Close of Business Tuesday: Batteries

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Chris Mohajer
Director
713-343-0648
cmohajer@uscallc.com

Please see important disclosures beginning on page 14.

Media Disclosures

Battery Companies: FLNC, FREY, STEM

	Yes	No
Stock Ownership		
Analyst		X
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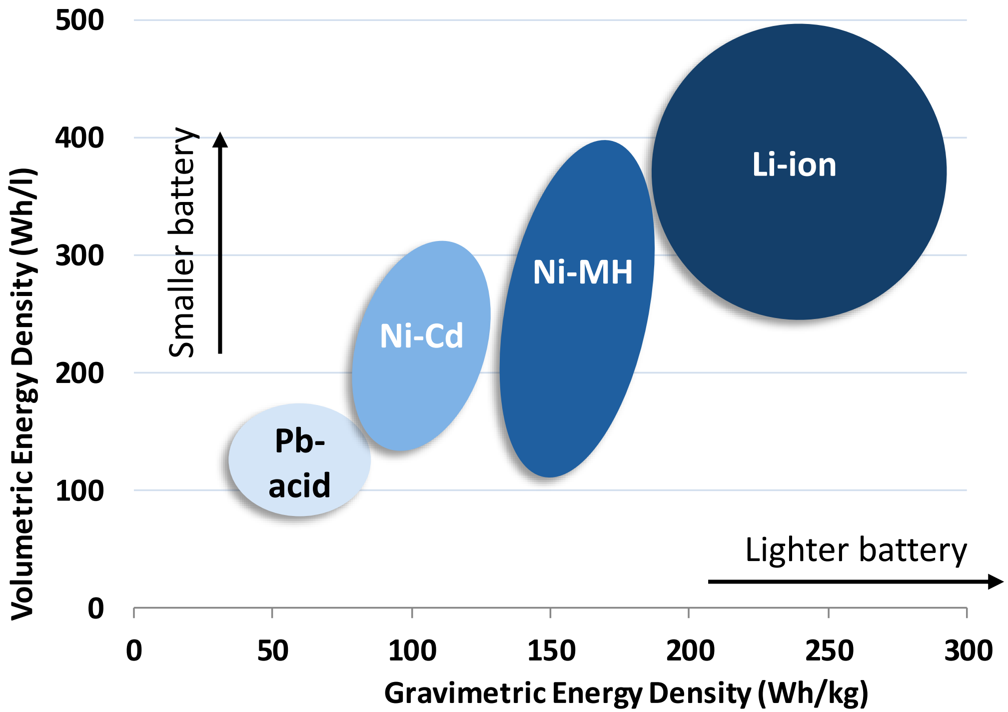
Battery Chemistries

- **Chemistry:** Over the years, the industry has invented a variety of battery chemistries. The four main rechargeable ones are detailed here. The new chemistries have produced both smaller and lighter batteries.



- **Pb Acid:** The Lead acid battery was invented in 1859. This was the first rechargeable battery. You can find a Lead acid battery in almost every car, plane, boat, and submarine.
- **Ni-Cd:** Nickel Cadmium batteries were commercialized in 1946. They were the only choice for portable radios and electronics until Lithium-ion came along in the 1990s. They are used today in niche aerospace applications.
- **Ni-MH:** The other prominent Nickel-based chemistry is Nickel-metal-hydride (NiMH). This was historically used by the Toyota Prius and other hybrid vehicles.
- **Li-ion:** Introduced in 1991, the Lithium-ion battery was one of the enabling technologies behind the consumer electronics revolution. ***It is the enabling technology behind electric vehicles.*** It's what we'll focus on for the rest of the presentation.

Source: Nature, USCA

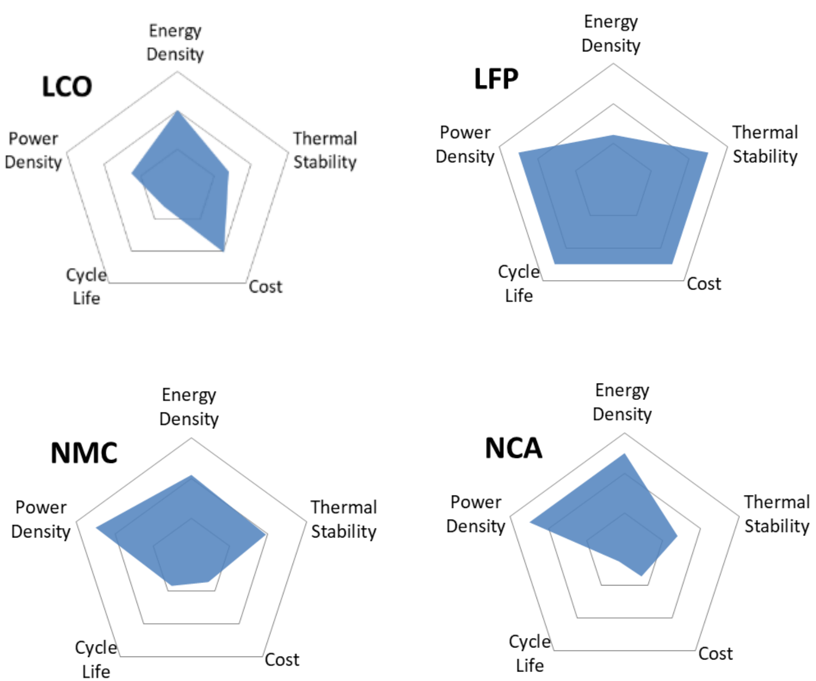
Is This Battery Any Good?

- **Battery Metrics:** There are several metrics that are used to measure battery performance. It's easy to make a battery excel in any one of these metrics. The trick is to optimize the tradeoffs for the specific application. Improving one property often comes at the expense of another.
- **Selective Disclosure:** A battery company will often share the metrics that make them look good while leaving out the metrics that make them look bad. There is a saying in the battery industry given that many have a penchant for stretching the truth: ***"liars, damn liars, and battery suppliers".***
- To help understand these metrics, we will describe some of them in the context of an EV:
  - **Volumetric Energy Density:** For a given space, how much range can my battery provide?
  - **Gravimetric Energy Density:** For a given weight, how much range can my battery provide? (Also called Specific Energy.)
  - **Power Delivery:** How fast can I charge? How fast can I discharge (accelerate)?
  - **Thermal Stability:** Is the battery ok at room temperature? Do I need to heat or cool it?
  - **Cycle Life:** How many times can I charge and discharge my battery before it dies?
  - **Calendar Life:** How many years will pass until my battery dies?
  - **Self Discharge:** If I leave my EV at the airport for a week, how much range does it lose?
  - **Energy Efficiency:** If I put 10 kWh in my battery pack, how much can I get out?
  - **Cost:** How much do I have to pay for the battery?
  - **Safety:** Under what conditions will it go catch fire or go boom?

Source: USCA

Cathodes – Why You Can’t Have It All

- **Cathodes Are What Differentiate Current Li-ion Batteries:** There are many different types of Lithium-ion batteries. When you hear about different technologies, you are often hearing about the different cathode chemistries.
- **Different Cathodes Have Different Tradeoffs:** Some chemistries are safer, some have more power, and some have more energy. ***Improving one property often comes at the expense of another.*** There is no one cathode to rule them all. Different applications have different requirements. ***It depends on what you are optimizing for.***
- The most common Li-ion cathodes are:
  - **LCO**: Lithium Cobalt Oxide – Popular in consumer electronics.
  - **LFP**: Lithium Iron Phosphate – Popular in power tools and stationary storage. Having a resurgence in low cost EVs. Slowly moving upmarket.
  - **NMC**: Nickel Manganese Cobalt Oxide – Default choice for EVs to date.
  - **NCA**: Nickel Cobalt Aluminum Oxide – Used by Tesla in most vehicles.
- **Cobalt Concerns:** All the above chemistries except for LFP use Cobalt. ***Most manufactures are trying to reduce their Cobalt content due to ESG concerns.*** Over 70% of Cobalt comes from the DRC (Democratic Republic of the Congo). Unfortunately, some of it is mined by hand by children. The euphemism for this type of extraction is “artisanal mining.”
- **Spider Charts:** The industry typically uses spider charts to visually highlight the tradeoffs being made. The outer rings of the charts indicate better values.
  - For example, the cathodes used in EVs (NCA & NMC) both emphasize energy density at the expense of cost and cycle life.
  - LFP emphasizes power density and cost at the expense of energy density.



Source: USCA, USGS, RMI

Anodes – Searching for the Next Big Thing

- **Graphite:** Most anodes today are graphite. The anode hasn't seen many changes in the past 40 years. The graphite is either mined (flake graphite) or it is distilled from petroleum coke (synthetic graphite).
- Silicon and Lithium Metal are competing to be the next anode material. They both could offer large performance improvements. Which one will prevail?
    - **Silicon:** Silicon would make a more performant anode compared with graphite, but it swells after repeated cycling. This swelling eventually makes the battery go boom. There are a few companies (Amprius, Enevate, Enovix, Sila Nano, and more) trying to solve this issue with a variety of innovative methods. In the meantime, companies have started to sprinkle small amounts of Silicon in their graphite anodes to increase performance. Tesla has around 5% Si in their anodes.
    - **Lithium Metal:** Li Metal has the highest theoretical energy density, but there are hurdles impairing the commercialization. Stan Whittingham's battery in the 1970s had a Li Metal anode, but dendrites would form and short out the battery. This is one of the many issues that still needs to be solved before these batteries are ready for prime time.

      The most promising way to enable the safe commercialization of Li Metal anodes is with introduction of solid-state batteries. Solid-state batteries switch out the flammable liquid electrolyte with a safer solid electrolyte. Companies in the space include Quantumscape, Solid Power, and SES. Some companies, like Cuberg, are making Li Metal anodes with liquid electrolytes.

Anode Comparisons

Anode Material	Specific Capacity (mAh/g)	Volume Change (%)	Benefits	Challenges
Graphite	372	10	Stable; widely used	Poor energy density
Silicon	3600	320	High energy density	Capacity fade due to damage from expansion and contraction
Li Metal	3862	None	Highest energy density; light	Unstable; slow charge rate

Source: USCA, ACS, ANL BatPaC, Argus, Company Reports

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A123 Case Study

- **Case Study:** A123 is a good example of how long it takes battery technologies to go from lab to market.

10 years from lab to market (1996–2006)

1996	Researchers propose LFP for cathode
2001	A123 Founded
2006	Batteries shipped to first customer (Black & Decker)
2009	Awarded $249mm federal grant (ARRA) Largest IPO of the year with $371mm raised
2012	Chapter 11 Bankruptcy
2013	Wanxiang purchased majority of business ex-defense for $257mm. Navitas purchased defense business for $2mm.

- **Lab to Market:** It took A123 ten years to scale up the technology from the lab before it hit the market. That's fast! It took ~20 years for the first Lithium-ion battery to go from lab to market.
- **Were They Anomalous?:** Enovix was founded in 2007, and Quantumscape was founded in 2010. The companies are 16 and 13 years old, respectively. Enovix's batteries are just hitting the market. Quatumscape doesn't have a battery on the market yet.
- **Money Go Bye-Bye:** Despite raising $350mm in private capital, raising $371mm in an IPO, receiving a $249mm federal grant, and receiving $135mm in tax breaks, A123 filed for bankruptcy and was sold to a Chinese company in a matter of years.
- **Simply Put:** ***Commercialization is tough.***

Note: A real case study of A123 would include Fisker and GM.
Source: Company Reports, GreenTechMedia, Washington Post

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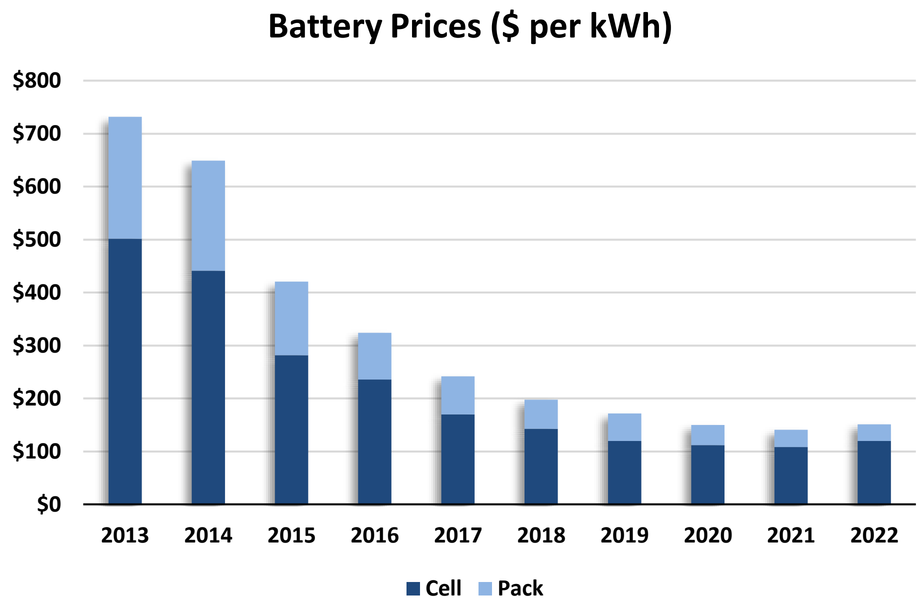
Batteries Are Getting Cheaper

- **Battery Pack Prices:** The volume weighted price of Li-ion battery packs for EVs has declined from $732/kWh in 2013 to $151/kWh in 2022.
- **Historical Prices**: Going back to 1995, the cell prices alone were $4,000 to $5,000/kWh. In 2000, cell prices were around $2,000/kWh. ***That's over a 90% price decrease in two decades!*** If you go back to 1991, the year the lithium-ion battery was first commercialized, prices have come down 97%.
- **The Exception:** 2022 was the first year that battery prices increased. The 7% increase was driven by rising prices of components.
- **Cell vs. Pack:** The cells have become a larger and larger percentage of the total price. The move to cell-to-pack architectures will accelerate this trend.



- **Volume Weighted Caution:** It's important to note that the caveats with volume weighing the prices. Large buyers like Tesla are skewing the average downward. Some automakers are paying over $200 per kWh for medium-sized contracts. Microvast's average selling price was $355/kWh in 2020. As Circular Energy Storage notes, smaller companies and startups can sometimes pay over $400/kWh. As an extreme example, a single cell bought online can be over $550/kWh.
- **Supply is Still Constrained:** Larger companies are securing supply. Smaller players are scrambling.

Note: Historical pricing data is volume weighted.
Source: BNEF, USCA, Company Reports, DOE, Circular Energy Storage, RSC, Our World In Data

Battery Minerals

- **IEA Forecasts:** The IEA put out their first ever *Critical Minerals Market Review, so* we wanted to take a look at the forecasted demand growth for several key battery minerals in different scenarios. Whether or not supply can keep up is a different question.
- **Context Required:** We only look at minerals required for EV batteries. Additional quantities of these minerals will be needed for stationary storage and other applications, but they end up being rounding errors. EVs are and will be the driver of battery minerals for the next few decades (if not forever). For Nickel, it's worth noting that a portion of demand will go towards the electric motor in an EV.
- **Two Scenarios:** The forecasted demand is based on two different scenarios. The first is the status quo assuming no new policies are put in place. The second looks at what it would take for the world to reach net zero emissions by 2050. The gap is massive.

Battery Mineral Demand (in thousand tons -kt)

	2022	2030		2040	
		Status Quo	NZE	Status Quo	NZE
Cobalt	65	74	188	105	244
Graphite	557	1,590	4,115	1,196	4,540
Lithium	69	228	592	433	1,106
Manganese	75	152	378	522	1,126
Nickel	323	988	2,414	1,516	3,451

Battery Mineral Demand (vs 2022)

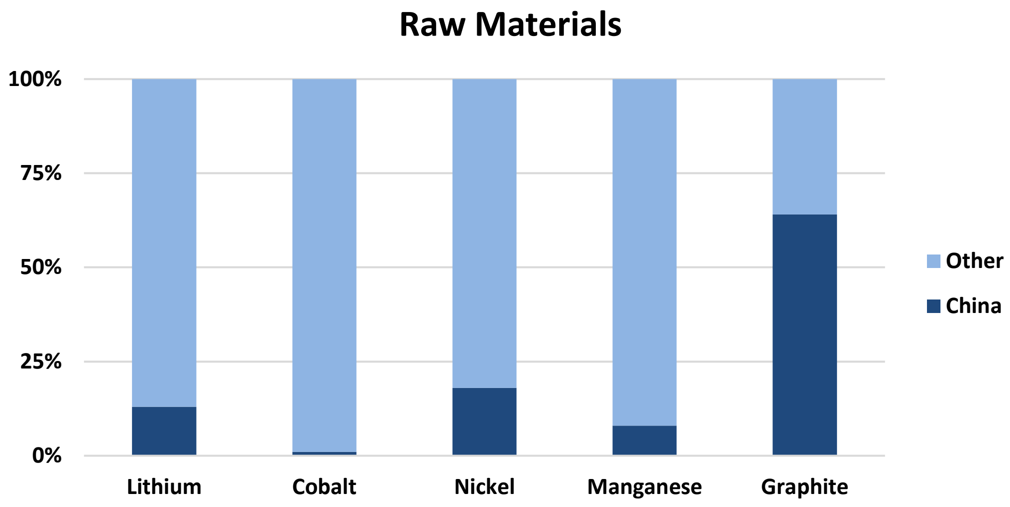
	2030		2040	
	Status Quo	NZE	Status Quo	NZE
Cobalt	1x	3x	2x	4x
Graphite	3x	7x	2x	8x
Lithium	3x	9x	6x	16x
Manganese	2x	5x	7x	15x
Nickel	3x	7x	5x	11x

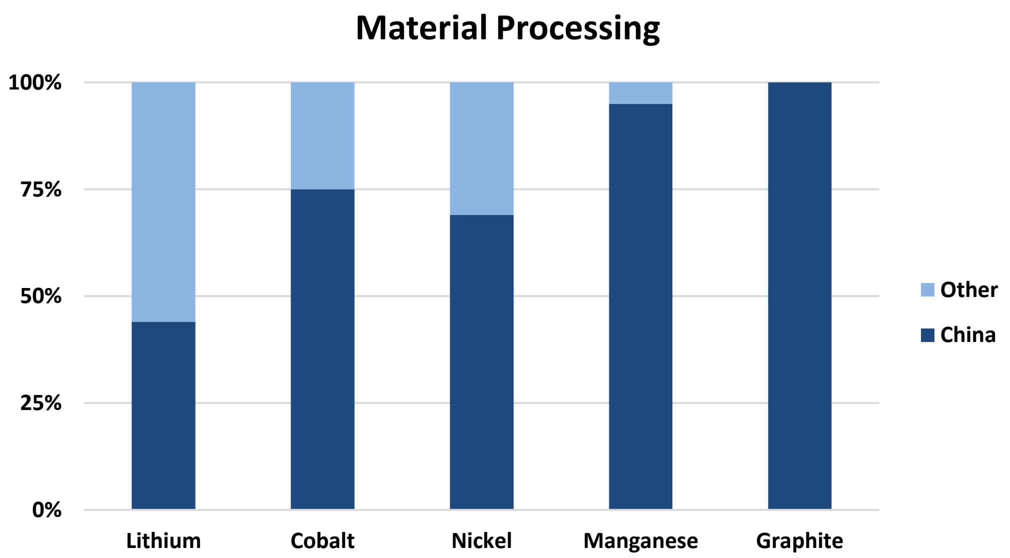
- **2030 Demand:** In both 2030 scenarios, lithium unsurprisingly has the strongest demand growth. While you can change cathode and anode materials in a battery for cheaper alternatives, you will always need lithium in a lithium-ion battery. Cobalt has the weakest forecasted growth thanks to long standing efforts to reduce cobalt concentrations in NMC/NCA cathodes and the push for LFP cathodes (which are cobalt free).
- **2040 Demand:** In the status quo scenario, graphite's forecasted demand actually decreases in 2040 when compared to 2030 thanks to battery anodes switching from graphite to lithium metal & silicon. Again unsurprisingly, lithium demand growth is the highest. It's forecasted to 16x by 2040 if we are going to meet our net zero emissions goals. That's a lot of new mines…

Source: USCA, IEA

The Supply Chain

- **Upstream:** While a lot of the media attention is on the raw materials, China only controls a small portion of the upstream (see top right chart).
- **Midstream:** That being said, China has a hold on the material processing (see bottom right chart) and the electrode production (78% cathode and 91% anode).
- **Downstream:** China also has a large share of the cell production (~70%), but that is starting to change.

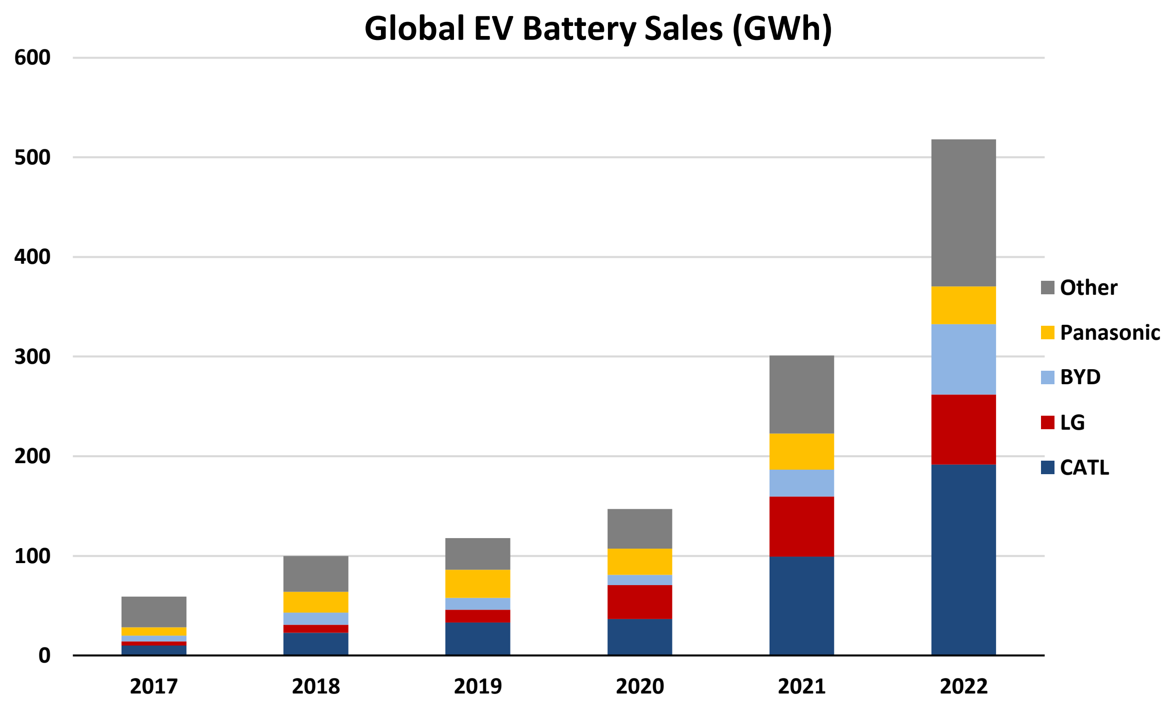




Source: Benchmark, Company Reports, USCA

Cell Manufacturer Market Share

- **Market Size:** Global EV battery sales have grown from 59 GWh in 2017 to 518 GWh last year with a CAGR of over 54%.
- **CATL's Rise:** Since 2016, CATL has been the largest provider for batteries for the EV space. They finished the year with 37% market share.
- **Japan's Fall:** The li-ion battery was commercialized in Japan by Sony. For years, Panasonic was the leader (in terms of tech and market share) in the EV battery space thanks to their deals with Tesla and Toyota. Now they are in fourth place with SK and Samsung coming up from the rear with ~5% market share each. SK looks to overtake Panasonic is the coming years thanks to their 129 GWh of capacity coming online in the U.S. with Ford in the next few years.



Source: USCA, Company Reports, SNE

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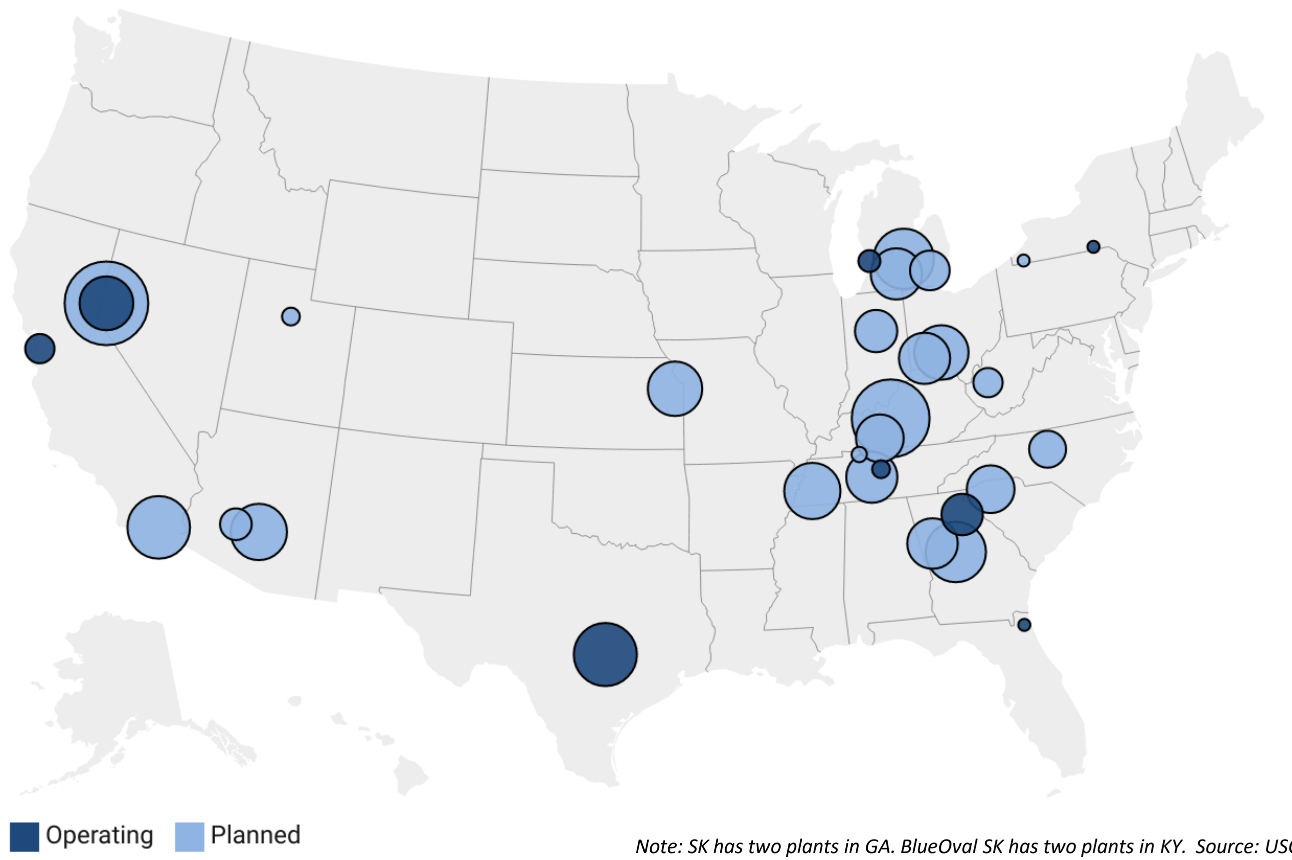
U.S. Gigafactories

- **Capacity & Context:** The total planned capacity in the U.S. is 1,044 GWh with an additional 115 GWh in Canada. Assuming an 85-kWh pack, that's enough for ~13.6 million EVs per year. For context, we estimate total battery demand from EVs and hybrids in the U.S. was ~43 GWh in 2021.
- **Notes:** Not all of these factories will be built. And none will operate at 100% of nameplate capacity. And some of the batteries will go towards stationary storage. But we will still see more announcements. Stellantis promised two more plants, and Ultium promised at least one more.
- **IRA**: If we assume all planned expansions will occur and an 80% capacity factor, the $35/kWh cell manufacturing tax credit totals $29B in subsidies per year. If we add in the $10/kWh module manufacturing tax credit, there are $38B per year in subsidies.



Note: SK has two plants in GA. BlueOval SK has two plants in KY. Source: USCA, Company Reports

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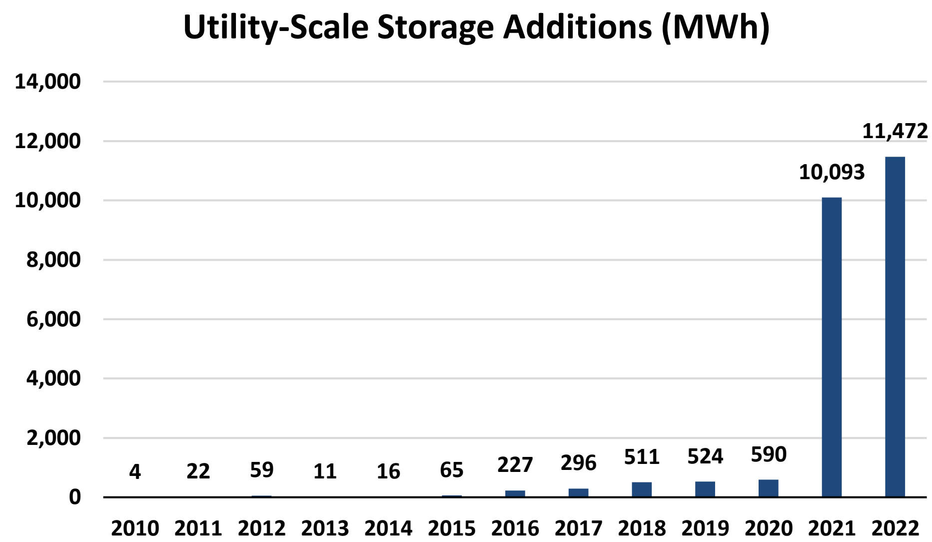
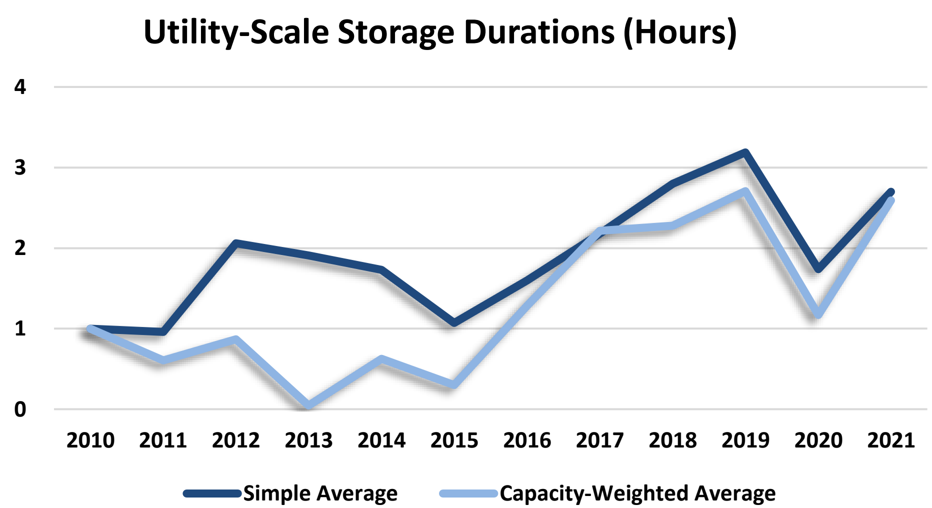
U.S. Utility-Scale Storage

- **Past 2 Years:** There is now 24 GWh of utility-scale battery storage on the grid. 90% was added in the past two years. And by utility-scale, we mean batteries larger than 1 MW.
- **Duration:** Dividing the total amount of energy by the total amount of power gives a capacity-weighted average duration of 2.1 hours. The simple average of duration is 2.3 hours.
- **Duration Notes:** It's worth noting that the simple average is larger for every year except for 2017. In 2017, there were seven batteries with a duration of four hours or longer added to the grid; these represent 87% of the energy capacity added that year. Two of the batteries added in 2017 had a duration of six hours. For what it's worth, there were three lithium-ion batteries with an 8-hour duration added between 2018 and 2019. The shortest duration storage device on the grid (also a li-ion battery) lasts a mere 13 minutes (0.2 hours) at max power.





Source: USCA, EIA

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Price Target Methodology: For Battery Companies, our price targets are based on a sum-of-the parts analysis. In our sum of the parts analysis, we value various business segments on a multiple of forward year(s) EBITDA or revenue, multiples ranging from 1x to 15x. The spectrum reflects a wide range of business models, company maturity, commodity sensitivity, volume risk, customer risk, margin profile, cash flow visibility, growth outlook, etc. We then net out debt to arrive at our price target.

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Opinion Key:
USCA uses a Buy, Overweight, Hold, Underweight and Sell rating system.

BUY - The stock has among the best combination of risk/reward and positive company specific catalysts within the sector. Stock is expected to trade higher on an absolute basis and be a top performer relative to peer stocks over the next 12 months.

OVERWEIGHT - The stock has above average risk/reward and is expected to outperform peer stocks over the next 12 months.

HOLD - The stock has average risk/reward and is expected to perform in line with peer stocks over the next 12 months.

UNDERWEIGHT - The stock has below average risk/reward and is expected to underperform peer stocks over the next 12 months.

SELL - The stock's risk/reward is skewed to the downside with possible negative company specific catalysts or excessive valuation. The stock is expected to trade lower on an absolute basis and be among the worst performers relative to peer stocks over the next 12 months.

Risks that may impede achievement of price target(s):
Industry wide risks include but are not limited to battery demand, commodity prices, economic outlook, access to capital markets, and interest rates.

IMPORTANT DISCLOSURES

Distribution of Ratings (as of October 10, 2023):

Recommendation	Count	Percent	Investment Banking Relationship	Count	Percent
Overweight/Buy	16	64%	Overweight/Buy	0	0%
Hold	9	36%	Hold	0	0%
Underweight/Sell	0	0%	Underweight/Sell	0	0%

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Contact Information

Sales Team

David King, CFA
Managing Partner
dking@uscallc.com
713-366-0530

Barry Guinn
Senior Managing Director
bguinn@uscallc.com
713-366-0534

Gil Beer
Executive Director
gbeer@uscallc.com
713-366-0518

Leslie Rich
Director
lrich@uscallc.com
713-366-0532

Amabelle Cowan
Director
acowan@uscallc.com
713-343-0658

Research Team

James Carreker, CFA
Managing Director
Midstream Energy
jcarreker@uscallc.com
713-366-0558

Samuel Cox
Analyst
scox@uscallc.com
713-366-0547

Chris Mohajer
Director
Battery Technology
cmohajer@uscallc.com
713-343-0648

Denise Cardozo
Research Assistant
dcardozo@uscallc.com
713-366-0563

Trading Team

Brad Stammen
Managing Director
bstammen@uscallc.com
713-366-0535

Clint Turner
Managing Director
cturner@uscallc.com
713-366-0536