U.S. Capital Advisors

Batteries

The Key Enabler for Decarbonization

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Please see important disclosures beginning on page 51.

Introduction

- **Why They Matter:** Batteries are the key enabling technology for both low carbon transportation and low carbon electricity. We are at inflection point in the battery industry.
- **Primer:** We hope this primer will give you an introduction into batteries. A lot of the early material is definitional. What's an anode? Who makes batteries? Do we have enough raw materials?
- **Level Setting:** We tried to make this introduction comprehensive while still being comprehensible. While there is a lot of science covered, we skipped a lot. Don't worry, we won't go too in the weeds.
- **Big & Small**: Battery manufacturers are either big or small. There are very few companies in the middle. We will discuss the industrial conglomerates making batteries today and the scrappy startups hoping to make batteries in the future.
- **What's Not Said:** Batteries are all about tradeoffs. Look for what metrics aren't shown. Those are often the metrics where the battery performs worse than the competition. Some batteries need to be heated or held under pressure to meet their performance specs.
- **Magic Bullets:** There are no magic bullets. There is no battery chemistry that is going to come out of nowhere and takeover the industry overnight. Existing chemistries will improve at 5-8% per year. New chemistries will slowly be introduced.
- **Does It Scale?:** At what scale are the new entrants producing batteries? If the company is still making coin cells in the lab, they are years away from reaching full production scale.
- **Batteries Are Tough:** Even the experienced cell manufacturers at LG and Samsung have had to issue battery recalls. When your unit sales are measured in the hundreds of millions, a very small percentage of failures can result a substantial absolute number of failures. Experienced end users like Apple and GM have had to issue battery recalls as well.
- **Warning:** These first few slides are going to be pretty dry, but the background is important. If you have a deep knowledge of batteries, skip to the next section. Our feelings won't be hurt.
- **Company Coverage:** We will initiate coverage of companies in the battery space, but we wanted to start with this macro-overview and give you time to digest it. ***This is the lens we will use to evaluate companies in the space.*** We'll be diving deeper into some of these topics in our Friday Notes.

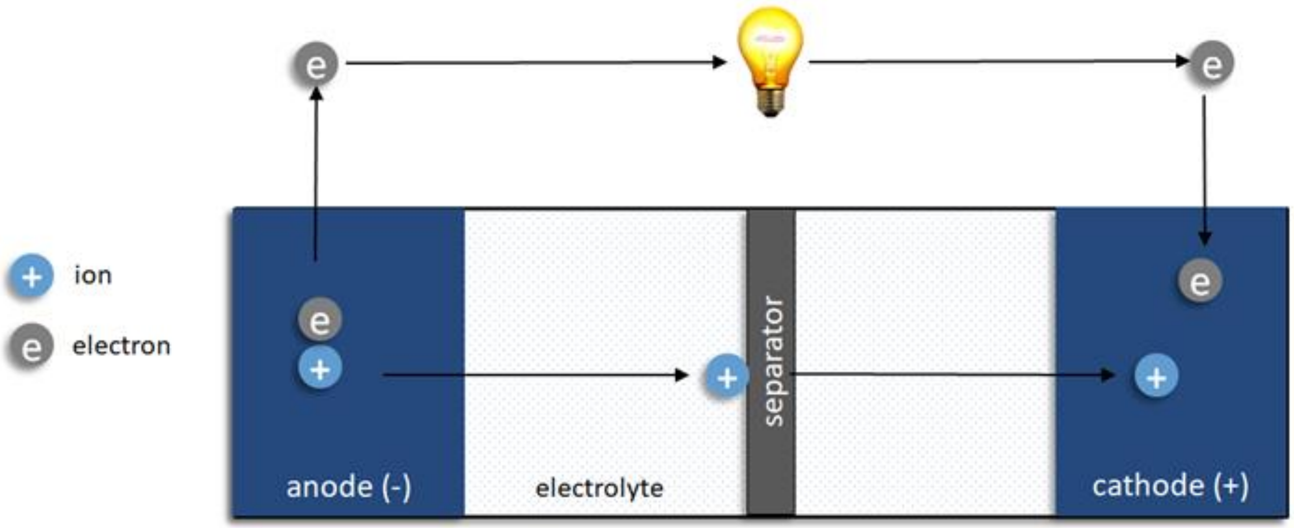
Cylindrical Battery Cell

BATTERIES – THE BASICS

Source: Northvolt

What is a Battery?

- **Electrochemistry:** A battery is an electrochemical energy storage and conversion device. It converts stored chemical energy into electrical energy. If the battery can reverse the reaction (convert electrical energy into chemical energy), then it is rechargeable.
- **A Battery Has Four Key Parts:** Anode, cathode, separator, and electrolyte. The anode is the negative electrode. The cathode is the positive electrode. The separator keeps the two electrodes from touching each other. (If they touch, the battery goes boom.) The electrolyte helps the ions flow between the anode and cathode.
- **Ion Flow:** When a battery is being discharged, ions go from the anode to the cathode. When a battery is being charged, this is reversed.
- **Batteries Are Like Ogres; They Have Layers:** Some small battery cells have a single layer of anode, cathode, and separator, but most batteries have several layers of these electrodes.



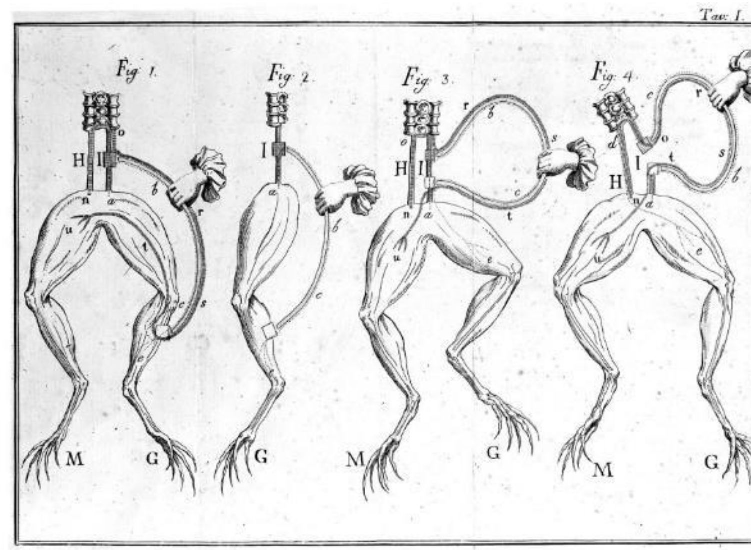
Source: USCA, Nobel Foundation

Battery History

- **Galvani Played With Frogs:** In the 1780s, Luigi Galvani was experimenting with static electricity using skinned frogs (as one does). His assistant touched one of the frogs' nerves with a statically-charged scalpel and the leg moved.

  While this story is probably apocryphal, Galvani published rigorous research a few years later describing what he called "animal electricity". Using different metals, he was able to consistently make the frog's leg move.

  You're not alone in thinking that prodding dead frogs is a bit strange; Mary Shelley said that Galvani's experiments helped influence her little-known book, Frankenstein.



- **Volta Did It Without a Frog:** Alessandro Volta took Galvani's research and wanted to see if he could make an electrical charge without the frog. He replaced the frog's leg with brine-soaked cloth.

  After experimenting with different metals, he deduced that Zinc and Copper worked best. In this example Zinc is the anode, Copper is the cathode, the cloth is the separator, and the brine is the electrolyte.

  Just like modern batteries, he discovered that it worked best if he repeated this stack of Zinc, cloth, and Copper several times. This stacked version is a Voltaic pile. Napoleon was a fan.

Source: USCA, Battery University, Lateral, Vox

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

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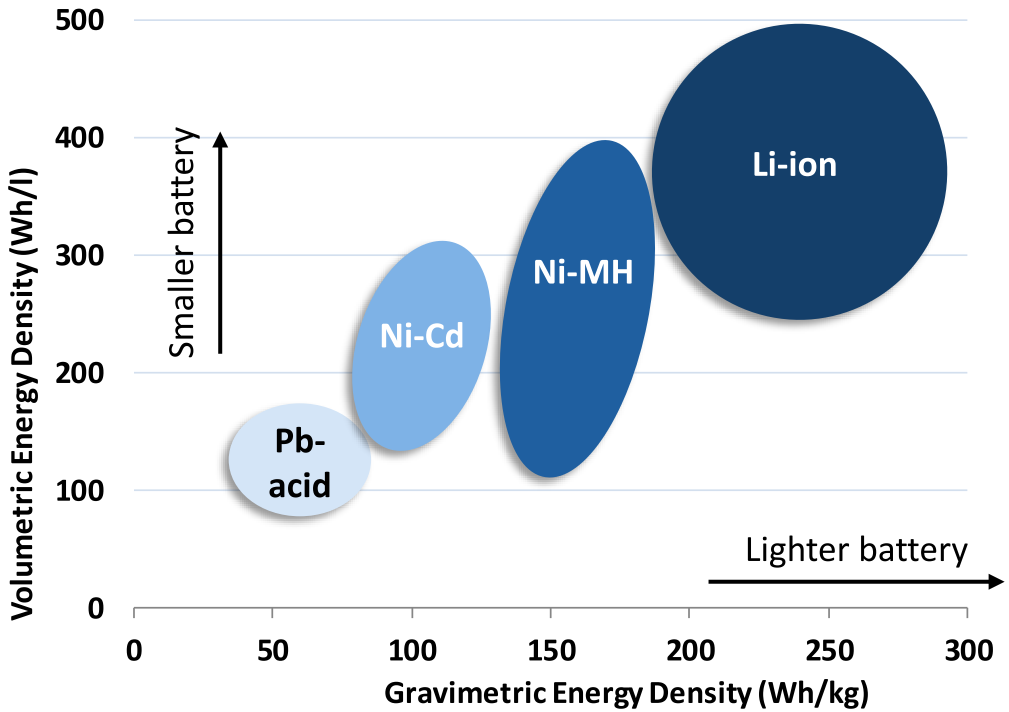
Battery Chemistries

- **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.

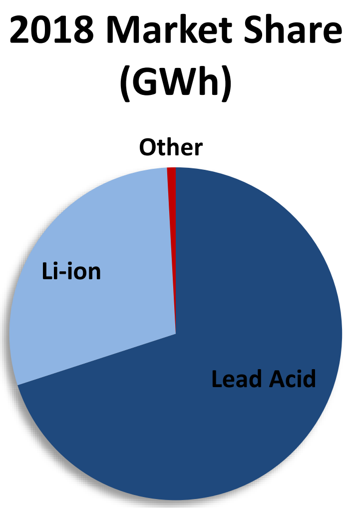


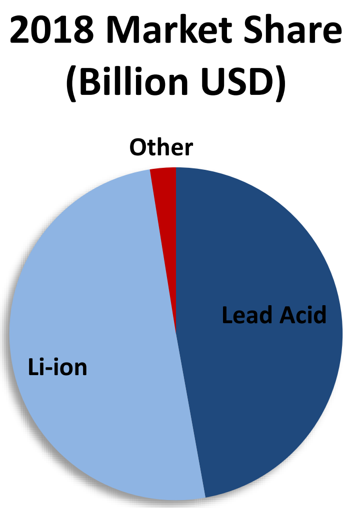
- **Pb Acid:** The Lead acid battery was invented in 1859. This was the first rechargeable battery. You can find a Lead acid battery in almost every car, plane, boat, and submarine.
- **Ni-Cd:** Nickel Cadmium batteries were commercialized in 1946. They were the only choice for portable radios and electronics 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

Market Share by Chemistry

- **The Past:** If you measure energy (GWh), lead acid has over 70% market share with just over 400 GWh. If you measure dollars, lead acid only has a 44% market share with just under $40B.
- **The Future:** While the lead acid market has been growing at 4% to 5% per year, the lithium-ion market is growing even faster and is expected to overtake the lead acid market in terms of energy around 2024.
- **Other?:** The Other category below includes Ni-Cd, Ni-MH, Zinc-based, Sodium-based, flow batteries, and other exotic chemistries.





Note: This is only for secondary/rechargeable batteries.
Source: Avicene Energy, USCA


Lithium Brine Evaporation Ponds in Chile

LITHIUM-ION

Source: ESA

Invention of Lithium-ion

➢ **Nobel Prize:** These three received the Nobel Prize in Chemistry in 2019 "for the development of lithium-ion batteries". All three are still alive and working in the field.

Stan Whittingham

While working at ***Exxon*** during the 1970s, Stan Whittingham discovered a cathode (TiS_2) that could intercalate (house) the Lithium ions.

Dendrites (unintended spikes) would eventually form and short out the battery, so the battery never left the lab. Exxon didn't think the total addressable market for Lithium batteries would be more than a few hundred million dollars, so they decided to license the technology. Oops.

John Goodenough

While working at Oxford in 1980, John Goodenough discovered that LCO (Lithium Cobalt Oxide) would be a better cathode. Most batteries in consumer electronics still use this cathode material.

Akira Yoshino

While working at Asahi Kasei in 1985, Akira Yoshino discovered that carbon from petroleum coke would be a safer anode. Most batteries still use a carbon anode, graphite.

While carbon is safer than the Li Metal anode that Whittingham and Goodenough used, it has a lower energy density. This tradeoff was made to bring the battery to market. Scientists and engineers are trying to switch the anode back to Li Metal, but there are still issues to work out. They are detailed on page 12.

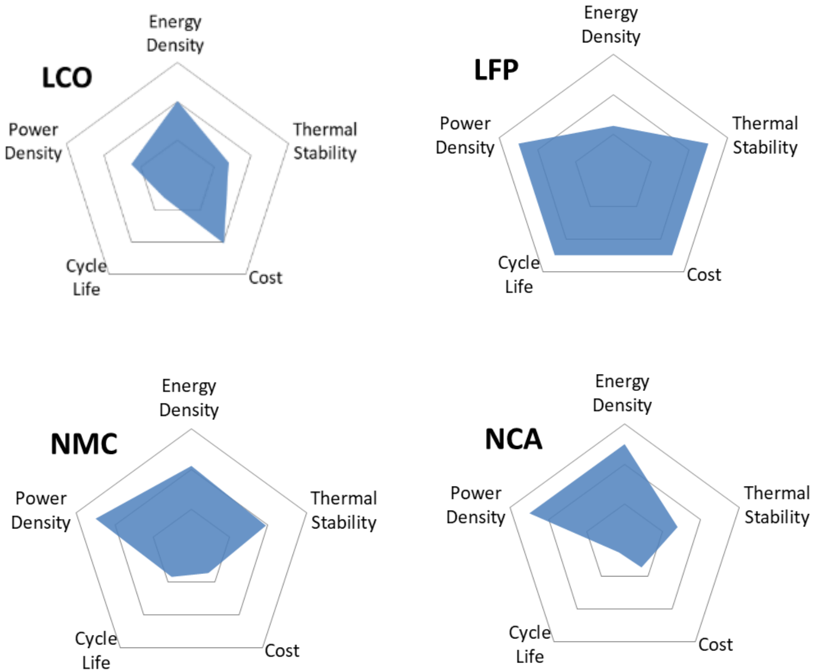
➢ **Commercialization:** It wasn't until 1991 that the Lithium-ion battery was finally brought to the market by Sony with the Handycam.

Source: USCA, Nobel Foundation, Company Reports

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

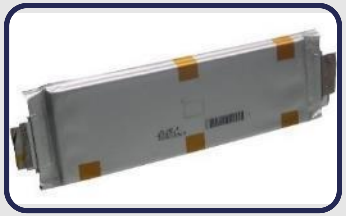
Source: USCA, ACS, ANL BatPaC, Argus, Company Reports

Cell Formats

- **Balance of Power:** Just a few years ago, automakers were forced to accept whatever cell format that manufacturers would give them. Now we see different automakers dictating to manufacturers not only cell formats but also chemistry tweaks.

Coin: These are small and squat cylinders are usually less than 25 mm in diameter and 5 mm in height. (Think roughly the size of two quarters stacked on top of each other.) They are used in small consumer electronics such as calculators, hearing aids, car keys, etc. Coin cells are also popular when testing new battery materials during R&D due to the small size. (They are too small to be used in EVs.)

Cylindrical: Original Li-ion batteries were cylindrical. The most common size historically has been 18650. These are 18 mm in diameter and 65 mm in height. (Think slightly larger than an AA battery.) This size was popular with the consumer electronics industry and was used in the original Tesla Model S (because it's all they could get their hands on). Most cylindrical cells have some basic safety features including vents and thermal fuses.



Pouch: As laptops got thinner and thinner, manufacturers switched from cylindrical cells to pouch cells. Since they have a polymer casing (as opposed to metal), they are lighter, which gives them higher energy density. This lightness comes at the cost of durability. This simple casing means that the safety features must be built into the battery module, pack, or final device (instead of the cell). Pouch cells come in all shapes and sizes, but the vast majority are rectangular prisms. The smallest ones fit inside an Apple Watch and the largest ones are as wide as a car. GM will use pouch cells in their new Ultium platform.

Prismatic: These are a mix between cylindrical and pouch. They are rectangular like pouch cells but have the hard casing of a cylindrical cell. VW is betting on prismatic cells.

Source: USCA, Company Reports

The Building Blocks

- Depending on the application, there are different building blocks for a battery.
  - **Electric Vehicles:** In most EV applications, battery cells are put into a module. Several modules are put into a battery pack (as shown on the next page). There is a trend of using fewer and fewer modules. Several manufacturers including Tesla & BYD have announced plans to go even further and get rid of the battery module with cell-to-pack architectures. This will make EV packs lighter.
  - **Consumer Electronics:** In consumer electronics, a laptop pack is usually made up of 2-8 cells. Smart phones usually only have one cell. Most consumer electronics devices don’t use modules; the total number of cells is too low.
  - **Stationary:** In stationary applications, the modules are installed in racks/cabinets.

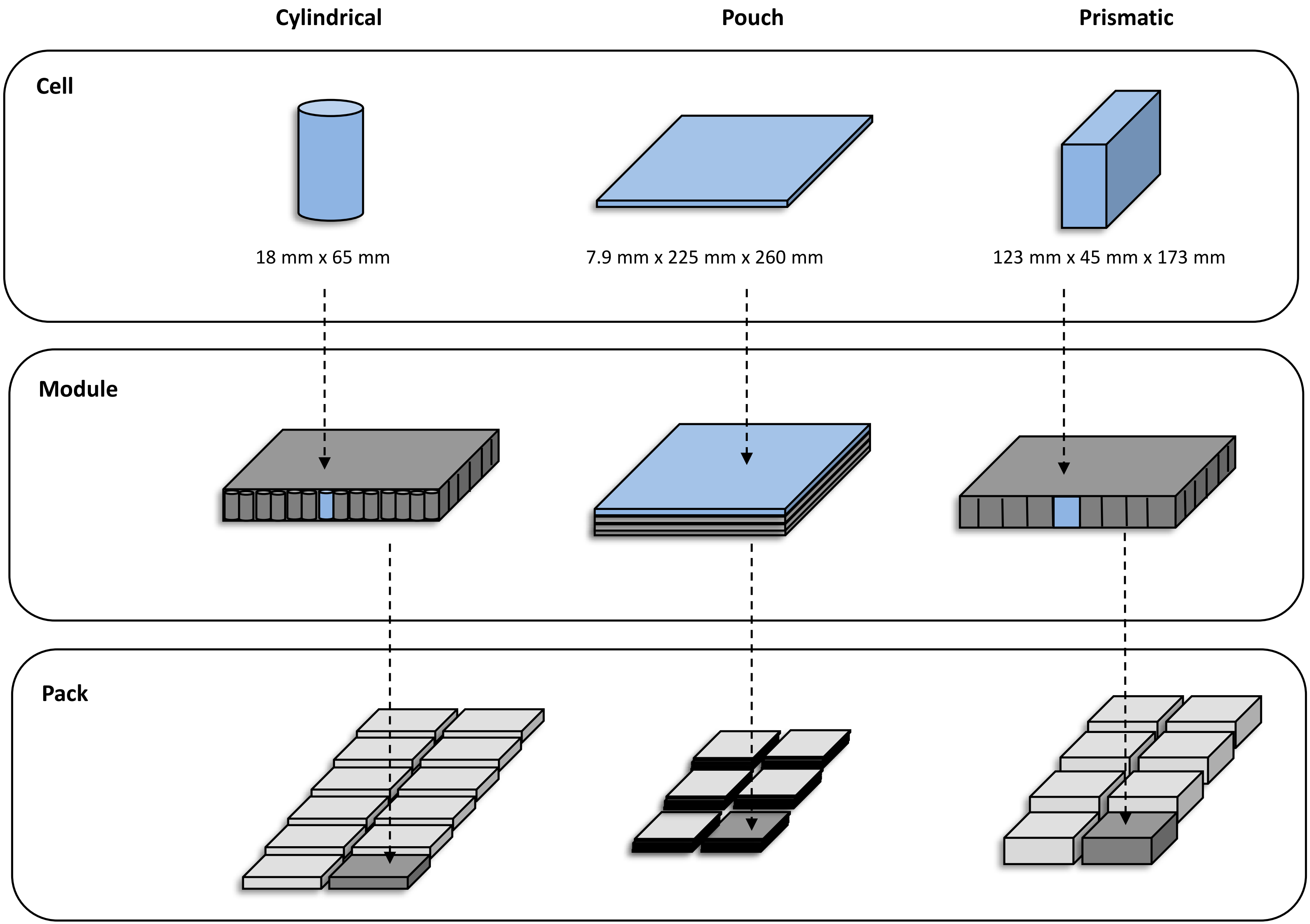
EV Battery Hierarchy

Vehicle	Pack Size	Modules per Pack	Cells per Module	Total Cells
BMW i3	42 kWh	8	12	96
Tesla Model S	85 kWh	16	444	7,104

- Most multi-cell systems have some sort of battery management system (BMS). The BMS is a hardware and software system that monitors and controls the battery.
  - **Why Do I Need a BMS?:** Batteries are dumb. Without a BMS (or smart charger), if you try to charge a battery when it’s full, it will keep charging until it catches fire.
  - **State of Charge:** Unlike a gas tank, it’s actually tough to measure the state of charge. The battery percent remaining you see in your EV is a BMS-provided estimation based on a variety of chemical, electrical, and external inputs. Both the numerator (capacity remaining) and denominator (total capacity) of that percent remaining are estimations. To make things more complicated, the denominator decreases overtime. Imagine if your gas tank shrank over time…
  - **Back to Sony:** One of the core innovations enabling Sony’s commercialization of the Lithium-ion battery was their smart charging algorithm.

Source: USCA, Company Reports, Electrek, InsideEVs

Cell, Module, and Pack



Source: USCA, Nature

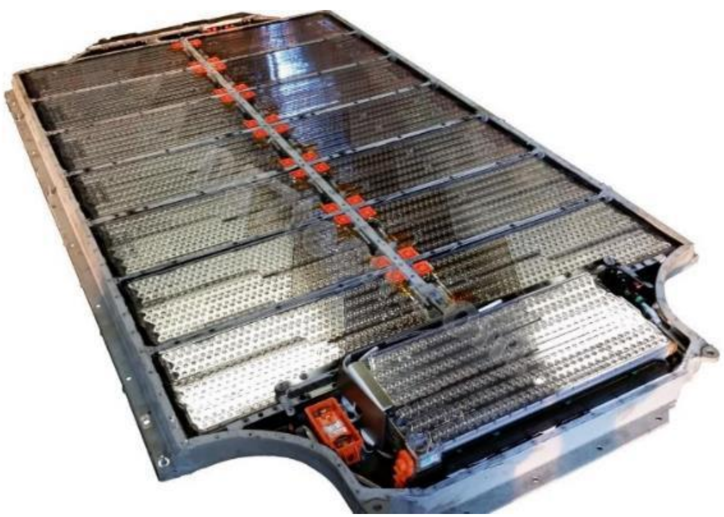
Markets Are Not Monolithic

- **How Do You Segment the Market?:** The Lithium-ion battery market can be sliced and diced in many different ways.
  - **By rechargeability:** primary (non-rechargeable) and secondary (rechargeable)
  - **By layer in the stack:** cell, module, and pack
  - **By cathode chemistry:** LFP, NMC, NCA, and LCO
  - **By anode chemistry:** Graphite, Silicon, and Lithium metal
  - **By form factor:** coin, cylindrical, pouch, and prismatic
  - **By application:** consumer electronics, transportation, stationary, etc. As hinted at earlier, ***we believe segmenting the market by application makes sense for our purposes*.**
- **What Are You Counting?:** Once you segment the market, how do you measure each segment?
  - **By unit sales:** Cells are differing sizes and have different performance characteristics. This is how automotive supply contracts are structured; they buy X quantity of Y part.
  - **By dollars:** Market is skewed by cost-insensitive customers/applications like defense applications. Cost reductions hide growth. Consumer electronics cells tend to be more expensive than automotive cells due to customized form factors and smaller volumes.
  - **By mass:** Shifts in form factors would skew results since cylindrical and prismatic cells weigh more than pouch cells due protective shells. Used by recyclers.
  - **By power (watts):** Would be equivalent to measuring the global automotive market in total horsepower shipped per year. Interesting, but not very useful. That being said, power plants are measured this way, so stationary storage stakeholders often use power as their metric of choice.
  - **By energy (watt-hour):** Has become the de-facto way to count market size. This is how cell, module, and pack manufacturers talk about their batteries and their factories. Tells you how long your laptop will last and how much range your car will have. ***We believe measuring each market by energy makes sense for our purposes*.**
- **Why Does This Matter?:** Depending how you measure the market you will reach different conclusions about market segments. As mentioned earlier, the Lead acid market is larger in terms of energy, but the Lithium-ion market is larger in terms of dollars.

Source: USCA

Applications

- **The Big Three:** The three largest segments in the Lithium-Ion battery market are Consumer Electronics, Transportation, and Stationary.
  - **Consumer Electronics:** Consumer electronics were the original market for Lithium-ion batteries when they were commercialized back in 1991. This segment has many products, but the largest users are smartphones and laptops. Tablets, wearables, and headphones are smaller but growing.
  - **Transportation:** The largest segment in terms of dollars and energy is transportation. While traditional EVs make up the majority of the demand, there are a variety of other sub-segments here including e-bikes, scooters, forklifts, boats, busses, and other specialized vehicles.
  - **Stationary:** The size of the batteries in the stationary market vary widely in size. The smallest ones fit inside EXIT signs, and the largest ones are the size of several buildings. One of the growing segments that has been traditionally dominated by Lead acid is telecom backup power.
- Other smaller segments include power tools, medical devices, aerospace, defense, and industrial applications.
- We're going to focus on **Transportation** and **Stationary**.



Source: USCA, Company Reports, ifixit, 057tech, Fluence

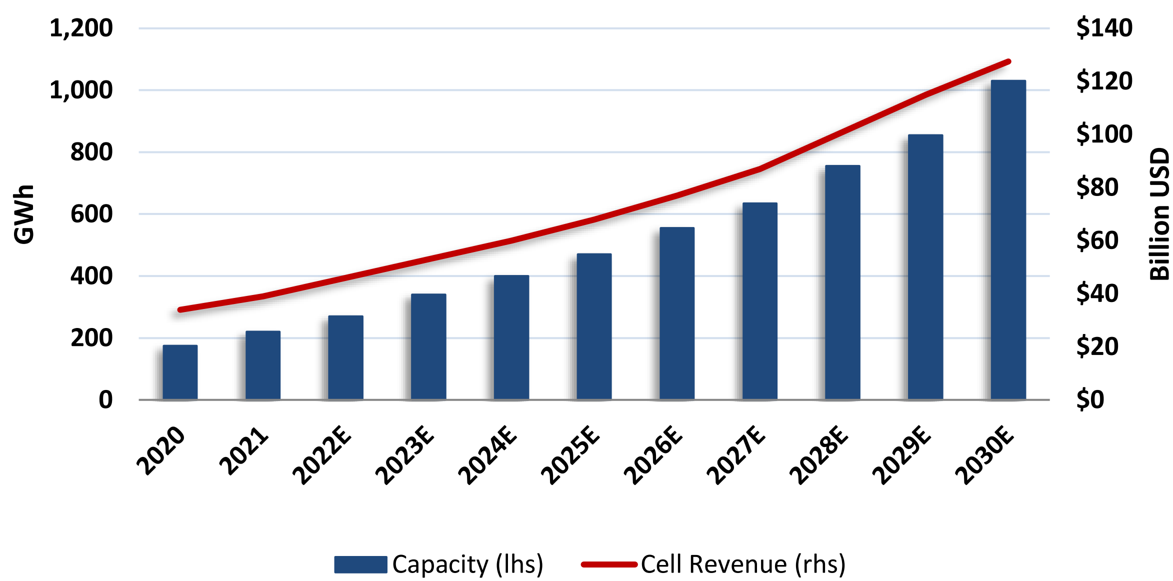
Tesla Model 3

TRANSPORTATION

Source: Tesla

Transportation TAM

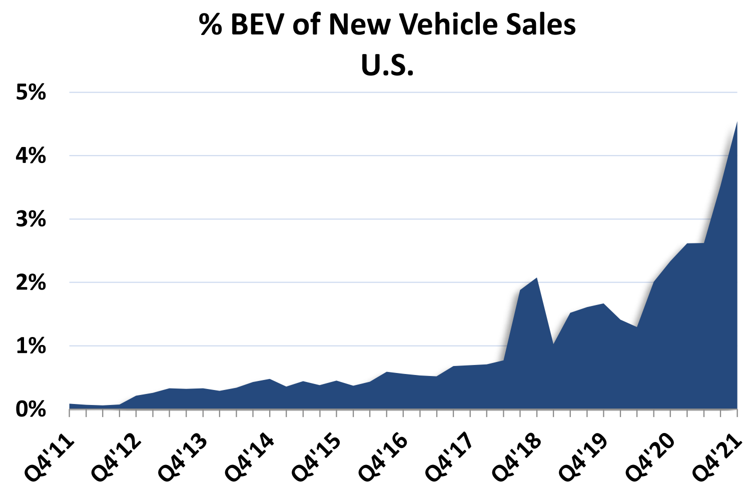
- **Global TAM:** The total addressable market for lithium-ion batteries for transportation (including hybrids) is forecast to be over 1,000 GWh by 2030. That is over $120B in battery cells. Total cost for the packs will be closer to $150B.
- **CAGR Comps:** If you calculate CAGR from 2015 to 2030, the market size in capacity (GWh) is growing 26% while the market size in dollars is growing 18%. Why the difference? Batteries are getting cheaper. (We go deeper into pricing on page 31.)



Source: *Avicenne Energy, USCA*

All About EVs

- **EV Sales:** Future battery demand will hinge on EV market penetration. The stationary storage market is a fraction of the size. In the U.S., battery EVs (BEVs) remain a relatively small percentage of total vehicles sold. BEVs represented ~4.6% of new vehicle sales in Q4'21. They are higher in China and Europe, at 12% and 10%, respectively for 2021.



- **Pull:** Global automakers are planning to spend $515B over the next decade on EVs and batteries. There is still debate on the timeline, but the automakers are acting like EVs are the future. Many are stopping development of new internal combustion engines (ICE).
- **Push:** Government incentives will remain a large driver of BEV penetration. The US is targeting 50% of sales to be electric by 2030. California and New York will ban the sale of new ICE passenger cars after 2035. Many European cities and countries have announced bans as well.
- **Norway Flow:** In 2020, 54% of new car sales in Norway were BEVs. While it's a high percentage, it's worth pointing out that 54% represents 77k vehicles out of 141k. The U.S. market by comparison was just under 15m for 2020. It was just over 17mm pre-pandemic in 2019. And keep in mind there are ~3.5 times as many used cars sold in the U.S. every year compared to new.
- **Norway Stock:** As of December 31, 2020, Norway had 340k registered BEVs out of 2.8mm total vehicles. That's 12% for context. Assuming the total number of vehicles in Norway stays constant (not going to happen), the total number of vehicles sold per year stays constant (not going to happen), every new BEV replaces an ICE vehicle (not happening yet), and 100% of new sales are BEVs (not happening yet), it will take 17 years to replace every ICE in Norway. Both push and pull incentives from the government could speed this up. (2021 data for registrations will be released on March 25th, but 64.5% of sales were BEV last year.)
- **China:** The Chinese BEV market requires a dedicated note to just scratch the surface, but we wanted to mention a few things. Subsidies for BEVs started in 2009 when the national government began incentivizing the purchase of electric busses and fleet vehicles. In 2010, subsidies for private EVs were added. Local governments added additional subsidies and more importantly used other tools including capping the number of license plates issued for ICE vehicles; BEVs were exempted. Other non-tariff barriers were used including domestic ownership and domestic content requirements. The best-selling EV in China is the $4,500 Wuling Mini. In 2022, 60% of EVs sold worldwide will be sold in China.

Source: Company Reports, Bloomberg, CleanTechnica, US BEA, Statistics Norway, Marco Polo, ZoZoGo, USCA

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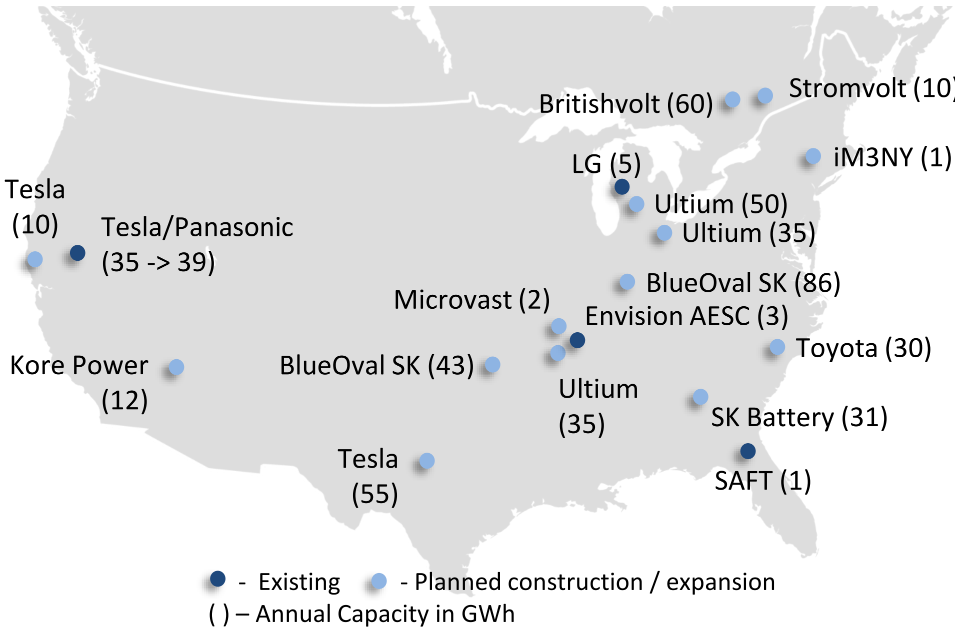
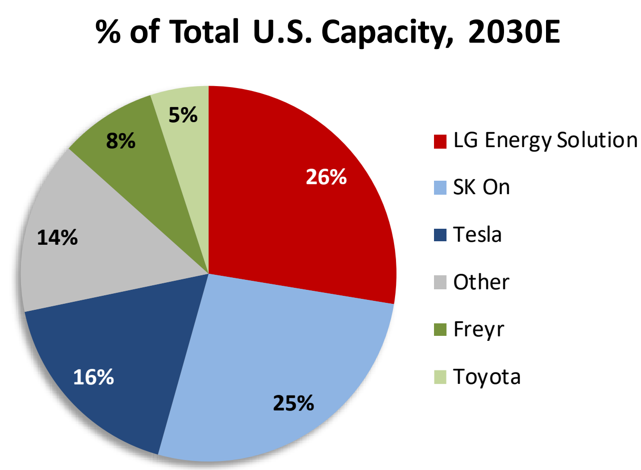
North America's Gigafactory Capacity

- **Current Capacity:** Currently, there is 43 GWh of annual cell capacity in North America with 81% of it coming from Tesla. Assuming 85 kWh battery pack sizes and 80% utilization, NA produces enough cells for 405k EV packs per year. 435k EVs were sold in the US in 2021.
- **Why The Delta?:** While the Tesla Gigafactory in Nevada can make 35 GWh of cells, it can make 55 GWh of packs. (It imports cells from Asia to fill that gap). Tesla exports some of vehicles made in Fremont. Also, five of the top ten selling EVs in the US have batteries coming from outside the country. They represent 73k vehicles. And the SAFT plant in Jacksonville, FL doesn't make EV batteries.
- **Capacity Growth:** ***By our count, there is 638 GWh (12x) of new capacity coming online in the next decade.*** We expect even more to be announced in the coming years. Not all of it will be built, but the pipeline is robust. ***Almost all Gigafactory capacity will be dedicated to supplying the EV industry.***
- **It's Not Enough:** The Biden Administration set a target of 50% EV sales by 2030. By our count, that would require 800 to 900 GWh of capacity. That's approximately $44B to $59B in required CapEx. And that doesn't include the cell capacity for stationary storage. (That being said, not all EVs sold in the US will use domestically produced batteries and not all domestically produced batteries will be for the US market.)
- **Context:** While our 638 GWh 2030 annual capacity figure may seem like a lot, China has 3,400 GWh in the pipeline, according to Benchmark Mineral Intelligence.

Location TBD: Freyr/Koch (50), Stellantis/LG (40), Stellantis/Samsung (23 -> 40)





Note: SK has two plants in GA. BlueOval SK has two plants in KY.
Source: USCA, EIA, Car & Driver, Benchmark Mineral Intelligence, Company Reports

Matchmaking

- The large automakers have started to pick their battery cell suppliers. Some of these are simple long-term purchase agreements, some are JVs, and some are still in the MOU stage. Some automakers (e.g., VW) are hedging their bets by selecting many suppliers. Some automakers (e.g., GM) have only announced one supplier.
  - **BMW:** CATL, Northvolt, and Samsung
  - **Daimler:** CATL, Farasis, LG, and SAFT (JV-Automotive Cells Company),
  - **Ford:** LG, SK On (JV-BlueOvalSK)
  - **GM:** LG (JV-Ultium)
  - **Honda:** CATL and Ultium
  - **Hyundai:** CATL, LG, and SK On
  - **Nissan:** CATL and Envision AESC*
  - **Renault:** Envision AESC* and Verkor
  - **Stellantis:** BYD, CATL, LG, SAFT (JV-Automotive Cells Company), Samsung, and SVOLT
  - **Tesla:** CATL, LG, and Panasonic
  - **Toyota:** BYD, CATL, and Panasonic (JV-Prime Planet Energy & Solutions)
  - **Volvo:** CATL, LG, and Northvolt (JV)
  - **VW:** CATL, Gotion, LG, Northvolt, Samsung, and SK On
- **An Aside on Tesla:** There are a few common misconceptions around Tesla and their batteries. To date, Tesla has not made their own battery cells beyond pilot scale. This is expected to change in 2022 as they start to produce their own cells in Texas. Also, ***the Gigafactory in Nevada is not a JV with Panasonic***. Panasonic leases space in the factory from Tesla.
- **Dieselgate Repentance:** VW has been one of the more aggressive automakers in the battery space. In December, they created a new company focused on batteries. It's wholly owned for now, but they are considering spinning off the battery business or taking external investment. ***If VW had 50% EV sales in 2030, they would need $20B in battery cells per year.*** As well as buying cells from others, they plan to build six Gigafactories in Europe. They have a 20% stake in Northvolt, a 25% stake in 24M, and a 26% stake in Gotion. They also have a JV with Umicore for cathode materials and an agreement with Vulcan Energy Resources for Lithium.

**AESC was conceived as a JV between NEC and Nissan. It's now an 80/20 JV between Enivsion and Nissan.*

Source: Company Reports, Bloomberg, The Verge, USCA

Chevy Bolt Recall – This Stuff Isn't Easy

- **Speed Bumps:** It won't all be smooth sailing. GM has recalled every Chevy Bolt ever made (approximately 142,000) due to two defects in the battery cells, which are made by LG Energy Solution. The defects are "a torn anode tab and [a] folded separator".
- **GM's Advice:** More than a dozen Chevy Bolts have caught fire so far. GM is advising current Bolt owners to:
  - Keep the battery below 90% state of charge.
  - Keep the battery above 70 miles of range (approximately 25% - depends on model year).
  - Not to charge the car in a garage overnight.
- GM doesn't seem to know which cars are affected. Not all are. GM is going to replace every battery module until they can remotely diagnose which ones have the defects. They are prioritizing vehicles that are frequently deep discharged.
- LG will cover $1.9 billion of the $2 billion recall. (That's over $14k per car!) GM has tied their EV future to LG. The two have a JV, Ultium Cells, where they are spending over $6 billion on three cell plants and plan to spend at an additional $2 billion on a fourth plant. GM has not publicly announced any other battery cell supplier agreements.
- It's worth pointing out that LG and GM are known in the industry to have both expertise and experience in EV batteries. As Benchmark's Caspar Rawles pointed out: "This stuff isn't easy!"
- Greg Less (technical director of the University of Michigan's Battery Lab) thinks that the two defects are caused by a piece of automation equipment during cell assembly:

  "It wouldn't surprise me if both defects are caused by the same thing…I would imagine that the separator must be folded at the edge near where the anode tab is at. What I'm guessing is that at some point during the handling of the cell, before it's fully packaged, some part of the robot machine is catching. The tab is catching, the separator is catching—something is catching very infrequently so that it hasn't been noticed, and it's causing this damage."
- We'll provide more information on A123 later (pages 36-37), but it's worth noting that a similar issue contributed to their bankruptcy:

  "one of four automated tab welding machines in the prismatic cell manufacturing process…was incorrectly calibrated, causing a misalignment of a certain component in some prismatic cells. This defect was undetected by standard visual and electrical inspection. When the defective prismatic cells were subsequently compressed as part of the module assembly process, a mechanical interference was created between the misplaced component and the foil pouch which contains the cell. In certain cases, this interference breaches the foil pouch electrical insulation causing an electrical short which can cause premature failure of the battery".

Source: Company Reports, Electrek, ArsTechnica, GreenCarCongress

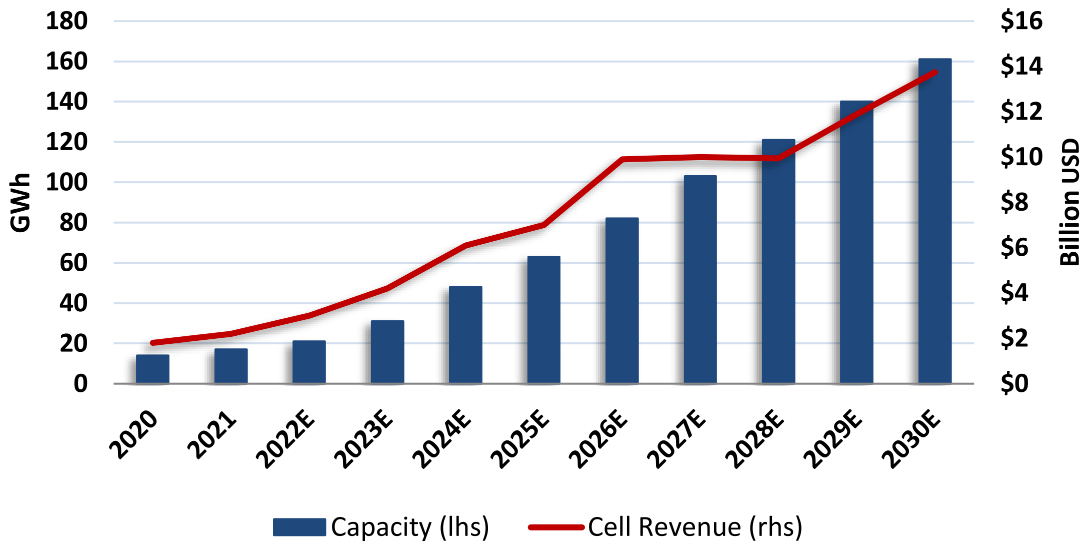
World's Largest Battery – Vistra's Moss Landing Energy Storage Facility (400 MW / 1,600 MWh)

STATIONARY STORAGE

Source: Vistra

Stationary TAM

- **Global TAM:** The total addressable market for stationary lithium-ion batteries is forecast to be over 160 GWh by 2030. That is over $14B in cell costs. Total installed cost for the stationary storage systems will be higher.
- **NA TAM:** Approximately 20% of the capacity will be installed North America. Asia Pacific will be the dominant market with half the capacity.



Source: USCA, CairnERA

Balancing the Electric Grid – We Take it for Granted

- **Electric Supply/Demand:** We take it for granted that our electric grid balances supply and demand 24/7 despite what can be some pretty big swings in demand and unplanned generation outages. The electric grid is older than both computers and the internet, so keep in mind that the grid is balanced without either one of those.
- **So, How is the Grid balanced?:** Historically the grid has been balanced by thermal generators (coal & natural gas power plants) ramping up and down supply to maintain a certain frequency. When supply exceeds demand, the frequency of the grid increases. When demand exceeds supply, the frequency decreases. What's frequency – the number of waves that pass a fixed place in a given amount of time. If the time it takes to pass a wave is ½ second, the frequency is 2 per second (or 2 Hz). The beauty of using frequency is that it is the same value no matter where you measure it on the grid (unlike voltage which varies). In North America, the grid frequency is 60 Hz (60 cycles per second). There is nothing magical about 60 Hz, it's just the setpoint we use. ***What is important, however, is that frequency be maintained within a very tight range.*** For example, during Winter Storm Uri in February 2021, ERCOT's frequency dropped to 59.4 Hz for ~4 minutes. If it had dropped below that level for just 9 minutes, the grid would have collapsed and would have experienced a total blackout that could have lasted months (more on that on page 29). ***That is just a 1% variance in frequency.***
- **Frequency Regulation:** If a large power load suddenly comes online, the frequency will fall since demand exceeds supply.
  - The first line of defense is ***inertia***. Traditionally our electricity has come from large coal, gas, nuclear, and hydro generators that spin to generate electricity. The spinning inertia of these generators will automatically resist changes in frequency for a few seconds before they start to slow and let the frequency drop. What happens after a few seconds?
  - There are sensors on the spinning generators that notice these changes in frequency. They will automatically start to ramp up to bring the frequency back to 60 Hz. Most generators are set to run below 100% capacity, so they can adjust for these changes. This headroom is called ***Spinning Reserves***. Since they had to ramp up to handle the large load, they are operating above their target set point, and there aren't enough Spinning Reserves on the grid to handle additional load coming online. What do you?
  - Grid operators will manually dispatch a new power plant to come online. The whole thing then happens in reverse. Inertia resists the rise in frequency, and the generators with Spinning Reserves will slowly ramp back down.
- **What about Renewables?:** Solar PV doesn't have inertia; nothing is spinning. Wind turbines have the inertia, but for a variety of power electronics reasons, they are rarely used for this (there is some testing going on, but let's just call it nil for now). ***So, it is largely conventional electric generation that historically been used to stabilize the grid.*** As we transition to a zero-carbon electricity grid, something has to replace inertia and spinning reserves if we want to keep the grid stable. ***Batteries can do it! We cannot stress the importance of this enough!***

Source: USCA, RMI, EIA, ERCOT, NREL, LBNL

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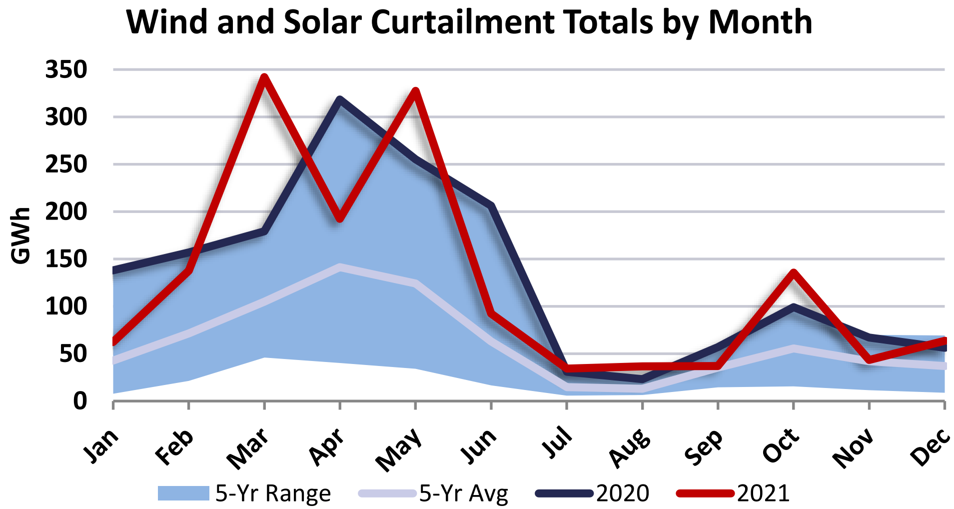
What Do Batteries Do For The Grid?

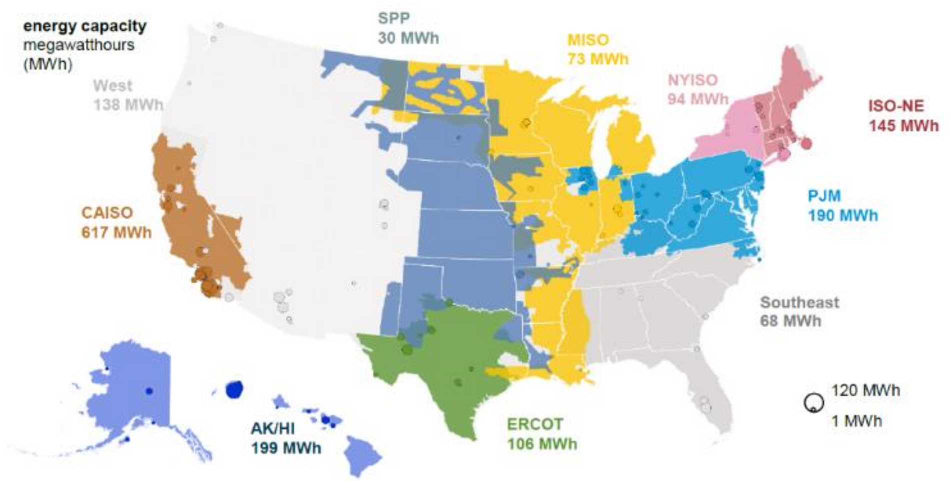
- **Staying on Frequency:** Frequency Regulation has become the most prevalent grid service for batteries in the US, with 59%* of batteries providing this service. These batteries provide power for a few seconds in lieu of inertia. The second most prevalent is Spinning Reserves with 39%*. The batteries don't spin, but the name has stuck around and indicates the duration of the service - a few minutes.
- **What Else Can Batteries Do?:** There is quite a bit more than Frequency Regulation and Spinning Reserves. The Rocky Mountain Institute, an energy transition think tank, has identified ***thirteen different services*** that energy storage systems can provide. They are split up by who benefits from the service:
  - **Customer Services:** Time-of-Use Bill Management, Increased PV Self-Consumption, Demand Charge Reduction, and Backup Power
  - **Utility Services:** Resource Adequacy, Distribution Deferral, Transmission Congestion Relief, and Transmission Deferral
  - **Grid (ISO/RTO) Services:** Energy Arbitrage, Frequency Regulation, Spin/Non-Spin Reserves, Voltage Support, and Black Start
- **Services Drive Specs:** The services provided depend on both the specific project needs and the broader grid needs. For example, given CAISO's robust *Resource Adequacy* market, the average duration for a battery in their service territory 3.6 hours*. In ERCOT's service territory, where batteries are more frequently used for *Energy Arbitrage* and *Frequency Regulation*, the average duration is 1.2 hours*.
- **Wasting Energy**: As the graph shows, renewable energy curtailments have been rising in California. Renewables are often curtailed when there is either too much supply on the broader system or too much supply at the local transmission/distribution level. Storage can help with both of these issues. ***Instead of wasting this energy, it could be stored and sold later.*** It's not just California; in 2019, 5% of ERCOT's solar generation was curtailed.



Note: These are for grid connected batteries larger than 1 MW.
Source: EIA, RMI, CAISO, ERCOT, USCA

Stationary Storage – Early Days

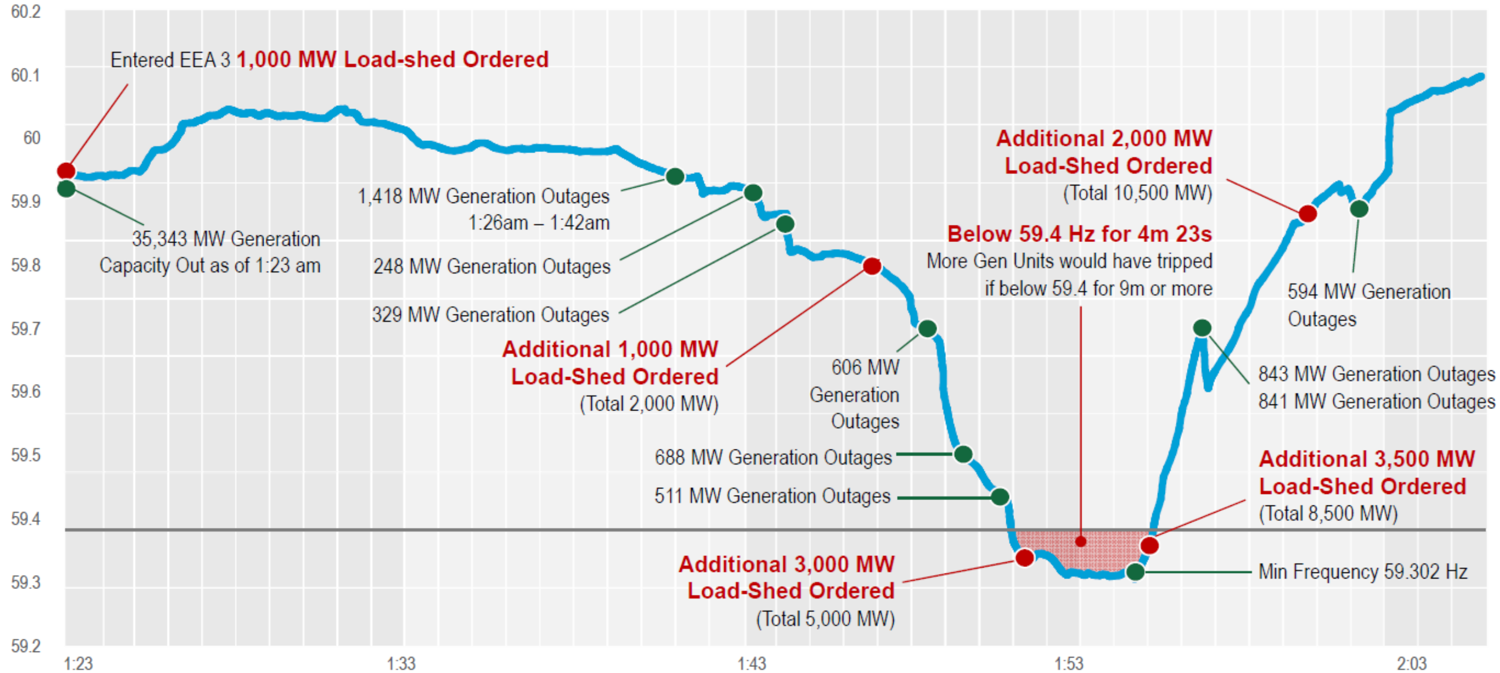
- **Installed Base:** Consensus has the 2019 US battery stationary storage installed base at approximately 3 GWh. In 2020, that number doubled to around 6 GWh. (In 2021, the installed base looks to have doubled again to over 12 GWh.)
- **Putting that in Context:** The US produced 4 million GWh of electricity in 2020. Assuming demand is even on a daily basis (it isn't), that's 11,000 GWh of electricity per day. If the batteries could provide enough power at the right locations (they couldn't), ***6 GWh of storage would cover 0.05% of US's daily electricity needs. That's 47 seconds worth of a day's demand.***
- **How Do We Store Energy:** Even though we don't have much battery storage, we do store energy. We have some pumped hydro (22 GW / 553 GWh), but energy is mostly stored upstream in piles of coal and tanks of natural gas. ***The five-year average of natural gas in storage in the US is over 700,000 GWh (700 TWh). The 6 GWh of battery storage in the US covers 0.0008% of that capacity. How do we reconcile that gap with the push to "electrify everything"?***
- **U.S. Storage Needs:** We don't need to store an entire year of electricity with batteries (4 million GWh), but estimates have the need ranging from 1 thousand to 50 thousand GWh (1 to 50 TWh). Using NREL's models, we forecast 1.1 TWh of storage under 8 hours in duration. That's 30 GW at one hour (30 GWh), 65 GW at four hours (260 GWh), and 100 GW at eight hours (800 GWh). This will mostly be lithium-ion batteries.
- **Long Duration:** There is more uncertainty around how much long duration storage we need. NREL forecasts 0 to 250+ GW with days to months long durations. The Long Duration Energy Storage Council forecasts 440 to 600 GW at a 15 to 75 hours (6.6 to 45 TWh). This probably won't be lithium-ion. The amount of required storage will be highly dependent on the generation mix.
- **Where are the Batteries?:** The right graphic is an EIA map of 2019 installed battery capacity. It only shows grid connected batteries larger than 1 MW. 37% of the *energy* (MWh) capacity is in California. The market for smaller batteries is even more concentrated in California with 83% of the *power* (MW) capacity.



Source: USCA, Company Reports, CAISO, ERCOT, NREL, EIA, EERE, ANL, NREL, LDES Council

Winter Storm Uri – Grid Fragility

- **ERCOT's Frequency:** On February 15, 2021, the frequency of ERCOT's grid dropped down to 59.4 Hz for 4 min and 23 sec. While a 1% drop for a few minutes doesn't sound like much, it really was quite dire. If the grid would have stayed below 59.4 Hz for 9 min, the ERCOT grid would have collapsed, and we could have had a total blackout for weeks or months. It takes that long to slowly bring the grid up sector by sector.
- **Black Start:** In order to slowly turn the grid back on you need Black Start capability. In ERCOT, there are 13 black start capable generators. Nine were down during Winter Storm Uri. These smaller black start generators are used to start the larger generators at power plants. But what starts the smaller generators? Batteries!
- **Smaller Batteries:** Individual lead acid batteries (much like those found in your ICE vehicle) are almost always involved in Black Start at a small scale. These batteries are used to start the smaller generators, which in turn are used to start the larger power plants. This is similar to how a battery starts an airplane's APU (auxiliary power unit), which in turn starts the main engines.
- **Bigger Batteries:** Large scale stationary batteries can be used for Black Start (by bypassing the smaller generators). That being said, the vast majority of stationary batteries do not have this capability yet due to software controls and the associated power electronics.



Source: WSJ, USCA, FERC, ERCOT

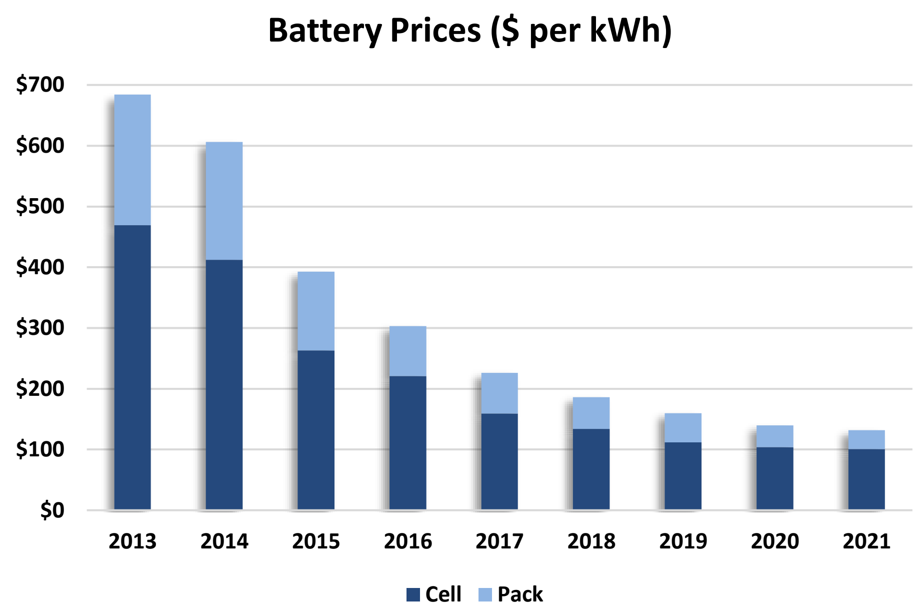
Coin Cells

STATE OF THE INDUSTRY

Source: Forbes

Batteries Are Getting Cheaper

- **Battery Pack Prices:** The volume weighted price of Li-ion battery packs for EVs has declined from $684/kWh in 2013 to $132/kWh in 2021.
- **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%.
- **Price Targets:** Price declines have started to level off as battery material prices skyrocket. The DOE is targeting $80/kWh by 2030. Other projections have cell prices going to $75/kWh by 2030.
- **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.
  - Tesla's Kurt Kelty in 2017 regarding their rationale for building Gigafactory 1:

    "We were concerned about there being enough cells in the future. It was important for us…to make sure that we had supply."
  - Romeo Power 2020 Q4 Letter:

    "Our near term production and revenues will be constrained by the shortage in supply of battery cells."

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

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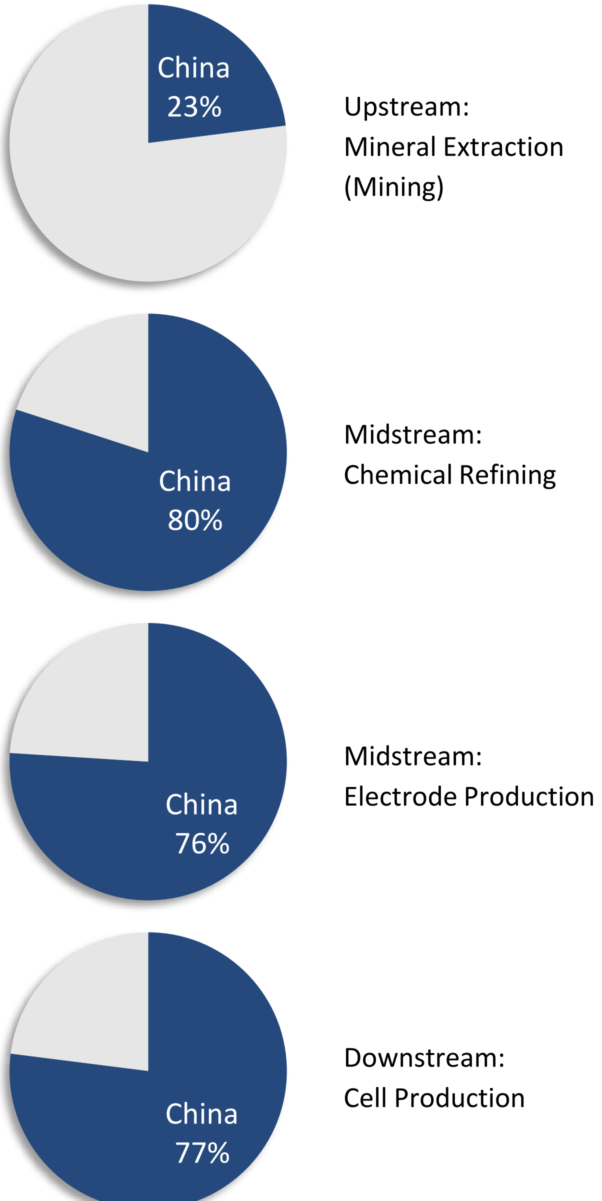
Who Makes The Batteries? – Asia Dominates

- **Benchmark Tiers:** All batteries are not created equal. Benchmark Mineral Intelligence ranks EV battery cell manufacturers in three tiers. They judge these companies on both quality and quantity. To classify as Tier One, the company must be qualified to supply to a multinational automotive OEM and have more than 5 GWh of annual production capacity.
- **Tier One:** The seven Tier One suppliers are:
  - BYD (China)
  - CATL (China)
  - Envision AESC (China/Japan)
  - LG Energy Solution (South Korea)
  - Panasonic (Japan)
  - Samsung SDI (South Korea)
  - SK On (South Korea)
- **Commonalities:** All the companies are based in China, Japan, or South Korea. CATL is unique in that they are only pure-play battery company (the rest are large industrial conglomerates), and they are relatively young (founded in 2011). LG Energy Solution and SK On were both recently spun out from their larger parent companies, but SK On is still wholly owned by SK Innovation.
- **Made in China. For Now?:** 77% of cell production capacity is in China. All of the Tier Ones are expanding internationally. CATL, LG, and Samsung have plants in Europe. Envision AESC, LG, Panasonic, and SK have plants in the US.
- **More than Cells:** China has a hold not only on the cell production (downstream), but also on the chemical refining and the electrode production (midstream). While a lot of the media attention is on the raw materials, China only controls a small portion of the upstream.



Source: Benchmark, Company Reports, USCA

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Cell Manufacturer Multiples

- **Multiples:** The tables on the right show multiples for the publicly traded Tier 1 cell suppliers mentioned on the previous slide. All of these are listed in Asia. (Envision AESC is the only private company.) Median EV/EBITDA and P/E multiples are 13.9x and 23.5x, respectively, for ’22.
- **CATL and LG Stand Out:** CATL and LG Energy Solution are outliers compared to the other companies listed. For ‘22 their EV/EBITDA multiples are 2.4x and 2.3x the median, respectively. Their ‘22 P/E ratios are 2.6x and 3.5x the median, respectively.
- **Batteries Only:** CATL and LG Energy Solution are the only pure-play public battery companies. SK On is a pure-play battery company, but it is wholly owned by SK Innovation, which has a petrochemicals business. BYD makes vehicles. Panasonic provides electronics to the automotive and aerospace industries. Samsung SDI is closer to being pure-play; in 2021, 81% of their revenue (but only 51% of their operating income) came from batteries.

EV/EBITDA

	2021	2022E	2023E	2024E	2025E	2026E
BYD	23x	17x	13x	12x	na	na
CATL	60x	34x	24x	21x	19x	na
LG Energy Solution	44x	32x	24x	18x	14x	12x
Panasonic	5x	5x	5x	4x	4x	3x
Samsung SDI	13x	11x	9x	8x	na	na
SK Innovation	8x	7x	6x	6x	na	na
Median	**18.2x**	**13.9x**	**11.4x**	**9.9x**	**14.2x**	**7.7x**

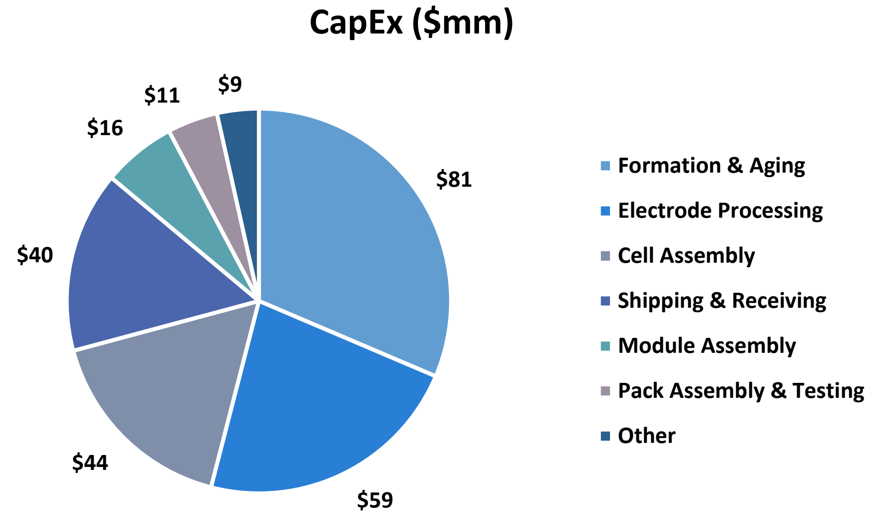
P/E

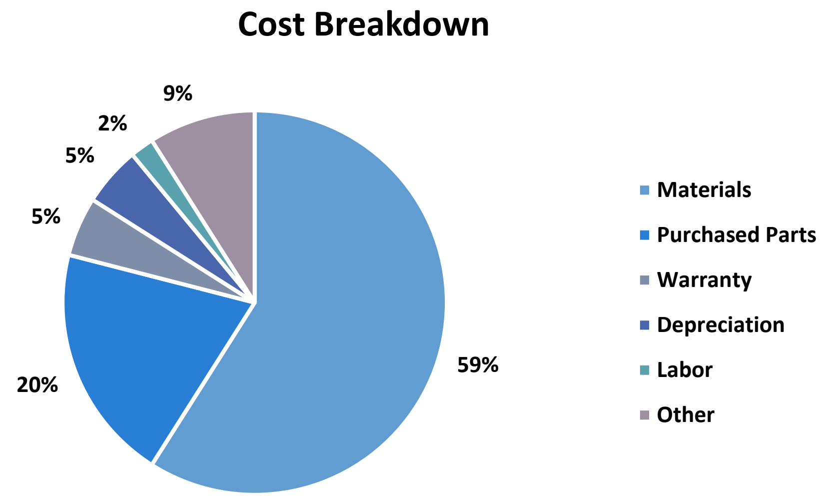
	2021	2022E	2023E	2024E	2025E	2026E
BYD	46x	26x	18x	17x	14x	11x
CATL	109x	62x	43x	40x	33x	27x
LG Energy Solution	130x	82x	55x	44x	na	na
Panasonic	11x	11x	10x	9x	9x	6x
Samsung SDI	26x	21x	18x	15x	na	na
SK Innovation	16x	14x	12x	na	na	na
Median	**35.9x**	**23.5x**	**18.1x**	**16.7x**	**13.9x**	**11.5x**

Note: Using consensus EBITDA and EPS as of 2.7.22
Source: Bloomberg, USCA

Battery Manufacturing Costs

- **Equipment CapEx:** The top chart shows the required equipment CapEx for a battery factory that starts with electrode materials and outputs full battery packs. The module and pack assembly account for 8% of the spend, so a factory only making cells, would have CapEx reduced accordingly. On the other hand, a factory that makes (instead of buys) the cathode/anode active materials would have CapEx increased.
- **CapEx Notes:** Formation and Aging is the single largest item. This is when you charge the batteries for the first time. As a rule of thumb, it's about a third of the equipment CapEx. Shipping & Receiving is high due to the automation equipment required and strict safety/environmental requirements.
- **Factory Total Costs:** The bottom chart shows the total cost breakdown. Given that they are the largest cost, raw material prices will have a large impact on total battery costs.
- **Factory Assumptions:** The numbers are for the factory in the U.S. making 100k packs per year. Each pack is 100 kWh using NMC 811 cells with a graphite anode.





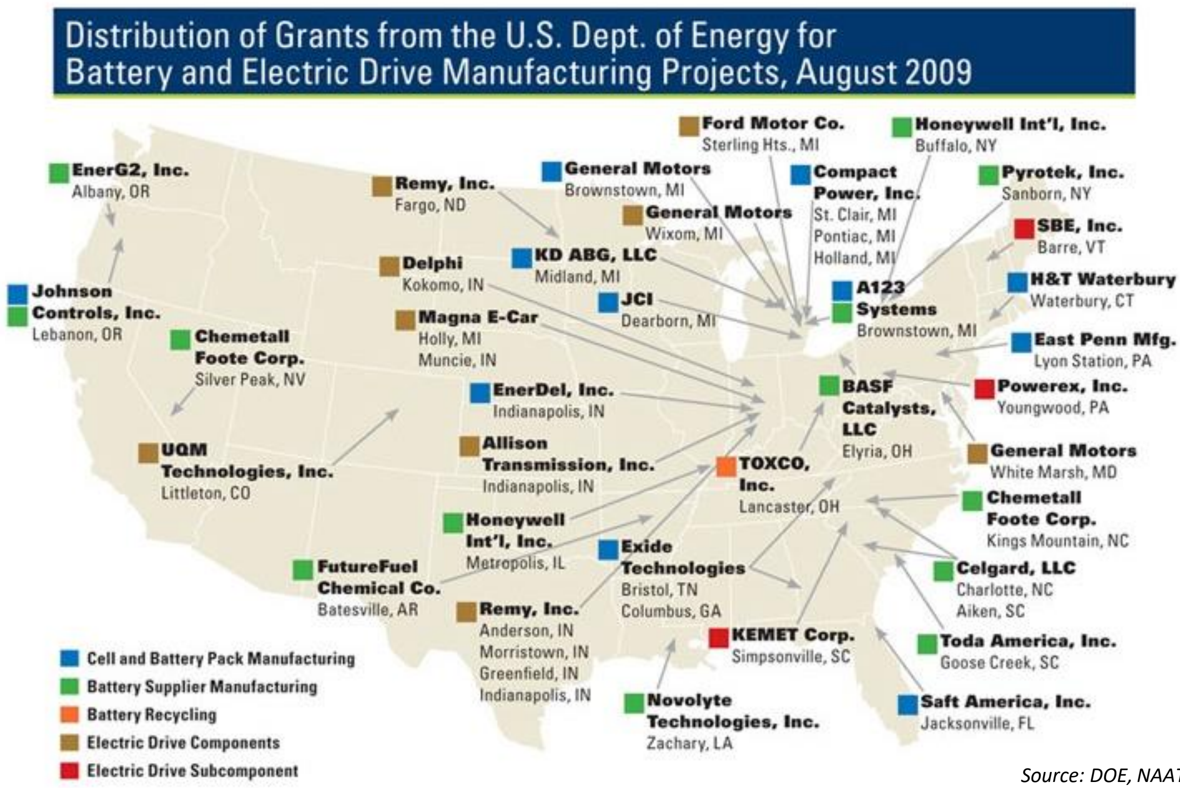
Source: USCA, ANL BatPaC

Money Printer Go BRRR

Money Printer Go BRRR

- Can we capture more of this value in the US?
- **Infrastructure Investment and Jobs Act:** The $550B package was signed into law in November 2021. It includes:
  - $3B for battery materials processing
  - $3B for battery manufacturing
  - $350mm for battery recycling
- We tried a smaller version of this a decade ago…

- **Stimulus Money:** As part of The American Recovery and Reinvestment Act of 2009 (ARRA), $2.4B was pumped into battery companies. The map below shows who received the money and where it was used. What do we have to show for it?
- **Supply Siders:** Nearly all the ARRA funds for battery companies were to help boost the supply. Little was done to boost the demand. The signed Infrastructure package does include funding to boost demand. The $2.2T Build Back Better Bill, which is in limbo, provides even more.



Source: DOE, NAATBatt, Congress, Company Reports

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A123 Case Study

- **Part 1:** A123 was one of the battery companies that received 2009 ARRA money. What happened?

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.

- **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.
- **Tell Me How You Really Feel:** After the bankruptcy auction, a former U.S. Assistant Secretary of Energy wrote:

> *"In the wee hours of last night, in a quiet bankruptcy auction, A123, once at the vanguard of advanced energy storage for mobility and security, was bought by the Chinese for less than the value of the Stimulus grant it was awarded. [...] If the U.S. government would exercise even a fraction of the involvement to ensure intellectual property it cultivates stays at home, rather than investing overwhelming hype on Ed McMahon-sized checks, press events, and ribbon-cuttings, the nation's energy economy would be less politicized, more competitive and more secure. This is a sad story and embarrassing end to a once promising American startup."*

Source: Company Reports, GreenTechMedia, Washington Post

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A123 Case Study

- **Part 2:** A123 is also a good example of how long it takes battery technologies to go from lab to market.

10 years from lab to market

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 15 and 12 years old, respectively. Neither company has a product on the market yet.
- **Simply Put:** ***Commercialization is tough.***

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

Commercialization Is Tough

- **Valleys of Death:** Why is it so hard to scale battery technologies from lab to market? Why does it take so long? Why don't we have any established American Lithium-Ion companies? There are two Valleys of Death that eat most climate tech startups:
  - The first valley involves translating fundamental research into a product. In the battery world, this involves moving from a coin cell into a standard sized cell.
  - The second valley involves scaling up the product. In the battery world, this involves moving to pilot-scale production.
- **Pizza Analogy:** Let's compare batteries to pizza…
  - Making a small single-layer battery cell by hand is like making a pizza bagel at home. Almost anyone can do it with basic tools.
  - Making a standard sized battery cell by hand is like making a standard sized pizza. You can do it at home, but you're starting to hit the limitations of your tools. Your consistency may not be great. You really do need a hotter oven. And you can't really make more than a few in a day.
  - Making a standard battery cell on a pilot line is like owning a small pizza shop in town. Despite all your friends telling you to open a restaurant, you learn that running a restaurant has little to do with cooking. You have completely different tools than you had at home. Hopefully, your quality is more consistent. Many companies fail here.
  - Making a battery at a Gigafactory is like running Dominos. It has almost nothing to do with cooking. The tools, inputs, and processes are completely different from your pizza bagel at home. Almost everything is automated.
- Making pizza at home and being the CEO of Dominos require very different skills. Most battery startups can't make the jump.

Source: USCA

The New Entrants

- Even though commercialization is tough, these are a few of the more established "new" companies that are trying. There are dozens more that are less mature. Below are the private and public battery companies that are trying to commercialize new battery materials.

Private Companies

Company	Technology	Founded	Headquarters	Capital Raised ($mm)
Sila Nanotechnologies	Silicon Anode	2011	Alameda, CA	$875
Form Energy	Flow Battery (not Li-ion)	2017	Somerville, MA	$360
24M	Thicker Electrodes	2010	Cambridge, MA	$317
Factorial Energy	Solid State	2013/2019	Woburn, MA	$240
Lyten	Lithium Sulfur	2015	San Jose, CA	TBD
Enevate	Silicon Anode	2006	Irvine, CA	$193
Ionic Materials	Solid State	2012	Woburn, MA	$65
Amprius	Silicon Anode	2008	Fremont, CA	$55

Public Companies

Company	Technology	Founded	Headquarters	Ticker	Market Cap ($mm)
Quantumscape	Solid State	2010	San Jose, CA	QS	$5,338
SES (Solid Energy Systems)	Solid State	2009	Woburn, MA	SES	$2,627
Enovix	Silicon Anode	2007	Fremont, CA	ENVX	$2,235
Solid Power	Solid State*	2011	Louisville, CO	SLDP	$1,069
ESS	Flow Battery (not Li-ion)	2011	Wilsonville, OR	GWH	$752
EOS	Zinc (not Li-ion)	2008	Edison, NJ	EOSE	$178

- Most of these companies plan to manufacture batteries. Some are taking a different path.
  - 24M plans to license their IP out to manufacturers. They were spun out from A123. Lessons learned?
  - Sila Nanotechnologies and Solid Power both plan to manufacture battery materials (instead of full cells).

*Note: *Also working on Silicon Anodes. Based on 2.7.22 share price.*
Source: Company Reports, Refinitiv, Crunchbase, USCA

Other American Battery Companies

- There are additional public US listed companies in the battery space that aren't centered around a materials innovation.

Additional US Listed Battery Companies

Company	Description	Founded	Headquarters	Ticker	Market Cap ($mm)
Albemarle	Lithium Supplier	1887	Charlotte, NC	ALB	$25,709
SQM	Lithium Supplier	1968	Santiago, Chile	SQM	$7,941
Livent	Lithium Supplier	1942	Philadelphia, PA	LTHM	$3,671
EnerSys	Lead Acid Manufacturer*	2000	Reading, PA	ENS	$3,078
Microvast	Li-ion Cell/Module/Pack Manufacturer	2006	Houston, TX	MVST	$2,119
Stem	Stationary Storage Software	2009	Milpitas, CA	STEM	$1,742
Li-Cycle	Li-ion Recycling	2016	Toronto, Canada	LICY	$1,208
Freyr	Li-ion Cell Manufacturer	2018	Oslo, Norway	FREY	$1,041
Romeo Power	Li-ion Module/Pack Manufacturer	2016	Vernon, CA	RMO	$285

*Note: *Also has emerging Li-ion business. Based on 2.7.22 share price.*
Source: Company Reports, Refinitiv, USCA

U.S. Capital Advisors

SPAC Projections

- **SPAC Structure Has Provided Long-Term Projections:** Since the vast majority of these stocks have gone public via a de-SPACing process (or have announced a deal), we have long-term projections provided in their SPAC presentations. We take the long-term projections with a healthy grain of salt, but it does provide some framework of how companies are thinking about their outlooks.
- **Positive EBITDA a Few Years Out:** Bottom right chart shows SPAC EBITDA projections. The green shading represents first year of positive EBITDA. Most of the companies expect to be EBITA positive by 2023. ***The three solid state battery companies don't expect to be EBITDA positive until 2026 or later.*** Quantumscape is projecting 2027.

Revenue Projections ($mm)

	2021	2022	2023	2024	2025	2026
Enovix	$7	$11	$176	$410	$801	
EOS	$50	$269	$736	$1,348		
ESS	$2	$37	$300	$803	$1,645	$2,572
Freyr	$0	$11	$321	$1,392	$2,875	$3,573
Li-Cycle	$12	$75	$264	$700	$958	
Microvast	$230	$460	$874	$1,545	$2,348	$2,987
Quantumscape	$0	$0	$0	$14	$39	$275
Romeo Power	$140	$412	$765	$1,156	$1,650	
SES (Solid Energy Systems)	$0	$0	$0	$100	$500	$3,200
Solid Power	$2	$3	$4	$10	$33	$132
STEM	$147	$315	$526	$748	$944	$1,167

EBITDA Projections ($mm)

	2021	2022	2023	2024	2025	2026
Enovix	($29)	($49)	$6	$140	$314	
EOS	($32)	$7	$59	$223		
ESS	($20)	($43)	$2	$131	$360	$739
Freyr	($35)	($44)	$7	$339	$703	$986
Li-Cycle	($6)	$3	$109	$339	$541	
Microvast	$12	$71	$177	$309	$465	$640
Quantumscape		($102)	($114)	($130)	($120)	($59)
Romeo Power	($54)	($19)	$91	$196	$338	
SES (Solid Energy Systems)		($100)	($100)	($100)	($100)	$500
Solid Power	($21)	($39)	($40)	($32)	($6)	$14
STEM	($25)	$28	$113	$204	$295	$417

Source: Company Reports, USCA

SPAC Valuations

- **How They Currently Trade:** Charts to the right show how the stocks currently trade on multiples of revenue (top) and EBITDA (below).
- **Inputs:** EV numbers are based on recent share price. Revenue and EBITDA numbers are the company projections provided in their SPAC presentations (and listed on the previous page).

EV/Revenue Multiples

	2022	2023	2024	2025	2026
Enovix	172x	11x	5x	2x	
EOS	0.1x	0.05x	0.03x		
ESS	20x	3x	0.9x	0.5x	0.3x
Freyr	38x	1x	0.3x	0.1x	0.1x
Li-Cycle	10x	3x	1x	0.8x	
Microvast	3x	2x	1x	0.7x	0.5x
Quantumscape			357x	128x	18x
Romeo Power	0.6x	0.3x	0.2x	0.1x	
SES (Solid Energy Systems)			26x	5x	0.8x
Solid Power	356x	267x	107x	32x	8x
STEM	4x	3x	2x	1x	1x
Median	**9.9x**	**2.5x**	**1.1x**	**1.1x**	**0.8x**

EV/EBITDA Multiples

	2022	2023	2024	2025	2026
Enovix	nm	316x	14x	6x	
EOS	5x	0.6x	0.2x		
ESS	nm	376x	6x	2x	1x
Freyr	nm	60x	1x	0.6x	0.4x
Li-Cycle	247x	7x	2x	1x	
Microvast	22x	9x	5x	3x	2x
Quantumscape	nm	nm	nm	nm	nm
Romeo Power	nm	3x	1x	0.7x	
SES (Solid Energy Systems)	nm	nm	nm	nm	5x
Solid Power	nm	nm	nm	nm	76x
STEM	48x	12x	7x	5x	3x
Median	**34.8x**	**10.3x**	**3.6x**	**2.1x**	**2.8x**

Based on 2.7.22 share price.
Source: Bloomberg, Company Reports, USCA

Pouch Cell

THE ROAD AHEAD

Source: GM

Raw Materials – Demand is Increasing

- **Demand Growth:** All these batteries will require raw materials. The IEA has put out two different forecasts for the battery mineral demand for EVs and stationary storage. The first is based on current policies in place. The second is based on meeting the targets in the Paris Climate Accords. Under the Status Quo, they see 20mm EVs by 2030 and 30mm by 2040. Under Paris, they see 40mm by 2030 and 70mm by 2040.

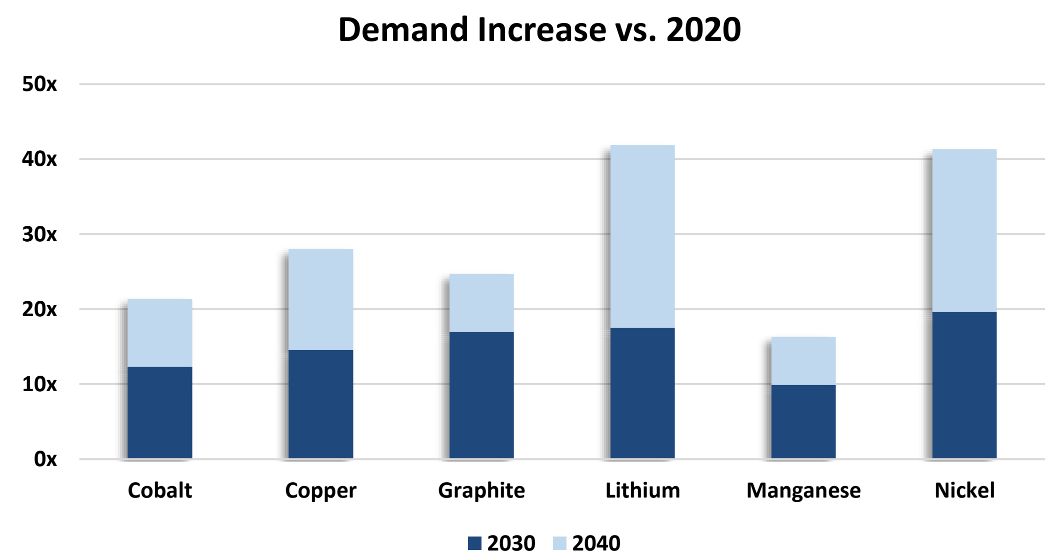
Battery Mineral Demand (in thousand tons - kt)

Mineral	2020	2030		2040	
		Status Quo	Paris	Status Quo	Paris
Cobalt	21	110	262	136	455
Copper	119	772	1,723	1,084	3,330
Graphite	156	1,151	2,641	1,204	3,849
Lithium	22	164	378	276	904
Manganese	26	106	253	126	418
Nickel	81	658	1,584	986	3,344

- **Demand Assumptions:** The IEA had to make a number of assumptions around cathode chemistries. For example, their 2030 forecasts only assume that 10% of batteries will use an LFP cathode. We think it will be higher. That would decrease Cobalt, Nickel, and Manganese demand while increasing Iron and Phosphorus demand. This shift would have less obvious consequences as well. Switching from NMC 811 to LFP for given EV pack of the same energy, you need 82% more copper at just the cell level.

- **More Demand Assumptions:** The IEA is also assuming very limited solid-state battery adoption by 2030, which we agree with. If this changes, graphite demand would decrease and lithium demand would increase.

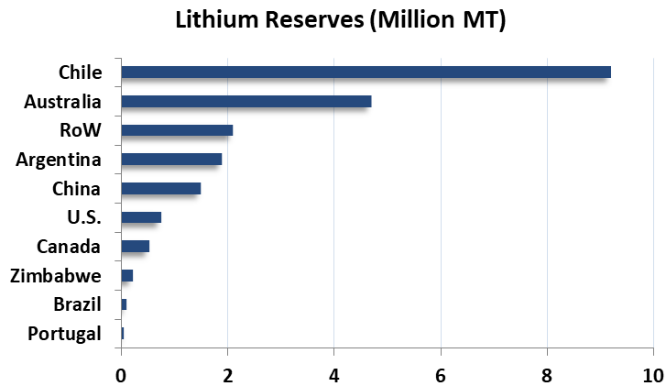
- **More Demand Growth:** On the right, you can see how by 2030 the demand for the key battery minerals will increase by an average of 15x compared to 2020 under the Paris Agreement. It's an average of 29x by 2040.

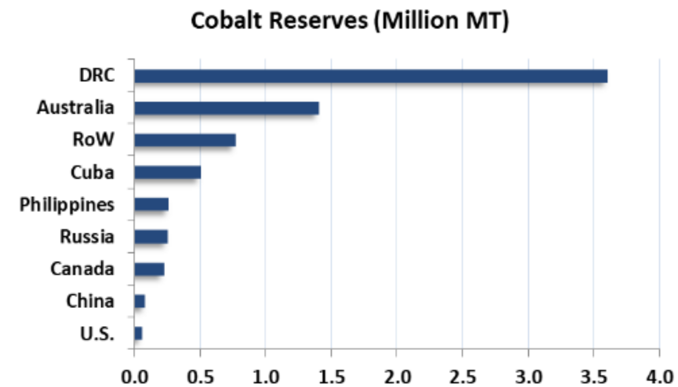


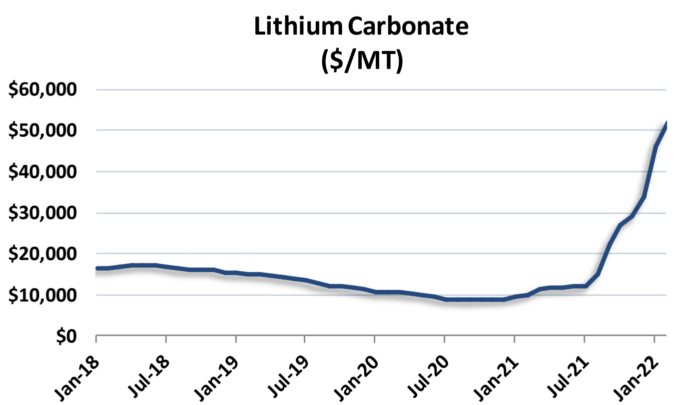
Source: USCA, IEA, ANL BatPac

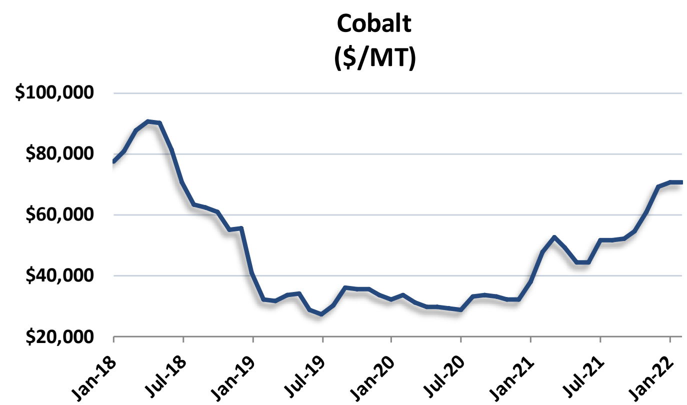
Raw Materials – Can Supply Keep Up?

- **Supply:** Can the supply keep up with the forecasted demand growth? It takes a few years to get a battery cell Gigafactory up and running. It takes even longer to develop a new mine. Thacker Pass, the largest known lithium deposit in the U.S., hasn't started production 10 years after its pre-feasibility study was first released. ***It takes an average of 16 years for a mine to go from discovery to production.***
- **Benchmark Mineral Intelligence Isn't Optimistic:** *"Mines and refineries require high sunk capital, often in challenging social and political environments. They take years to find, define, licence and construct…Green Subsides will not, for example, finance nickel and cobalt mining in Indonesia…There is no geological shortage of these materials, there is a planning and financing shortage."*
- **To the Moon:** This medium-term supply shortage is causing prices to skyrocket. Lithium Carbonate prices are up 496% Y/Y. Cell prices (and profit margins) will be directly impacted by commodity prices. Depending on the battery, raw materials account for 50-70% of the cell cost.





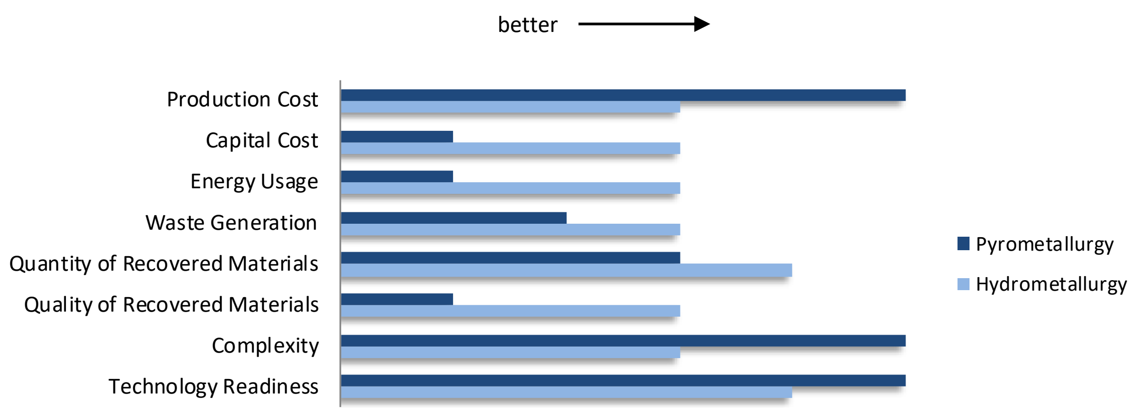




Source: USGS, Bloomberg, Benchmark, Qnovo, ESE, IEA

End-of-Life – Keeping it Green

- **Recycling:** One way to address the medium-term raw materials shortage is through recycling. Once the raw material supply/demand imbalance is corrected, battery recycling will still be necessary. Storing waste batteries en masse is both "unsafe and environmentally undesirable".
- **Early:** It will take time to scale up recycling capabilities; currently only 5% of battery cells in the US are recycled. Most recycling today is of batteries from consumer electronics, EV recalls, and manufacturing scrap, which is a substantial portion of a factory's output as it scales production (40% or more to start).
- **Pyrometallurgy:** One of the two main ways to recycling lithium-ion batteries is through pyrometallurgical recovery. You are essentially burning the battery in a high temperature furnace.
- **Hydrometallurgy:** The other main process is through hydrometallurgical recovery. You are essentially leaching the chemicals from the battery with an acidic solution.
- **Why not both?:** Many companies (including Redwood Materials) use a combination of both pyrometallurgy and hydrometallurgy. Li-Cycle is unique in that they exclusively use a hydrometallurgical process.
- **Recycling Summary:** The below chart summarizes the key differences between pyrometallurgy and hydrometallurgy.



- **Second Life:** An EV battery is typically considered spent after it has less than 80% of its original capacity remaining. These batteries are still functional and can be used for applications that are not as sensitive to energy density (i.e., stationary storage). This second life for a battery can last for many years, but the battery will eventually need to be recycled. As Taylor Swift observed: "Nothing lasts forever".

Source: USCA, Company Reports, Nature, Wired, Greenbiz, TSwift

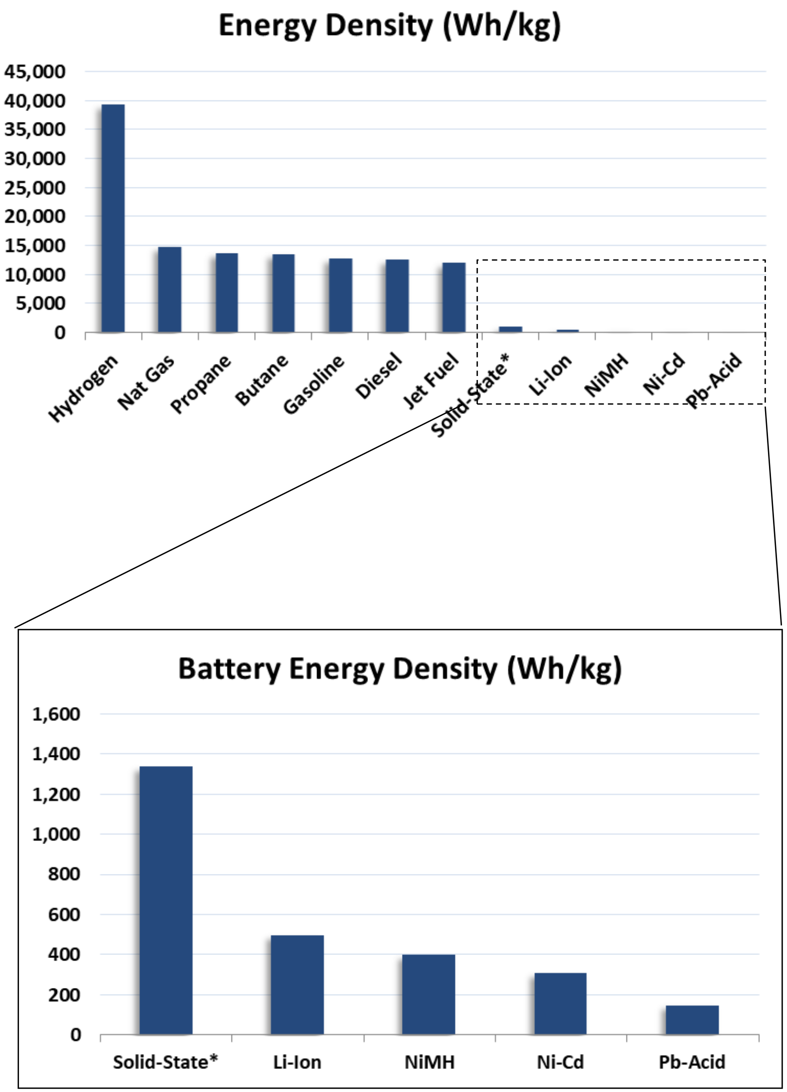
Lessons From Lead

- **What About Lead Recycling?:** While only 5% of the Lithium-ion batteries in the U.S. are recycled, 99% of Lead acid batteries in the U.S. are recycled. Western Europe also has a high recycling rate of its Lead acid batteries, but it's worth noting that the rest of the world does not.
- **Mining vs. Recycling:** In 2020, 73% of the U.S.' supply of lead came from recycling. How long until lithium (and other li-ion battery materials) reach that high?
- **Recycling Lessons:** The reverse logistics industry that powers the collection and aggregation of used Lead acid batteries will need to be built for the lithium-ion industry as well. Recyclers of Lead acid batteries benefit from standardization. Lithium-ion batteries will continue to vary in shape, size, and chemistry, so recyclers must be able to accept a varied feedstock.
- What other lessons can we learn from the Lead acid industry?
  - **Localized Manufacturing:** Manufacturing facilities will be located near the end users. Batteries are heavy and expensive to transport. Lithium-ion batteries are lighter than Lead acid batteries, but they are more dangerous. Tradeoffs! In their S-1, Fluence detailed an incident where $30mm of lithium-ion batteries went up in smoke while aboard a cargo vessel. Foreign Lead acid and foreign lithium-ion companies have already set up factories in the U.S.
  - **Consolidation:** Over time there has been consolidation in the lead acid industry across the world. Different countries have consolidated at different paces. Will the same thing happen in the lithium-ion industry?

Source: USGS, BCI, USCA

Lithium's Limits

- **Energy Density:** Lithium-ion batteries will continue to be the dominant chemistry in most applications. That being said, there are certain applications that are better suited for other chemistries or non-battery technologies.
- **You Want to Be Light:** Li-ion technology is not yet advanced enough to be implemented into long-range aircraft. ***Jet fuel has an energy density 24x greater than current state of the art lithium-ion batteries.*** The amount of energy in a Boeing 747-8 fuel tank is equivalent to over 27,000 Tesla Model S battery packs. Lithium-ion can make sense for aerial drones and smaller aircraft with shorter ranges.
- **You Want to Be Heavy:** In some applications, you actually need the weight of the battery. When switching forklifts or aircraft tugs from Lead acid to Lithium-ion batteries, additional counterweights are added to help balance the vehicle.
- **Long Duration:** Lithium-ion will continue to be used for stationary applications under ~8 hours in duration. What's used in longer duration is up for grabs, but flow batteries are a perennial favorite.
- **Long Haul:** Class 8 long-haul trucks will be one of the last road transportation segments to electrify. The size of batteries combined with the recharging requirements make the economics hard to justify. Fuel cell or other net-zero technologies may win out here.



** - highest reported, laboratory scale*

Source: Company Reports, Bloomberg, Volts, USCA

Oil and Gas…and Batteries?

- The petroleum industry and the battery industry are more connected than most imagine at first glance.
  - As mentioned on page 10, one of the inventors of the Lithium-Ion battery, Stan Whittingham, conducted his research while employed by ***Exxon***.
  - Also mentioned on page 10, one of the other inventors, Akira Yoshino, used carbon from petroleum coke for the battery's anode. (For a 100-kWh EV battery pack that uses 100% synthetic graphite, you need between 170 kg and 240 kg of pet coke for the anode.)
  - In October 2000, ***Texaco*** acquired GM's share of the NiMH battery company GM Ovonics Battery System. Six days later, the merger with ***Chevron*** was announced. The battery company was renamed Cobasys in 2004 and sold to a Samsung/Bosch battery JV in 2009.
  - In May 2016, ***Total*** acquired battery manufacturer SAFT for $1.1B.
  - In October 2019, ***Koch*** participated in the Series C round for Wildcat Discovery Technologies, a battery materials R&D lab. In 2021 alone, ***Koch*** made ten battery investments: 24M (private), Aspen Aerogels (ASPN), EOS Energy Storage (EOSE), ESS (GWH), Freyr (FREY), Li-Cycle (LICY), Lithion (private), Microvast (MVST), SES (SES), Solid Power (SLDP), and Standard Lithium (SLI).
  - In June 2021, ***Schlumberger*** and Panasonic announced a partnership for lithium production.
  - In August 2021, ***Philips 66*** acquired 16% of Novonix. The petroleum coke that Philips 66 produces will be used by Novonix to make graphite for battery anodes.
  - In December 2021, ***Equinor*** acquired 45% of stationary storage developer Noriker Power.
  - ***Occidental Petroleum*** and All-American Lithium formed a JV for lithium production.
  - Cell manufacturer SK On was recently spun out of ***SK Innovation***, which has both an E&P and a refining business.
  - Cell manufacturer LG Energy Solution was recently spun out of ***LG Chem***, which has a large petrochemical business.
  - ***BHP*** supplies several of raw materials used in batteries (especially Nickel).
  - There is a whole industry of niche battery companies that supply the oil and gas industry as well. The batteries that go down-hole have to withstand temperatures over 300° F.
  - The site of the Tesla Gigafactory was originally owned by ***Gulf Oil***. They intended to use it as a big game hunting reserve but sold it in 1998 when oil prices crashed.

Source: Company Reports, Economist, Bloomberg, Argus, USCA

What's Next?

- Hopefully, this deck provided a useful introduction to batteries.
- We'll be diving deeper into some of these topics in our Friday Notes. Future topics include the resurgence of LFP, more on stationary storage, and cell size/format considerations.
- The pace of EV adoption will determine lithium-ion battery demand. Other market segments like consumer electronics and stationary will have a sizeable market, but they won't determine the pace of growth.
  - EVs are still nascent, so expect both techno-economic changes and government policy to have large impacts on demand.
  - If EV demand comes, lithium-ion demand will grow in lockstep.
  - If EV demand comes, Gigafactory capacity will be spoken for in the medium term (three to six years).
  - If EV demand comes, midstream and upstream will be capacity constrained for the medium term.
- We will start to see performance gains from Silicon anodes and Li metal anodes trickle in during the next five years. Wider adoption will take closer to 10 years. There will be different battery chemistries for different applications.
- As charging becomes more ubiquitous, will EV battery pack sizes shrink? 80% of car trips in the U.S. are under 14 miles.
- 40% of car trips in the U.S. are under 4 miles. Is the car the right tool for the job? Or does an e-bike or e-scooter make more sense? Does it make sense to use a 9,000-pound vehicle to transport one 185-pound human?
- At the end of the day, the only zero emissions car is the one that doesn't get built.

Source: USCA, Micromobility Industries

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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.

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Risks that may impede achievement of price target(s):
Industry wide risks include but are not limited to environmental and regulatory for both pipeline and E&P, aging infrastructure and availability of midstream infrastructure to accommodate new production. Competition for and availability of service crews and drilling rigs. Commodity prices, the economic outlook, access to capital markets. Interest rates. Asset recontracting. Cost overruns.

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Price Target Methodology:

C-Corps

For C-Corps, 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, with multiples ranging from 3 to 12x. The spectrum reflects a wide range of contract lives, commodity sensitivity, volume risk, customer risk, cash flow visibility, growth outlook, etc. LP units are valued at our LP price target. GP values are determined by allocating a proportionate share of the consolidated equity value commensurate with the percent of total distributions the GP receives. We then net out C-Corp level debt and add back in forward year GP distributions received.

MLPs

For MLPs, our price targets are also based on a sum-of-the parts analysis. We value various business segments on a multiple of forward year(s) EBITDA, with multiples ranging from 4x to 13x. The spectrum range reflects a wide range of contract lives, commodity sensitivity, volume risk, customer risk, cash flow visibility, growth outlook, etc. We then net out forward year debt and minority interest to arrive at a consolidated equity value. From there we allocate equity value to the MLP based on the proportionate share of distributions the LP receives and add back in forward year distributions to be received.

MLP yield refers to the cash distributions paid out by the MLP, part of which may be treated as a return of capital rather that interest or capital gains.

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Distribution of Ratings (as of February 4, 2022):

Recommendation	Count	Percent	Investment Banking Relationship	Count	Percent
Overweight/Buy	26	63%	Overweight/Buy	4	15%
Hold	14	34%	Hold	2	14%
Underweight/Sell	1	2%	Underweight/Sell	0	0%

Historical Ratings and Price Targets may be found by clicking the link below:

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For a hard copy of our price target/ratings history or a hard copy of any report, please call 888-601-USCA (8722), or write to U.S. Capital Advisors, 4444 Westheimer Suite G500, Houston TX 77027.

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