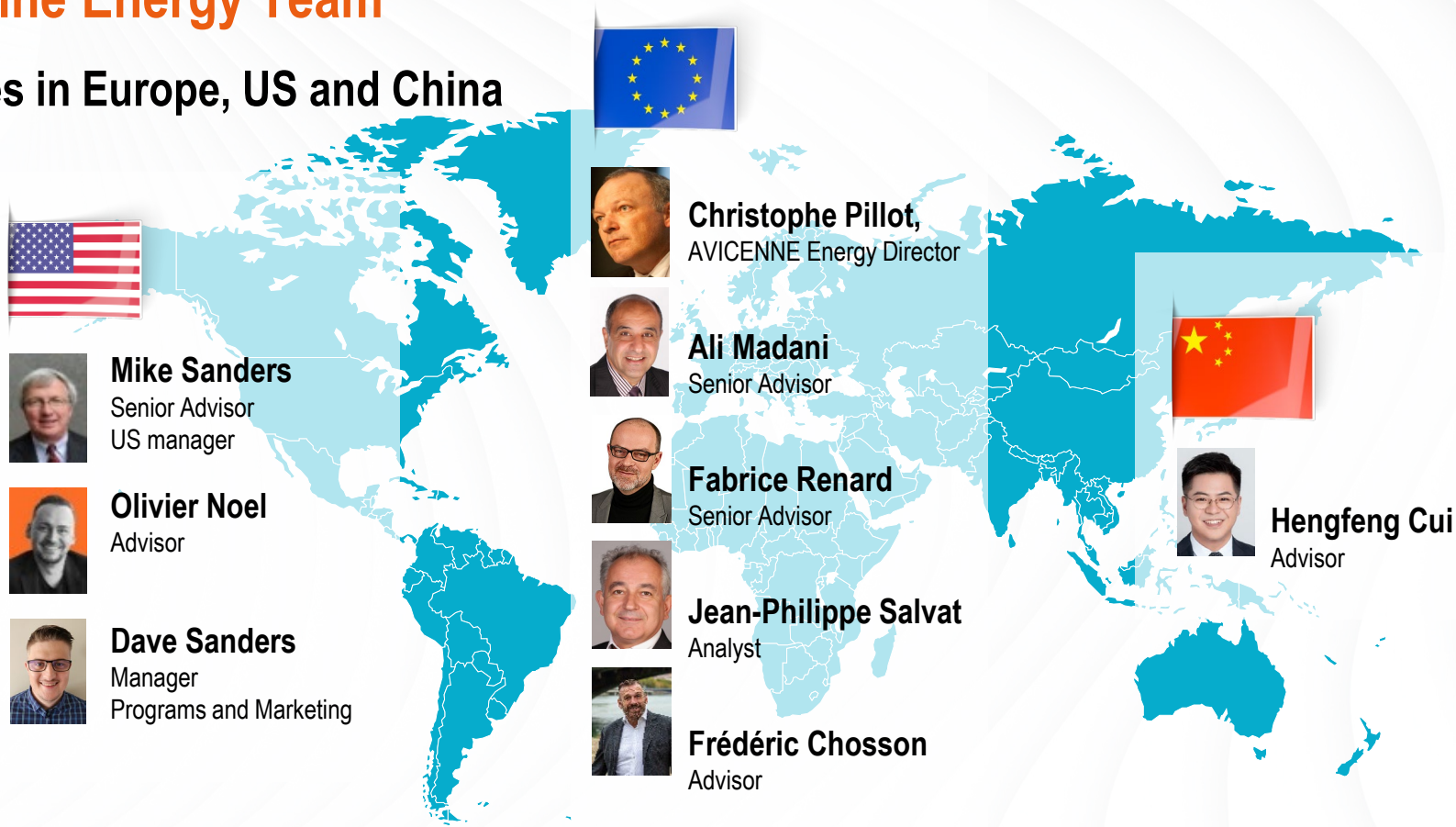

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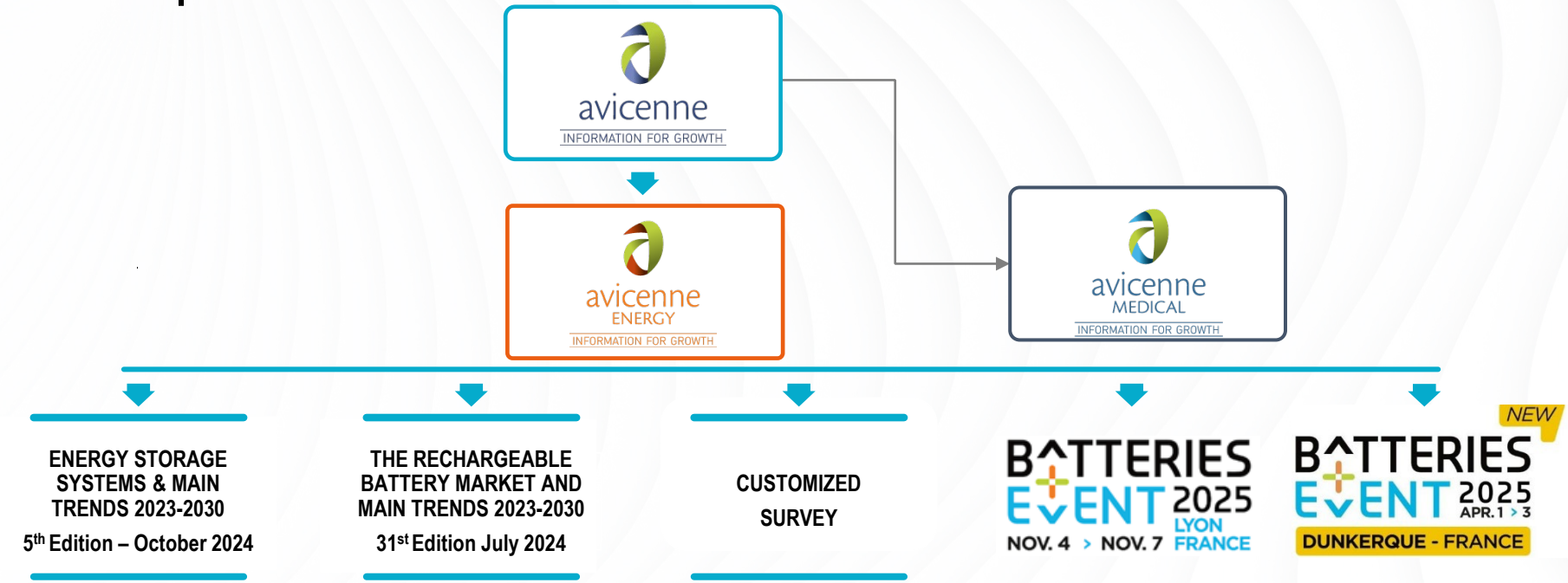
Avicenne profile

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



The future of battery Industry

BATTERIES EVENT 2025
NOV. 4 > NOV. 7 LYON FRANCE

SAVE THE DATES

2025 > NOV. 04 > NOV. 06 LYON – FRANCE | NOV. 04 TUTORIALS

2026 > OCT. 13 > OCT. 15 LYON – FRANCE | OCT. 13 TUTORIALS

What is happening NOW ?

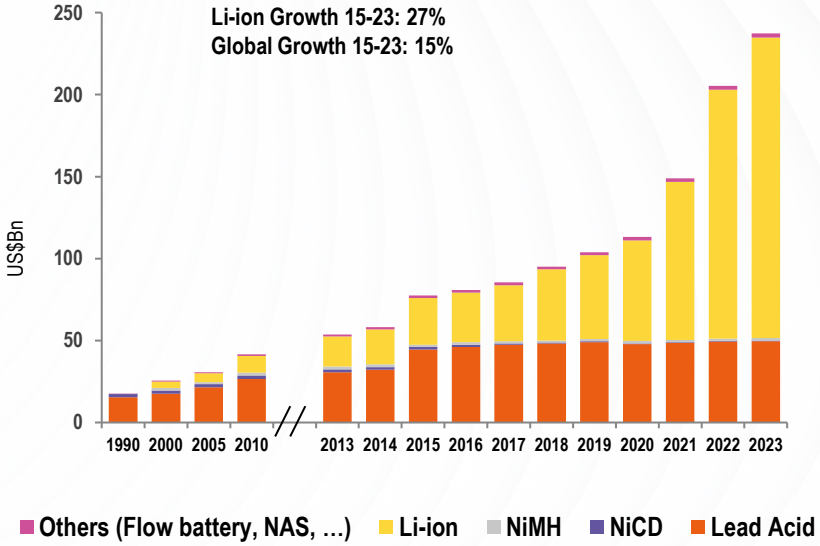
References

More than 400 customers all over the world

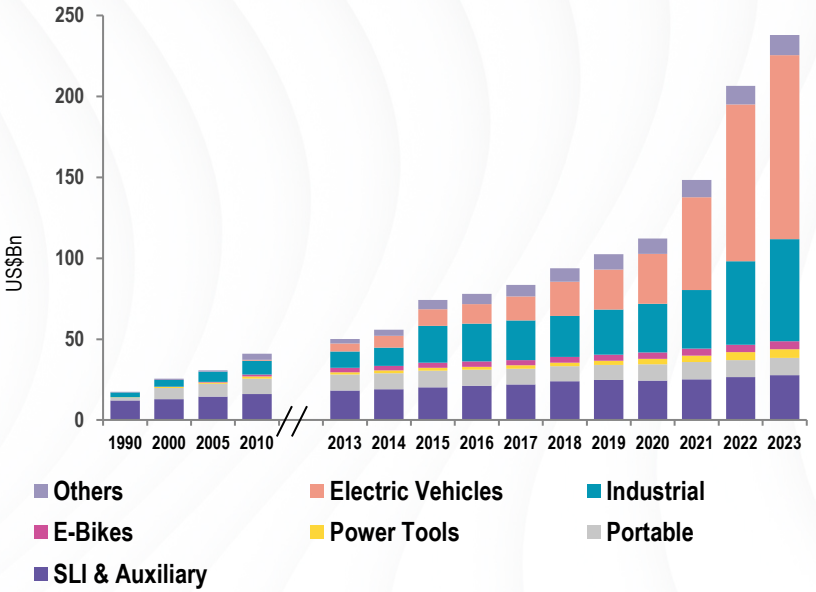
The worldwide battery market

In 2023, the total world battery market at Pack level is US$235 Billion, with a 15% average growth per year (2015-2023)

Worldwide battery market by Chemistry, 1990-2023, US$Bn



Worldwide battery market by application, 1990-2023, US$Bn



Source: Avicenne Energy 2024

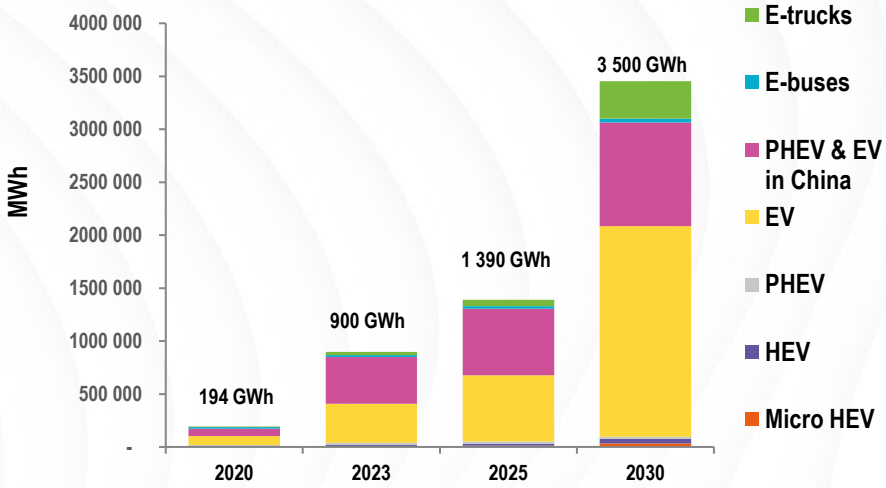
xEV market

A fast growing market - $CAGR_{20-30}$: 34%

- **X-EV worldwide in 2023**
  - 900+ GWh
  - CAGR 22-23: 28%
  - Main cell suppliers: CATL, LGES…
- **Chemistries: NMC hi Ni, NCA, LFP**

- **X-EV forecasts**
  - ≈30% to 35% EV and PHEV sold per year in 2030
  - ≈1.4 TWh in 2025 & 3,5 TWh in 2030
  - CAGR 20-30: >30+%

Batteries produced for X-EV, e-buses and e-trucks market 2020-2030, MWh

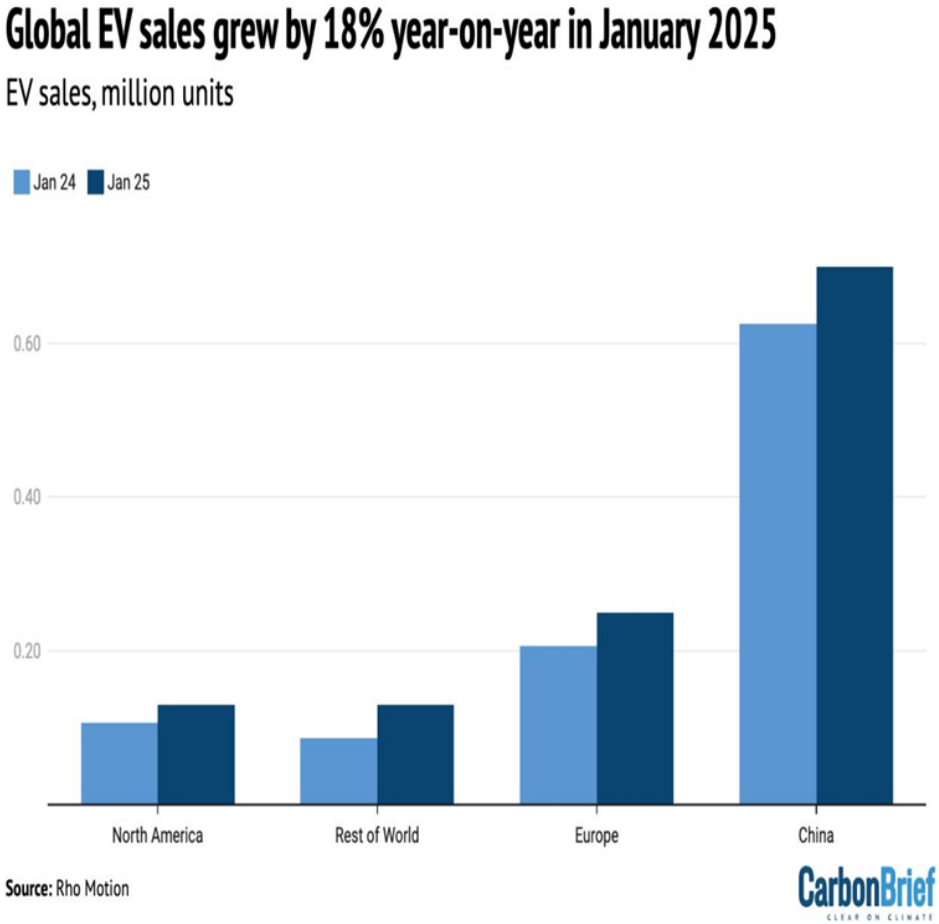


Cars (M)	China			EU, US, Others			World		
	2020	2025	2030	2020	2025	2030	2020	2025	2030
HEV				4.7	10.5	16.8	4.7	10.5	16.8
P-HEV	0.24	3,5	5,3	0.7	1.4	1.5	0.9	4,9	6,8
EV	1.1	7,5	11,4	1.2	6,7	17,6	2.3	14,3	29

Source: Avicenne Energy 2023

EV Sales Globally – January 2025

- One of the largest uncertainties for the battery market is EV growth to drive battery demand
- All Regions delivered a strong January up 18% globally
- US due to political changes and government funding uncertainty – up ~15%
- EU was near flat in 2023 and growth was expected to restart with new model launches – up nearly 20%
- ROW and China led growth



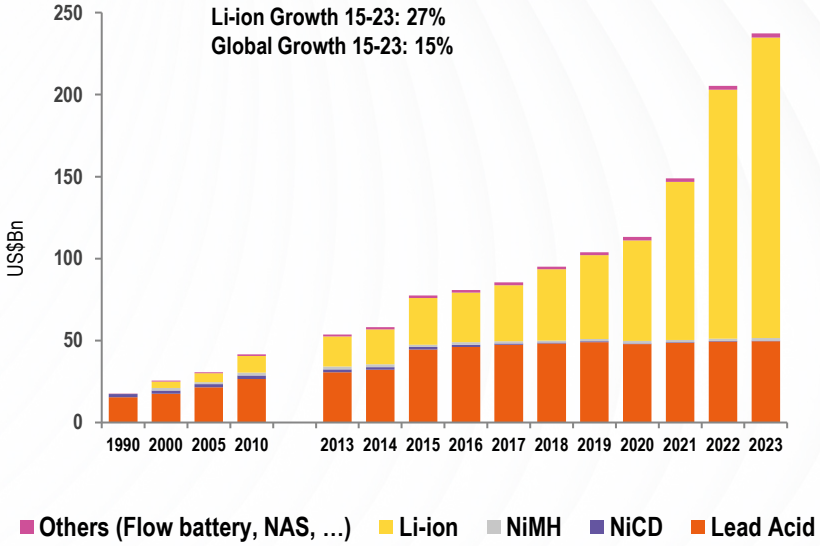
February 25

Source: Rho Motion

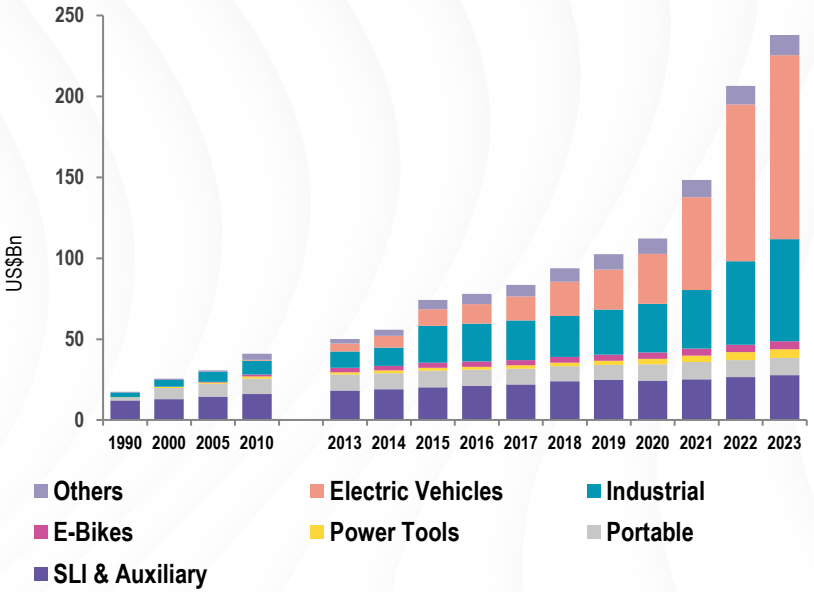
The worldwide battery market

In 2023, the total world battery market at Pack level is US$235 Billion, with a 15% average growth per year (2015-2023)

Worldwide battery market by Chemistry, 1990-2023, US$Bn



Worldwide battery market by application, 1990-2023, US$Bn

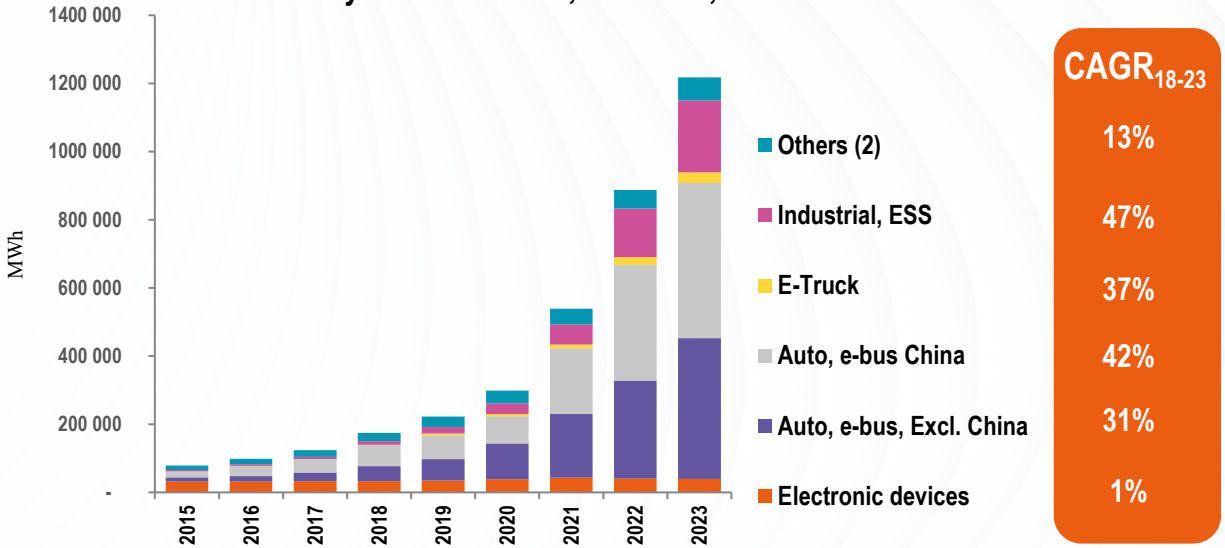


Source: Avicenne Energy 2024

The Lithium-ion battery market 2000 - 2023

In 2023, EV, e-buses & e-trucks account for 75% of the li-ion battery market with a total LIB market of 1 200 000+ MWh

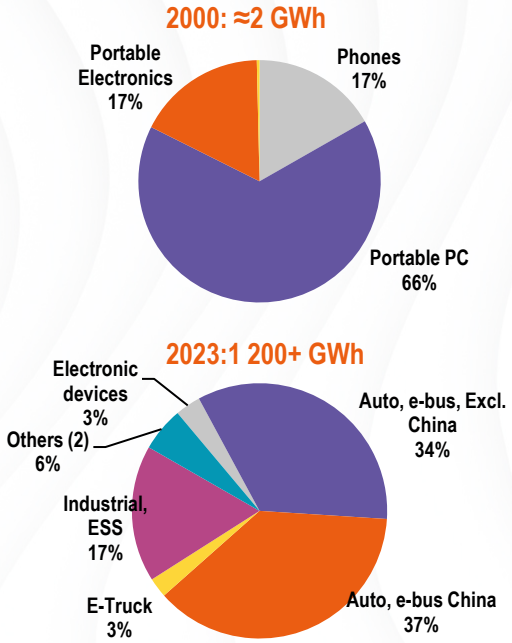
Li-ion Battery sales worldwide, 2000-2023, MWh



(1) Pack level

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

CAGR $_{15-23}$: 37% per year in volume

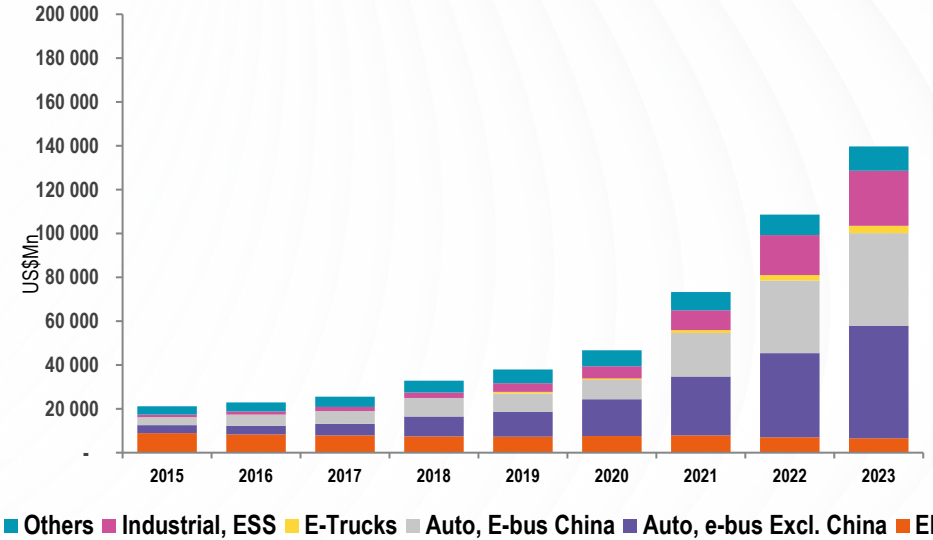


Source: Avicenne Energy 2024

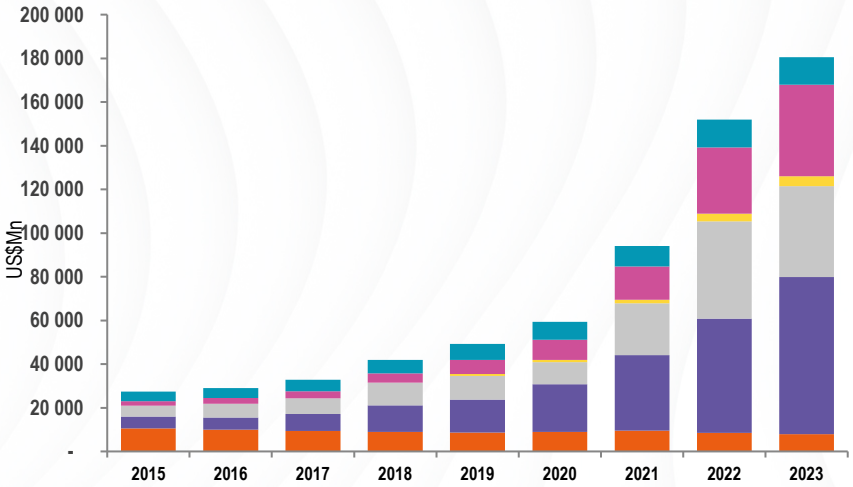
The Lithium-ion battery market: main applications

In 2023, the total sales of Lion-ion cells represent a market value of US$ ≈ 140 Bn, while at Pack level it represents a total value of US$≈180 Bn[1]. Li-ion cells market $CAGR_{18-23}$ is 20% in value

Li-ion cells sold worldwide, 2015-2023, US$Mn



Li-ion packs sold worldwide, 2015-2023, US$Mn



(1) Pack level

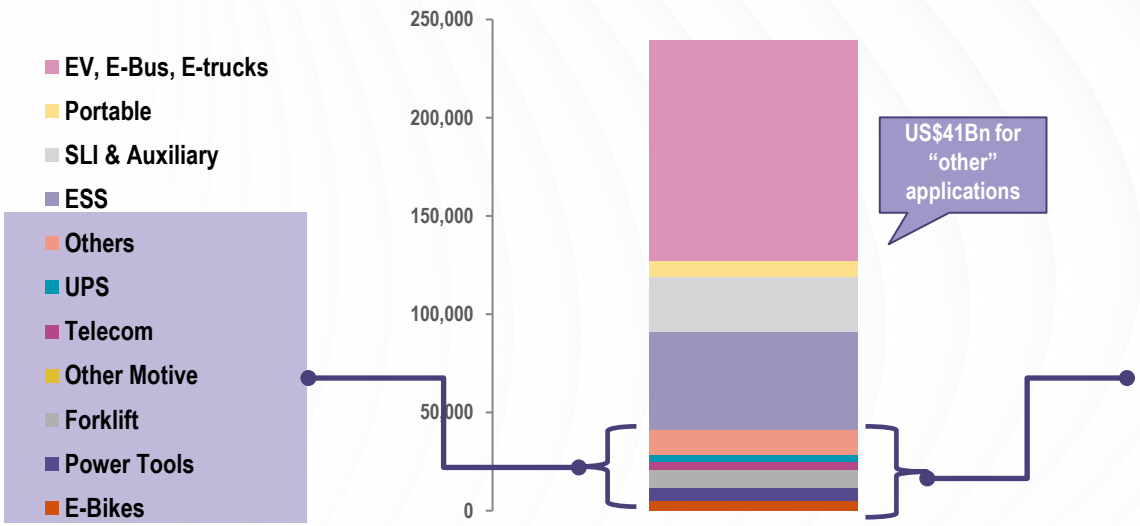
(2) Others: medical devices, power tools, gardening tools, e-bikes…

Source: Avicenne Energy 2024

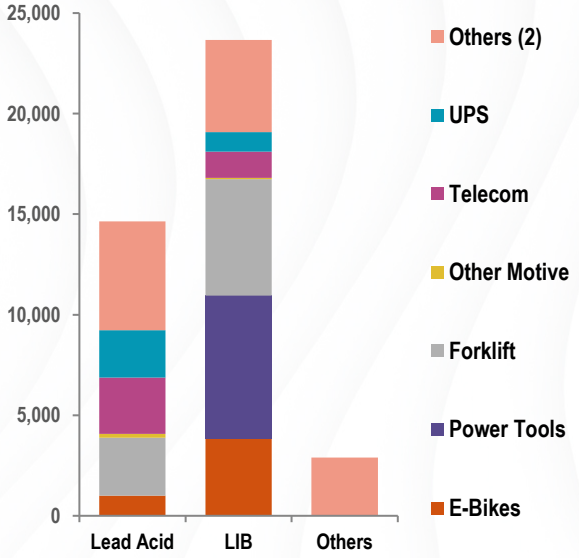
The worldwide battery market in 2023

Beyond EV, Portable, SLI market & ESS, a lot of "other"applications are growing, representing an additional market of US$ 41Bn[1] in 2023

Worldwide battery Market split in applications, 2023, US$Mn



Worldwide « other » battery applications split in applications & chemistry, 2023, US$Mn



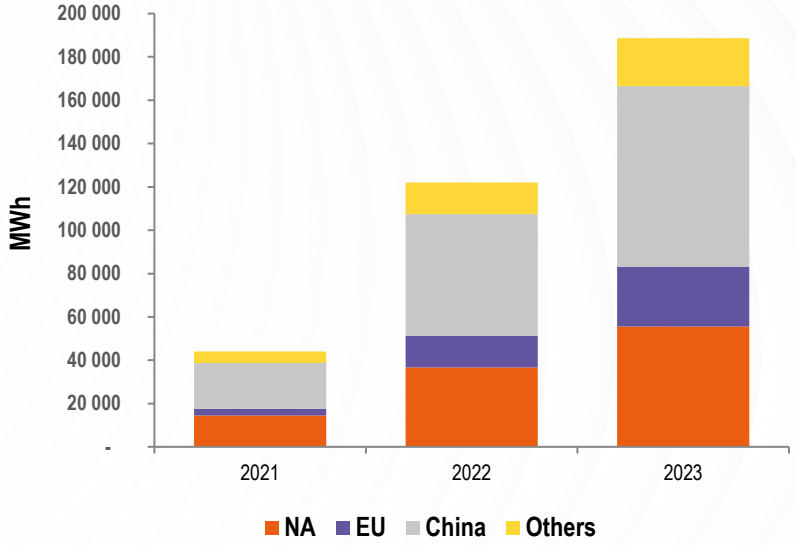
1- Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC DC converters, invertors…) not included

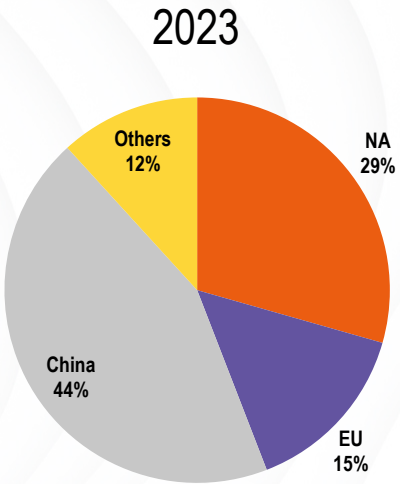
2- Other app: marine, train, aviation, space, medical, caravaning, Low speed electric vehicles, Golf Kart…

Source: AVICENNE Energy 2024

ESS for the grid by region

44% of the ESS market in China





Source: Avicenne Energy, SNE Research 2024

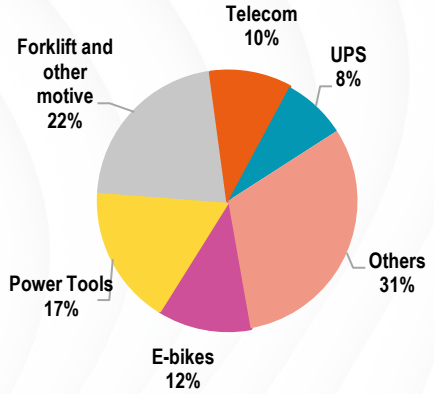
"OTHERS" applications

In 2023, the so called "other" applications represent a market of US$41Bn[1] at pack level

All the app except PC, tablets, Phones, xEV, E-buses, Trucks

- E-bikes, 3 wheelers
- Power tools including gardening tools, cordless vacuum cleaner
- Forklift, Automatic handling equipments, Motive industrials, Automated Guided Vehicles, Scrubber Dryer Machines,
- Stationary including Telecom, UPS, Back-up
- Medical
- Marine
- Aviation
- Railways
- Low Speed Electric Vehicles
- Others…

Other applications market share in 2023, % of value



1 2 3 4 5 6 7 8 9









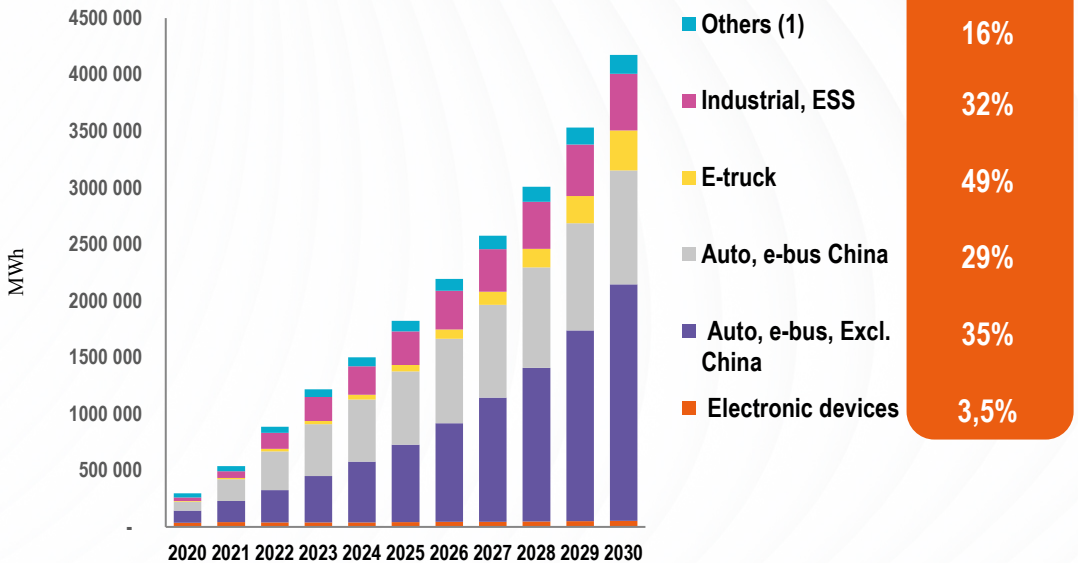
[1]: Pack level: Pack including cells, cells assembly, BMS, connectors – Power electronics (DC-DC converters, invertors…) not included

Source: Avicenne Energy 2023

Li-ion battery market forecasts

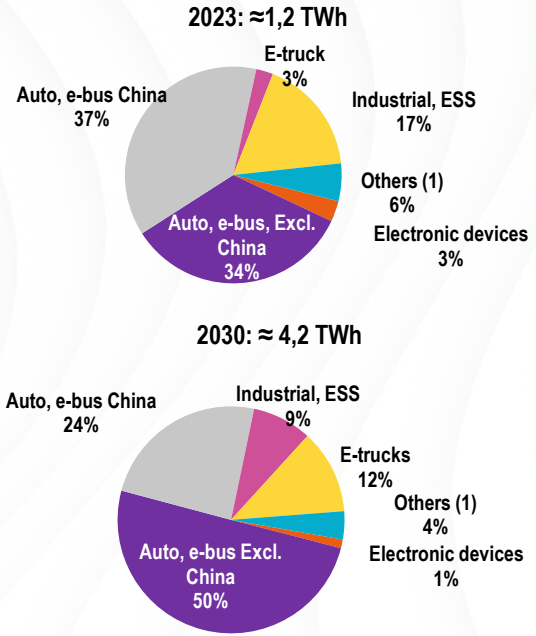
The Lithium-ion battery market will grow from ≈+1200 GWh in 2023 to ≈4,200 GWh in 2030, with a $CAGR_{20-30}$ of 30% in volume

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



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

Li-ion Battery sales, Worldwide, per application :

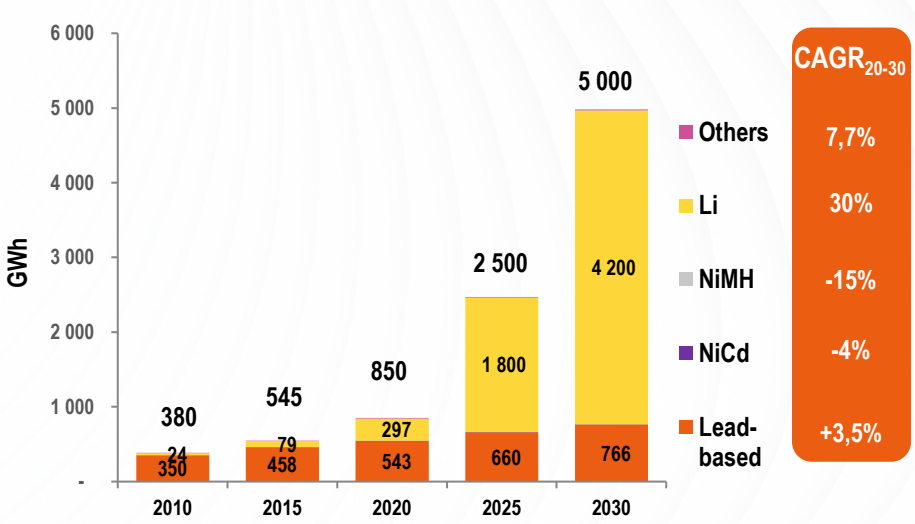


Source: Avicenne Energy 2023

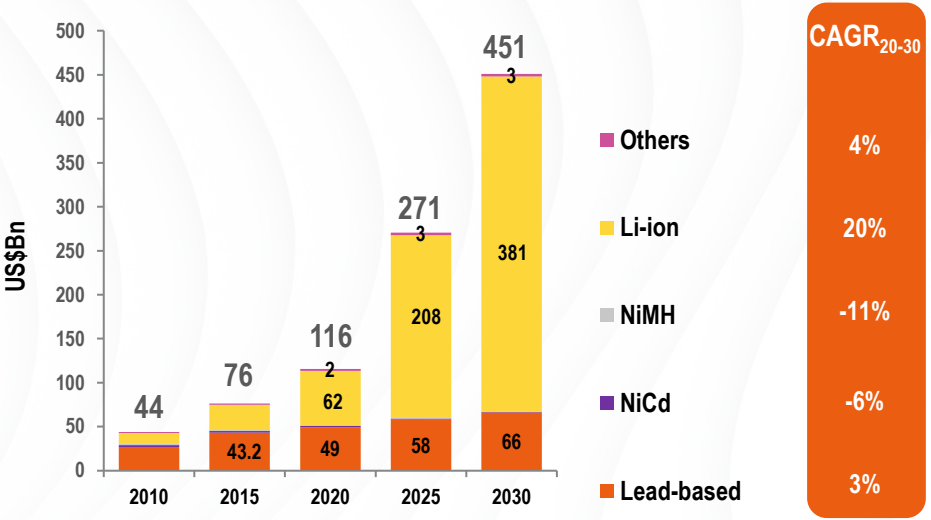
Worldwide battery market

Lead-based and li-ion batteries will remain in 2030, the 2 most important markets and will reach 5 TWh & US$≈430Bn in 2030. The $CAGR_{20-30}$ in value is 15%

The worldwide battery market in value by chemistry, 2010-2030, GWh



Market value at Pack level[1], 2010-2030, in US$Bn



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

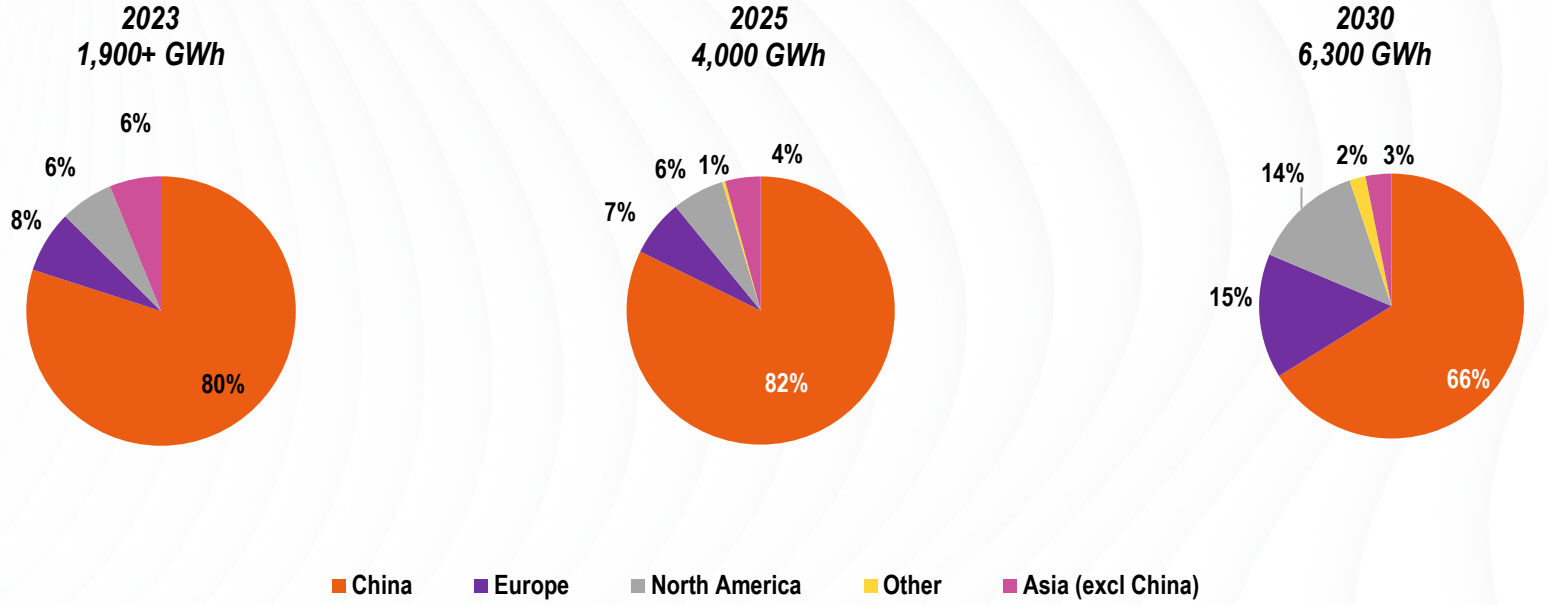
(1): Li for xEV including all kind of electric passenger cars HEV, PHEV & EV, E-buses, E-trucks, E-vans

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

Source: Avicenne Energy 2023

Worldwide production capacity

The Production capacity is estimated to grown from 1,9TWh in 2023 to 6,3 TWh in 2030, with the production capacity outside Asia reaching 2 TWH by 2030, representing +30%



Source: Avicenne Energy 2023

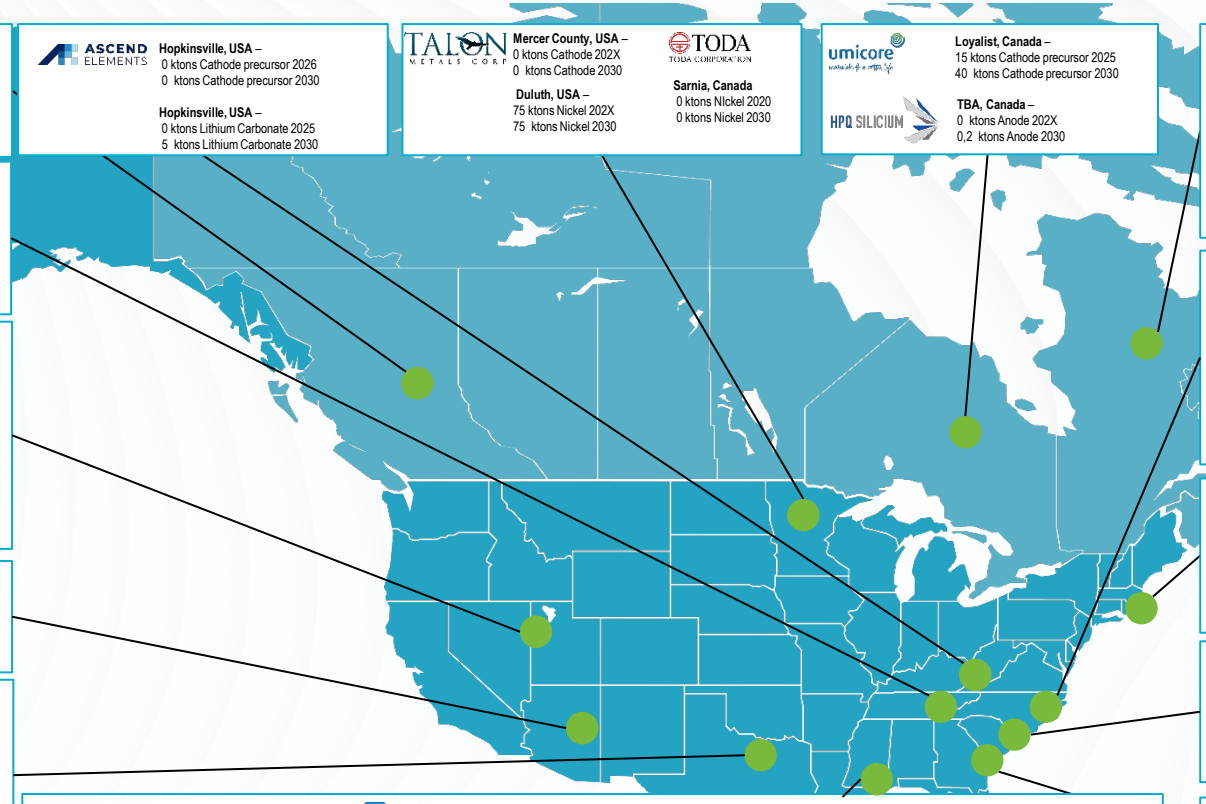
Announced North America production capacity in 2030 ≈ 1,450 GWh

- Moses Lake, USA — 5 GWh 2025 - 20 GWh 2030
- Carlsbad, USA — 0.1 GWh 2020 – 0.25 GWh 2030
- Sylmar, USA — 0.07 GWh 2020 – 0.07 GWh 2030
- Fremont, USA — 0.2 GWh 2020 – 0.4 GWh 2030
- Fremont, USA — 0.05 GWh 2020 – 0.05 GWh 2030
- Fremont, USA — 3 GWh 2022 – 5 GWh 2030
- Livermore, USA — 0.1 GWh 2022 – 0.1 GWh 2030
- Chico, USA — 0.15 GWh 2025 - 0.15 GWh 2030
- Glendale, USA — 20 GWh 2025 - 86 GWh 2030
- Sparks, USA — 5 GWh 2025 - 10 GWh 2030
- Reno, USA — 0.15 GWh 2023 – 0.15 GWh 2030
- Reno, USA — 35 GWh 2020 - 39 GWh 2025, 45 GWh 2030
- Tucson, USA, — 2 GWh 2025 -20 GWh 2030
- Tucson, USA, — 0.1 GWh 2023 - 0.1 GWh 2030
- Queens Creek, USA — 17GWh 2030, 5 GWh 2025 – 36 GWh 2030
- Buckeye, USA – 0.4 GWh 2020 – 0.4 GWh 2030 (plant 1), 6 GWh 2025 – 12 GWh 2030 (plant 2)
- Tuscon, USA, — 1 GWh 2025 - 5 GWh 2030
- Stanton, USA — 0 GWh 2025 - 43 GWh 2030
- Glendale, USA — 86 GWh 2030
- Clarksville, USA — 4 GWh 2030
- Spring Hill, USA — 15 GWh 2024, 35 GWh 2025 – 50 GWh 2030
- Austin, USA — 1 GWh 2022, 10 GWh 2030
- Smyrna, USA — 3 GWh 2020, 3 GWh 2030
- Brighton, USA — 0.5 GWh 2025 – 5 GWh 2030
- Louisville, USA — 0.5 GWh 2025 – 1 GWh 2030
- Louisville, USA — 0.2 GWh 2025 – 0.2 GWh 2030
- De Soto, USA — 10 GWh 2025 -30 GWh 2030
- St Thomas, Canada — 90 GWh 2030
- Mississauga, Canada — 0.2 GWh 2020 -0.2 GWh 2030
- Windsor, Canada — 10 GWh 2022 - 45 GWh 2030
- Alliston, Canada — 36 GWh 2030
- Guelph, Canada — 2.8 GWh 2030
- Guelph, Canada — 0.1 GWh 2025 – 0.1 GWh 2030
- Windsor, Canada — 10 GWh 2025 – 49.5 GWh 2030
- Montréal, Canada — 30 GWh 2030
- Canada — 10 GWh 2030
- Mirabel, Canada — 5 GWh 2025 - 5 GWh 2030
- Montréal, Canada — 0.5 GWh 2020 - 0.5 GWh 2030
- Weirton, USA — 0.5 GWh 2025 - 0.5 GWh 2030
- Bridgeport, USA — 5 GWh 2030
- Bridgeport, USA — 1 GWh 2030
- Minneapolis, USA — 0.3 GWh 2020 – 0.3 GWh 2030
- Holland, USA — 15 GWh 2025, 25 GWh 2030
- Van Buren Township, USA — 0.01 GWh 2023, 5 GWh 2025 - 20 GWh 2030
- Lansing, USA — 30 GWh 2025, 50 GWh 2030
- Ann Arbor, USA — 0,1 GWh 2020, 0,1 GWh 2030
- Marshall, USA — 0 GWh 2025, 20 GWh 2030
- Big rapids, USA — 30 GWh 2030
- Manteno, USA — 40 GWh 2030
- Holland, USA — 0,5 GWh 2020, 0 GWh 2030
- Midland, USA — 0.7 GWh 2020, 0.7 GWh 2030
- Indianapolis, USA — 0.8 GWh 2020 - 1.5 GWh 2030
- New Carlisle, USA — 30 GWh 2030
- Kokomo, USA — 33 GWh 2030 (plant 1) - 34 GWh 2030 (plant 2)
- Jeffersonville, USA — 10 GWh 2025 - 40 GWh 2030
- Lordstown, USA — 30 GWh 2022 - 40 GWh 2030
- Methuen, USA — 0.1 GWh 2025 - 0.2 GWh 2030
- Woburn, USA — 0.2 GWh 2021 - 0.2 GWh 2030
- Cockeysville, USA — 0.2 GWh 2020 - 0.2 GWh 2030
- Jamestown, USA — 0.5 GWh 2025 - 1 GWh 2030
- Newark, USA — 0.5 GWh 2020 – 0.5 GWh 2030
- Endicott, USA — 10 GWh 2030
- Endicott, USA — 1 GWh 2020 - 1 GWh 2030
- Glendale, USA — 20 GWh 2025 - 86 GWh 2030
- Bowling Green, USA — 10 GWh 2025 - 30 GWh 2030
- Joplin, USA — 0.2 GWh 2020 – 0.2 GWh 2030
- Liberty, USA — 15 GWh 2025 - 40 GWh 2030
- Florence, USA — 0 GWh 2026 - 50 GWh 2030
- Greenville, USA — 4 GWh 2030
- Raleigh, USA — 1 GWh 2030
- TBA, USA — 35 GWh 2030
- Newman, USA — 50 GWh 2030
- Atlanta, USA — 20 GWh 2030
- Commerce, USA — 9.8 GWh 2022 - 9.8 GWh 2030 (plant 1), 11.7 GWh 2022 – 11.7 GWh 2030 (plant 2)
- Bartow County, USA — 5 GWh 2025 – 35 GWh 2030
- Savannah, USA — 30 GWh 2030
- TBA, USA — 30 GWh 2030
- Jacksonville, USA — 1.5 GWh 2020 - 1.5 GWh 2030
- Nuevo Laredo, Mexico — 0.2 GWh 2020 – 0.4 GWh 2030
- Saltillo, Mexico — 50 GWh 2030
- Ciudad Juárez, Mexico — 30 GWh 2030
- Pryor, USA — 30 GWh 2030
- Marshall County, USA — 21 GWh 2030

*Not exhaustive

Source: Avicenne Energy May 2024

North America battery materials*



Slocan Valley, Canada– 2,1 ktons Anode 2020 7,5 ktons Anode 2030

Canada 0 ktons NIckel 202X 0 ktons Nickel 2030

Hopkinsville, USA – 0 ktons Cathode precursor 2026 0 ktons Cathode precursor 2030

Hopkinsville, USA – 0 ktons Lithium Carbonate 2025 5 ktons Lithium Carbonate 2030

Mercer County, USA – 0 ktons Cathode 202X 0 ktons Cathode 2030

Duluth, USA – 75 ktons Nickel 202X 75 ktons Nickel 2030

Sarnia, Canada 0 ktons NIckel 2020 0 ktons Nickel 2030

Loyalist, Canada – 15 ktons Cathode precursor 2025 40 ktons Cathode precursor 2030

TBA, Canada – 0 ktons Anode 202X 0,2 ktons Anode 2030

Lac Knife, Canada– 1 ktons Anode 2025 1 ktons Anode 2030

Lac Guéret, Canada– 1 ktons Anode 2025 1 ktons Anode 2030

Lac Guéret, Canada– 1 ktons Anode 2025 1 ktons Anode 2030

Chattanooga, USA – 30 ktons Anode 2025 30 ktons Anode 2030

Etowah, USA – 30 ktons Lithium hydroxide 2025 30 ktons Lithium hydroxide2030

Franklin, USA – 0 ktons Carbon Additives 2025 0 ktons Carbon Additives 2030

Kings Mountain , USA – 100 ktons Lithium hydroxide 2030

KingBessemer City, USA 15 ktons Lithium hydroxide 2022 – 15 ktons Lithium hydroxide 2030

Kings Mountain , USA – 30 ktons Lithium hydroxide 2030

Fernley, USA – 0 ktons Cathode 202X 0 ktons Cathode 2030

Silver Peak, USA – 1 2 ktons Lithium 2020 12 ktons Lithium 2030

Tonopah, USA – 5 ktons Lithium 2025 5 ktons Lithium 2030

Rochester, USA – 1 ktons Lithium Carbonate 2025 8,5 ktons Lithium Carbonate 2030

0,5 ktons Nickel Sulfate 2025 4,8 ktons Nickel Sulfate 2030

1 ktons Cobalt Sulfate 2025 7,5 ktons Cobalt Sulfate 2030

Yuma County, USA – 7 ktons Cobalt 2025 7 ktons Cobalt 2030

Casa Grande, USA – 0 ktons Anode 2020 0 ktons Anode 2030

City TBA - Chester County, USA 50 ktons Lithium hydroxide 2030

Beech Island, USA – 2 ktons Additives 2020 10 ktons Additives 2030

Austin, USA – 0,1 Additives 2020 0,1 ktons Addictives 2030

Conroe, USA – 32 Electrolyte Solvent 2020 32 ktons Electrolyte Solvent 2030

Corpus Christi, USA – 10 Lythium hydroxide 2020 30 ktons Lythium hydroxide 2030

TBD, USA – 0 Nickel 2028 20 ktons Nickel 2030

TBA, USA – 0 ktons Electrolyte Solvent 202X 0 ktons Electrolyte Solvent 2030

TBA, USA – 8 ktons Manganese Sulfate 2025 32,5 ktons Manganese Sulfate 2030

St Gabriel, USA – 10 Lithium Salts 2030

Vidalia, USA – 11 ktons Anode 2025 45 ktons Anode 2030

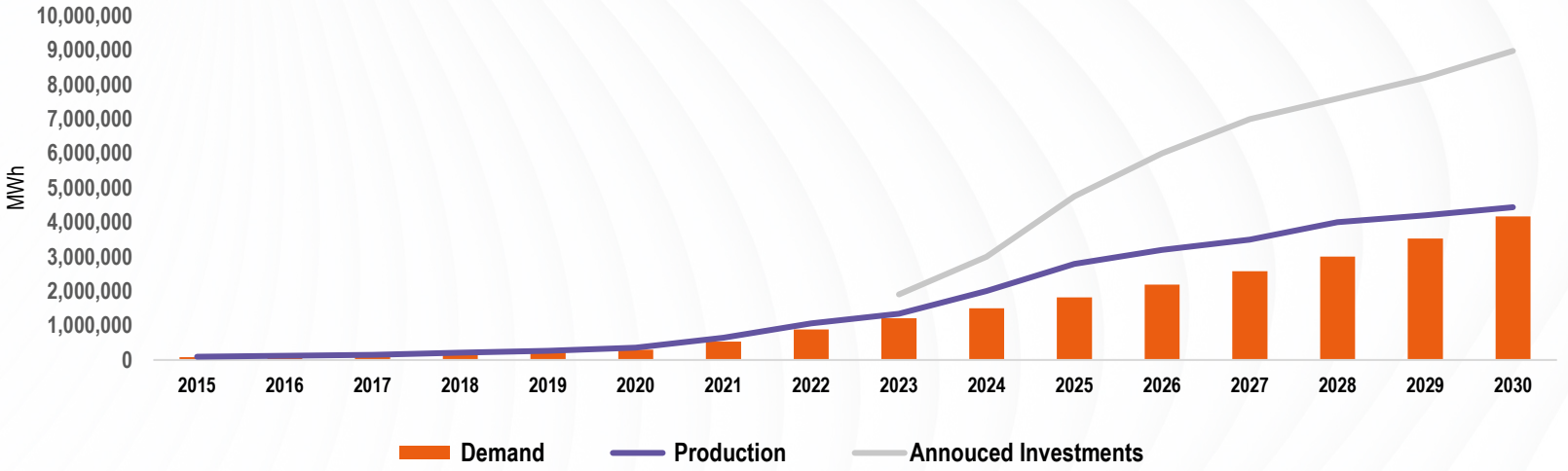
Augusta, USA – 0 ktons Cathode precursor 202X 0 ktons Cathode precursor 2030

Source: Avicenne Energy 2024

*Not exhaustive

Supply & Demand Worldwide

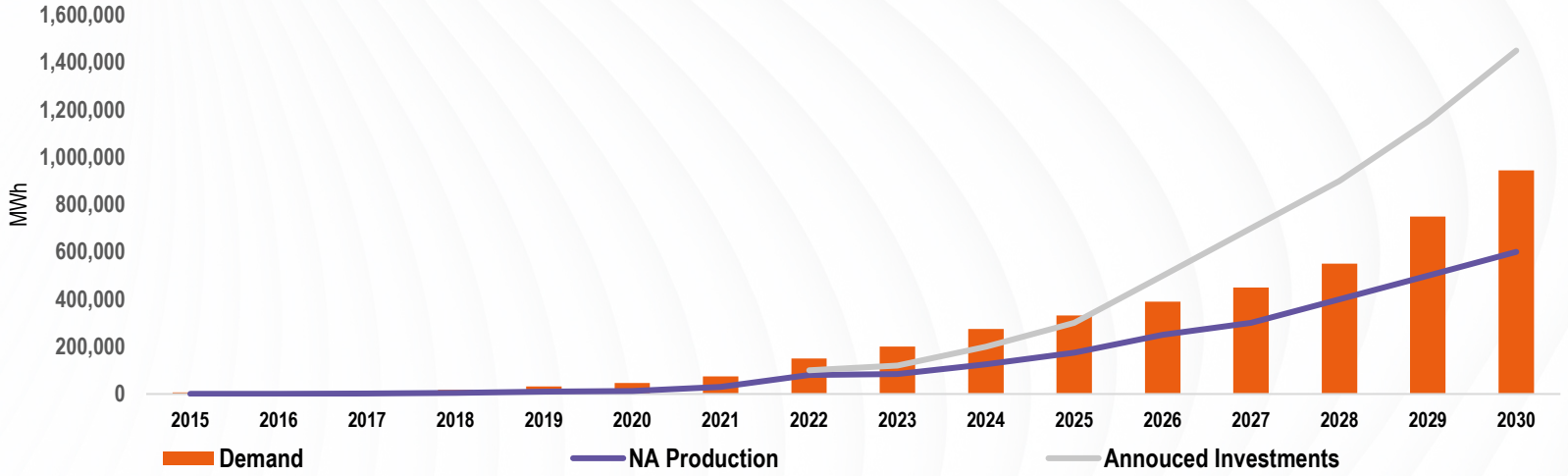
Potential Production: from 1,340 GWh in 2023 to 4,440 GWh in 2030 (oversupply)
Announced investments are not credible



The lithium manufacturing base is developing very strongly, driven mainly by **E-mobility**
Today, production is higher than the demand. From 2025 to 2030 demand (> 4225 GWh) will always be lower than the production (4440 GWh in 2030)
Cell manufacturers announced 9 TWh in 2030 but Avicenne's forecast is 6,4 TWh of capacity & 4,4 TWh of real production by 2030: some projects will be cancelled; some will be delayed, and the % of scrap also has to be taken into account

Supply & Demand in NA

Production: from ~85 GWh in 2023 to >600 GWh



The lithium manufacturing base is developing very strongly, driven mainly by **E-mobility**
Cell manufacturers announced ~1450 GWh in 2030 but Avicenne's forecast is ~600 GWh of real production by 2030: some projects will be cancelled, some will be delayed and the % of scrap also has to be taken into account. With that, supply and demand should be aligned from 2025 to 2030

Potential subsidies in US

The US IRA announcement of a US$ 369 Bn aid, covers all measures related to electrifying mobility, & all sectors in energy security & climate change programs over the next ten years

- There are sometimes misunderstandings about the $369Bn associated with the IRA announcement, as it covers all support and tax measures not just for electrifying mobility, but for all sectors that will contribute to energy security and climate change programs over the next ten years.
- In October 2022, the Department of Energy awarded $2.8Bn to 20 US companies as part of the bipartisan Infrastructure Act, with the specific aim of relocating the battery supply chain to the US; there were probably nearly 200 applications in the competition.
- Additional 3 B$ to support 25 projects in September 2024
- For a new project, there is no certainty of receiving federal aid through an upcoming BIL Support is more certain at state and county level, with smaller funding envelopes of the order of several tens of millions of dollars.

Source: US - DOE

Source: Avicenne Energy 2024

US new taxes on Chinese products

In 2024, US President Joe Biden hikes import tariffs on key products coming from China, including EV tariffs of 100% and sees further possible ban on Chinese EV in the US

2024 US increase on Chinese import tariffs under Section 301 of the Trade Act of 1974

		2023	2024	2025	2026
EV BESS GRID AVIATION COMPUTER	EVs	25%	100%	100%	Possible Ban
	Semiconductors	25%	[illegible]	50%	50%
	Permanent Magnet	0%	0%	0%	25%
	Steel & Aluminium	[illegible] to 7,5%	25%	25%	25%
	Solar cells	25%	50%	50%	50%
BATTERY	EV	7,5%	25%	25%	25%
	[illegible]	7,5%	7,5%	7,5%	25%
	Parts	7,5%	25%	25%	25%
	Critical Minerals	0%	25%	25%	25%
	Natural Graphite	0%	0%	0%	25%

Some carried over, reinstated and others in limbo

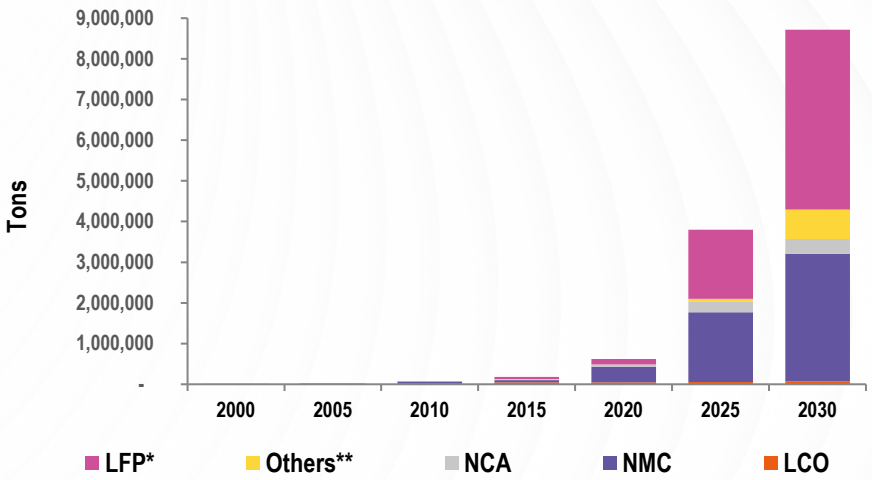
New Tariffs

Source: Whitehouse.gov, Avicenne Energy 2024

Cathode Active Material demand 2030 forecasts

In 2030, the main chemistries used will be NMC based & LFP/LFMP representing together ~85% of the market

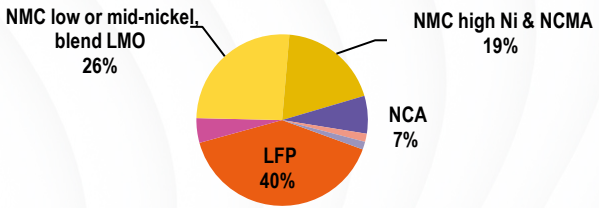
Cathode active materials by chemistry in Tons, 2000-2030



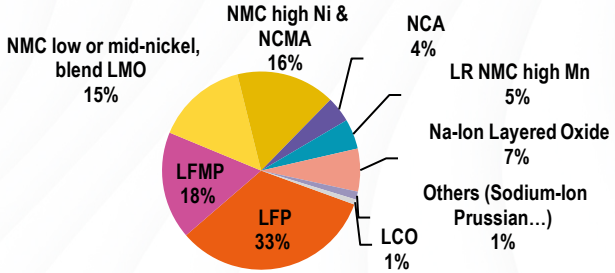
*: LFP: LFP+LFMP, NMC: Low-mid and High NMC, Lithium Rich High Mn

**: Others: Na-ion, Zinc…

Cathode Active Materials in 2025: 3,800+ kTons



Cathode Active Materials in 2030: 8,700+ kTons



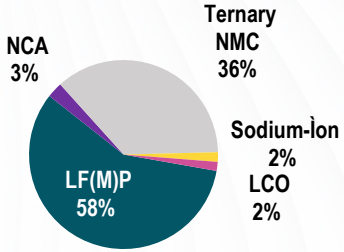
Source: Avicenne Energy 2023

Significant Lithium-ion Production Chemistry Variations by Region

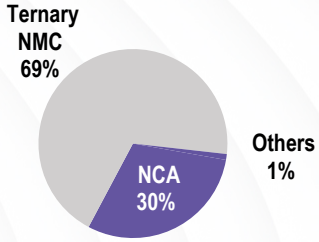
Penetration of Phosphate and Sodium-based chemistry will take time out of China

2025

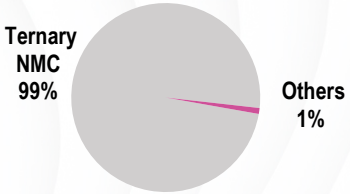
China: 1 265 GWh



North America: 270 GWh

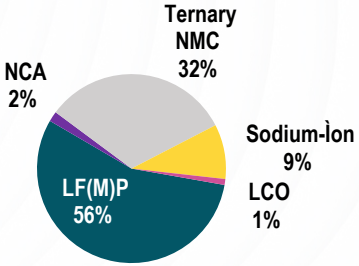


Europe: 300 GWh

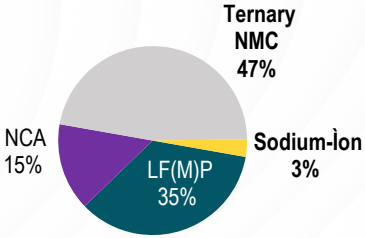


2030

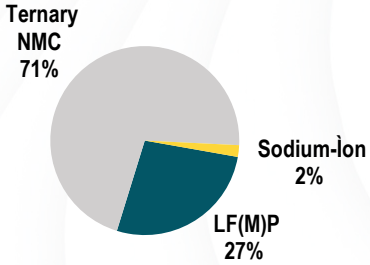
China: 2,470 GWh



North America: 850 GWh



Europe: 950 GWh

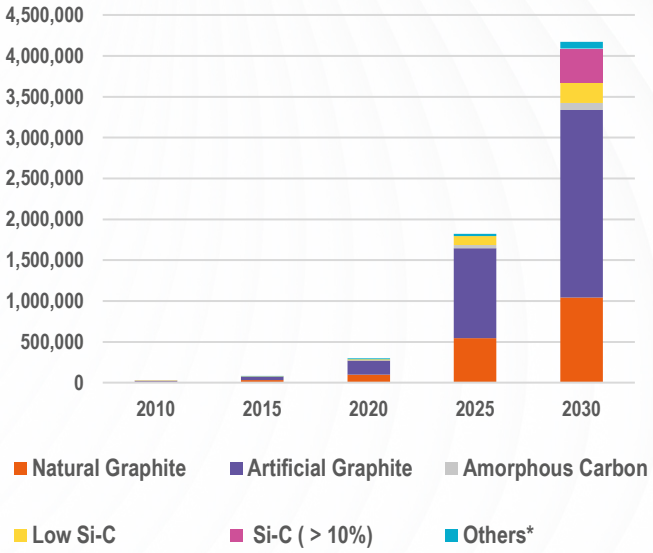


Source: Avicenne Energy 2024

Anode Active Material demand 2030 forecast

In 2030, AG will remain the major anode material with 56%,while Si Composite based anodes will jump from 6% in 2023 to 16% market shares

Anode active materials in Tons, 2000-2030



Graphite trend

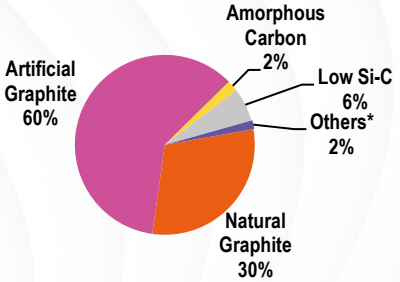
NATURAL GRAPHITE:

- Price was lower than AG but is almost the same today. (from US$5 to 8/kg – average: US$7/kg in 2023)

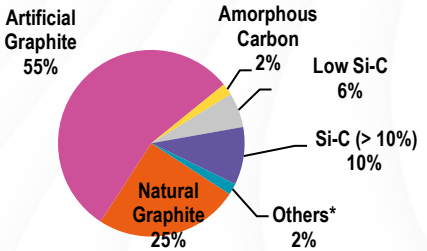
ARTIFICIAL GRAPHITE:

- Price almost the same than NG, 4-8$/kg – Average: 7$/kg
- Environmental impact concerns
- Higher purity
- Lower electrical resistance
- Higher safety
- Better lifetime

Anode Active Materials in 2023: 1 200 kTons

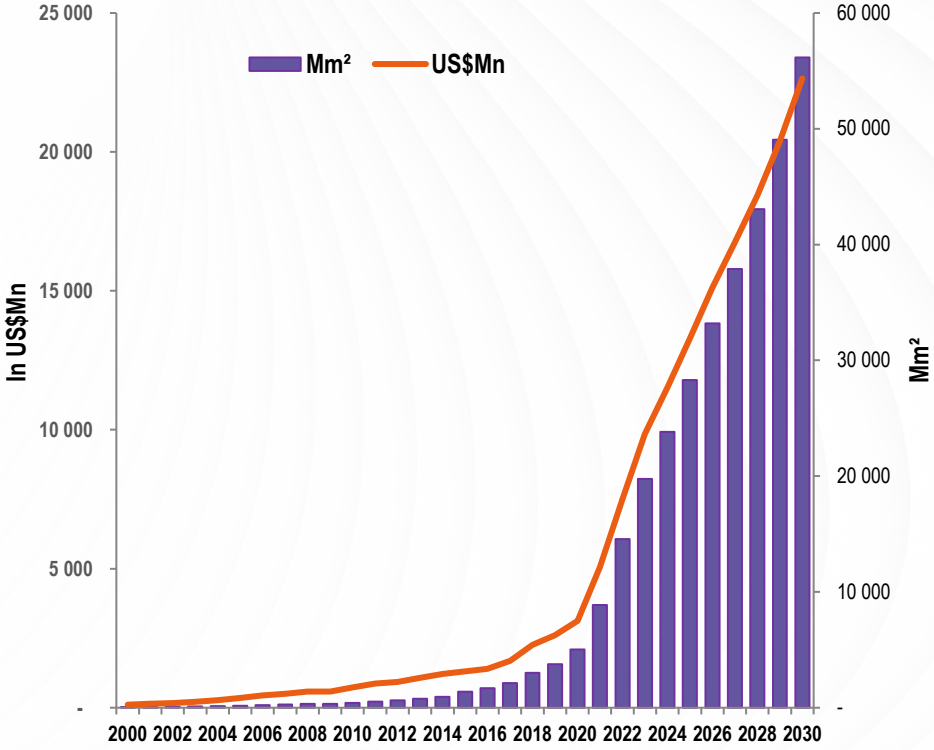


Anode Active Materials in 2030: >4,100+ kTons



Source: Avicenne Energy 2023

LIB separator market in US$Mn & Mm², 2000-2030



LIB separator market

In Value:

From US$10Bn in 2023 to reach 22+ in 2030

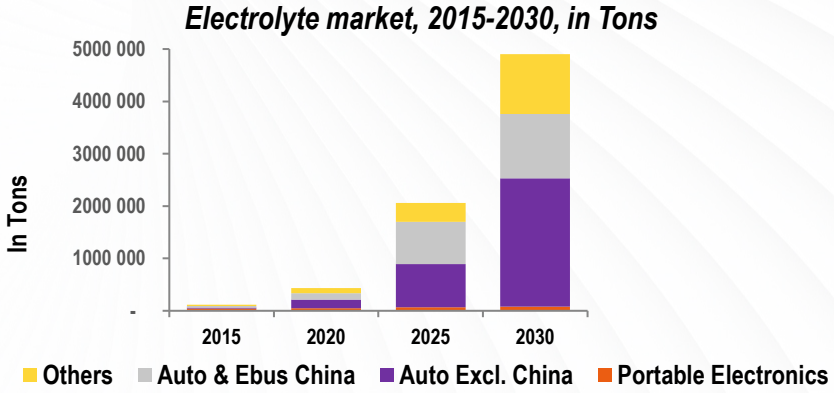
$CAGR_{20-30}$: 22%

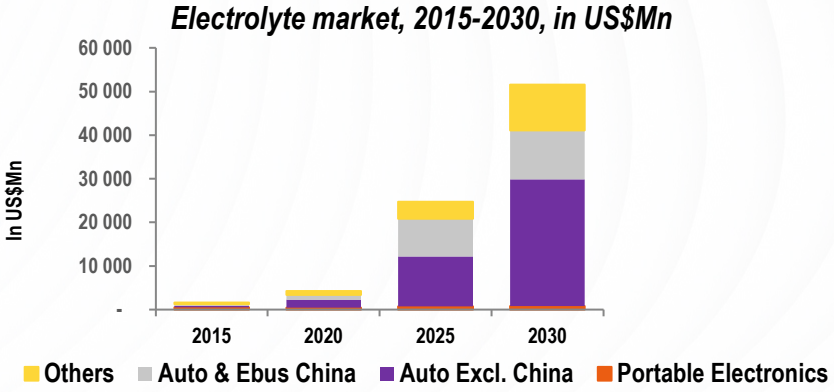
In Volume:

From 20 Mm² in 2023 to reach 56 Mm² in 2030

CAGR20-30: 27%

Source: Avicenne Energy 2023





Electrolyte market forecasts 2000 – 2030

From 430+ kTons in 2020 to 4,900+ kTons in 2030 with a CAGR20-30 of 27.4%

- If globally advanced electrolyte with more additive is a major trend, we saw in China for low to mid-end application a return to more basic formulations to reduce costs
- New cathode material development that will need higher voltage window
- First up to 4.6 volts (2020–2025): requirement of new additives, mostly fluorinated
- In a second step, to 5 volts. That will require the replacement of the carbonate solvent by other solvent like fluorinated solvent
- Automotive market, and more likely large format batteries will require also special formulation with dedicated additives to match the specifications required by the customers in term of temperature range, lifetime, power and safety
- Cost erosion will continue as it happen in the past, even for new product.

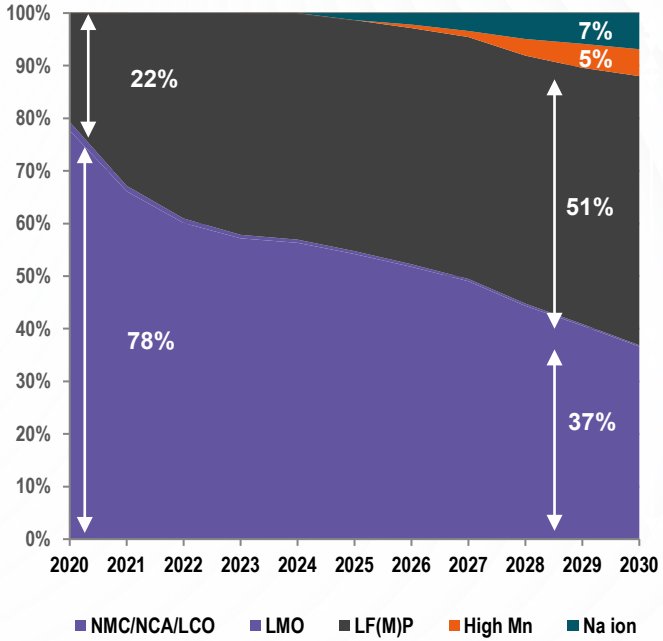
Source: Avicenne Energy 2023

Design to cost: competition Phosphate-based / Sodium-based / High Manganese

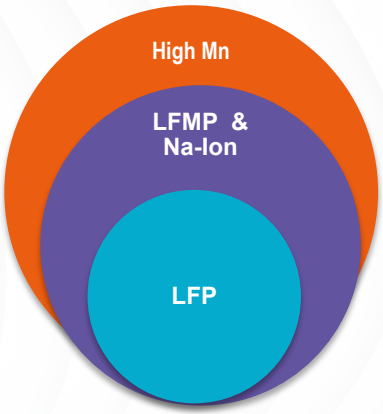
Key points :Technologies aimed at improving performance, in particular the switch to solid-state and the gradual integration of silicone in the anode, have no direct impact on CAM

Technologies aimed at reducing the cost in $/kWh are essentially in direct competition with LFP, all other things being equal, sodium-ion is essentially aimed at ESS and certain light vehicles, high Mn is being promoted by the major ternary CAM manufacturers but remains very uncertain in terms of cost

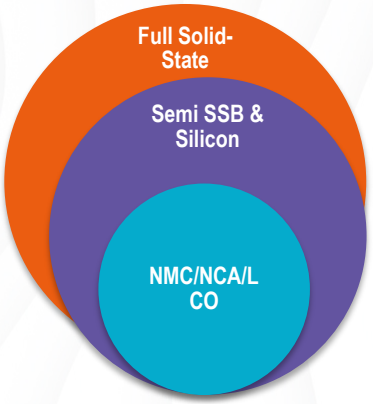
CAM split in volume of material



Design to Cost
Cost reduction
in $/kWh



Design to performance
Increase in performance
in kWh per kg or kWh per litre



Source: Avicenne Energy 2024

Sodium Ion battery technology available

Prussian analog can address some ESS applications.The most promising volume for Sodium-ion for mobility will be layered oxide, based on an NMC like mid-nickel with cobalt substitution

	CATL^{gen1} Northvolt-Altris	CATL^{gen2} Faradion, HiNa, BYD-Mobility, Tiamat^{gen2}	Tiamat^{gen1}	BYD-ESS$^{(*)}$ Zoolnasm	Natron
	Prussian White	Layered oxide	Polyanion NVPF	Polyanion NFS/NFPP	Prussian Blue
Power	+++	+	++	(*)	+++
Energy	++ (150 to 160 kWh/kg)	++ (150 to 200 kWh/kg)	+ (100 to 120 kWh/kg)	(*)	- (0 to 50 kWh/kg)
Cycle life	-	-	++	++	+++
Cost of raw materials	+	+	- (Vanadium or Ti)	++	+
Typical competition	Energy Li-Ion	Energy Li-Ion	LTO	Energy Li-Ion	Supercap

(*) : to be confirmed

CATL, Tiamat… are also developping the layered oxide structure

Each company has its own receipt, for reference:

- **Tiamat: Na-V-P-F**
- **Faradion: Na-Ni-Mn-Mg-Ti**
- **HiNa: Na-Cu-Fe-Mn-O**

Source: Avicenne Energy 2024

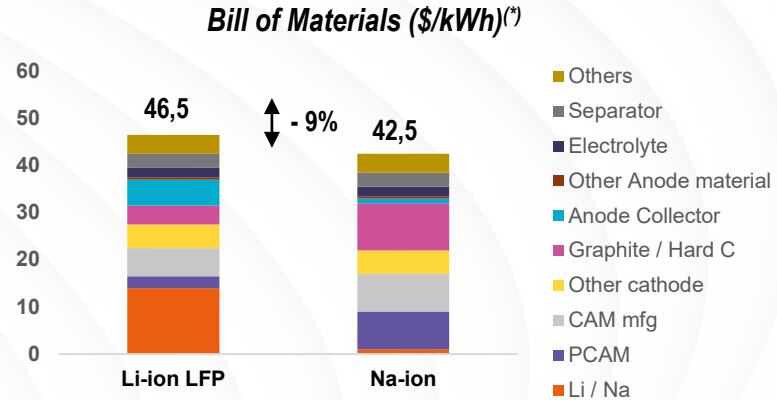
Sodium Ion battery SIB 2024

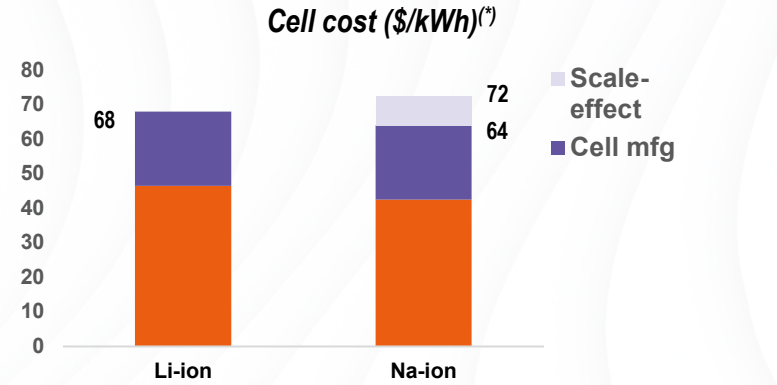
Avicenne's overall approach for Na-Ion cost is based on:

- Na is cheaper than Li (+)
- Al collector cheaper than Cu (+)
- Na-ion could probably use similar cathode process than Li-ion batteries (=)
- For Na Layered Oxide, PCAM higher than FePO4 (-)
- Hard carbon is more expensive than Graphite (-)

In China, Na-ion cell could be competitive than typical LFP cell

- If we consider that the two chemistry LIBs and SIBs have the same capacity in terms of kWh per kg
- for a lithium price above 22,5 $/kg LCE at the same giga scale
- for a lithium price above 35 $/kg LCE for a mid-size giga in Na-ion



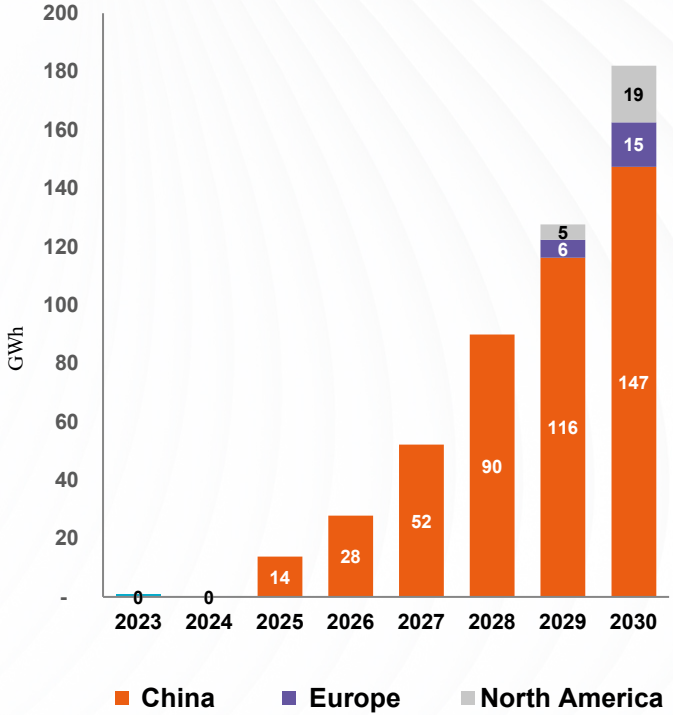


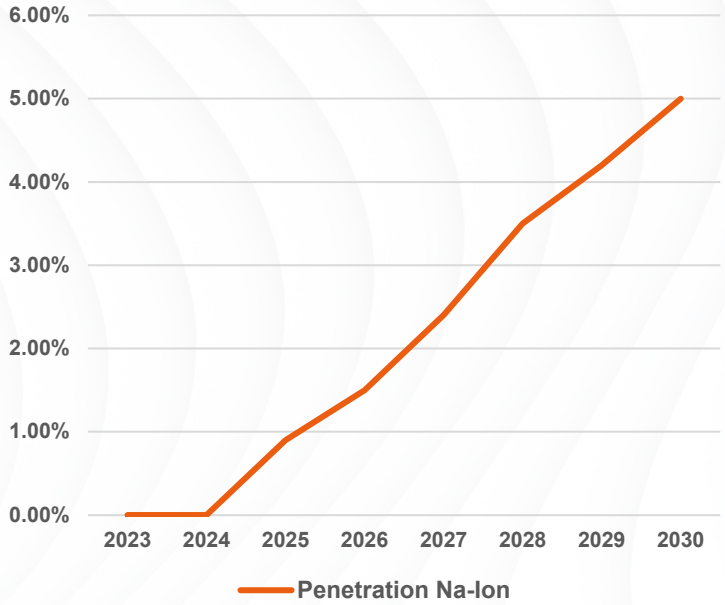
(*) For Li_2CO_3 at 30$/kg and Layered Oxide

Source: Avicenne Energy 2024

Sodium-Ion Production by 2030 by region

By 2030, Sodium-ion could substitute 5% of the Lithium-Ion mainly for ESS and for light EV





Source: Avicenne Energy 2024

Solid-State for EV

Current Major Issues

- **High Temperature Operation** – the only demonstrated technology for solid state by Bollore in the Blue Car
- **Durability** – most of the developers have focused on non-automotive applications to demonstrate technology and have commercial production at very small scale
- **Processing costs** – Many of the battery developers lack significant scale to understand coating and laminating process and leaders are just moving to pilot production
- **Lithium Requirements and Costs**– Lithium anode production methods, safety validation and costs
- **Conductivity** – Conductivity of polymeric and inorganic solid state remain significant hurdles
- Before EV, the next penetration of solid – state will concern **Portable Electronics**

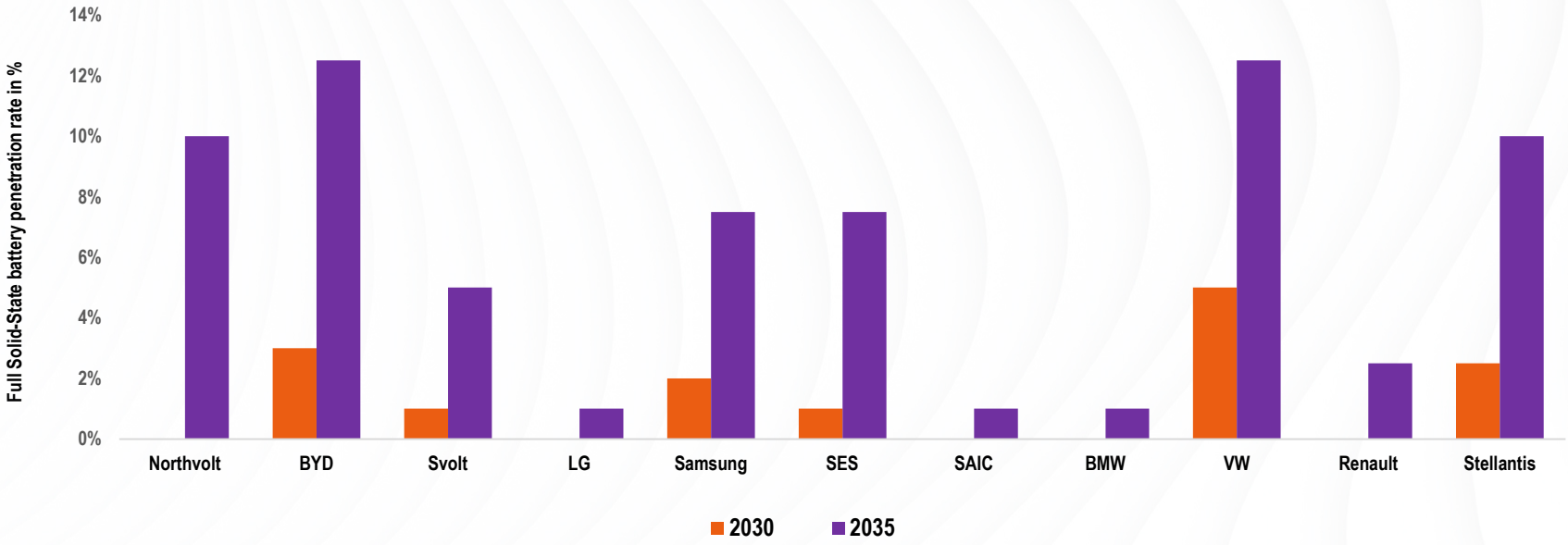
Points of attention on the forecasts

- For large application like EV, **the first generation with existing Carbon/Silicon** at the anode side should be more easily deployed in the short or medium term than full solid-state (with Lithium at anode side) and probably first in Asia with companies well advanced in China: **CATL, ProLogium, WeLion, …** with **a gel electrolyte** composed by ≈ 90% of dry polymer with a few % of ceramic (oxide) and the remaining with liquid by impregnation
- For the automotive industry, the first deployments will be mostly reserved **for high-end premium cars** (NIO, Porsche, BMW M series....) with limited series to amortize the extra cost and validate the technology
- In view of the lack of maturity of the various technologies being deployed, the forecasts are subject to a **significant margin of error**
- **Extend of deployment** in the medium to long term will also depend on the ability to achieve a target of **US$65/kWh** to compete with Lithium-Ion (US$50 to 80/kWh in 2025)

Full Solid-State battery penetration in EV

By 2030, the different actors implicated in batteries production & EV estimated a very low penetration rate for full Solid-State batteries, with a maximum forecast of 12% by 2035

Forecast of solid-state penetration by battery industry players 2030-2035



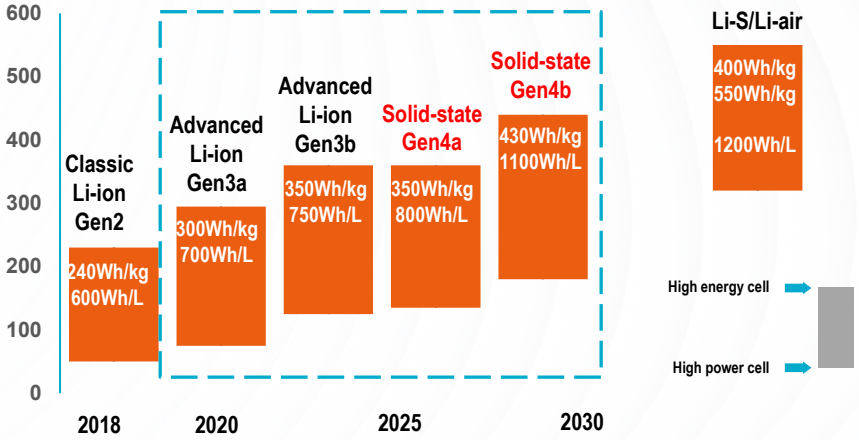
Source: Avicenne Energy 2024

Solid-State battery for automotive: semi/hybrid versus all solid-state

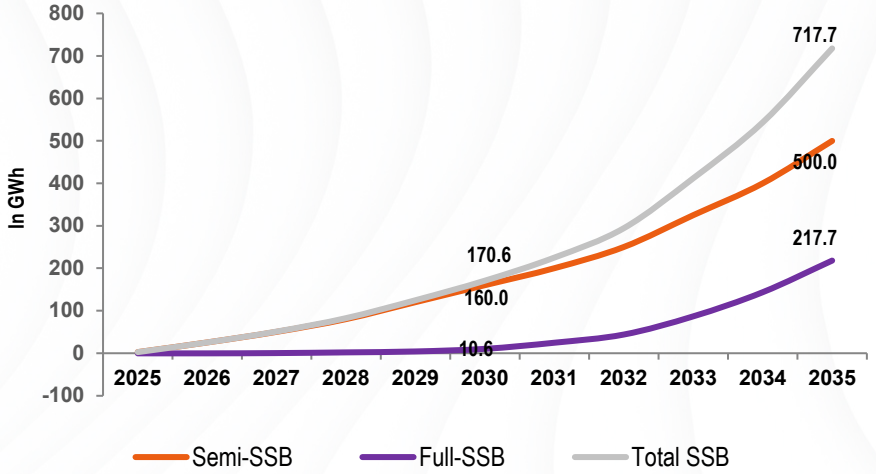
For large application like EV, the first generation **(Gen4a)** is called **semi-solid or hybrid solid state** and can be synthetically described as: **Lithium-Ion in which the electrolyte and separator are replaced by a solid/liquid electrolyte**; cathode and anode active materials **remain the same**; safety will be improved but not the energy performance

Second Generation **(Gen4b)** is **all solid-state battery** and can be synthetically described as: **Lithium-Ion in which the electrolyte and separator are replaced by a solid electrolyte**; graphite-based anode active material is **replacing by lithium**; safety and energy performance will be improved

Cell energy density roadmap



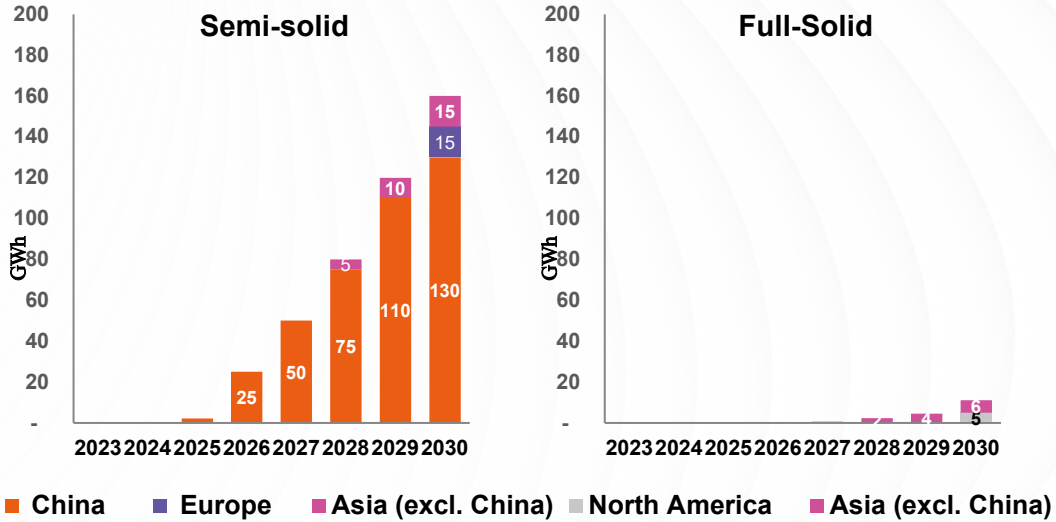
Solid-State Battery for xEV, 2025-2035, in GWh

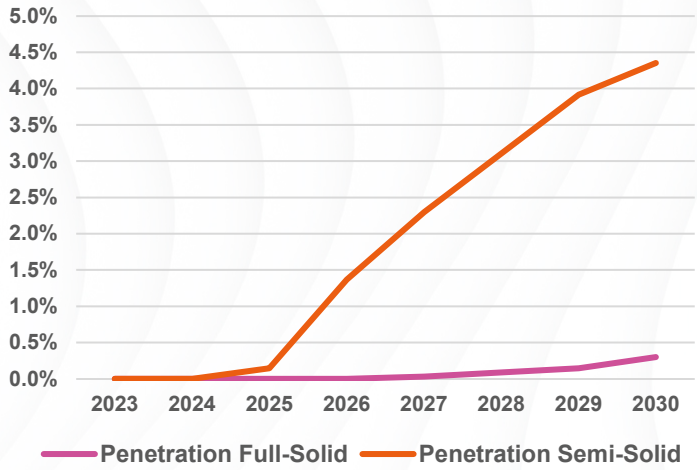


Source: Avicenne Energy 2024

All Solid-state and semi-solid state battery production by 2030 by region

By 2030, full solid-state battery will continue to be developed, but will only be industrialised on a very small scale. On the other hand, some major Chinese players will gradually move from conventional lithium-ion to semi-solid-state. We could envisage an overall impact of around 5% on the materials concerned.





Source: Avicenne Energy 2024

Key takeaways

- An incredible growth: ≈30% in volume and ≈20% in value for the next ten years
- Main drivers: EV market thanks to regulation and incentives
- Hundreds of US$Bn will be invest in US & Europe by 2030
- Accurate forecasting is needed in the supply chain to avoid costly timing errors
- Europe will not be ready to meet all the demand in 2030
- Today, EU & US have a lack of Gigafactories, Raw materials, Equipments & Talents
- Recycling could account for 15-20% of the metal demand in 2030
- On a very long-term basis, we can imagine that recycling will supply 90+% of the metal needs

Source: Avicenne Energy 2024

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