McKinsey & Company

Strategies for critical metals

June, 2022

Ken Hoffman
Ken_Hoffman@mckinsey.com

Who will be the winners in the battery market and why

Cell production bottlenecks may be caused by the raw materials stream – inconsistency adds to the inability to produce high quality batteries in large amounts

Energy density is the key

Solve the issues of both consumers

Development of new vehicles shrunk from 10 years to 3-4 years– raising risk for suppliers

Median consumers look for an EV that has the same to better attributes to their current car

Current average range 650-900 km[1]

Current Avg refueling time: 5-7 mins[1]

1. Average range and refueling time of a gasoline or diesel fueled vehicle

Winning questions

What are consumers of batteries looking for?

- Range
- Refuel time

What are automakers looking to build?

- Technology industry not automotive
- Commercialization has been an issue
  - Quality of raw materials
  - Consistency and quantity

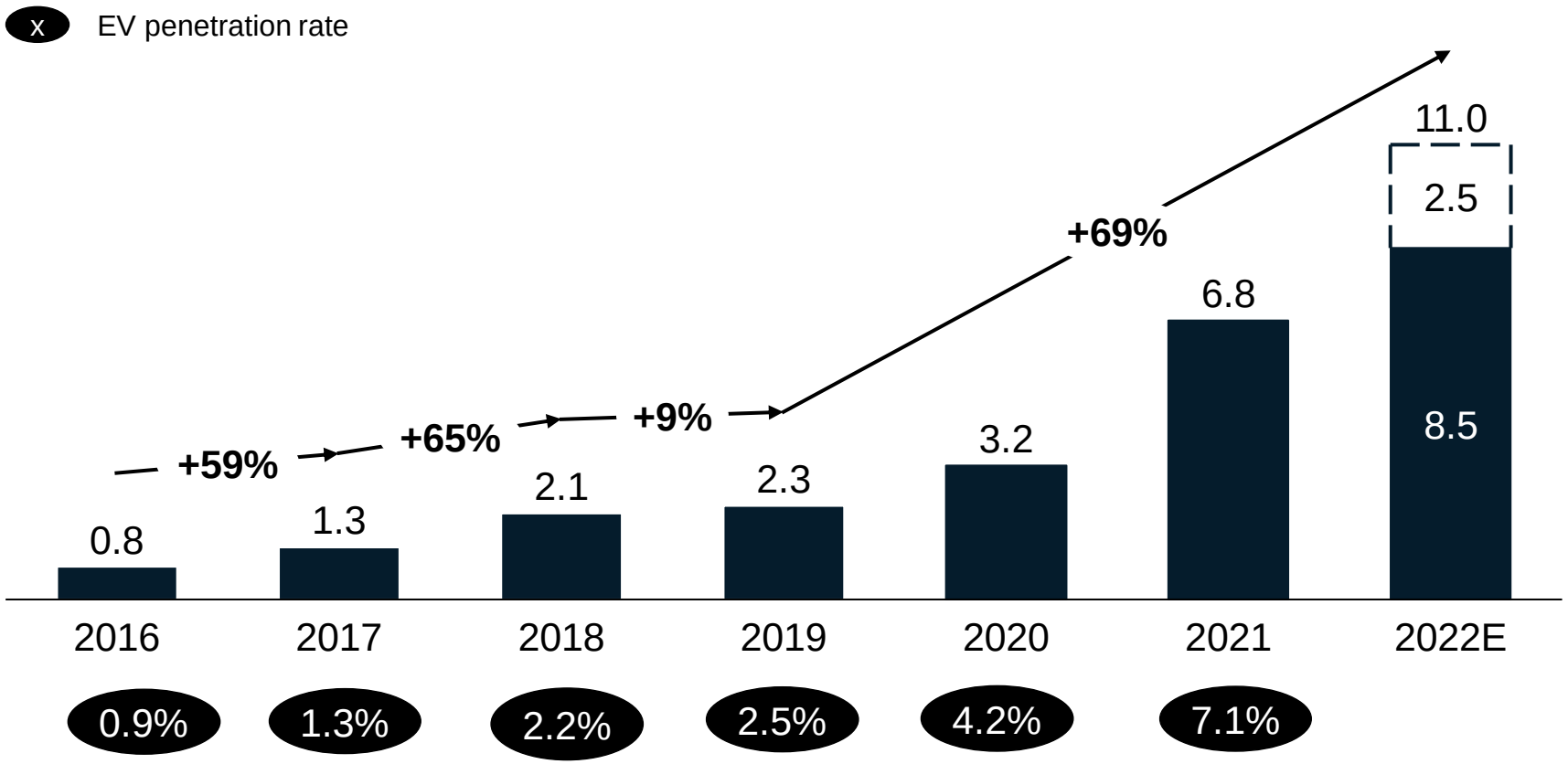
What is the value chain and how do you participate?

- Battery materials are NOT commodities
- Commercial considerations as important as mine parameters

YTD 2021 EV sales have more than doubled 2020 levels, with chip and cell constraints hurting supply

Yearly global electric[1] light vehicle sales development

mn units



1. BEV and PHEV

Source: EV-volumes.com, IHS Markit (Light Vehicle Alternative Propulsion Forecast Jan 2021 2021 estimates based upon trend from EV-volumes data)

Key insights

Electric vehicle sales reached 6.75 mn units in 2021 a more than doubling of demand from 2020

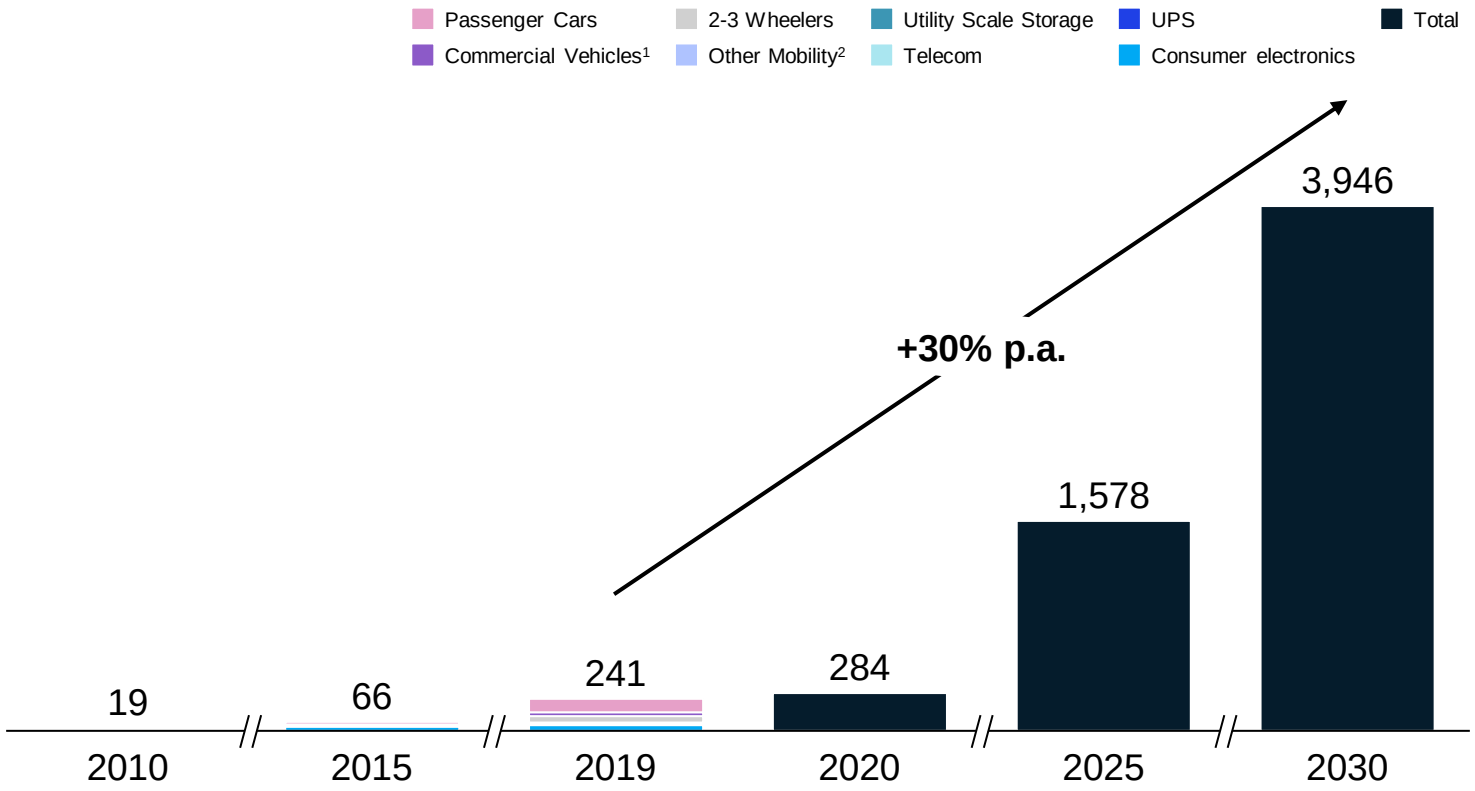
Demand for LFP batteries soared by over 170%, while NMC battery production rose by almost 100%

Demand continues to rise sharply in the beginning of 2022, but raw material prices have forced major price hikes in EV's

Li-ion battery demand is expected to grow 30% p.a. in the coming years…

Driven by EVs, other road transport, and grid applications

Global Li-ion battery cell demand by sector, GWh



1. Includes trucks, buses, and LCVs
2. Includes Aviation, Marine, Consumer electronics, etc
3. Plug-in electric vehicles: BEV+PHEV
4. Total Cost of Ownership (TCO),

Source: IHS; WEF; McKinsey Battery Demand Model

- Global PEV[3] sales are expected to exceed 200 million by 2035, driving global battery demand
- TCO[4] parity between electric and diesel is reached first for urban eBuses and light-duty eTrucks
- Grid battery storage is expected to increase with increasing shares of intermittent renewable electricity generation

Production is becoming more localized, with an increasing share of capacity additions in Europe and US

Announced battery cell production capacity, GWh p.a.

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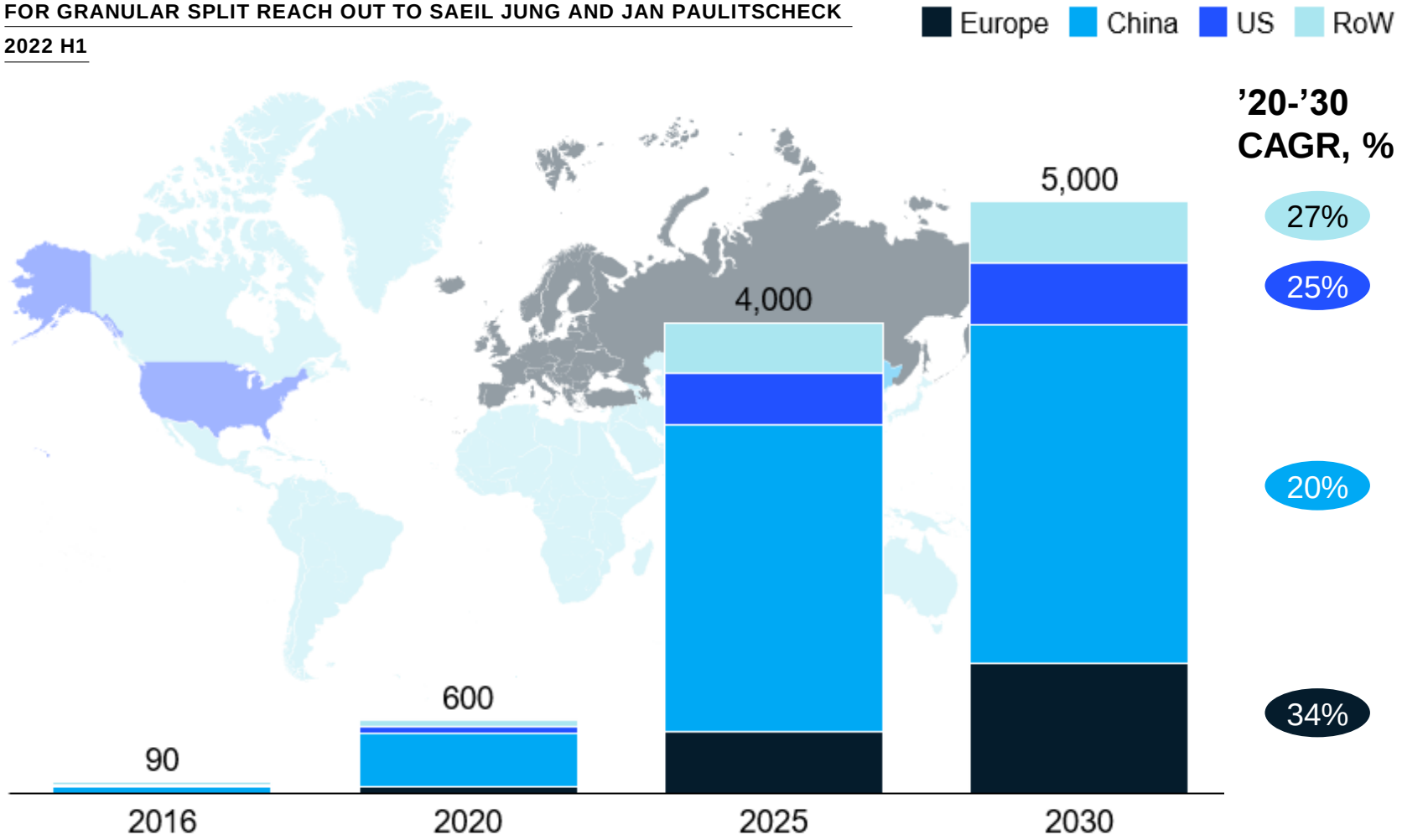
2022 H1



Source: McKinsey Battery Insights - Battery Supply Tracker, Team Analysis

Key takeaway

Cell suppliers are increasingly announcing **capacity closer to OEMs in Europe, the US and rest of world with the combined geographies exceeding 40% of global capacity in 2030**

Announced new capacities are exceeding expected demand, with realized supply likely to be lower than announced e.g., due to failed capacity additions, yield implications, or ramp-up delays

To match expected demand investments of USD ~700bn are required until 2030

Cumulative Capex investment required, 2020 – 2030, USD bn

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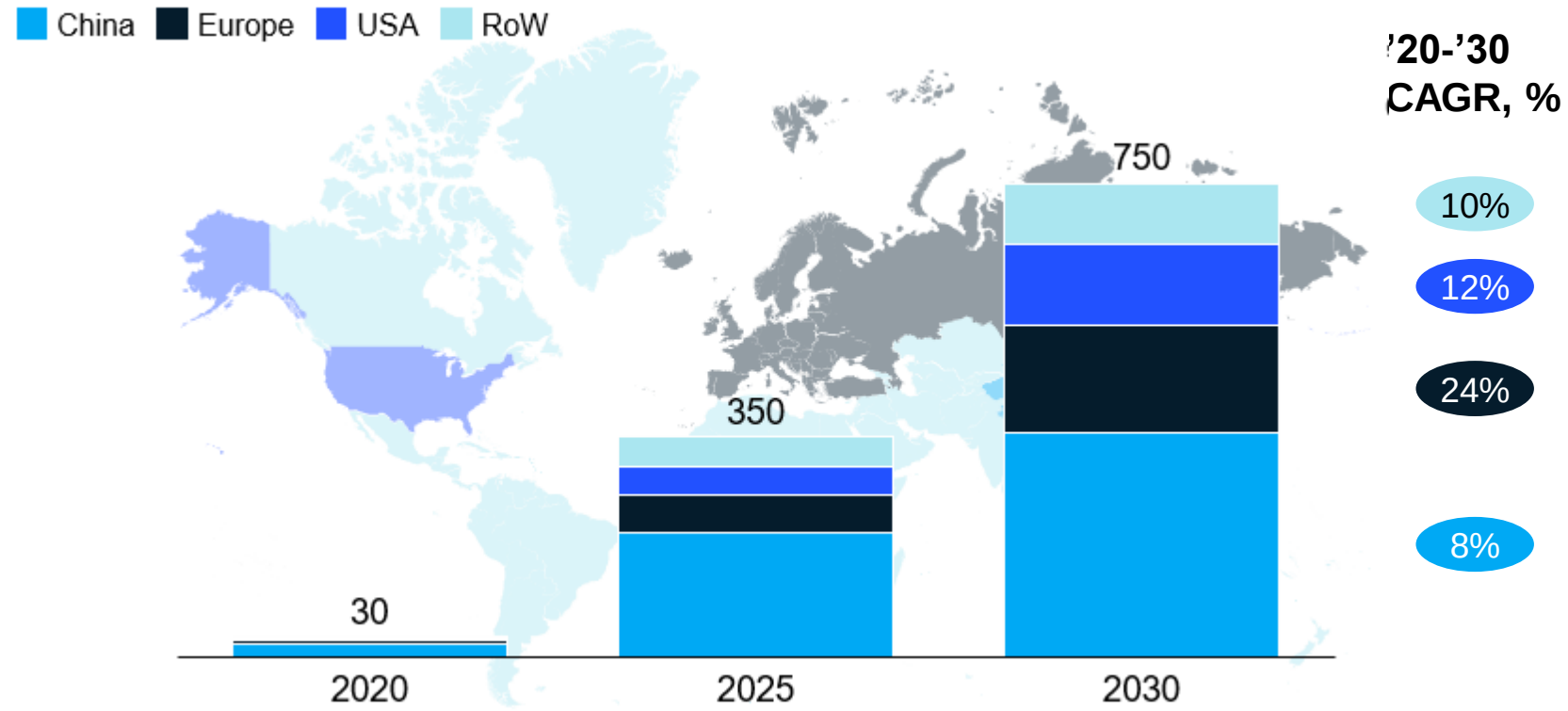

Avg. Capex required per year (USD bn)	29	67	96

Source: McKinsey Battery Insights - Battery demand model, Cost model, CAPEX model, Supply tracker, Team analysis

Key takeaway

While China will remain major production location, **localization of capacity is expected to drive Capex growth in Europe and the US.** In 2030, cumulative Capex requirements of Europe and US combined are expected to exceed those in China

Battery recycling will emerge as a source of sustainable raw materials with 16,300 kt of material available in 2040

Available material for recycling by source, 2020 – 2040, kt

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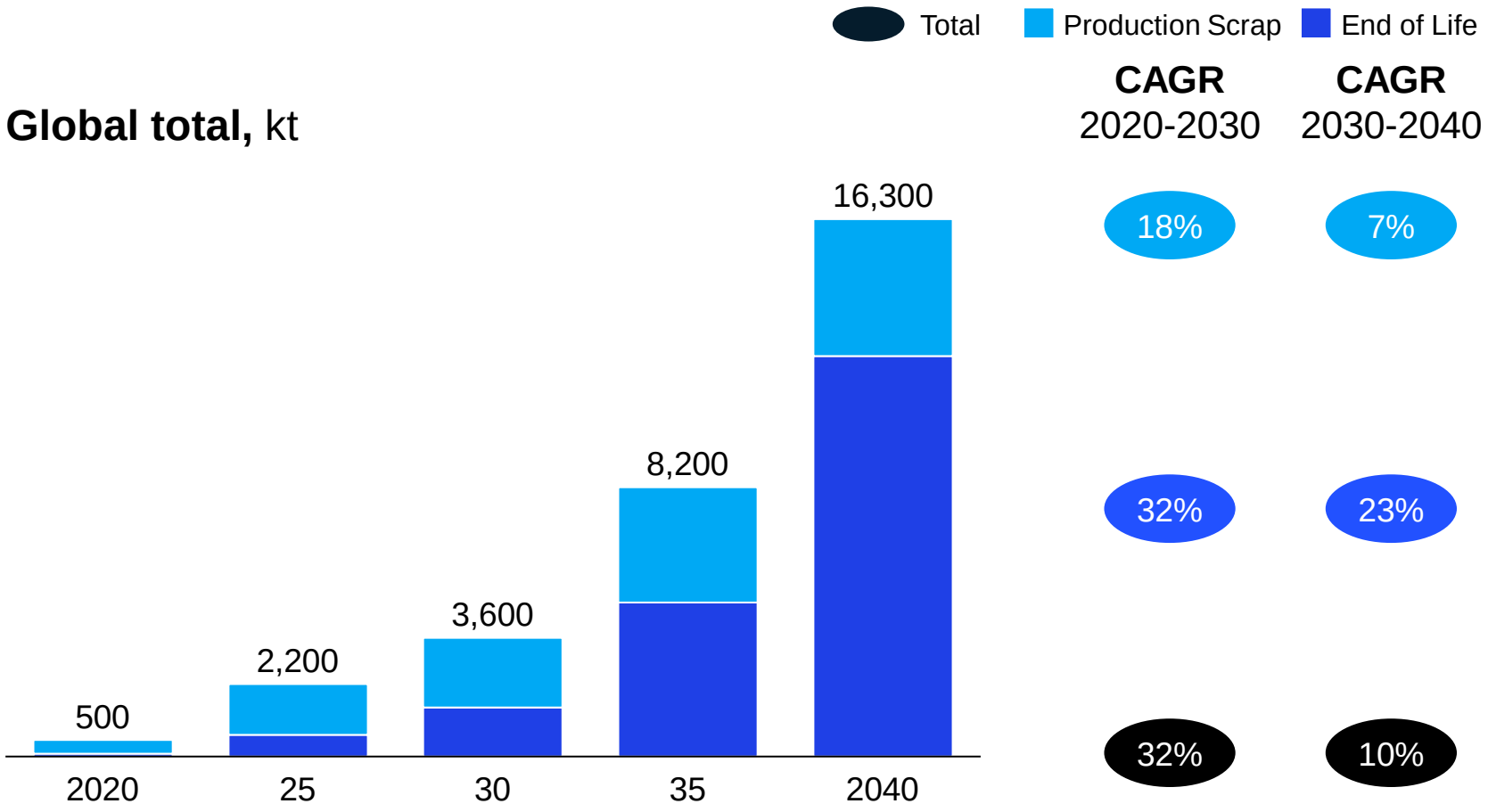


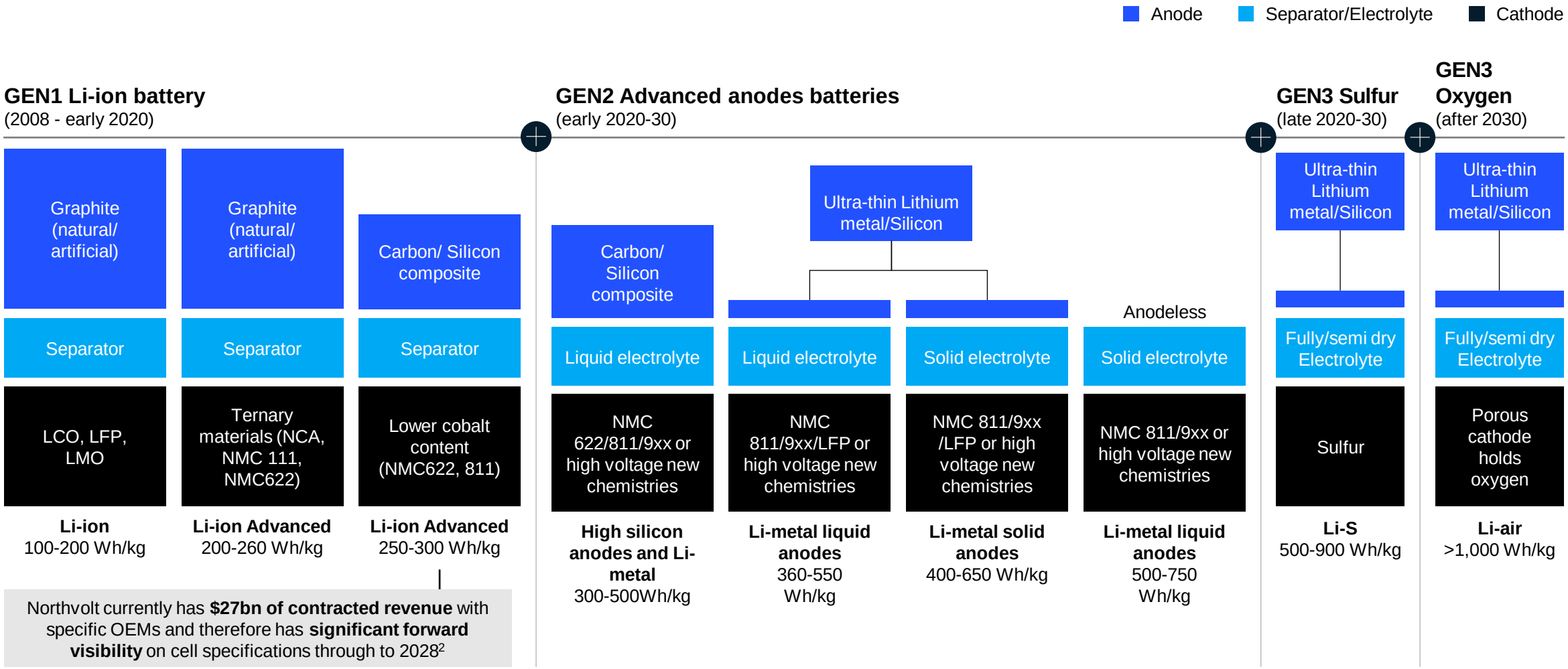
Source: McKinsey Battery Insights - Battery Demand Model, press search

Key takeaway

- Global available volume for recycling is expected to **increase 7-fold between 2020 and 2030**
- **Production scrap will remain the main source of material until 2035**, with recycling of End Of Life batteries becoming the major source afterwards

We see battery chemistry evolving over three horizons

The scale-up of new generation batteries would not cause a strong change in the choice of raw materials



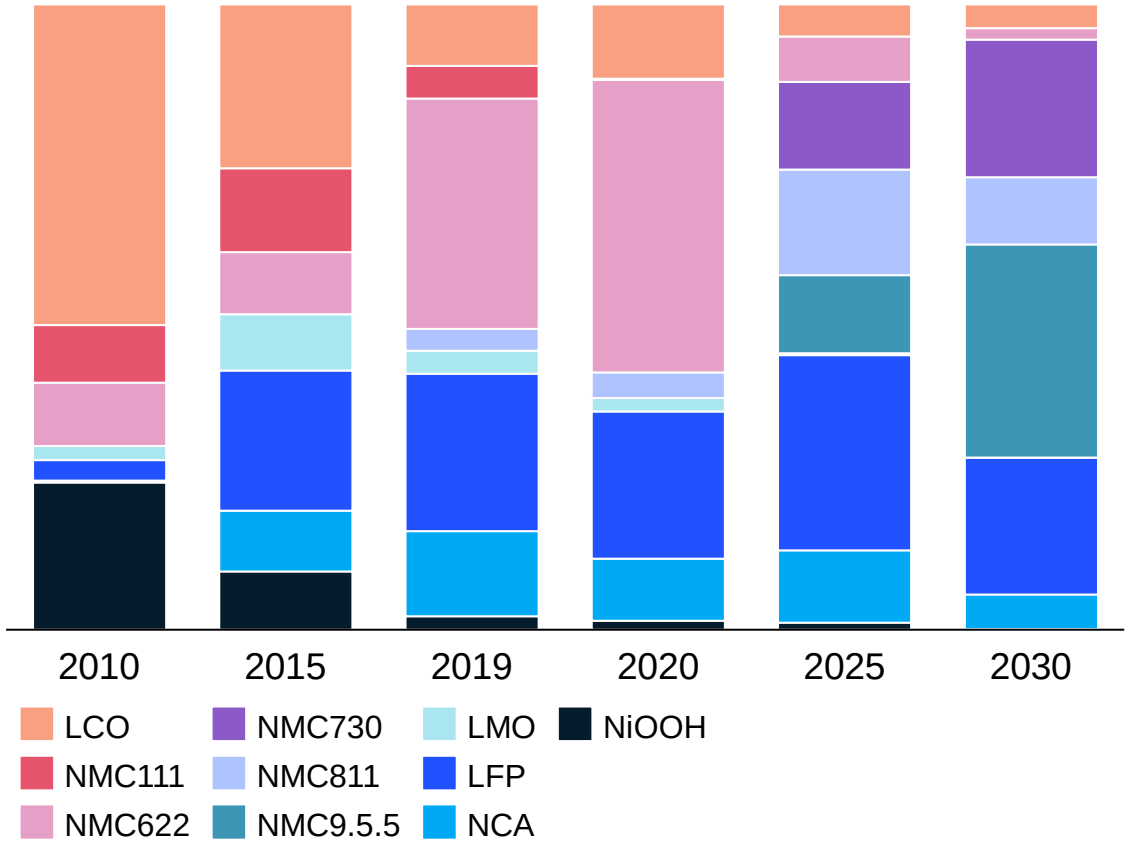
Northvolt currently has **$27bn of contracted revenue** with specific OEMs and therefore has **significant forward visibility** on cell specifications through to 2028[2]

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

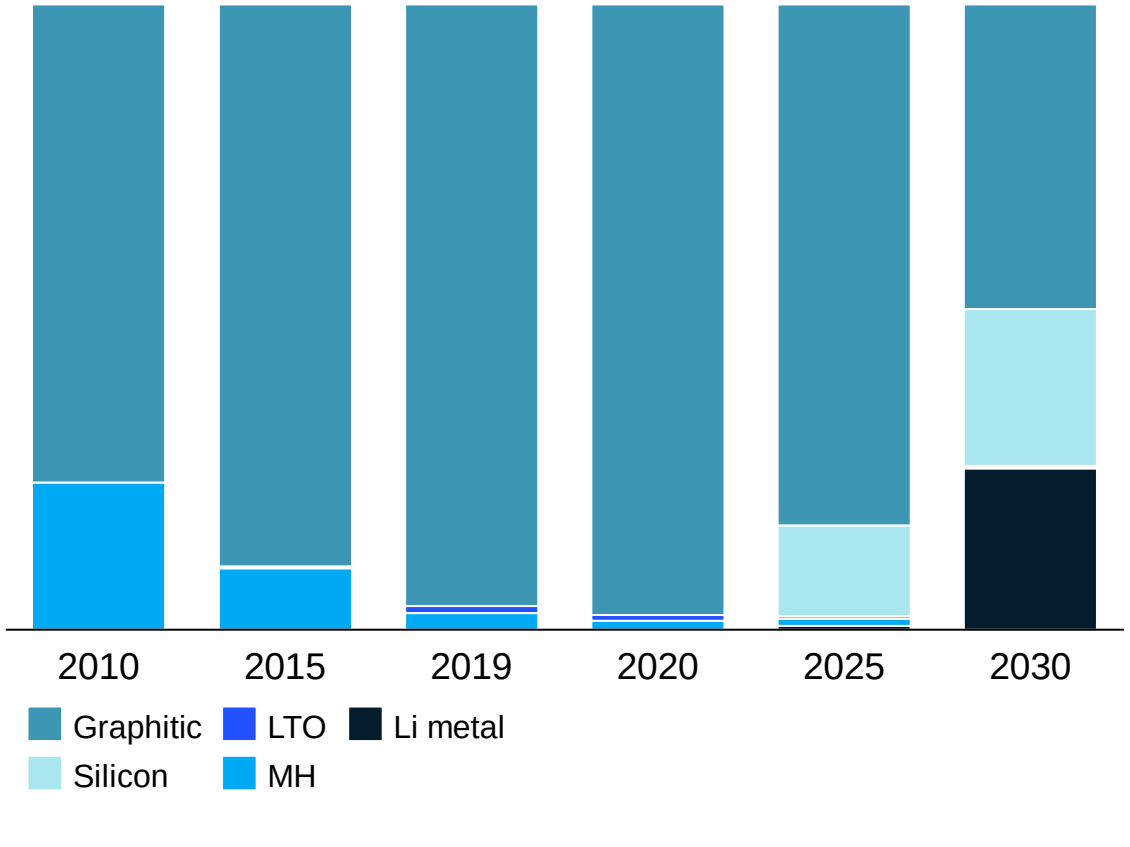
Source: Team analysis, Bernstein

Backup: Cathode and anode technology evolution to drive the market towards lithium hydroxide and lithium metal adoption

Cathode Split, GWh



Anode Split, GWh

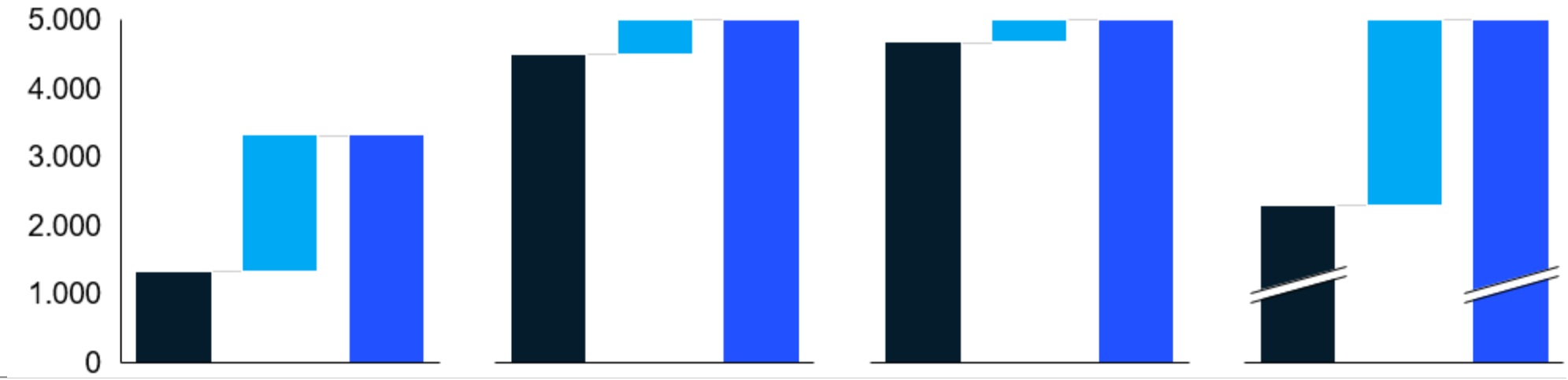


Source: McKinsey Battery Demand Model

EV growth implies the need for new mines OEM's will increase the importance to secure long-term sourcing options

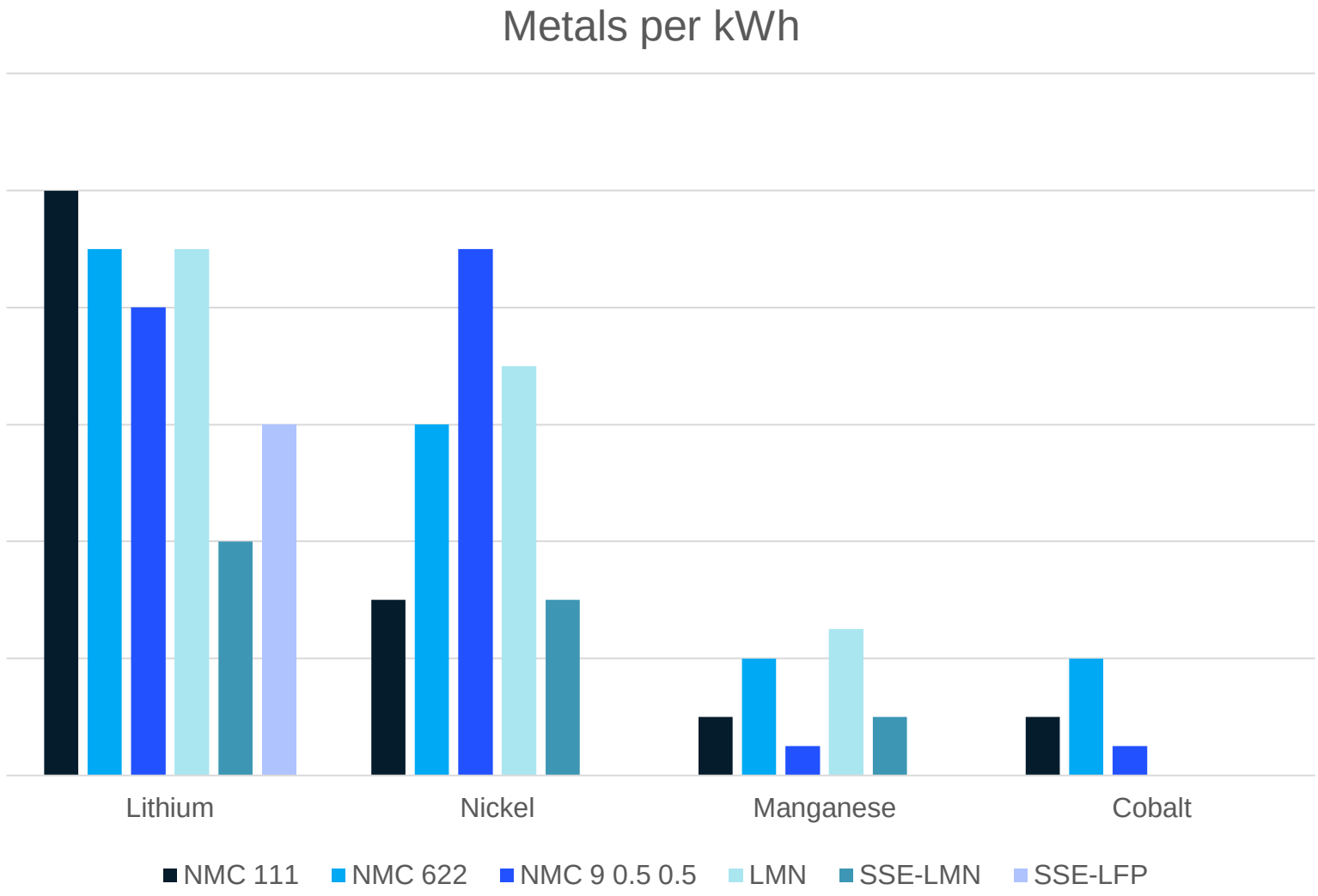
Expected demand and supply for key metals in 2030

2021 H1 **For most recent data contact MineSpans Team**

Raw Material	Refined Lithium	Refined primary Nickel	Cobalt	Manganese
Demand vs currently financed Supply, 2030, kt				
Key demand drivers	Increasing adoption of EVs	Stainless steel and battery cell production	Increasing adoption of EVs	Stainless steel and battery cell production
Key supply drivers	Brownfield developments, new mining technologies (i.e., DLE, geothermal/ oilfield brines processing)	New technology (HPAL plants) and expansion of production	End prices incentivizing investment in HPAL projects	Grade erosion of South African grades

Source: MineSpans; McKinsey Basic Materials Insights

The Paradigm shift of new battery technologies to the raw material challenge– Why new chemistries stretch out raw material needs



New Anode Technology Batteries

Competitors fall into three innovation categories

Innovation category	Explanation	Energy density cap	Examples
Improvements to Li-ion	Incremental energy density improvements to cathode & anode, cell design, heat dissipation techniques etc.	350-400Wh/kg	24M, FREYR Clean battery solutions, Panasonic, TESLA, microvast
Novel ways of incorporating high silicon in anode	High (>10%) silicon loading in the anode, enabled through novel solutions to current swelling & conductivity challenges	400-450Wh/kg	SILA, ENOVIX, amprius, Group 14 ENGINEERING, nexeon, ADVANO, NANOGRAF TECHNOLOGIES, ENEVATE
Shift to lithium metal anode	Use of Lithium metal as anode material to significantly increase potential energy density; includes solid state and semi-solid state cells	500-650Wh/kg	SolidPower, QuantumScape, CATL, ionic MATERIALS, A123 SYSTEMS, SES, TOYOTA, ProLogium, SAMSUNG

The 3 types of SSB technologies have distinct advantages and shortcomings

	Description	Competitors
Polymer	• Combination of Polymers with lithium-salts • PEO-LiTFSI most investigated system, but suffers from poor ionic conductivity at room temperature	Bolloré, Hydro Québec, ionic materials
Oxide/ Phosphate	• High safety due to low reactivity • Prone to mechanical failure and hard to process due to brittleness • Pressurized cells required for a constant electrode-electrolyte contact • Low cycle life due to contact loss of electrode-electrolyte interface • Mainly garnet & perovskite (oxides) and NASICON (phosphates) materials	QuantumScape, solid energy
Sulfide	• Highest ionic conductivity in solid state • Safety issues due to high reactivity during manufacturing • Good electrode-electrolyte contact and processability due to ductility • Small potential stability window requires electrode coating • Example cells include argyrodite, LGPS, LPS, LSPS, LSPS-MS	SolidPower, TOYOTA, SAMSUNG, Panasonic

Source: Expert Interviews, McKinsey Analysis

What are the best ways to ensure long term delivery of EV Battery materials with Miners

Equity, JV, or direct Investment

Benefits:

- Allows direct precipitation in commodity price movements
- Will help fund industry expansion
- Stake could be sold at a later date

Cons:

- Not guaranteed to increase supply
- If miner has ESG issues, could reflect poorly on major investors
- If majority investor, does the OEM want to become a “miner”, if a minority investor, what control does it have to influence supply?
- No guarantee of lower commodity costs
- Force Majeure risks

LT supply agreement

Benefits:

- Simple
- Low cost to implement

Cons:

- No impact on pricing, as these contracts are based upon index pricing plus/minus quality or market
- LT agreements with price ceilings have seen these contracts broken in high price environments
- Takes on mining risks such as weather events, strikes, geopolitical risks etc which could impact supply.

Streaming

Benefits:

- Long-term, low-cost supply of material at a fixed cost
- Allows for price certainty over a long period of time
- In high price environments, could be seen as a negative interest rate on investment or very high IRR

Cons:

- Large upfront cost
- In a low-price environment, very high implied interest rate/low IRR
- Takes on mining risks such as weather events, strikes, geopolitical risks etc which could impact supply.
- Has yet to be done publicly for lithium or nickel