# Graphite Supply Chain 2016

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Focus · Discipline · Excellence

# Outline

Brief Introduction to SG

Core Capabilities

Markets we serve

Activities in Li-ion Battery Markets

Questions?

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# Company Profile

**Ownership-** Family-owned & Partial ESOP

**Since 1917-** Providing carbon-based solutions

**Employees-** 260+ globally

**Turnover> $100M-** >35% non-N. American sales

**Operations-** 5 production sites; 2 R&D facilities

**ISO 9001:2015-** USA and Europe; ISO 14001:2004- Europe

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# Superior Values


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# SG Capabilities

Advanced electro-thermal purification technology,

Thermal synthesis, Precision processing- grinding,

sizing, blending, Carbon/Graphite sourcing,

Consultative Approach

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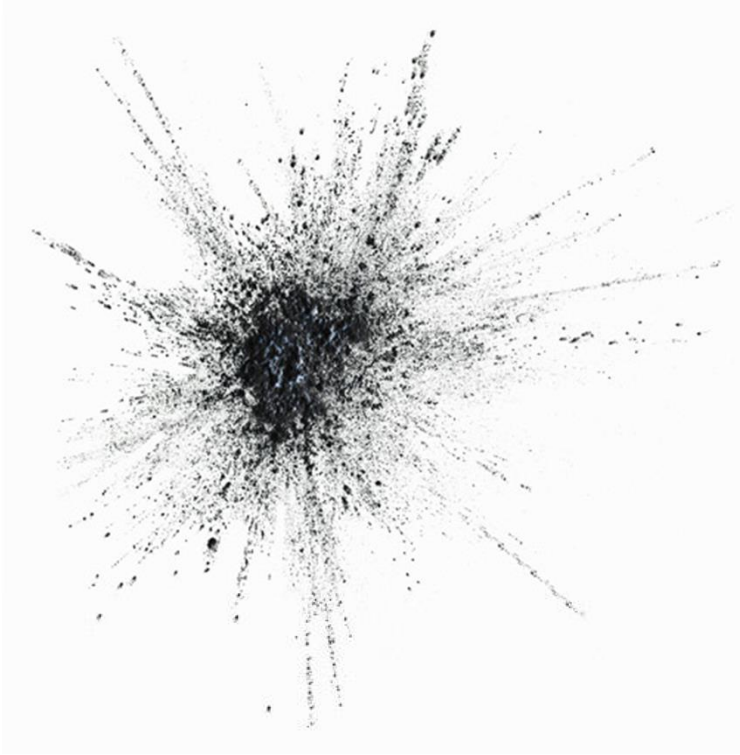
# Advanced Electro-thermal Purification

Continuous purification process utilizing temperatures in excess of 2400°C

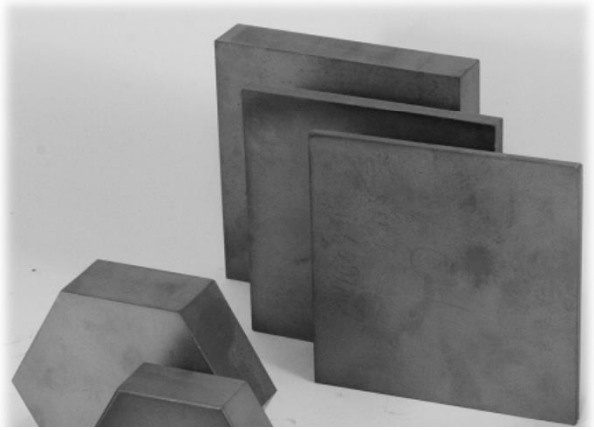
# Precision Processing -Grinding & Sizing

Engineered granular particulates processed from various carbon precursors



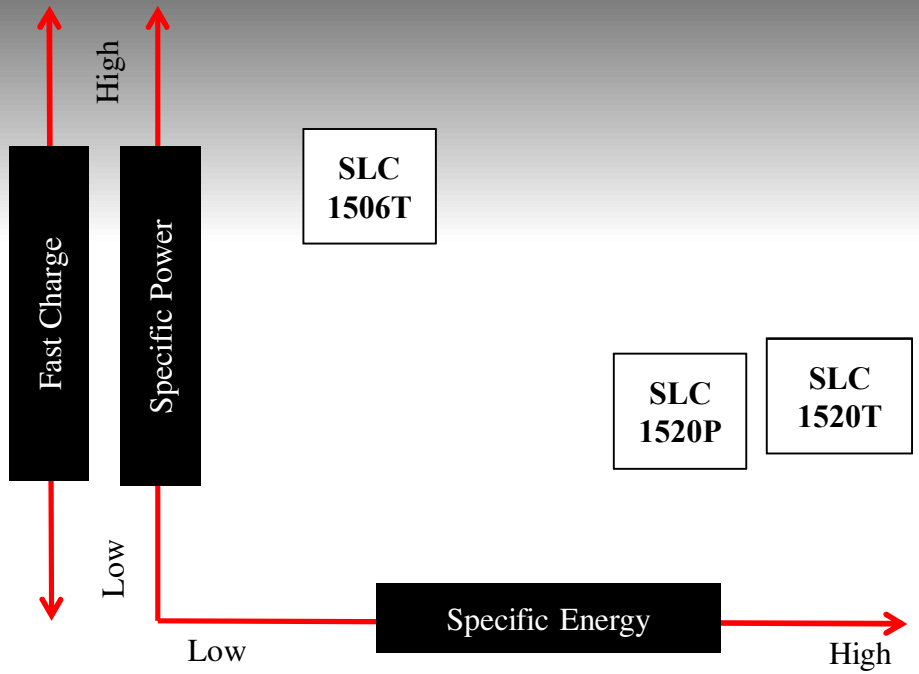
# Advanced Ceramic Shapes & Powder

Processing of α-SiC, β-SiC and B4C



# Markets We Serve

# Anode Active Materials for Li-ion Batteries
## -- FormulaBT® SLC series




**All SLC grades have similar Cycle Life, Calendar Life, Temperature Range and Safety performance**

**Anode Active Materials for Li-ion Batteries**

The primary function of FormulaBT SLC grades is to be used as anode active materials for high energy/high power Li-ion batteries.

# Performance Criteria for Li-Ion Batteries

| Application | Energy Density by volume | Energy density by weight | Cycle life | Calendar life | High Power | High temp. 55 degC | Low temp. -10 degC |
|---|---|---|---|---|---|---|---|
| Portable (cell phones, laptop, tablets, etc.) | +++ | +++ | ++ | ++ | + | + | + |
| Power tools | ++ | +++ | +++ | ++ | ++ | + | + |
| E-Bikes | ++ | +++ | +++ | ++ | ++ | + | + |
| Small EV (scooters, 3 wheelers) | ++ | ++ | +++ | +++ | ++ | ++ | ++ |
| HEV | + | + | +++ | +++ | +++ | +++ | +++ |
| PHEV | +++ | ++ | +++ | +++ | +++ | +++ | +++ |
| EV's | +++ | +++ | +++ | +++ | ++ | +++ | +++ |
| Stationary | + | ++ | +++ | +++ | + | + | + |

| | |
|---|---|
| +++ | very important |
| ++ | quite important |
| + | not so important |

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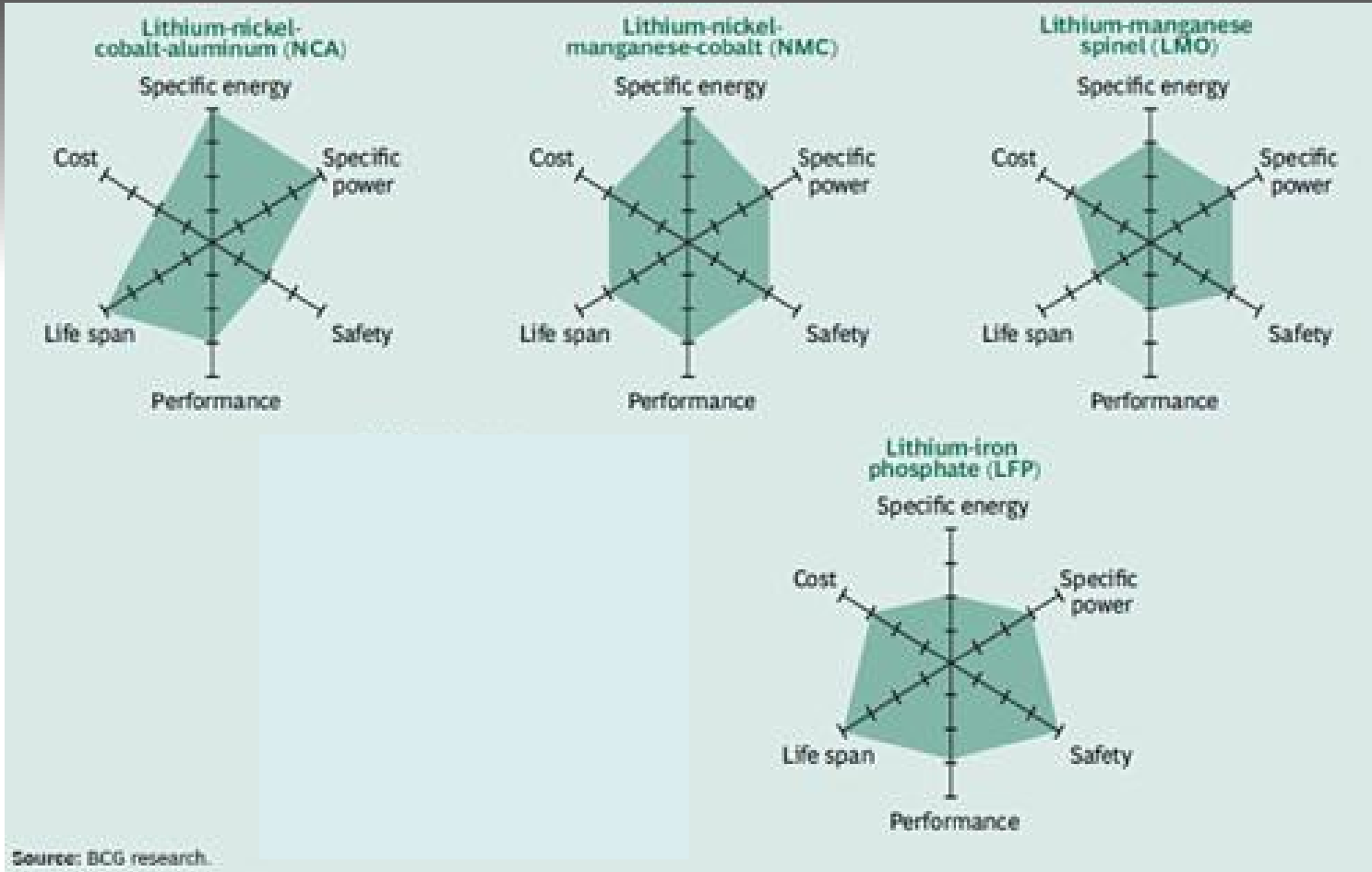
# Criteria for Cathode Materials

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# Anode Materials for Power Applications

| Anode | Capacity (mAh/g) | Advantage | Disadvantage |
|---|---|---|---|
| **MCMB** | 320-330 | Cost(-), Capacity | Cycle, Low Temp, Rapid charge |
| **Synthetic Graphite** | 300-320 | Cost, Capacity | Cycle, Low Temp, Rapid charge |
| **Natural Graphite** | 350-365 | Cost (+), Capacity (+) | Cycle(-?), Calender life (-), Low Temp, Rapid charge |
| **Hard Carbon/Soft Carbon** | 250-450 | High Rate, Longevity, Low Temp | Capacity, Initial Efficiency, Voltage delay |
| **Li4Ti5O12** | 150-170 | High Rate (+), Longevity(+), Low Temp(+), Safety(+) | Capacity (-), Cost |
| **Alloy anode type** | | | |
| **Li** | 1840 | High capacity | chemically unstable and dendrite chanllengs |
| **Sn** | 990 | | Large volume change during charging/discharging, unstable SEI |
| **Si** | 4200 | | |
| **Al** | 990 | | |

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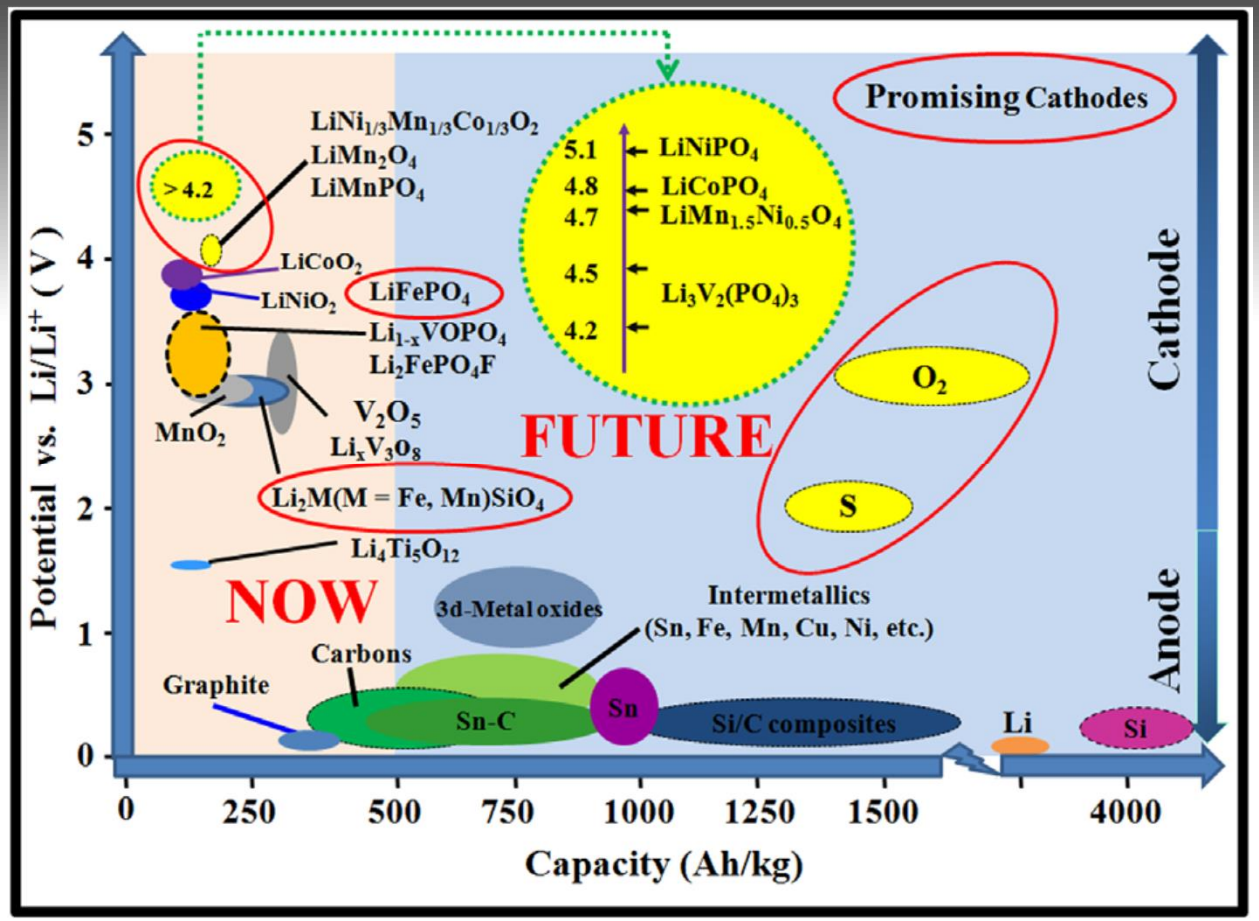
# Technical Trends in anode and cathode materials




Source: J.M. Tarascon,M.Armand,Nature414(2001)359

# Li-ion Battery Development

| Gene. | Cathode | Anode | Electrolyte | Time | Market |
|---|---|---|---|---|---|
| 1st | 4.2V $LiCoO_2$ | Coke | PC/DMC $LiPF_6$ | 1991- | CE |
| 2nd | 4.3 V $LiCoO_2$ | NG<br>AG<br>$Li_4Ti_5O_{12}$ | EC-DMC,<br>$LiPF_6$ | 1994- | CE |
| | $LiMn_2O_4$, | | | | EV |
| | $LiNi_{1/3}Co_{1/3}Mn_{1/3}O_2$ | | | | grid |
| | $LiFePO_4$ | | | | power tool |
| 3rd | 4.4-4.6 V $LiCoO_2$ | Soft carbon<br>Hard carbon<br>SnCoC<br>$SiO_x$<br>Nano-Si/C | **EC-DMC,**<br>**$LiPF_6$**<br>+ VC, FEC,<br>BP, ES, PS,<br>LiBOB, LiTFSI,<br>Silane, LiFSI,<br>Ionic liquid… | 2005- | CE<br>EV<br>HEV<br>Grid<br>Others |
| | $LiNi_{x\geq 0.5}Co_yMn_zO_2$ | | | | |
| | $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ | | | | |
| | $LiFe_{1-x}Mn_xPO_4$ | | | | |
| | $xLi_2MnO_3$-$Li(NiCoMn)O_2$ | | | | |
| | $LiNi_{0.5}Mn_{1.5}O_4$ | | | | |

What are the fourth generation Li-ion batteries?

Source: Journal of The Electrochemical Society 162(14):A2509-A2528

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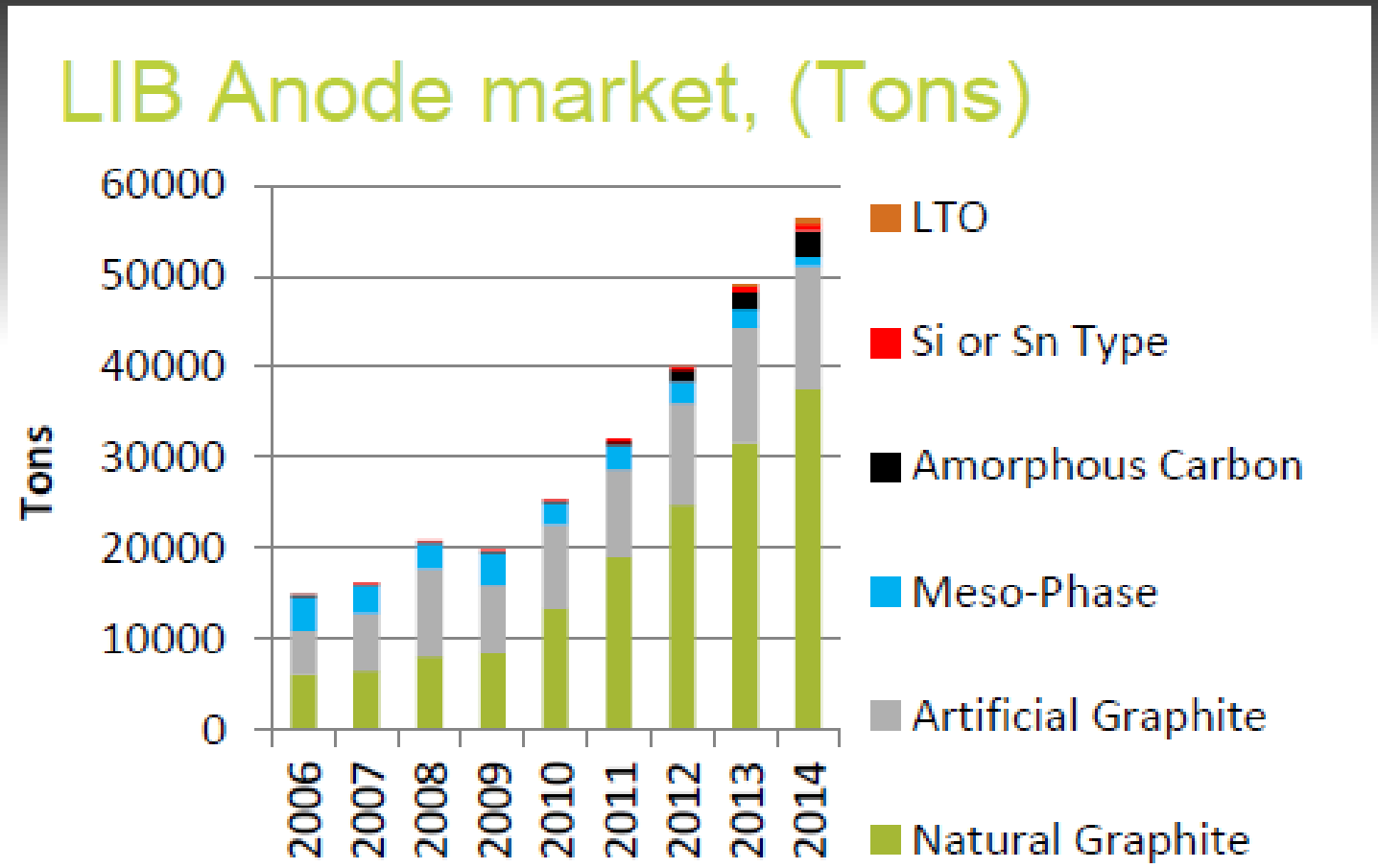
# Anode Materials Market 2006-2014




From: Avicenne Energy, Qinghai EV Rally 2015

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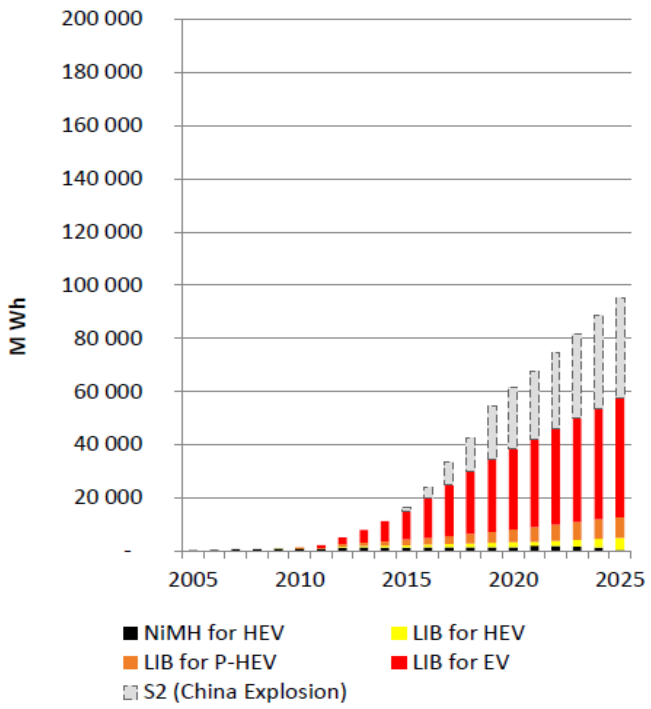
# Total Battery Forecast

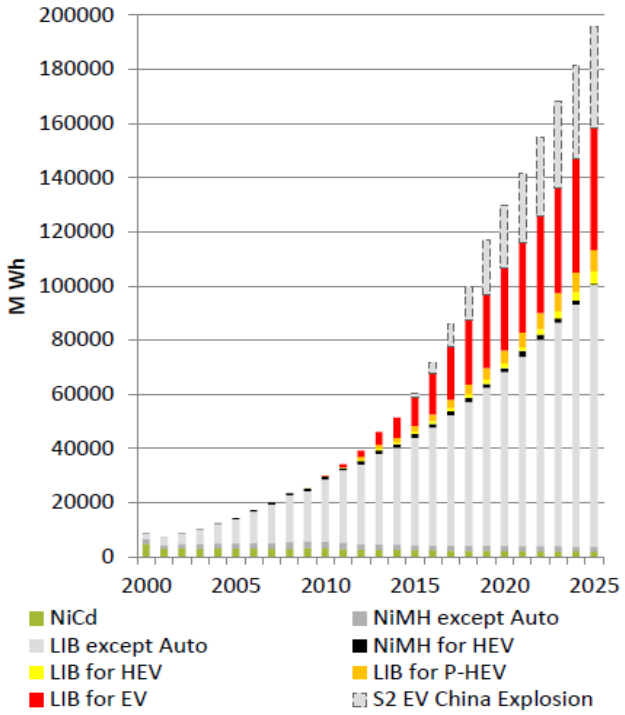
## TOTAL BATTERY DEMAND 2025 FORECASTS

**Scenario 2: thanks to very high incentives, China could change the game**

EV, HEV & P-HEV Battery needs (MWh)
CAGR 2014-2025: +16% / S2:+22%




Total battery demand (MWh)
CAGR 2014-2025: +11% / *S2: +13%*




Source: ICBR 2015, Avicenne Energy

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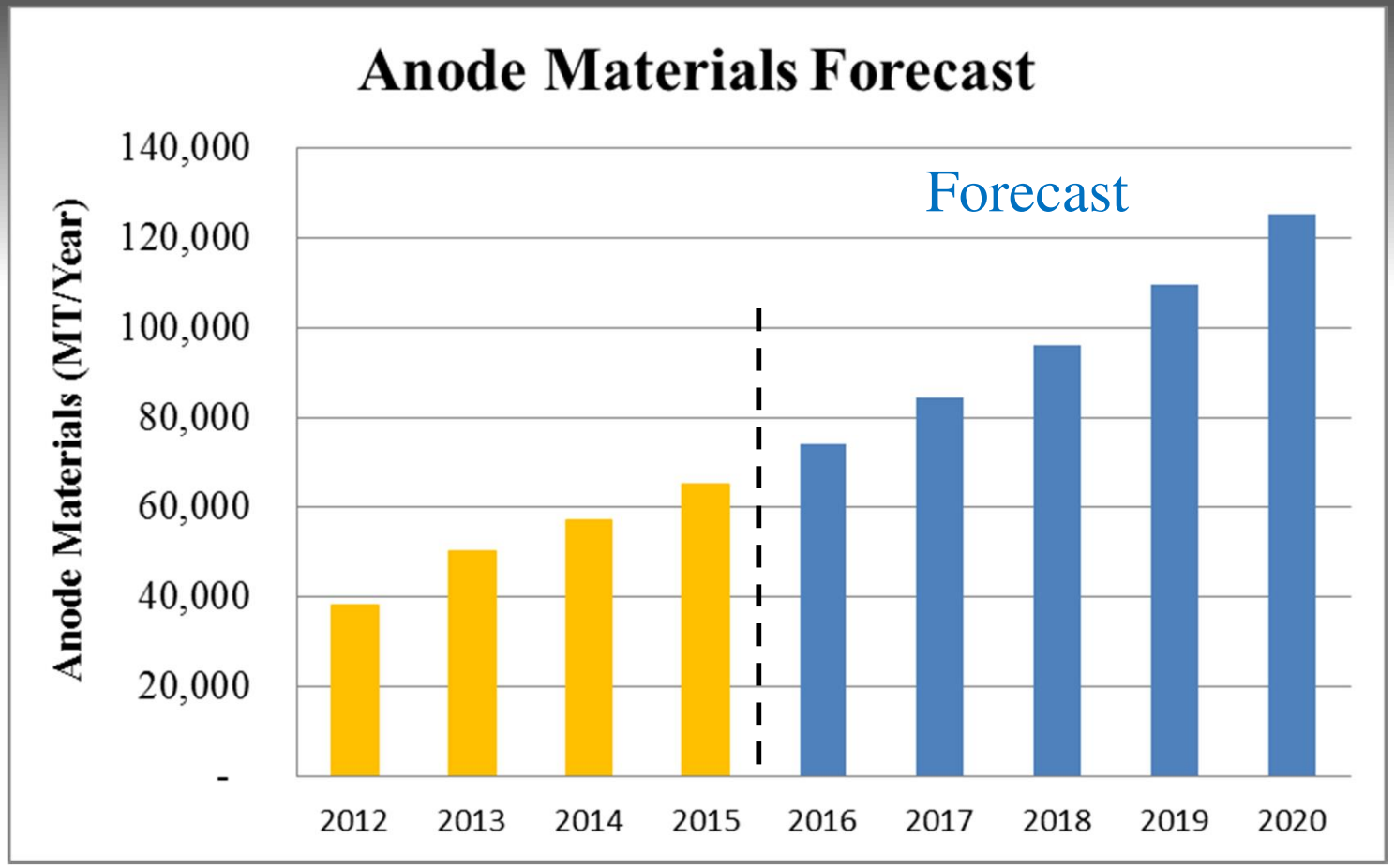
# Anode Material Forecast 2016-2020

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# Questions

**Electro-Thermal Purification • Graphite Electrodes • Ceramics Materials • Coatings • Precision Processing**


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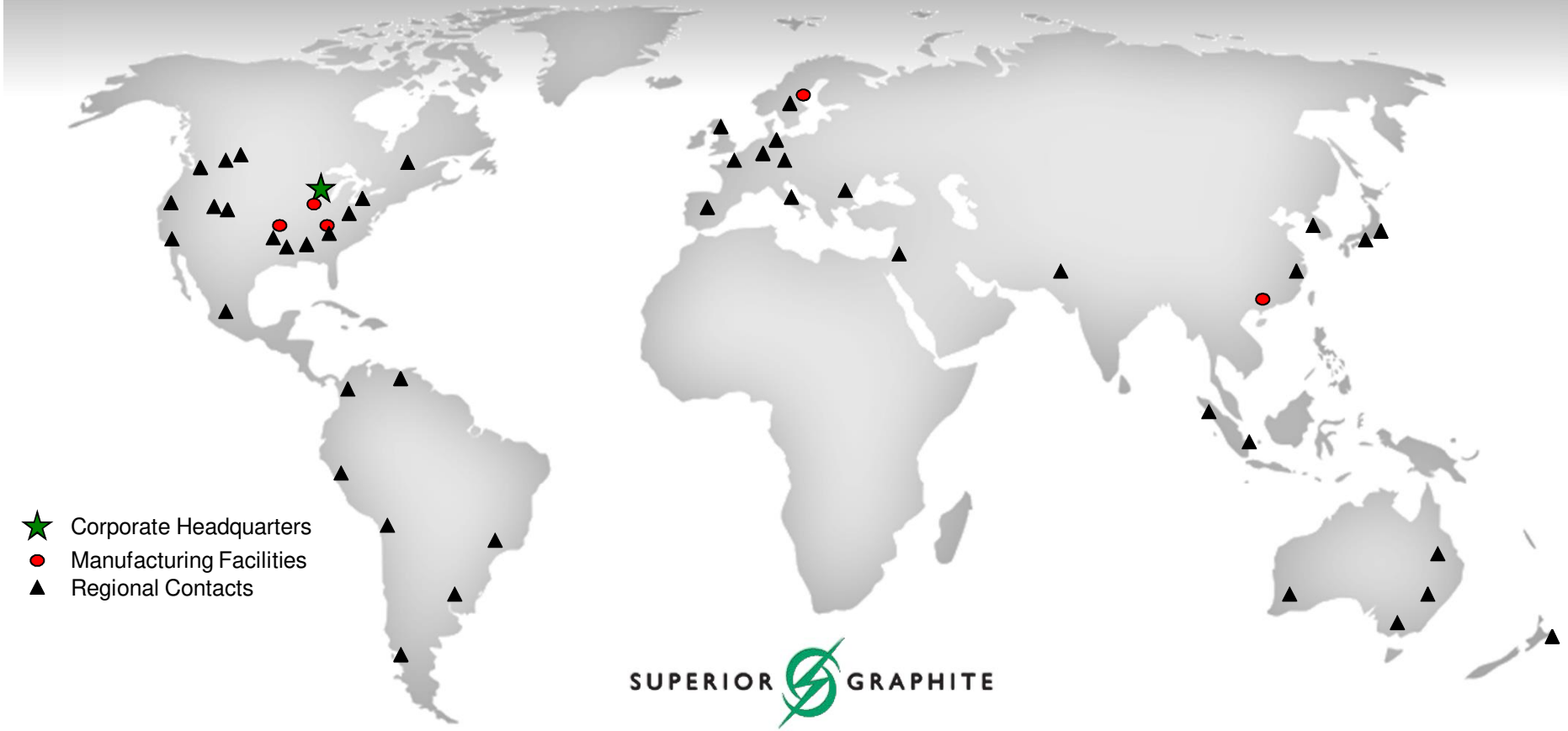


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