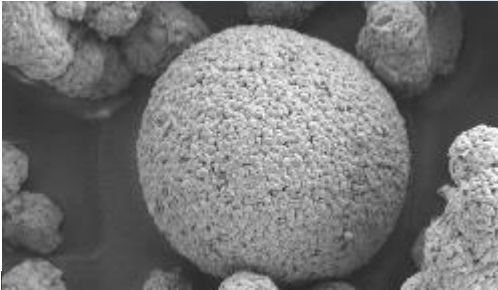




DoE Battery Critical Materials Supply Chain Opportunities Workshop



Manufacturing of Battery Critical Materials

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June 29, 2020

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Three Major Li-ion Battery Markets



Industrial Stationary

Evolving market, ~20% CAGR



Transportation

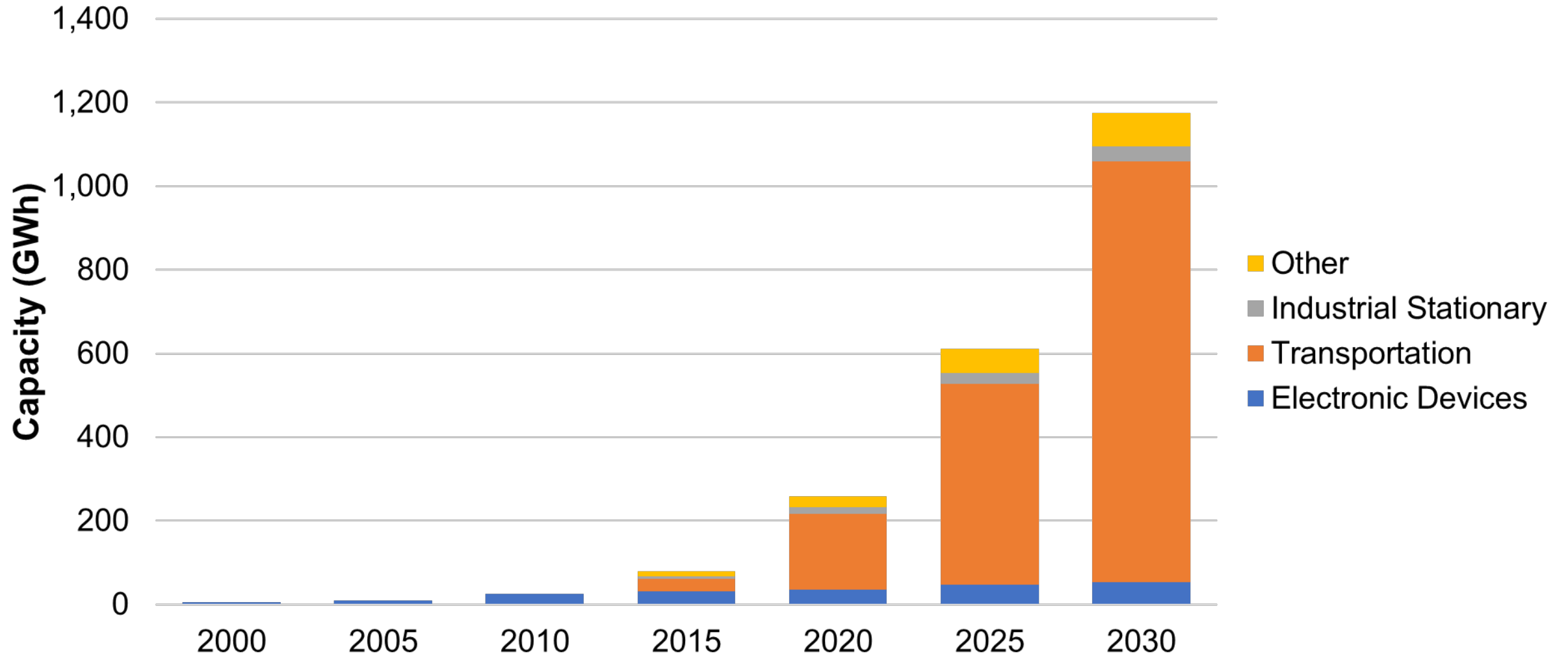
Rapidly growing market, ~30% CAGR



Electronic Devices

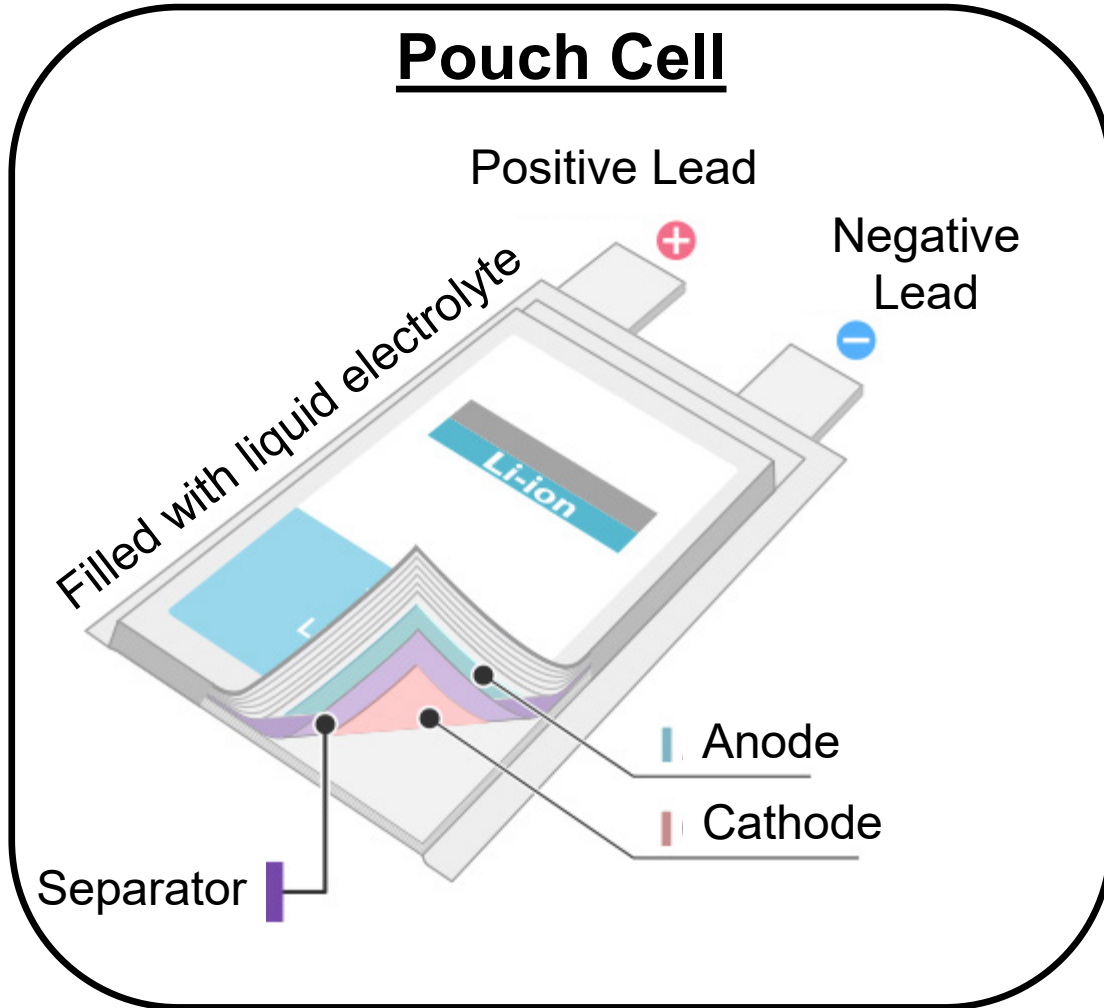
Mature market, ~5% CAGR

Global Lithium-ion Battery Market (GWh)

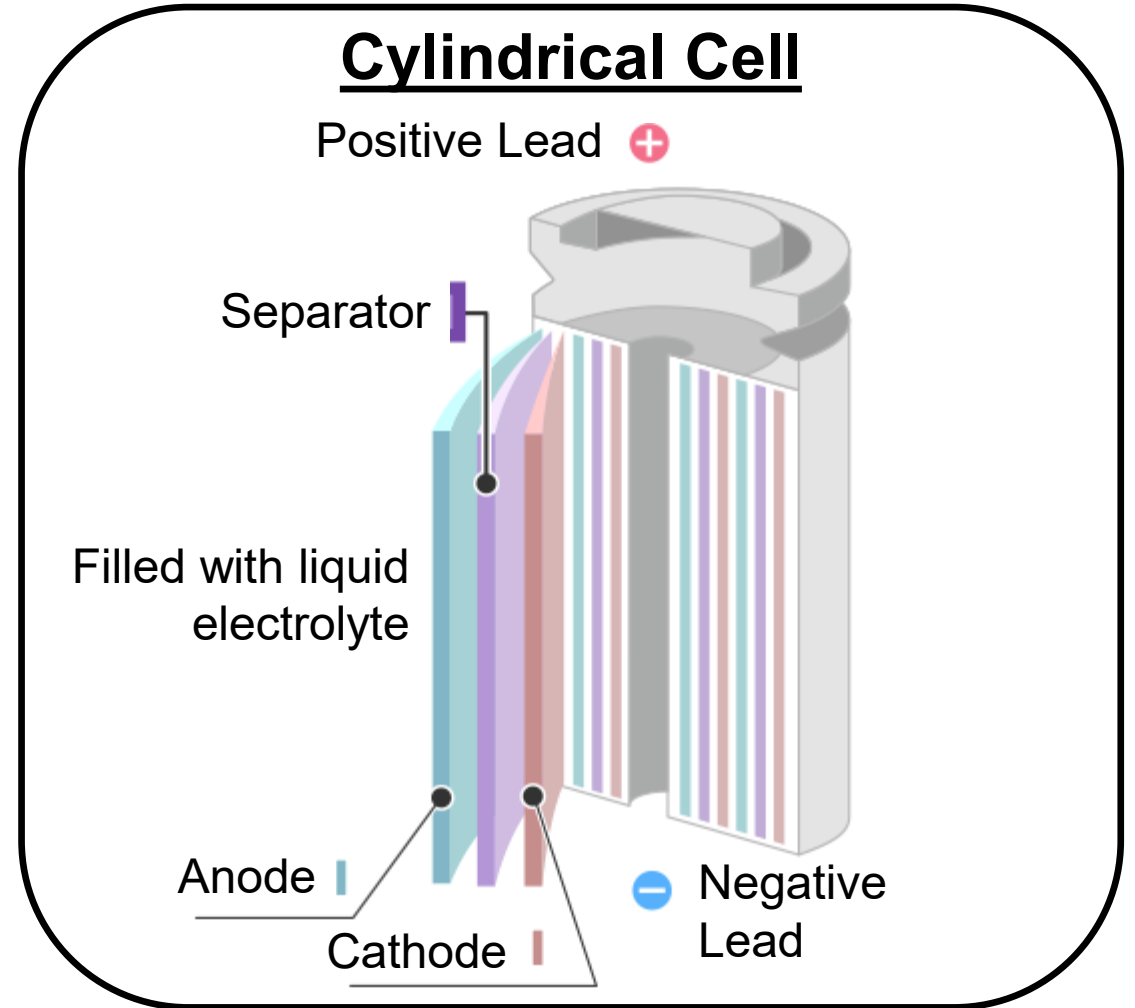


Anatomy of a Li-ion Battery Cell

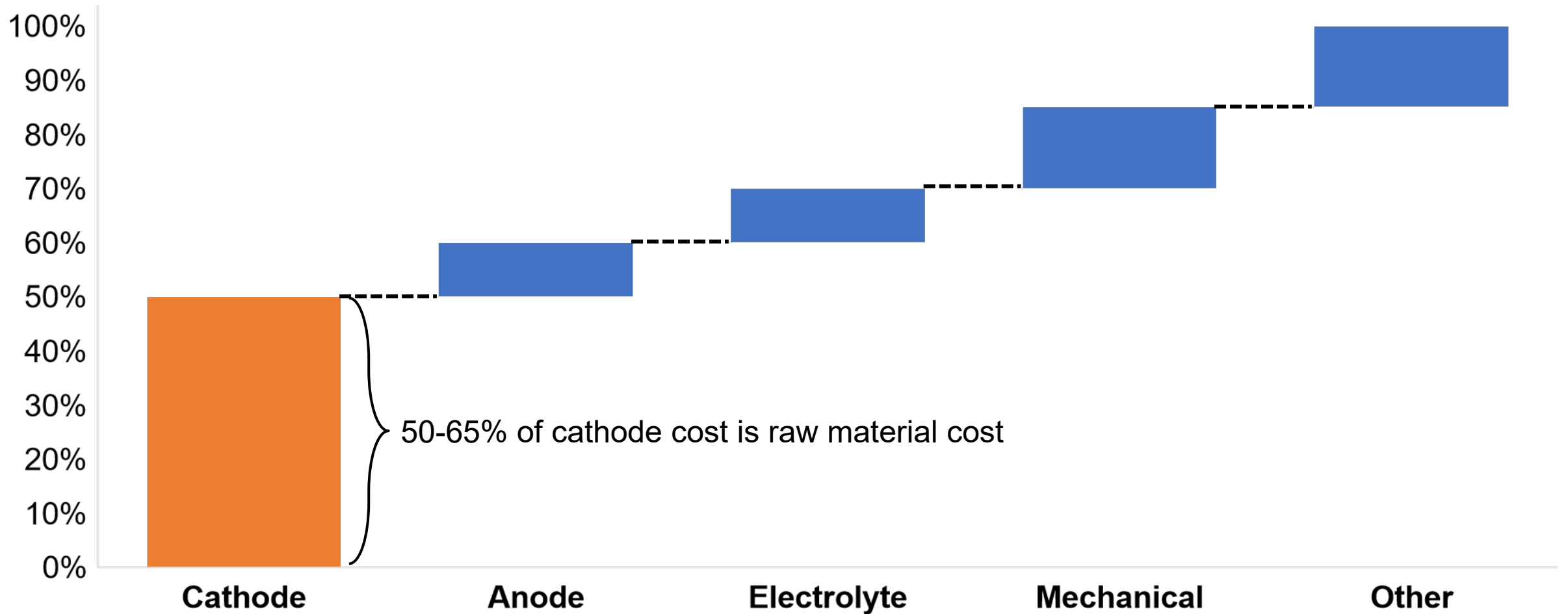
Pouch Cell



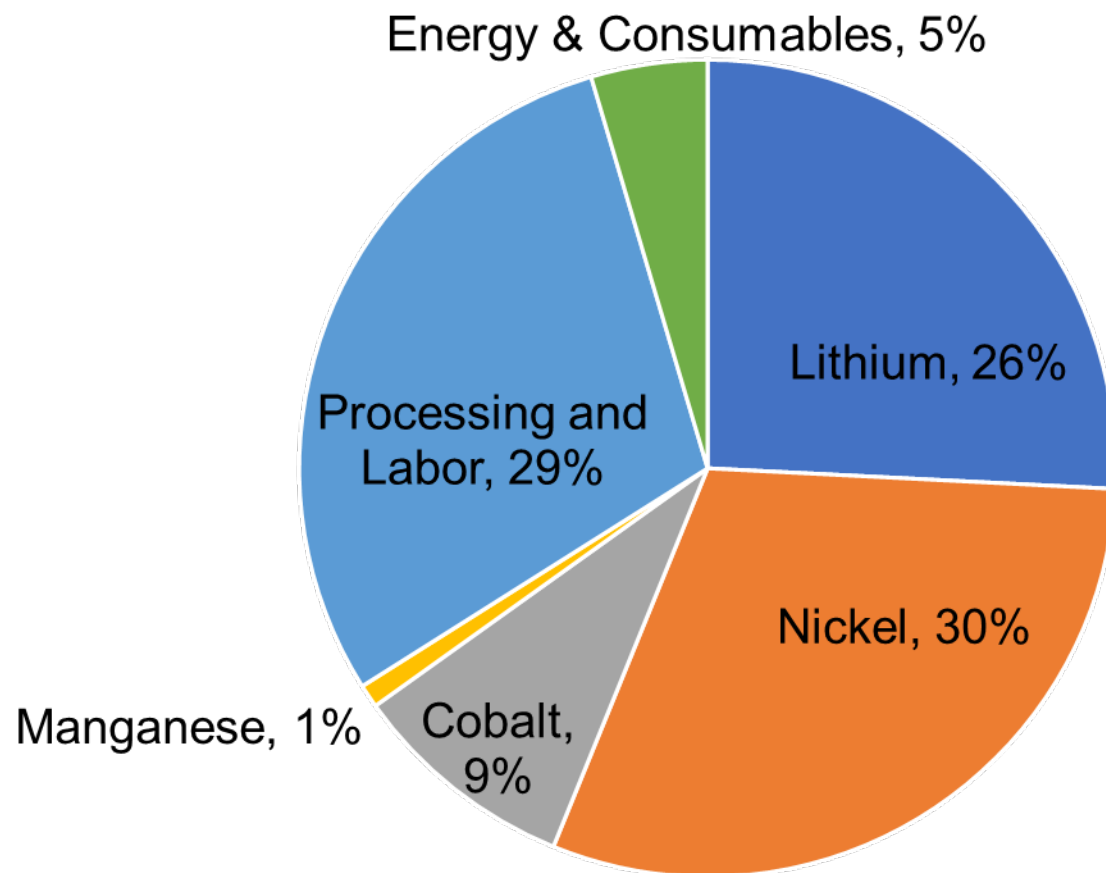
Cylindrical Cell



Contributions to Cell Cost



Lithium and Metals Comprise 65% of the NMC811 Cathode Cost



Transportation cost of cathode from the source to the cell production site is not included

How to achieve cost reduction across the supply/manufacturing chain?

- Significant economies of scale in the supply and procurement of critical metals.
- Significant economies of scale in plant size and the production of materials and cells.
- Reduced transportation costs through vertical integration and co-location of facilities.

Global EV and Battery Cathode Markets

<u>Year</u>	<u>Global EV Sales</u>	<u>Global EV Market (\$)</u>	<u>Global Li-ion EV Cathode Market (\$)</u>	<u>Global Li-ion EV Cathode Market (tons)</u>
2020	~2 MM	~\$80 B	~\$5 B	~200,000 tons
2025	~10 MM	~\$400 B	~\$25 B	~1,000,000 tons
2030	~25 MM	~\$1 TN	~\$65 B	~2,500,000 tons
2035	~50 MM	~\$2 TN	~\$130 B	~5,000,000 tons

\$ 25/kg cathode powder

Assumption: 300 mile EV range → ~ 100 kg cathode/EV → **~\$ 2,500 cathode/EV**
~\$ 40,000 / EV

How much of this market do we want supplied domestically?

- Li-ion batteries are strategic products that are widely used by critical infrastructure sectors (e.g., defense, energy, emergency services).
- The cathode material drives the cost and performance of Li-ion batteries.
- High-nickel cathode material is key to high performance Li-ion batteries, especially for EVs.

US EV and Battery Cathode Markets

<u>Year</u>	<u>US EV Sales</u>	<u>US EV Market (\$)</u>	<u>US Li-ion EV Cathode Market (\$)</u>	<u>US Li-ion EV Cathode Market (tons)</u>
2020	~0.3 MM	~\$12 B	~\$1 B	~30,000 tons
2025	~1.5 MM	~\$60 B	~\$4 B	~150,000 tons
2030	~4 MM	~\$150 B	~\$10 B	~400,000 tons
2035	~8 MM	~\$300 B	~\$20 B	~750,000 tons

Assuming 15% of Global Market

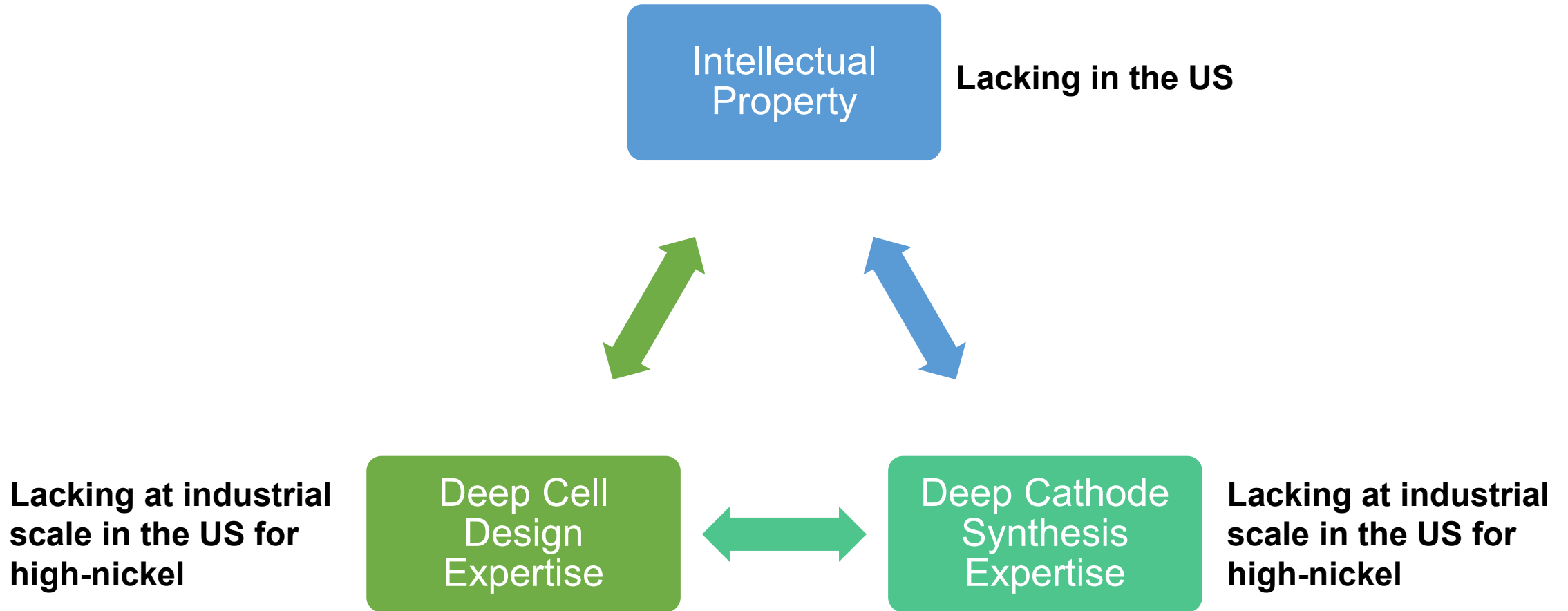
- + The cathode market for electronic devices and industrial stationary storage
- + The large supply of cathode material for the current DoD electrification program

What would it take to have cathode production in the US in 2025?

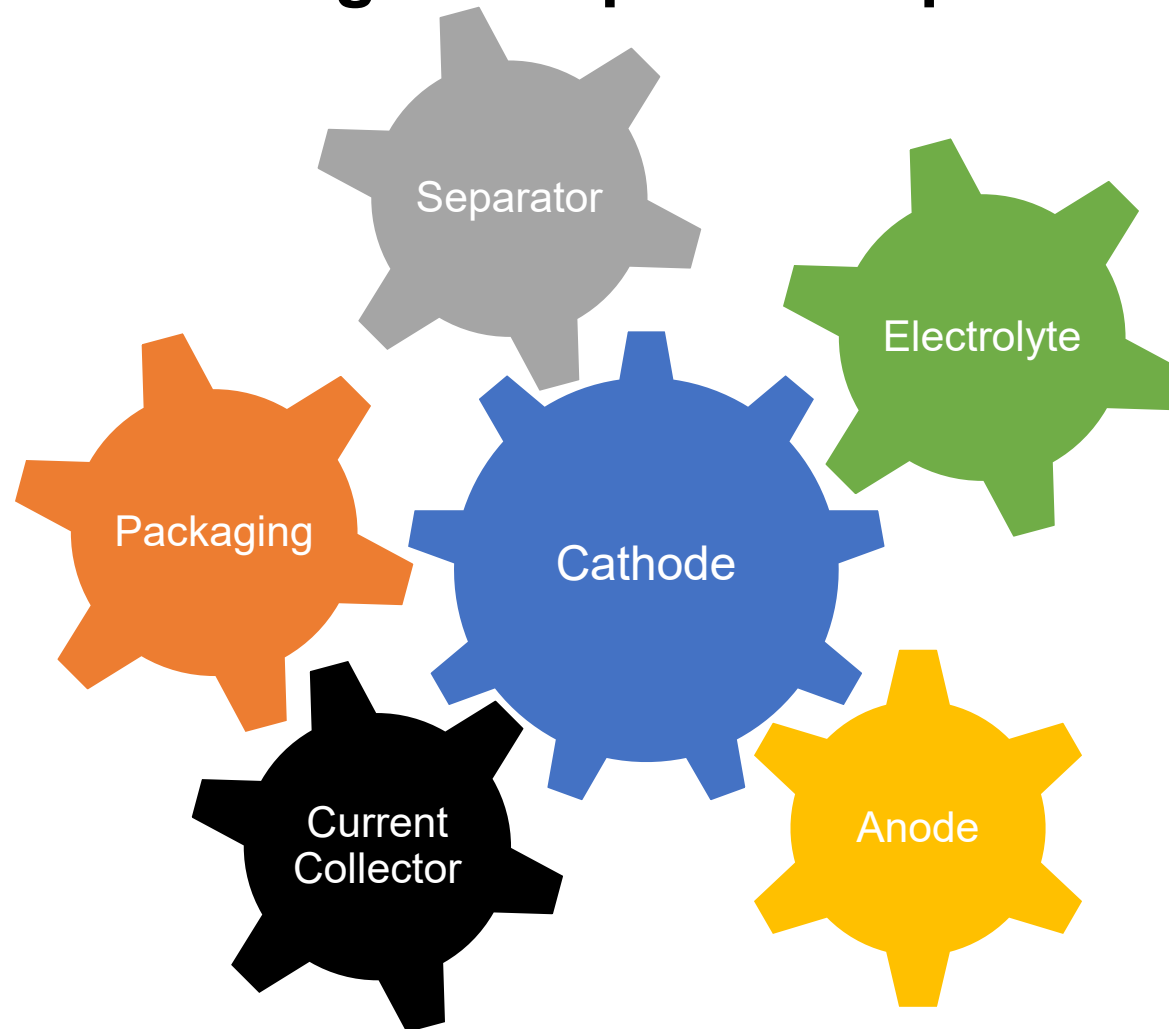
- CAPEX

- 150,000 tons by 2025 increasing to 400,000 tons by 2030
- At 10,000 metric tons/year per cathode plant → ~ 15 cathode plants by 2025
- At ~ \$50 MM CAPEX per cathode plant → Less than ~ \$1 B investment to make cathode in USA
- For at least a \$5 B US cathode market per year (allowing for DoD, stationary, and electronics)

What else is necessary for US cathode manufacturing in addition to CAPEX and demand?



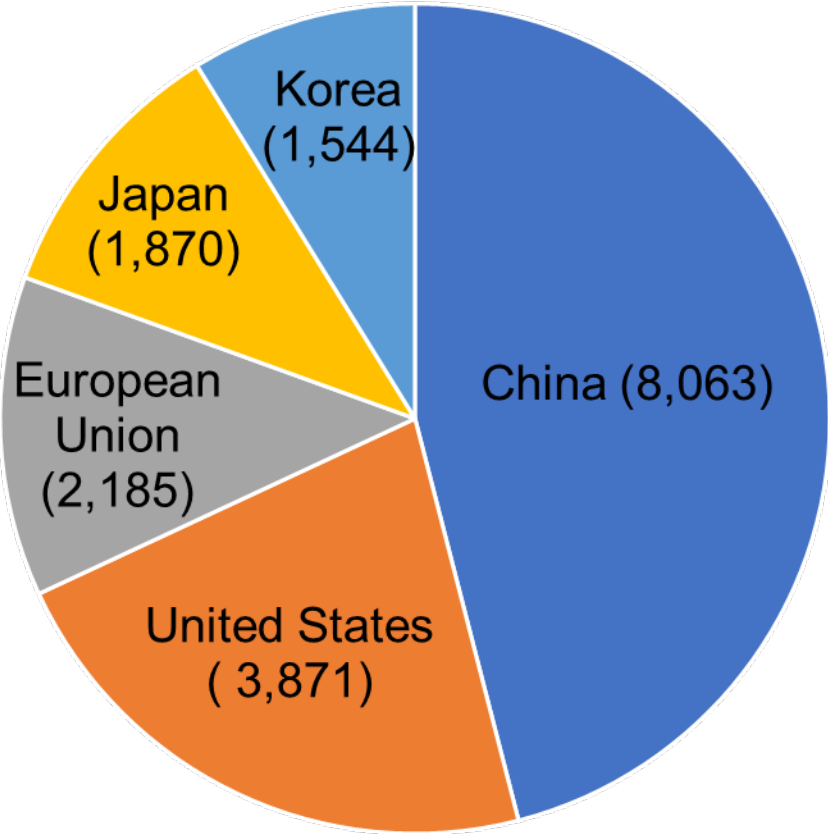
Deep cell design knowledge is required for precise component control.



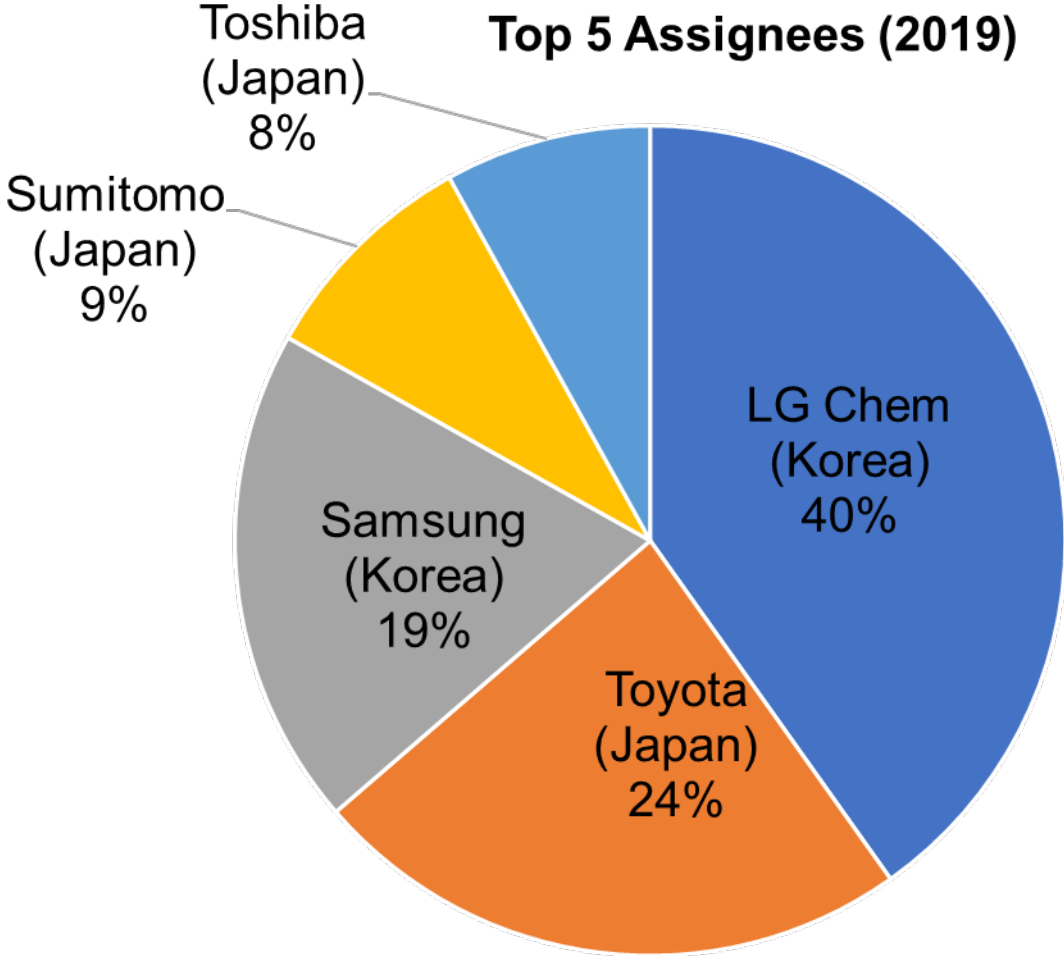
There are multiple choices for each component

2019 Li-ion Battery Patent Landscape

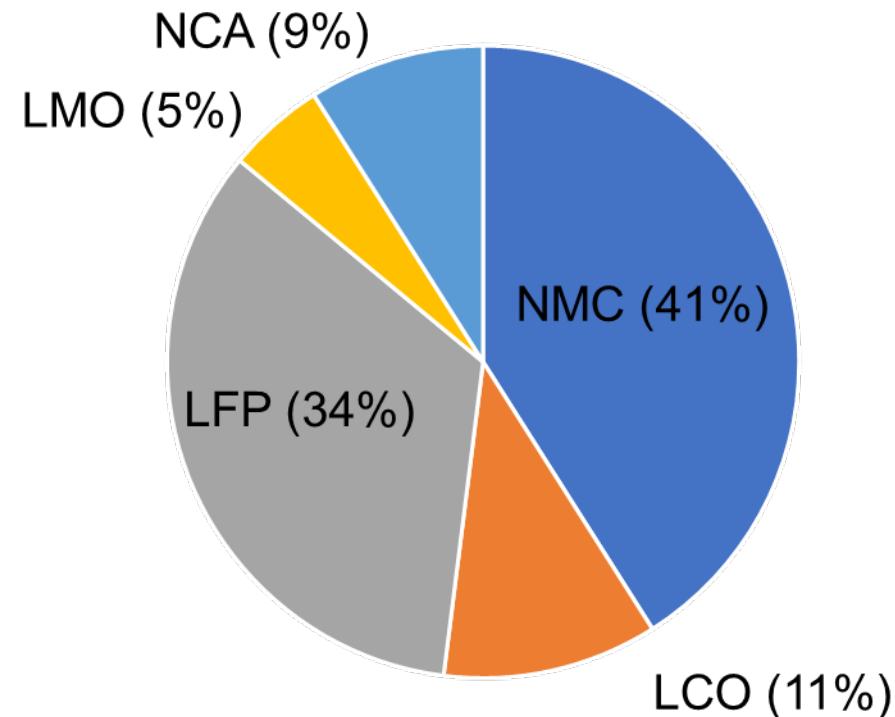
Top 5 Patent Offices (2019)



Top 5 Assignees (2019)



Current Cathode Material Market Share



- Key cathode active materials were invented in the USA.
- The compositional patents have either expired or will soon expire.
- Key processing patents of these materials are held by foreign companies.

About CAMX

Intellectual
Property

**CAMX has global
composition IP in
high nickel classes**



**CAMX has deep cell
design expertise
(multiple ongoing DoD
demonstration
programs)**

Deep Cell
Design
Expertise



Deep Cathode
Synthesis
Expertise

**CAMX has a functioning
industrial pilot plant in
Massachusetts**

Manufacturing of Battery Critical Materials

- The CAMX-invented GEMX™ cathode platform is based on engineering grain boundaries to overcome the problems associated with high-nickel, low-cobalt cathode materials.
- The GEMX™ cathode platform applies to all high-nickel materials, in particular NCA, NMC, and LNO.
- The GEMX™ cathode platform is protected by granted patents worldwide.

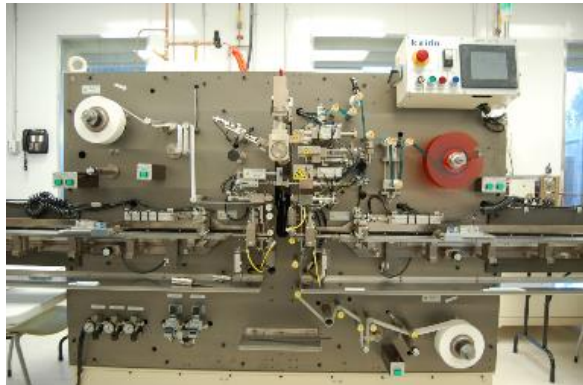
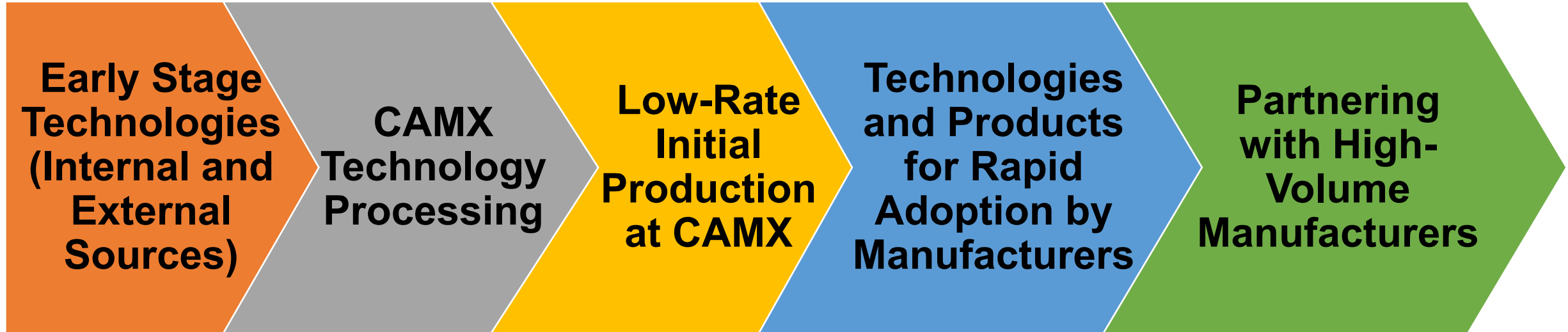
gNCA™	gNMC™	gLNO™
➤ gNCA™ demonstrates similar performance as conventional NCA (15 mol % Co) but with significantly less Co	➤ gNMC™ with 10 mol % Co exhibits superior performance compared to commercial NMC(811)	➤ gLNO™ has best combination of capacity and life

Patents are valid beyond 2030

The GEMX™ Cathode Platform in the Market

- Recently Samsung **ACQUIRED** a global license to the GEMX™ cathode platform.
 - Samsung is already selling cells with GEMX™ equivalent cathode material in the US and internationally.
 - Samsung and a Korean partner are adding a 150,000 ton capacity to an existing 30,000 ton plant in South Korea to be completed by 2023.
 - CAMX believes a significant fraction of this capacity will be dedicated to gNCA™ and gNMC™ equivalent cathode materials.
- Previous licensees of GEMX™ include Johnson Matthey and of CAMX's earlier cathode platform CAM-7®, BASF and Johnson Matthey.

CAMX Business Model



- De-Risked
- Scaled-up
- IP-Protected
- Accelerated Growth
- Shortened Time to Market & Profitability
- Lower Risk & Cost
- CAMX Staff Engageable for Interactive Technology Transfer

- It is strategically important and economically viable to have cathode production in the US.
- The investment required is modest compared to the size of the market and its strategic importance.
- CAMX is well-poised to partner with domestic companies for rapid creation of a domestic cathode supply chain for US and international markets.

For inquiries info@camxpower.com