McKinsey & Company

Playing not to catch up, but to get ahead

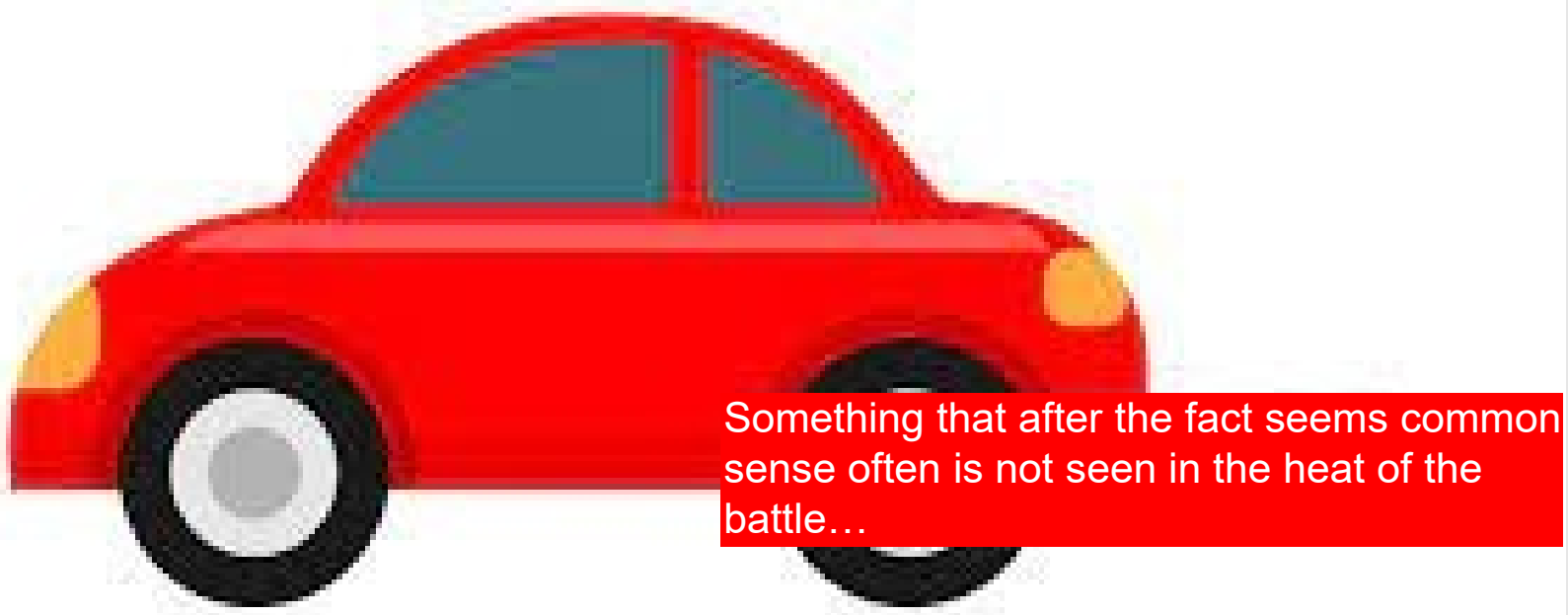
February, 2024

In a fast moving market the goal is to get ahead, not simply catch up

- **Cell technology is expected to be diverse**
- **Technology is expected to evolve rapidly**
- **Value chains need to be robust to meet near as well as longer term demand**
- **Having partnerships allows insight to where future trends may be heading**
- **Funding of the massive build out on value chains will come from many sources**
- **Know the story of the “Red Car”**

Understanding the “red car”

There are other colors



Something that after the fact seems common sense often is not seen in the heat of the battle…

Moral of story: There will never be a “one battery” solution.

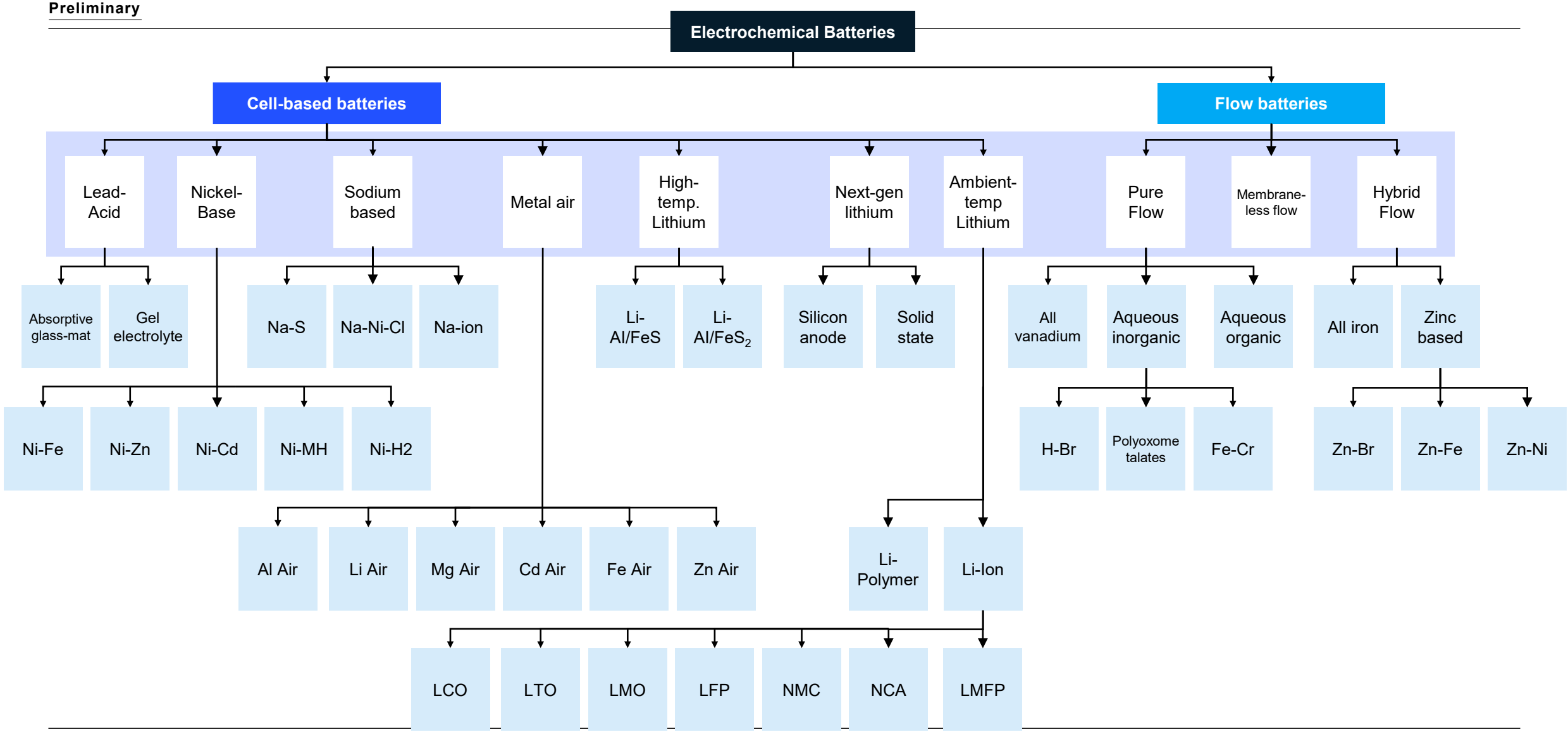
Costs are a big part of the battery adoption story, meaning you can price a good technology out of the market

Suppliers should always be aware to reduce costs to help their battery technology win

Having a deep understanding of other technologies costs and capabilities will be a must to survive.

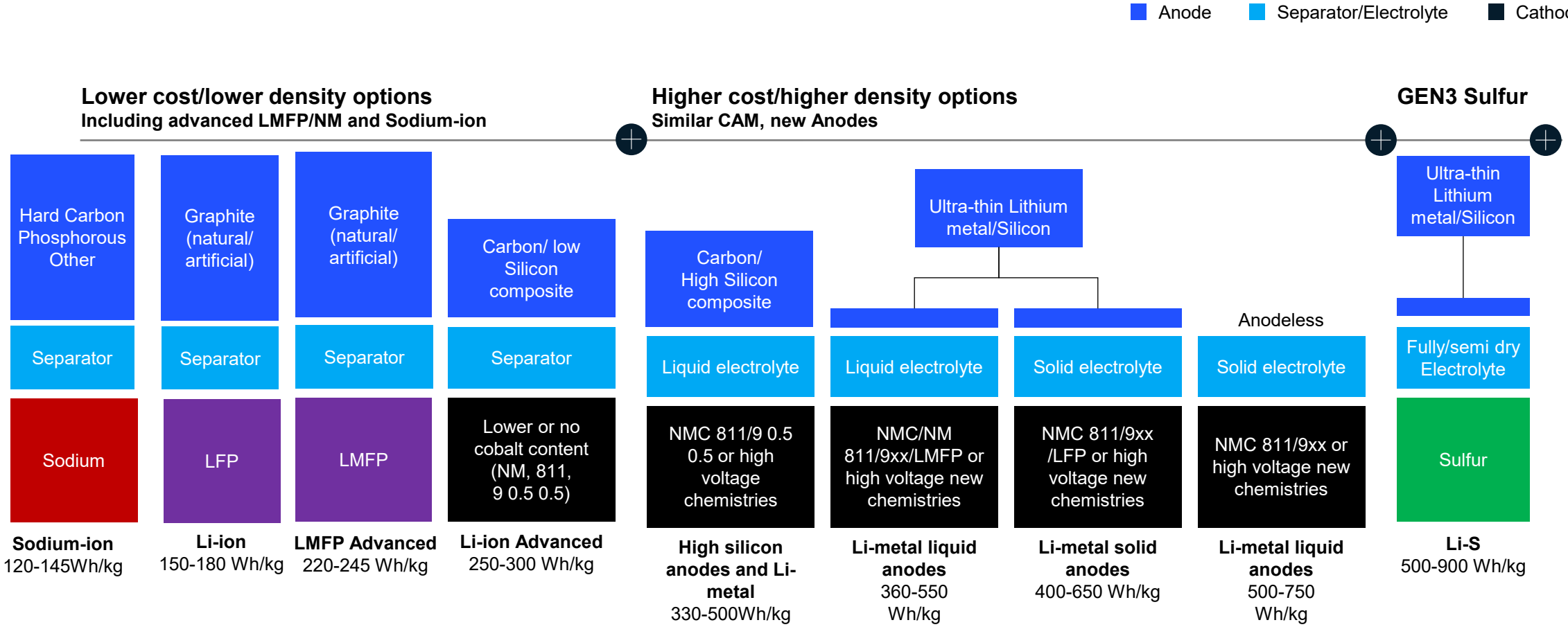
Cell Technology is very diverse--The type of potential solutions to the world's battery needs is vast and changing every day

Preliminary



We see battery chemistry evolving rapidly and not in a straight line, OEM's focus on density, charging speed, costs, and durability

Understand cathode AND anode material qualities and implications



1. Very early stage reflexion
2. Based on 7-year contracts in average, last known supply order signed with Volkswagen in March 2021

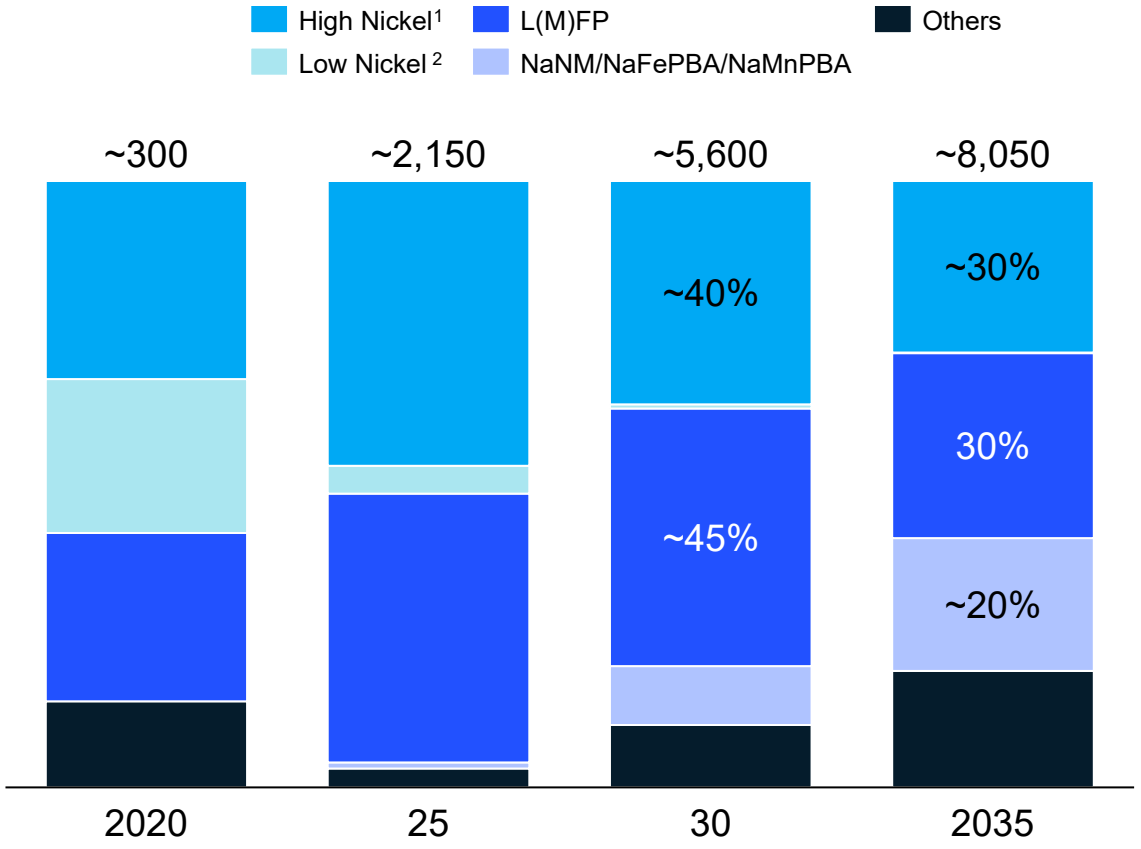
Source: Team analysis, Bernstein

Although there is uncertainty surrounding Na-ion cathodes, developments towards cheaper and/or better performing chemistries are expected for Li-ion batteries

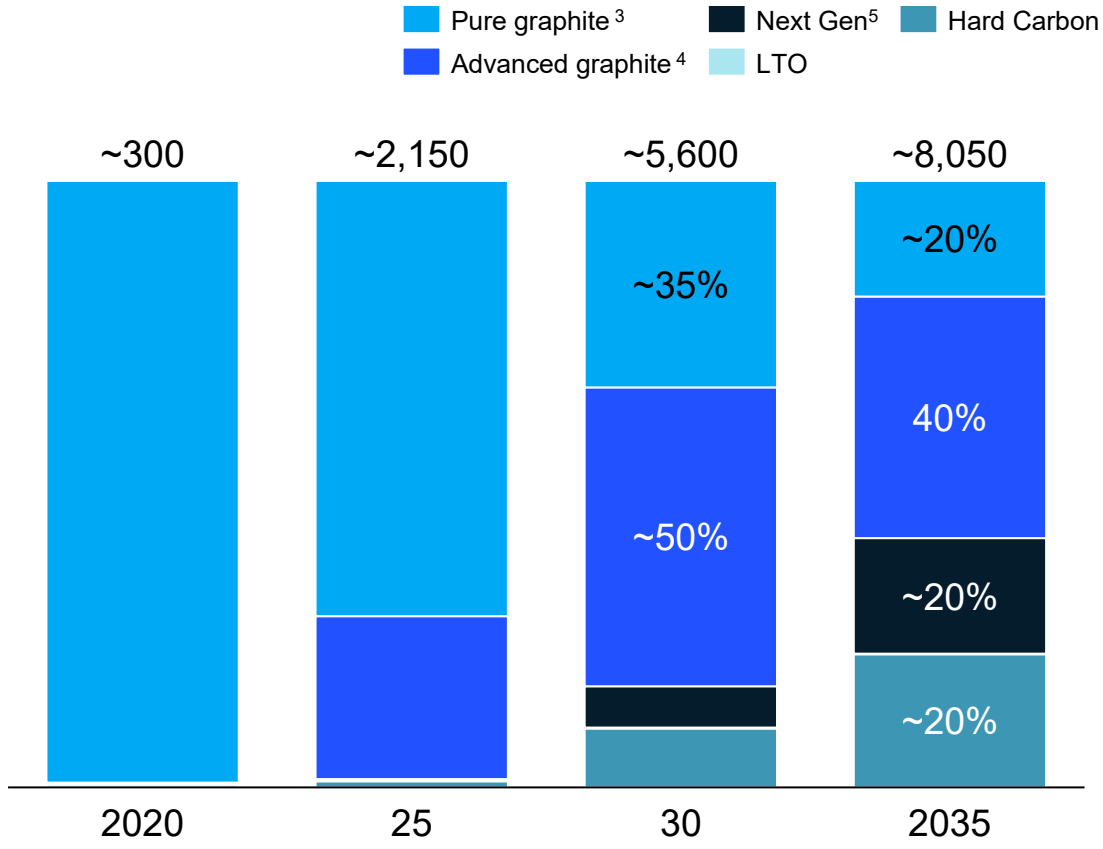
2023 Q3 **Further Acceleration Scenario**

Li-ion Na-ion Li-S Pb-a V-RF Ni-MH

Global cathode split, Global, GWh



Global anode split, Global, GWh

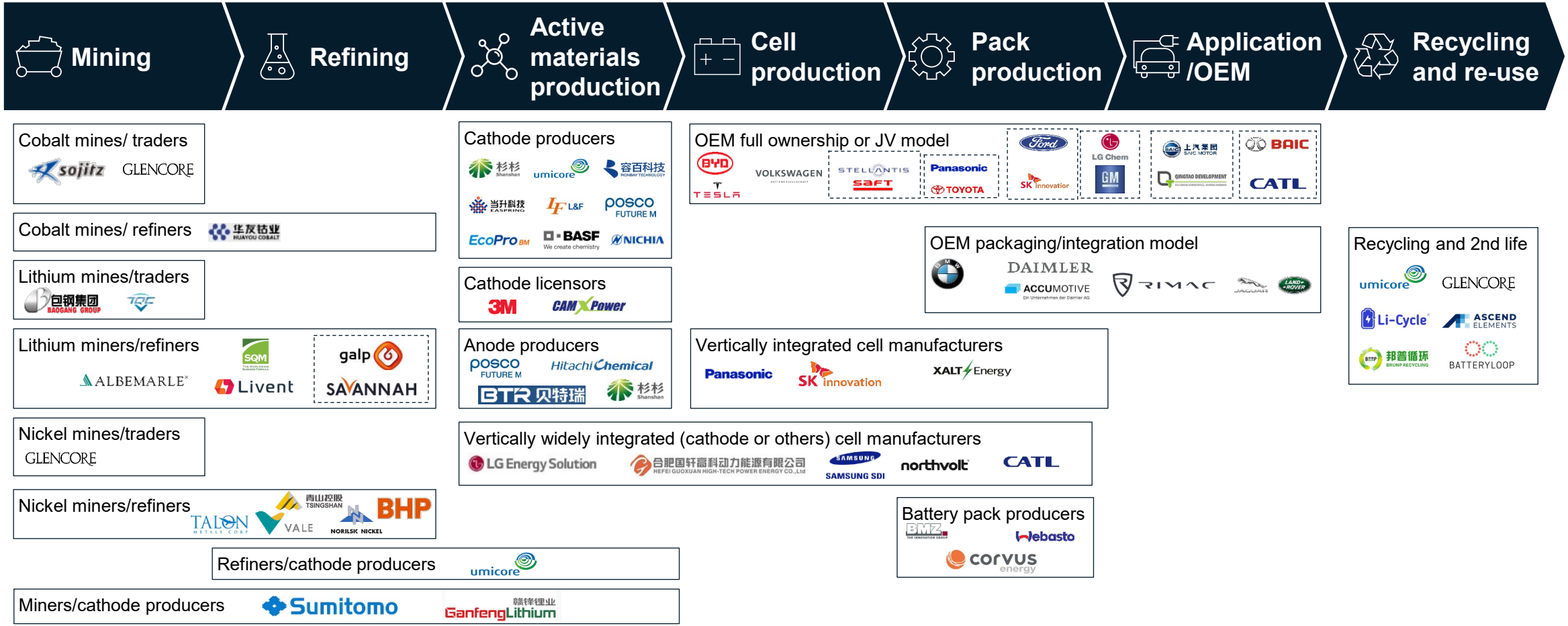


1. High Nickel: NCA, NMC 955, NMC 811;
2. Low Nickel: NMC 111, NMC 532, NMC 622
3. Nat. and Syn. Graphite
4. Nat. and Syn. Graphite blended with 5-15% Silicon
5. Majority Silicon and Li Metal

Source: McKinsey Battery Insights Demand Model

Battery value chain interfaces are shifting, with increasing trend to vertically integrate across value chain steps

Not exhaustive **Q1 2023**



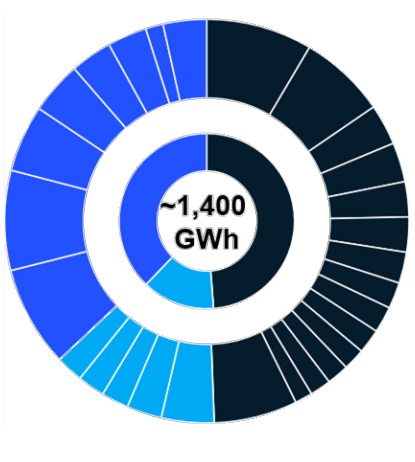
Source: Web and press search

Large differences in cell supplier archetypes developing between region

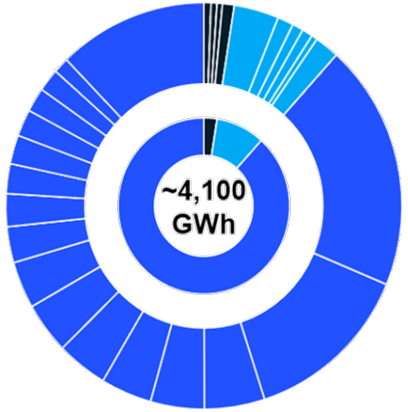
Q3 2023

Startup[2] | OEM JV or OEM subsidiary | Incumbent

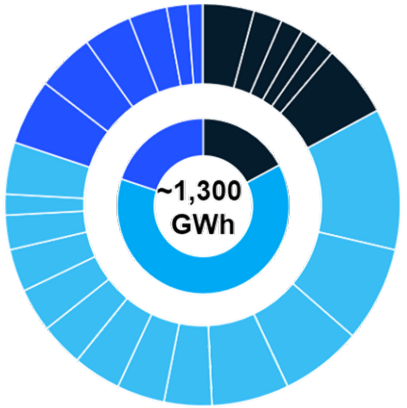
Europe Announcements, GWh, 2030



China Announcements, GWh, 2030



North America Announcements, GWh, 2030



Example Players

	CATL, LG Energy Solution				MORROW, VERKOR, FREYR
	BYD, CALB, EVE	Envision AESC	SVOLT	万向集团 WANXIANG GROUP	JUCHUANG
	Panasonic, SK on	ultium cells	Ford, SK on	sv STATEVOLT	iM3NY

1. As of 2022

Source: McKinsey Battery Insights – Supply model, team analysis

Key insights

Europe with the **largest share of capacity from startups** (~40%) will need significant financing from investors to deliver all the announced capacity

China **largest share of incumbents** (~85%) with **>50%** of capacity from current **global top-10 battery manufacturers,** lower risk on execution of projects as high density of experienced players

North America has **~70%** **of capacity from OEM JVs** (e.g., Ford & SK On, GM & LG Energy solution)

Cell manufacturer led raw material sourcing is driven by procurement

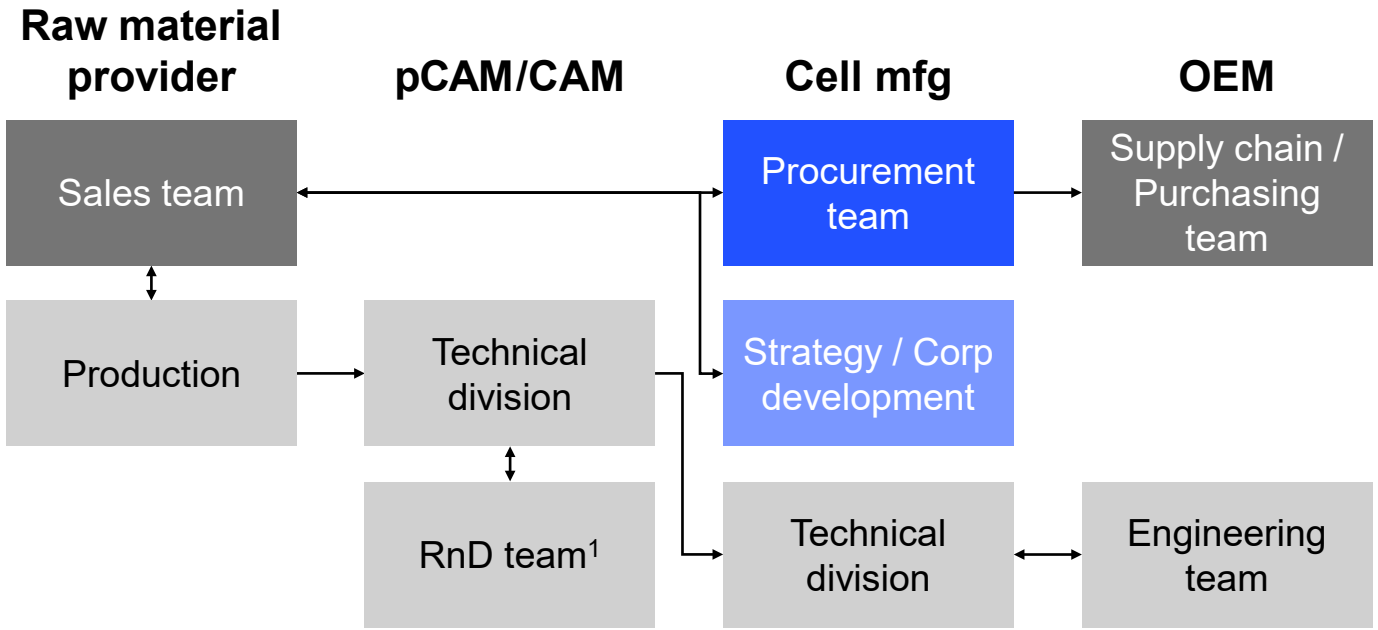
Motivation

- Focus on reducing costs
- Obtain transparency into cost structure of CAM
- Leverage scale and capabilities to go upstream to capture the value and pass through index rate to consumers

Main activities

- Supplier qualification (product quality, volume, location, price)
- Setting up the frame contract (CAM/Cell/OEM)
- Supplier relationship management

Decision makers



1. Involved only if new chemistry/specification is being qualified

Source: Expert interviews

Implications for raw material producer

Approach potentially used by large cell manufacturing players (LG, SK, CATL) which can leverage scale and relationships

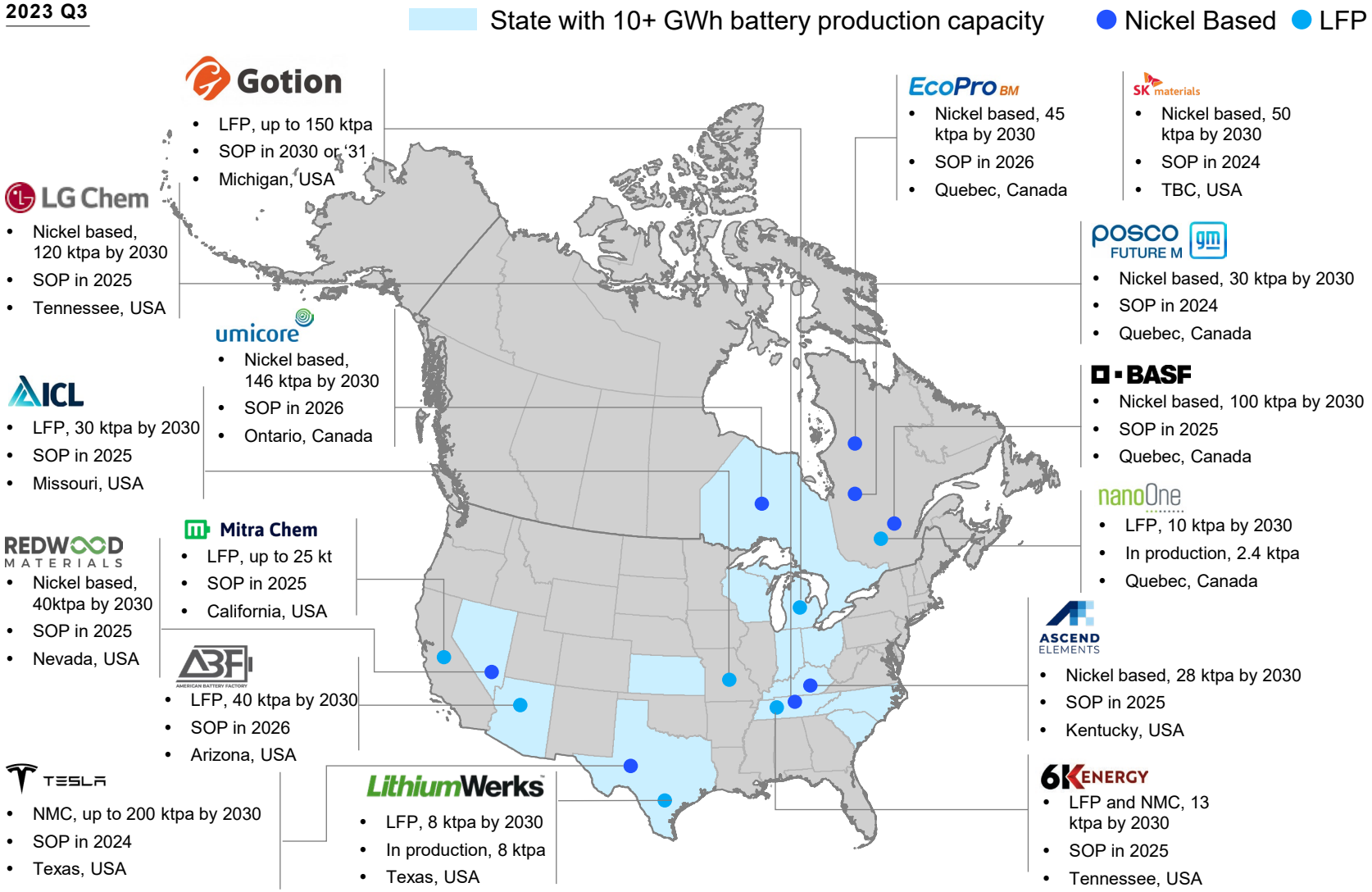
Producer can establish relationships with large cell manufacturers with track record of direct raw material sourcing, however this is lower priority compared to OEMs and pCAM players

For strategic long-term collaboration producer can also engage with strategy / corporate development teams

North American CAM production capacity will reach~1,000 ktpa by 2030

US CAM capacity in 2030, based on announcements

2023 Q3



Source: McKinsey Battery Insights – Battery Component Tracker, Press search, Team analysis

Key insights

CAM production capacity in North America to reach **~1,000 ktpa by 2030** with majority of production capacity dedicated to nickel-based cathodes

A wide range of archetypes:

- **European** (e.g., BASF, Umicore) and **Asian incumbents** (e.g., EcoPro, LG Chem)
- **North American battery recyclers** (e.g., Ascend Elements, Redwood)
- **Vertically integrated OEMs** (e.g., Tesla, GM/Posco Future M)

pCAM led raw material sourcing is the standard approach for raw material market

Commercial entry point | Contract flow | Material flow

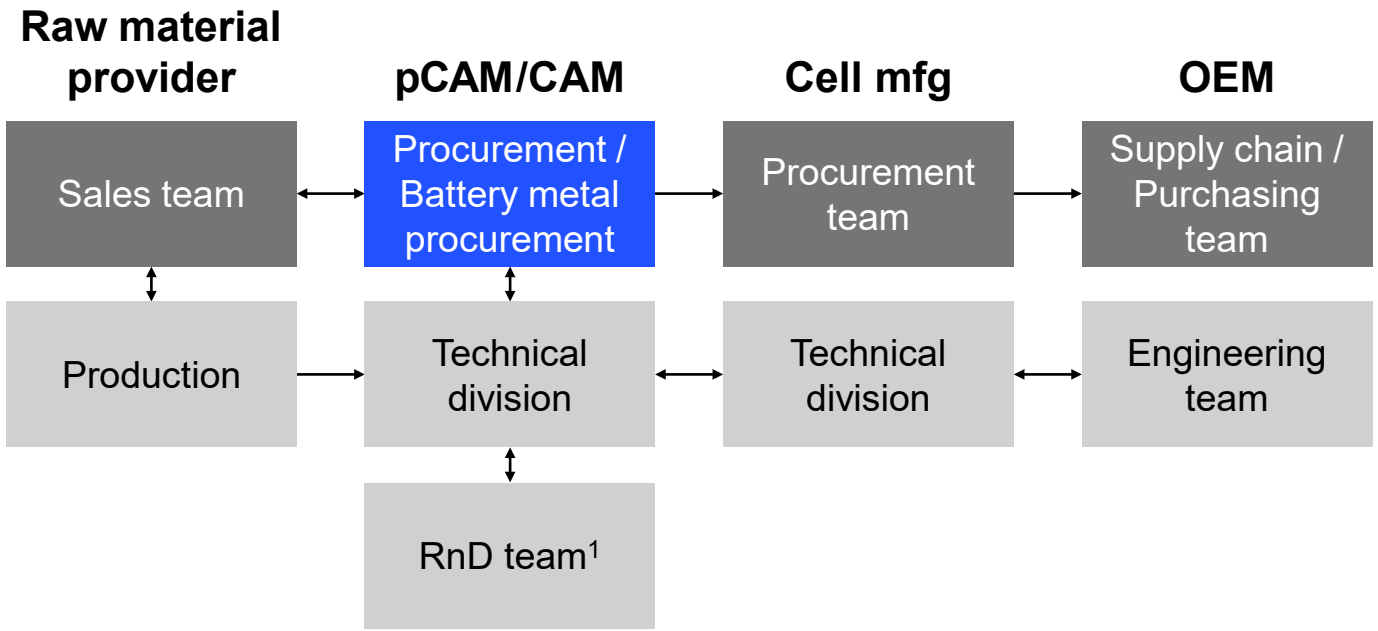
Motivation

- Control over the raw material procurement to preserve the margin
- Metal arbitrage is currently the main source of revenue for pCAM producers

Main activities

- Supplier qualification (product quality, volume, location, price)
- Technical qualification for the raw material
- Setting up the agreement with raw material supplier
- Supplier relationship management

Decision makers



1. Involved only if new chemistry/specification is being qualified

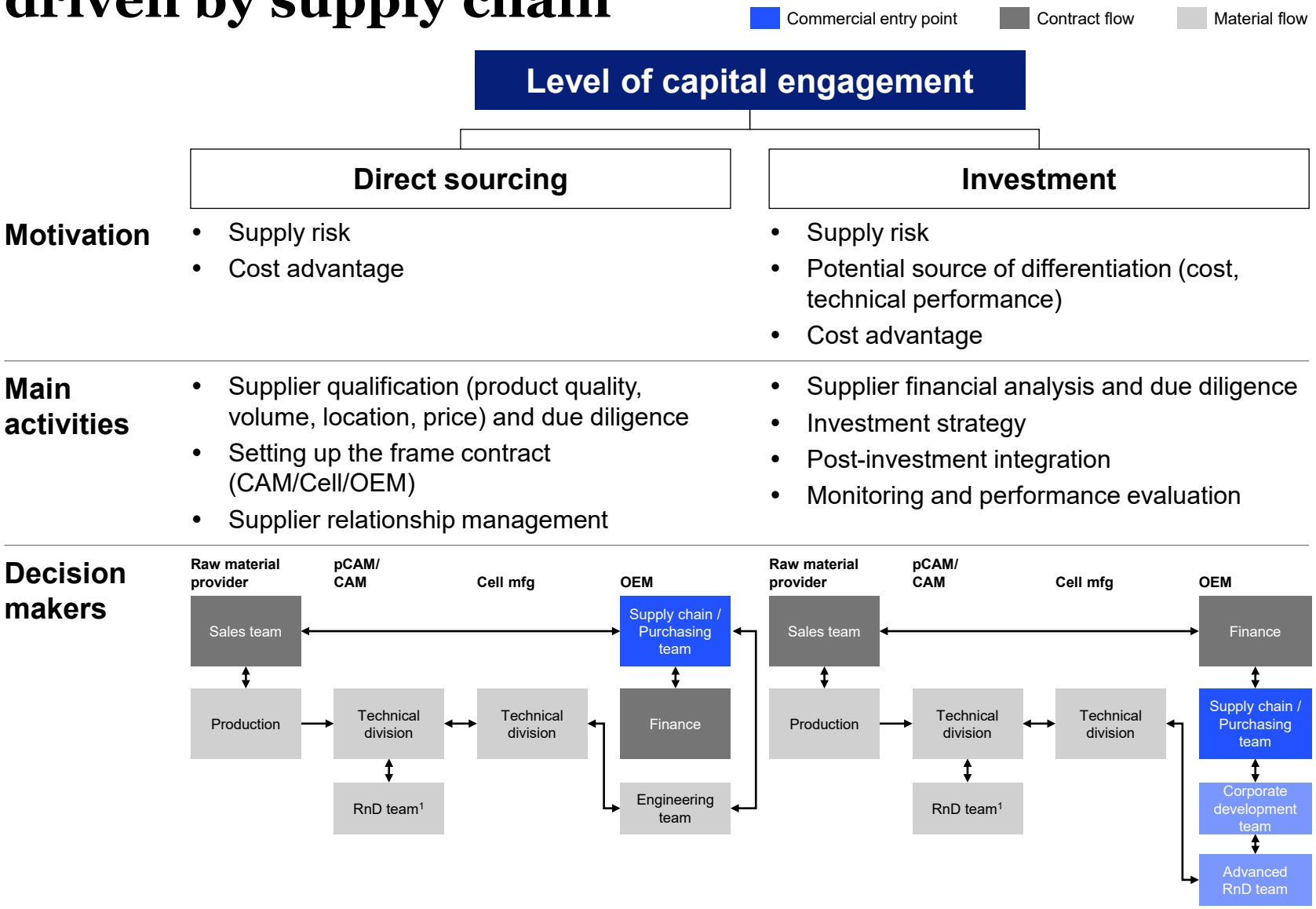
Source: Expert interviews

Implications for raw material producer

Producer has to qualify the product and establish direct relations with battery metal procurement teams within pCAM producers

> "Cell supplier owns all of the sourcing for the raw materials that go directly into making a battery. The CAM supplier owns the pCAM sourcing and the pCAM producer would own the manganese sulfate sourcing. So everyone owns only one tier above them. That's the standard model "
>
> **Former Supply Chain Manager, Battery Strategy at leading EV OEM**

OEM led raw material sourcing is currently driven by supply chain



1. Involved only if new chemistry/specification is being qualified

Source: Expert interviews

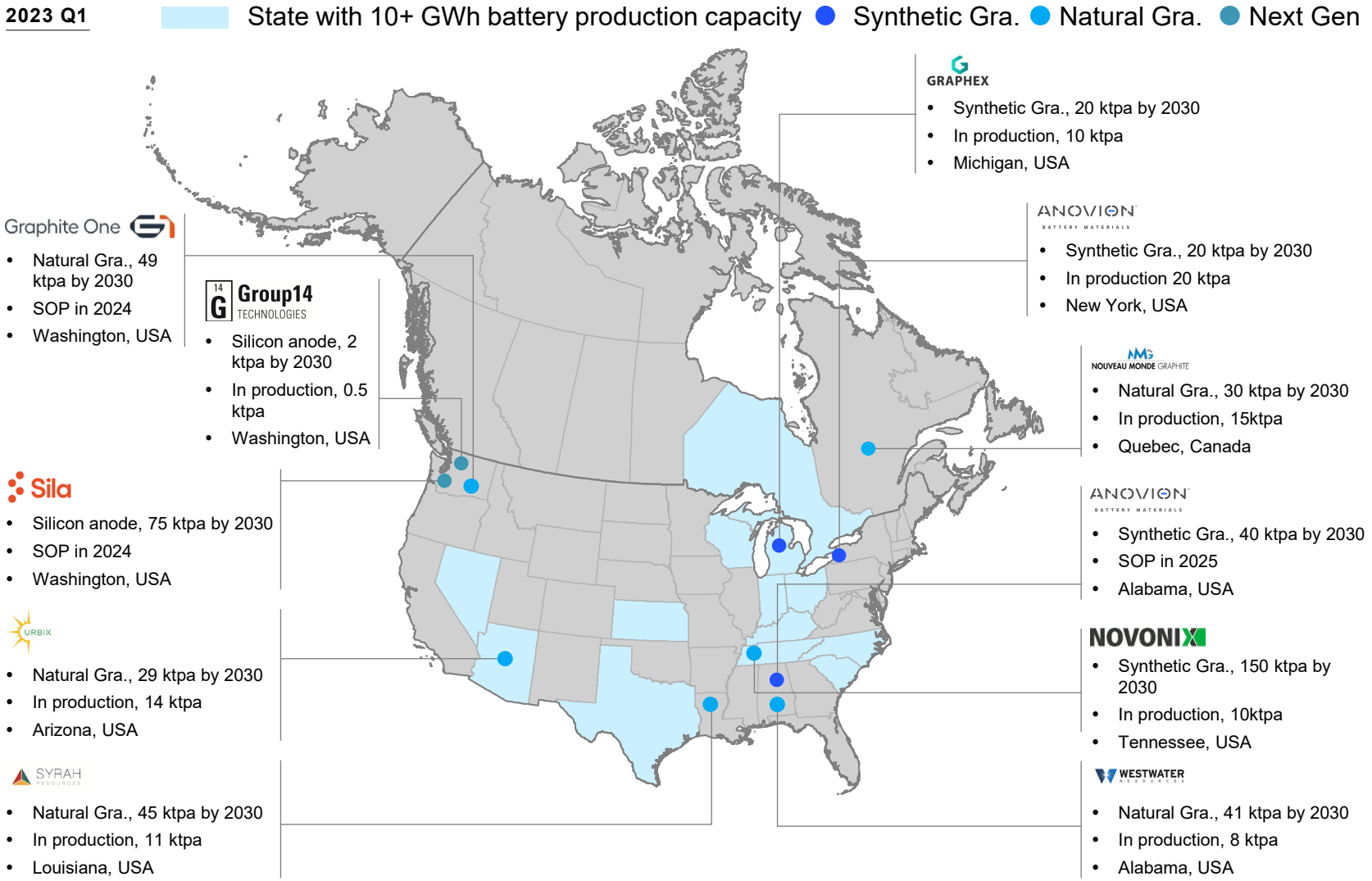
Implications for raw material producer

Currently OEMs are highly motivated to establish direct relationships with raw material producers due to supply security concerns. This is clearly visible from their active involvement into upstream value chain for Li, Ni and Co; IRA has only accelerated OEMs' desire for a compact, localized supply base for battery materials.

For strategic long-term opportunity discussions, entry point would be through corporate development and RnD teams.

AAM capacity in North America will reach~300 kt by 2030, with production split across natural, syn. graphite and silicon anodes

North America AAM capacity in 2030 in kt, based on announcements



Source: McKinsey Battery Insights – Battery Component Tracker, Press search, Team analysis

Key insights

AAM production in North America to reach **~300 kt by 2030, with production split between natural and synthetic graphite**

Smaller players such as Sila and Group14 Technologies are entering the market **with additional capacity announcements to produce next-generation anode materials** (e.g., silicon)

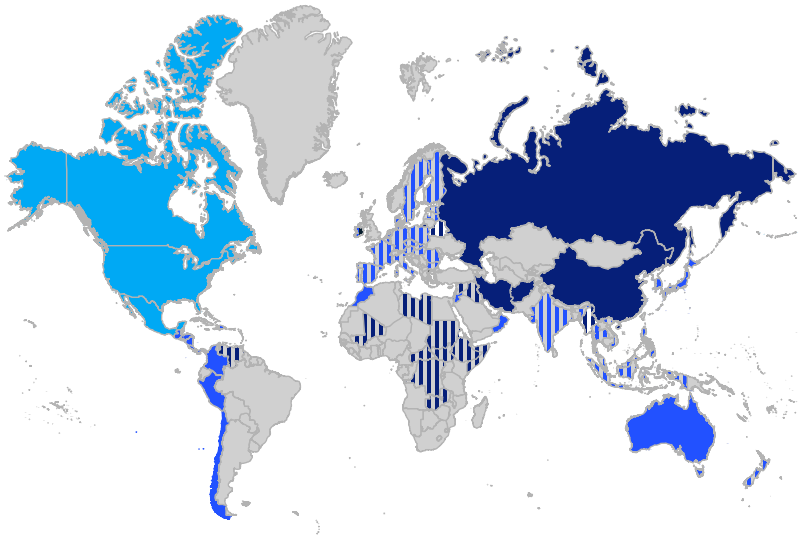
To qualify for tax credits, EVs will need to source batteries from free trade countries

Sec. 13401 Clean Vehicle Credit (30D)

April 2023

Map of free trade agreements

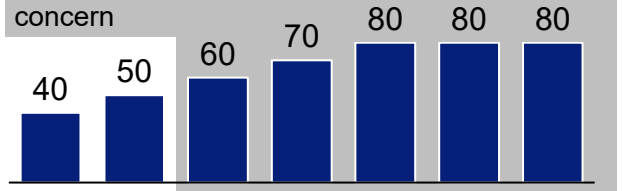
- Covered nation[1]
- Countries with OFAC sanctions[3]
- USMCA
- Countries with active US free trade agreements[4 5]



Battery sourcing requirements

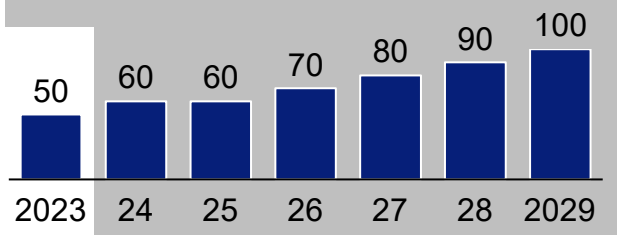
Share of battery materials extracted/processed in US or country with free trade agreement[2] percent

After 2024, no battery minerals may come be extracted, processed or recycled by entities of concern



Share of battery manufactured in North America percent

After 2023, no battery components may be manufactured by entities of concern



1. As defined in section 2533c(d) of title 10
2. Recycled materials only qualify if recycled in North America
3. Includes a mix of OFAC-sanctioned countries and countries with significant numbers of sanctioned industries and companies
4. EU, IPEF currently negotiating agreement to qualify for critical minerals
5. Australia, Bahrain, Canada, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Israel, Japan, Jordan, Korea, Mexico, Morocco, Nicaragua, Oman, Panama, Peru, and Singapore

Source: US Inflation Reduction Act (2022), 10 USC § 4872(d)(2), Infrastructure Investment and Jobs Act (2021)

Battery sourcing requirements

Each of the two battery requirements is worth $3,750 in tax credits if other price and localization requirements are fulfilled; complying with both achieves the full $7,500 credit

To qualify for EV tax credits, an increasing share of battery materials must be extracted and processed in countries with free trade agreements; batteries recycled in North America count

By 2029, all EV batteries must be produced in North America, beyond material source requirements

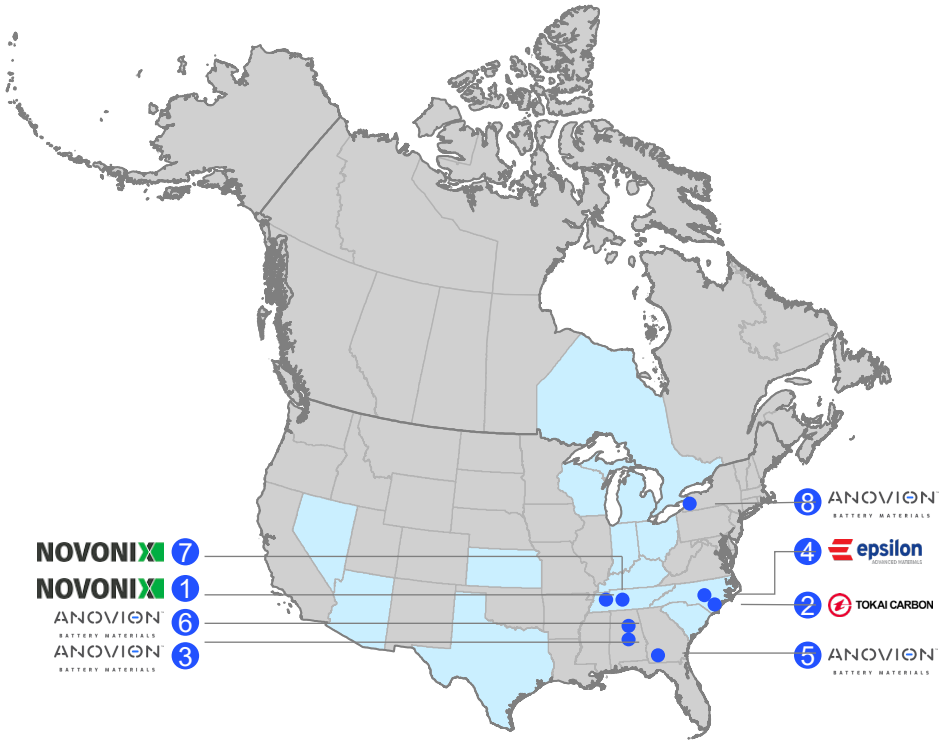
After 2023, **battery critical minerals and components may not be manufactured in "foreign entities of concern**," excludes minerals from China, Russia, and OFAC sanctioned countries/companies or the entire 30D credit is forfeited

Some countries have OFAC sanctions that affect state-owned businesses, individual companies, or sectors

IRA compliant synthetic graphite supply estimated to be ~560kt, with ~350kt produced in the US, by 2035

State with 10+ GWh battery production capacity · Synthetic graphite plant · IRA country · FTA countries

2023 Q3



Player	State, country	SOP year	Current supply, ktpa	Estimated supply 2035[4], ktpa
1 NOVONIX	Tennessee, USA	2025	0	128
4 epsilon	North Carolina, USA	2026	0	47
3 ANOVION	Alabama, USA	2025	0	34
2 TOKAI CARBON	North Carolina, USA	2024	0	34
5 ANOVION	Georgia, USA	2025	0	34
6 ANOVION	Alabama, USA	2025	0	30
7 NOVONIX	Tennessee, USA	Active	3	26
8 ANOVION	New York, USA	Active	15	17
IRA country total			18	350
Vianode	Quebec, Canada	2027	0	73
POSCO	Pohang, South Korea	Active	6	51
POSCO	Site 2 plant, South Korea	2026	0	30
RESONAC	Yamazaki, Japan	Active	17	17
RESONAC	Omachi, Japan	Active	17	17
TOKAI CARBON	Japan	Active	3	10
JFE	Kurashiki, Japan	Active	5	5
Nippon Carbon	Toyama, Japan	Active	3	3
Nippon Carbon	Shiga, Japan	Active	3	3
ShinEtsu	Gunma, South Korea	Active	1	1
OSAKA Titanium technologies Co.,Ltd.	Amagasaki, Japan	2026	0	1
FTA[1] countries total			55	209
Non-IRA/FTA[2] countries total		Active	21	217
FEOC[3] total		Active	762	1,128

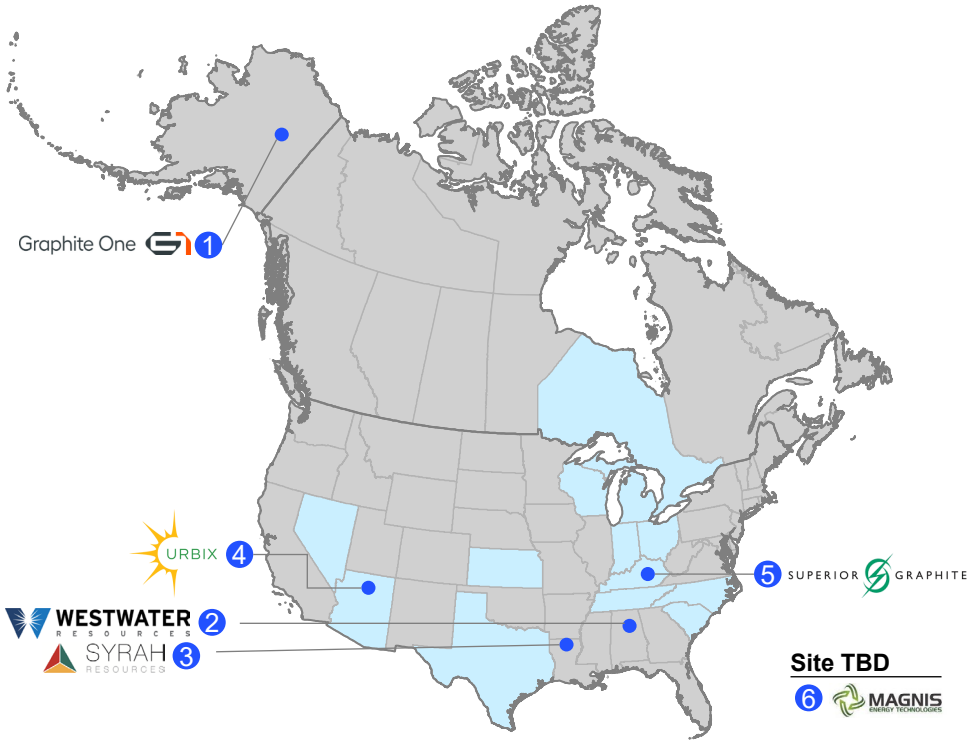
1. Countries with active US free trade agreements: Australia, Bahrain, Canada, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Israel, Japan, Jordan, Korea, Mexico, Morocco, Nicaragua, Oman, Panama, Peru, and Singapore
2. Countries that are non-IRA, don't have an active US free trade agreement, or not considered a "Foreign Entities of Concern"
3. Countries considered "Foreign Entities of Concern": China, Russia, Iran, and North Korea
4. Synthetic graphite supply based on announced capacities and then adjusted for production ramp up and steady state utilization, see appendix (P.134) for detailed description

Source: McKinsey Battery Insights – Battery Component Tracker; Press search,

IRA compliant natural graphite supply estimated to be ~385kt, with ~170kt produced in the US, by 2035

State with 10+ GWh battery production capacity | Natural graphite plant[5] | IRA country | FTA countries

2023 Q3



	Player	State, country	SOP year	Current supply, ktpa	Estimated supply 2035[4], ktpa
1	Graphite One	Alaska, USA	2024	0	42
2	WESTWATER RESOURCES	Alabama, USA	2023	2	34
3	SYRAH RESOURCES	Louisiana, USA	2023	4	34
4	URBIX	Arizona, USA	2023	5	24
5	SUPERIOR GRAPHITE	Kentucky, USA	2026	0	20
6	MAGNIS ENERGY TECHNOLOGIES	TBD, USA	2025	0	15
IRA country total				11	169
	POSCO	Sejong 1, South Korea	Active	36	85
	POSCO	Sejong 2, South Korea	Active	34	68
	NOUVEAU MONDE GRAPHITE	Quebec, Canada	Active	5	26
	EcoGraf	Western Australia, Australia	2024	0	17
	MITSUBISHI CHEMICAL / TOKAI CARBON	Kagawa, Japan	Active	7	7
	MITSUBISHI CHEMICAL / TOKAI CARBON	Yamaguchi, Japan	Active	4	4
	MITSUBISHI CHEMICAL	Hofu, Japan	Active	1	4
	MITSUBISHI CHEMICAL / TOKAI CARBON	Kagawa, Japan	Active	2	2
	NIPPON DENKO	Niigata, Japan	Active	1	1
	IMERYS	Fukuoka, Japan	Active	1	1
FTA[1] countries total				91	215
Non-IRA/FTA[2] countries total			Active	40	97
FEOC[3] total			Active	250	380

1. Countries with active US free trade agreements: Australia, Bahrain, Canada, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Israel, Japan, Jordan, Korea, Mexico, Morocco, Nicaragua, Oman, Panama, Peru, and Singapore
2. Countries that are non-IRA, don't have an active US free trade agreement, or not considered a "Foreign Entities of Concern"
3. Countries considered "Foreign Entities of Concern": China, Russia, Iran, and North Korea
4. Natural graphite supply based on announced capacities and then adjusted for production ramp up and steady state utilization, see appendix (P.134) for detailed description
5. May not strictly be a Nat. Gra mine location, could also be a processing plant that is importing Nat. Gra from other countries but being processed in an IRA-compliant manner

Source: McKinsey Battery Insights – Battery Component Tracker; Press search; Team analysis

How to build a NA value chain

- Have an internal team that understands and has a view of battery cell technology development
- Develop your strategy, commercial, technology, financial
- Plan who your partners will be both upstream and downstream
- Map out the industry players and work to find offtakes and prepayments (equity investments are harder to come by)
- Do not ignore help by your state and federal resources
- Do not make any investments without partners aligned
- Have a realistic CAPEX spend, missing milestones will be a death knell to your business

Appendix

Introduction to Battery Insights

Value proposition and assets

Our insights

- **Access to in-depth battery insights and expertise** covering key dynamics in the market, technology, and sustainability
- **Up-to-date industry perspectives** by continuously integrating and analyzing the latest industry data and announcements
- **Customized analytics support and benchmarking** leveraging advanced data modeling

Our value proposition

A dedicated team of battery experts

- **Team of 15+ researchers and consultants** with main hubs in Europe, Asia and North America
- **Access to 60+ experts** with relevant industry experience and academic expertise
- **150+ battery projects** supported in the past 6 months

Proprietary assets and data analytics

- **10+ data-driven assets** to provide customized analysis
- **Direct subscriptions** for access to tech-enabled insights on demand via user-friendly dashboards
- **Flexible support models** ranging from expert workshops to on-site project support

We support clients along the entire battery value chain

Battery raw material mining and refining	Active material production and battery components	Battery cell production	Battery pack assembly and integration	End applications	Remanufacturing, battery 2nd life, and recycling

To learn more, reach out to Battery_Insights@mckinsey.com

Source: McKinsey Battery Insights solution

Battery Insights works hand in hand with the Battery Accelerator Team, we act as a differentiating thought-partner for our clients

Battery Insights

Intelligence unit with 15+ dedicated analysts and associates, developing in-depth insights and expertise in battery markets, technology, and sustainability

+

Battery Accelerator Team

100+ practitioners, focusing on capital and operational excellence for battery industrialization

Deep expertise in battery market and technologies

15+

Proprietary tools covering all major aspects of the battery value chain

60+

Industry and academia experts within McKinsey

150+

Battery engagements supported in the past 6 months

25+ business building projects

for cells, cathode-active materials, mining, recycling

Several multi-company coalitions supported

within sustainable mobility, e.g. Global Battery Alliance, EU charging masterplan

Close connection to upstream and downstream capabilities

MineSpans

Metals and Mining analytics through 1.5 million data points covering 4500+ mines

EV Insights

Database for analyzing and benchmarking, access to 100+ vehicle tear-downs

Energy Insights

Comprehensive analytical insight into the energy sector

EV Charging

Building networks, assessing charging behavior & tech for commercial/private vehicles