AlphaSense

How Can Battery Producers Raise Performance and Reduce Costs?

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Executive Summary

AlphaSense experts argue that battery manufacturers can produce better performing and lower cost batteries through novel battery chemistry usage and innovative manufacturing techniques. Because the lithium-ion battery sector may reach oversupply conditions in 2030, industry participants must achieve either performance differentiation or cost leadership by then otherwise they risk being forced to exit the space.

In 2024, Europe's battery supply chain certification program will further accelerate the need to utilize more ESG-friendly chemistries and manufacturing techniques. Finally, auto original equipment manufacturers (OEMs) must increase their manufacturing flexibility to cope with the coming innovation.

Context

Pressure to improve battery performance, lower battery cost, improve supply chain availability, and raise environmental, social, and governance (ESG) standings are motivating battery manufacturers to search for new battery chemistries and improve their manufacturing techniques.

While President Biden's Inflation Reduction Act (IRA), greatly expanded the prospects for US battery production, lithium-ion batteries for electric vehicles (EVs) and stationary power (known as energy storage systems or ESS) still lack the energy density and price points that mainstream users want. The Berkeley Research Group says that the IRA created $110b in clean energy manufacturing investments, 200 new battery supply chain facilities, and 170,000 clean energy jobs.

Despite the ramp in battery production, EV batteries still lack the energy density to provide car buyers with the range they desire at a price they can afford. Today's EV batteries also lack the charging speed that auto buyers need to eliminate their range anxiety. Utility scale ESS batteries lack the energy density to last through an entire night or day cycle which prevents utilities from viewing renewables as a complete replacement of fossil fuel for baseline power.

Additionally the industry needs batteries made with materials that have greater supply chain availability. With most lithium and rare earth processing located in Asia, battery producers have sought alternative chemistries with materials that are more widely available. This more flexible approach to supply should reduce reliance on specific countries and regions.

A Wood Mackenzie expert notes that:

> *China and Indonesia account for almost 70% of global finished nickel supply.*
>
> – Report | Wood Mackenzie

Finally, the existing battery chemistry supply chain causes great environmental damage in some regions and societal harm in others. The majority of global cobalt production hails from the Democratic Republic of Congo, a country with a record of human rights abuses. In 2024, the European Parliament will require the battery manufacturers to conduct due diligence on the human rights and environmental consequences of the entire supply chain. Beginning in July 2024, battery manufacturers selling in Europe will have to show the CO_2 footprint of their products: from material extraction to production and recycling. In 2027, the European Parliament will create maximum CO_2 levels for batteries.

Problem Statement

Battery manufacturers continue to produce batteries with energy densities and price points that auto OEMs and utilities find suboptimal. Additionally, the battery supply chain is suboptimal for both manufacturers and for those with ESG concerns. To resolve these issues, AlphaSense experts suggest the following:

1. Novel battery chemistries that use less lithium, nickel, manganese, and cobalt.
2. Manufacturing techniques that reduce scrap and utilize digital prototyping.

Drivers

Novel battery chemistry and improved manufacturing techniques will decrease cost, increase power density, reduce charging time, and reduce supply chain complexity.

Battery Chemistry

Lithium, Nickel, Manganese, and Cobalt (NMC)

NMC is currently the most popular chemistry for EV lithium-ion batteries. NMC batteries have the highest energy density among battery types. The largest capacity NMC batteries have an energy density of 270-300 Wh/kg. NMC batteries have a C rate of 1.5-2 C, which is higher than most battery types. C rate measures the amount of current in which a battery is charged; higher C rates are better as they result in shorter charging times for EVs.

While NMC batteries have higher energy density and C rates than most battery types, the disadvantage of NMC is the supply chain issues with lithium, nickel, and cobalt. Governments argue against the environmental degradation caused by artisanal cobalt miners and their child labor usage in Congo. Lithium processing is mostly done in China which has caused supply bottlenecks and nickel is expensive.

Despite the massive recent lithium deposit discovered in Nevada and Oregon, Elon Musk, CEO of Tesla, argues:

> *The economic significance of the deposit to the electric car industry depends on efficient refining processes. Refining is more important than the availability of lithium ore itself.*
>
> – Report | EnergyPortal.eu

Lithium, Iron, Phosphate (LFP) Batteries

LFP is a chemical standard that is rising in adoption for EV batteries. LFP energy density is 160-180 Wh/kg. The C rate is 1.0-1.5 C. While LFP is cheaper than NMC, it has lower performance characteristics than NMC, especially in cold temperatures. Nonetheless, China's Contemporary Amperex Technology Co. Limited (CATL) has found a use for LFP in areas in addition to EVs like 120-ton ore trucks and marine service vessels where charging efficiency and cost take precedence over high energy density. Additionally the Chinese ESS market has increased its adoption of LFP batteries with its current share at 28%.

Sodium Ion Batteries (Na-ion)

Na-ion batteries have the potential to reduce battery costs and improve supply chain availability because they contain small amounts of lithium, nickel, and cobalt. Additionally, unlike LFP, they thrive at high temperatures. Na-ion batteries have an energy density at 120-130 Wh/kg. Their C rate is slightly lower than LFP at 0.8-1.2 C. The disadvantages of Na-ion batteries are the low energy density and low C rate versus NMC or LFP batteries. However despite these drawbacks, an executive at VinFast, a battery pack developer, expects technical progress with Na-ion batteries in 2026 and perhaps early adoption by 2030.

Wood Mackenzie's research shows that Na-ion battery capacity growth is ramping up fast:

> *We've tracked announcements of over 150 GWh of Na-ion production capacity, enough to power three million EVs each year. And while that capacity figure is 10 times smaller than for lithium-ion, we're still only at the starting line of the sodium-ion story.*
>
> – Report | Wood Mackenzie

However, Wood Mackenzie is less optimistic about Na-ion battery adoption due to its low energy density which translates into limited range. They also argue that:

> *Na-ion lacks NMC's established supply chains and production processes. Matching this will require billions of dollars of investment in gigafactories alone.*
>
> – Report | Wood Mackenzie

Finally they note that Na-ion may be more suitable for stationary storage and the electric two- and three-wheeler market rather than EVs. Other experts note that sodium-ion batteries may become a complementary choice rather than a full displacement of lithium-ion. China's CATL is leading the way with Na-ion usage by mixing sodium-ion and NMC batteries in Chery's EVs to balance cost and performance. Experts also expect BYD, China's leading EV seller, to mix sodium-ion and LFP batteries in some models.

Silicon Anode Batteries

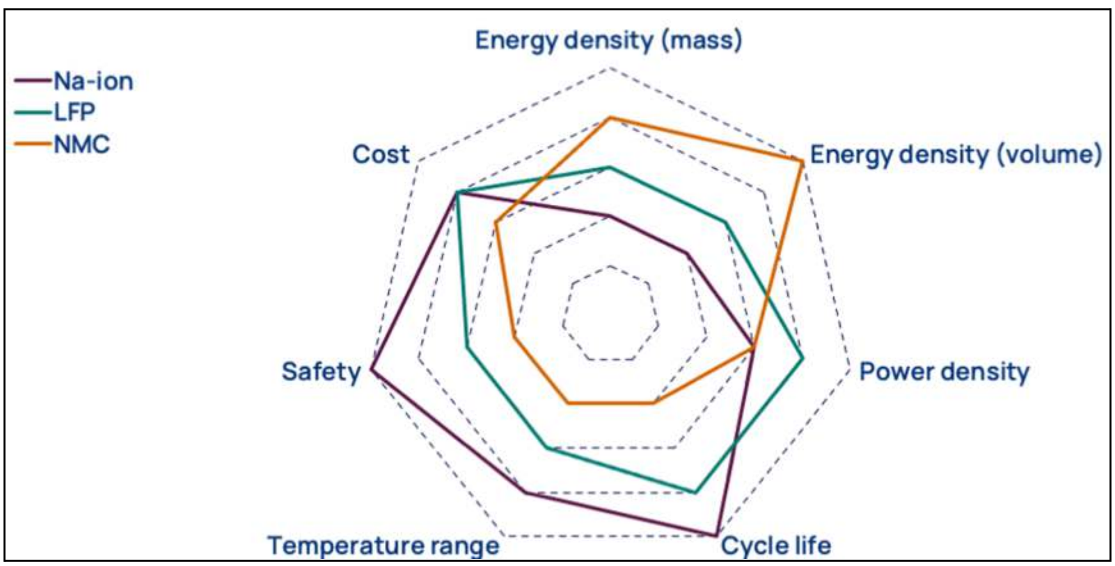
While graphite is the dominant anode material, silicon anode batteries are achieving eight minute charge times and twice the energy density of conventional graphite anode batteries. Additionally, silicon anode batteries have a safety advantage over NMC as they are five times more stable than NMC. Battery stability results in fewer fires.

The cost premium of silicon anode batteries over NMC is their primary disadvantage. A VinFast battery pack executive expects silicon anode batteries to reach cost parity with NMC by 2026. The VinFast battery expert notes:

> *They are more than 5X more stable than NMC.They have good life cycles. Their energy density is also very good.*
>
> – Expert Transcript | [Group Lead, VinFast]

It's early days for the technology as both start-ups and legacy battery firms are on their A and B prototypes. Promising start-ups in silicon anode batteries include Enovix, Amprius, Sila, Group14, SiliB Israel, and Sicona.

Battery Attributes By Chemistry



Source: Wood Mackenzie

Advanced Manufacturing Techniques

In addition to materials science, improved manufacturing techniques can also drive battery cost down and raise battery performance. AlphaSense experts recommend the techniques outlined below for lower cost and higher performance.

Reducing Scrap

A lower scrap rate enables battery producers to move down the cost curve. Additionally, a reduced scrap rate mitigates the environmental impact of battery production. A Capgemini research report argues that many gigafactories suffer from a high scrap rate, in some cases above 30%. The Capgemini experts note:

> *A 10% point scrap rate reduction can save $200-$300 million per annum for a 30GWh factory.*
>
> – Report | Capgemini SE

A former LG Energy engineer suggests that gigafactories can reduce scrap by improving their winding process, the manufacturing step combining the electrode and separator layers. He notes that 4% of scrap arises just from changing rolls when assembling layers. The expert recommends:

> *Lowering the impact of those changeovers between cathode and anode rolls, that's where the majority of scrap is coming from.*
>
> — Expert Transcript | Former Engineer, LG Energy Solution

Improving Milling Process

EnergyPortal.eu, a UK-based energy journal, cites University of Birmingham researchers who discovered that changing the milling process can increase battery performance.

> *Ball milling, a process of grinding materials with small balls, creates high-pressure on battery materials and significantly changes the properties of the materials, which ultimately improves their performance in lithium-ion batteries.*
>
> – Report | Energyportal.eu

Ball milling led to both increased energy density and battery lifespan. Unlike most battery manufacturing advances, ball milling utilizes existing manufacturing equipment, thus lowering production costs.

Incorporating Digital Manufacturing Techniques

Incorporating digital manufacturing techniques such as digital twins and AI can lower manufacturing costs by limiting expensive factory modifications after production has started. Capgemini and Siemens argue in a recent report that a simulation-first approach to gigafactory development minimizes extensive prototyping process and costly factory changes.

The integration of virtual and physical data identifies potential production issues, accelerates physical commissioning, and helps manufacturers resolve issues quickly. Capgemini and Siemens leverage digital twins of the cells and the gigafactory as a whole. Capgemini and Siemens claim:

> *With the digital twin primed, our collective solution saves twice the time during production ramp-up.*
>
> – Report | Capgemini SE

Capgemini and Siemens also claim that with digital manufacturing techniques:

> *Companies achieve scrap rate reductions three times faster.*
>
> – Report | Capgemini SE

Implications

Improving Survival Chances In An Oversupplied Market

Differentiation

The IRA may unintentionally oversupply the battery market. In the first half of 2023, the US announced battery production capacity growth of 350 GWh, almost equaling all of 2022's capacity. In a recent report, Wood Mackenzie argues:

> *Our base case scenario suggests that supply will be sufficient to meet demand in 2032, however in our highest supply scenario, it could outstrip demand by 66%. Should all projects move ahead, oversupply could exceed 2,400 GWh by 2032. As supply consistently keeps pace with, or exceeds demand over the next decade, investment cancellations seem likely.*
>
> – Report | Wood Mackenzie

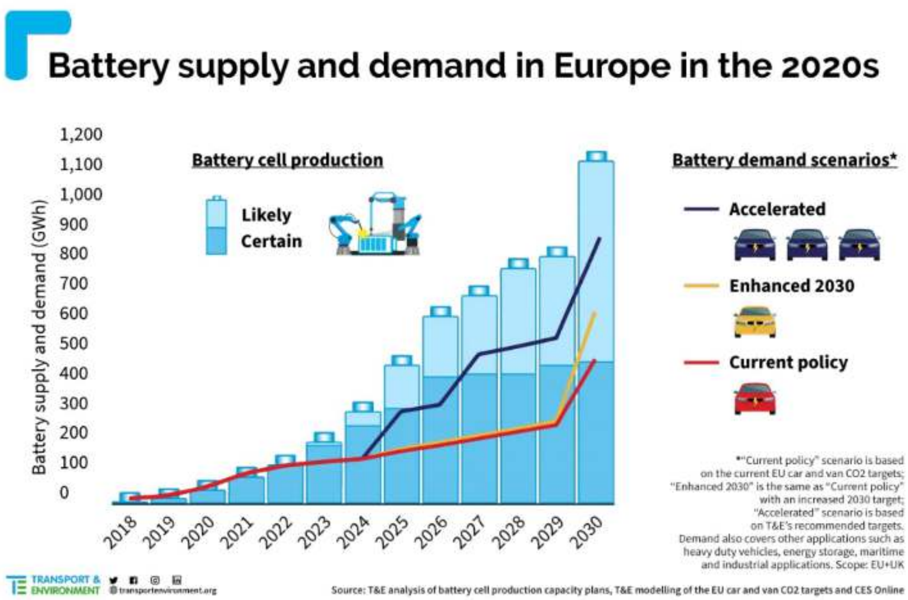
Manufacturers employing novel battery chemistries and advanced manufacturing techniques will likely produce batteries with differentiated performance characteristics which should increase their likelihood of success in an overcrowded market. While several manufacturers will likely need to scale back their battery ambitions, the most innovative firms will probably evade that fate.

Partnerships

A former Lucid director argues that partnerships are the best business model in battery development. He notes:

> *Battery technology is a long game. You can spend 10 years on a particular technology and never see it. It's like drug discovery. You can have a lot of strikes before you hit gold. I think that ultimately the more diversity you have in your approach to energy storage, the better off your company is going to be.*
>
> — Expert Transcript | [Former Director, Lucid Motors]()

European Battery Supply and Demand to 2030



Source: Nevada Sunrise Metals Corp.

Looking Ahead

Industry participants should expect Europe's supply chain certification program to accelerate the shift to better battery chemistries and improved manufacturing techniques. Europe's certification program will likely focus the industry on the prospect of battery recycling. In China, CATL leads on battery recycling. In North America, Redwood Materials and Li-Cycle are constructing facilities that separate battery metals like lithium and nickel. Redwood Materials recently launched copper foil, its first recycled product

Questions remain around how recycled materials affect battery performance. Additionally, it is unclear how manufacturers will adjust their factory processes to incorporate recycled materials and if these modifications will result in lower costs.

To cope with the battery and manufacturing innovations, auto OEMs will need to increase their flexibility. A former LG Energy engineer thinks rigid auto OEMs manufacturing processes slow innovation. The expert argues:

> *The Six Sigma rules don't always perfectly apply to the battery field. I've seen batteries get thrown away because they had too much capacity and that just doesn't make sense.*
>
> – Expert Transcript | Former Engineer, LG Energy Solution

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