WHITEPAPER: LITHIUM-SILICON BATTERIES AT GLOBAL SCALE

— BY GROUP14

The Electrification of Everything

As discussed in "The Transition to Lithium-Silicon Batteries" whitepaper, an array of experts from both government agencies and academia are predicting a coming tidal wave of energy demand, illuminating why it is strategically important for U.S. industry to establish a leadership role in the development and production of lithium-based batteries, especially next-generation batteries.

With the introduction of a new battery technology that can help usher in the electrification of everything comes differing perspectives and even misunderstandings about it. In "The Transition to Lithium-Silicon Batteries" whitepaper, we examined why it is important to transition from li-ion to lithium-silicon batteries. With this follow up paper, we intend to help stakeholders, investors, and customers better understand the importance of global manufacturing scale and how Group14 is achieving scale for our advanced anode technology for lithium-silicon batteries without requiring astronomical CapEx investments in manufacturing.

A Reminder About Why we Should Transition to Lithium-Silicon Batteries

We start with a quick review of why we need to transition from lithium-ion batteries with graphite anodes to lithium-silicon batteries with silicon-based anodes. Previously we discussed how the challenges of silicon chemistry had stopped the widespread adoption of silicon-based battery technologies. As a reminder, up until today, the hurdle for widespread silicon anode chemistry adoption has been that lithium atoms inside of silicon atoms can cause 3x expansion of the silicon when lithiated, producing obvious problems of stability and mechanical stresses for batteries. But if solved, silicon-based chemistries have the potential to create a step-change in energy storage possibilities. At Group14, we set out to successfully solve the swelling challenge by creating a nanocarbon scaffold that acts as the host structure for silicon and stabilizes the lithiation and delithiation processes, producing our product, SCC55™. Our innovation results in greatly improved energy density and cycle efficiency for the lithium battery

cells it lives in. When adopted globally, silicon-based batteries will enable the true electrification of everything.
As a refresh, the benefits of our silicon-based anode material, SCC55™, are vast. By replacing graphite, SCC55™ transforms lithium-ion batteries into ultra-performing lithium-silicon batteries which have:

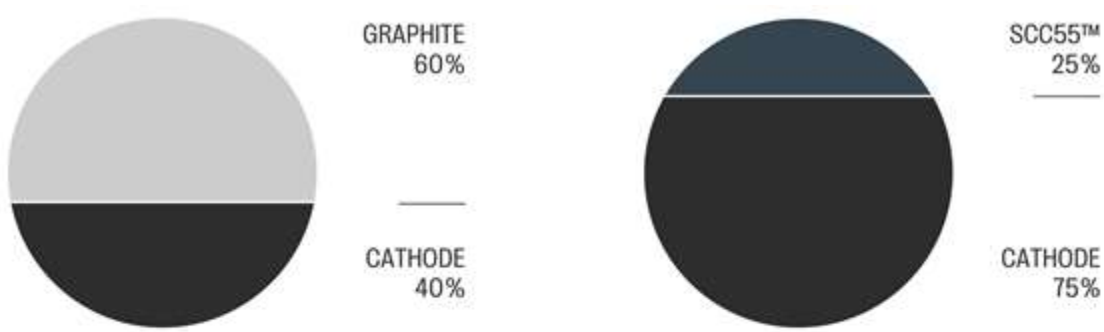
1. Higher energy density, holding >50% more charge vs. traditional graphite anode batteries
2. Significantly faster charging than li-ion batteries using graphite
3. Comparable stability to graphite over 1000 deep-discharge cycles, allowing others to innovate things that they haven't been able to imagine before

Further, SCC55™ can drop into existing battery cell manufacturing lines to create better-performing batteries immediately, with no additional requirements for implementation at the cell level. This true drop-in power provides three important characteristics for manufacturing at scale:

1. Immediate adoption and implementation into the manufacturing line, with no retraining required
2. Zero CapEx needed for retrofitting on the manufacturing line
3. Significant reduction in time to market for new products

Drop-in technology is a critical technological step that ensures a product is easily manufacturable at scale and at a digestible cost from the first factory to all subsequent production facilities. The exciting potential of silicon-based battery materials that are drop-in ready and manufactured at industrial scale is that they have significantly better performance than li-ion batteries using graphite.

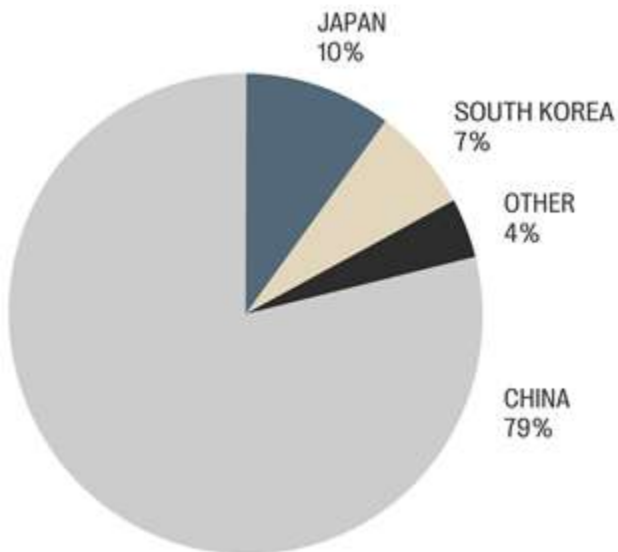
Conventional li-ion battery with graphite vs. lithium-silicon battery with SCC55™



One key performance improvement with SCC55™ pertains to battery energy density. The above chart demonstrates the space required in a battery cell for the anode between graphite and our SCC55™. When SCC55™ is utilized, it opens up 40%-60% more space for the cathode. Since the cathode is what carries the lithium, more cathode means significantly more lithium and thus, radically improved energy density.

The Need to Move Away from Graphite Goes Well Beyond Performance Barriers

World Anode Capacity by Country, 2019



Wood Mackenzie. From: Lithium-ion Batteries: Outlook to 2029. (2021).

As we can clearly see in the above Wood Mackenzie chart, nearly all graphite and raw materials for anodes in li-ion batteries are coming from Asia. The motivation to move away from graphite is not purely based on it reaching its ceiling of potential performance in batteries. We are living in the midst of what can only be described as a graphite supply conundrum that is creating a looming global battery supply chain threat. Apart from lithium, there is one material that all current lithium-ion batteries depend on; graphite. Graphite is a strangely unnoticed piece of the lithium-ion battery; but the amount required for today's batteries is tremendous (i.e., Tesla's Model S batteries contain up to 85 kg of graphite, and grid storage needs much more). In other words, the graphite anode part of the li-ion battery equation is massive. But where does graphite come from? Are there differences between graphites? Why is it hard to move away from graphite? Graphite comes in two forms: natural graphite (which is produced from a mined product [is quite rare] or as a byproduct of coal mining or oil refining), and synthetic graphite (which is produced from petroleum coke or coal tar). To date, the world's natural graphite production has been singularly dominated by China and Japan. Control of graphite abroad means that the US and other countries are challenged to ensure the affordability of Li-on batteries as-well-as ensure supplies of graphite do not run out. In other words, we are unable to meet the tidal wave of electrified demand efficiently, affordably, and most importantly, reliably. A response to the graphite supply squeeze has been to invest in synthetic graphite production, a solution that cannot meet the looming demand either. In order to ensure that consumer electronics, mobility technologies, EVs, and aerospace accelerate to their greatest potential and proliferate beyond the next ten years, we must transition away from the geographically controlled resource of graphite.

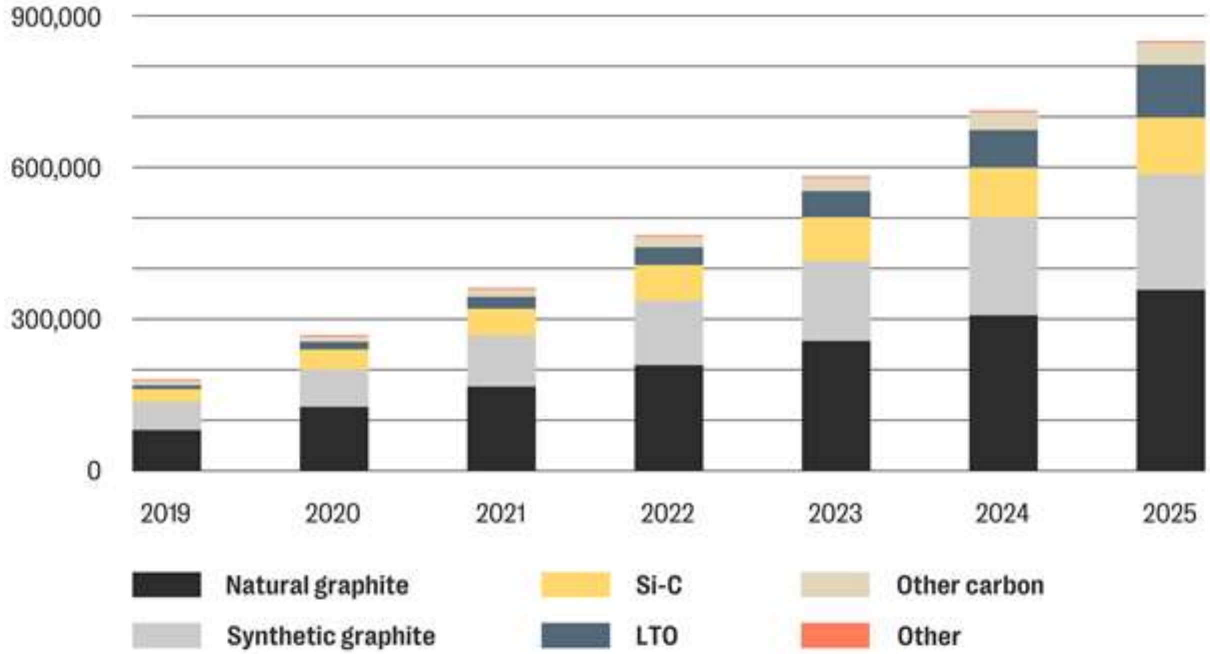
Since graphite supply is so tightly bound to a relatively small geography, the world's battery supplies are really at the whim of a few countries. Additionally, since graphite is used in most all li-ion batteries, it is challenging to adopt materials to replace it while simultaneously fulfilling current lithium-ion demand (unless materials are at drop-in scale). Further, we know from our previous whitepaper that graphite has reached its greatest potential and is now holding the world back from electrified innovation with greater potential.

The conundrum facing us across all sectors is that if we don't move beyond graphite, we won't be able to advance technologies dependent on batteries much further than what we see in the market today. An inability to advance technology prevents step-change advancements critical to global progress (i.e., the transition from gasmobiles to EVs) from ever happening.

An interesting twist in the graphite conundrum is the observation that while graphite has been used in liquid-based batteries, it is observed to be less suited for solid state applications, greatly reducing its flexibility and viability for battery innovations both today and tomorrow. It should be noted that silicon-based anodes (unhindered by the supply chain squeezes of graphite) are observed to be flexible for use in any battery technology (liquid-based and/or solid state). Thus, the flexibility of silicon-based anodes in different battery systems means they can elevate all battery applications: lithium-silicon, solid state, and beyond.

Material usability in different battery systems is critically important to meeting the energy demands arriving in the years to come. The below Wood Mackenzie chart demonstrates the near exponential global consumption of graphite predicted to meet electrification demand. Transitioning away from graphite ensures technological progress into the future while continuing to use graphite will only lead to further technological stagnation.

Forecast Consumption of Raw Materials in Anodes by Type, 2019-2025 (tpy)



Wood Mackenzie. From: Lithium-ion Batteries: Outlook to 2029. (2021).

Further, the observed global dependence on a single geographic region for graphite anode supply greatly hinders the speed and reliability at which the world can electrify as-well-as drives up the cost incurred to electrify, opening the door to supply volatility due to political interference and resource nationalism.

Adding to the graphite conundrum is the reality that flake graphite, a primary source for natural graphite, will already be in a deficit by 2023. And if the world's energy demand is growing by 58%, graphite demand will mirror this forecast by rising nearly 10x over the next decade, creating a truly wicked supply problem unless alternatives are quickly adopted. Meanwhile the few countries supplying the world's graphite will continue to meet the demand while also maintaining a vise-like grip on supply. As these realities collide, they set the stage for a catastrophic supply chain crisis. In other words, the electrification of everything is chained to a dated material, graphite, that is not sufficient for the technological dreams of tomorrow nor can meet the tidal waves of global and domestic energy storage demand. This point alone tells the story of why it is so critical to begin creating domestic battery supply chains and highlights the urgency to move away from li-ion batteries dependent on graphite to lithium-silicon batteries that can be manufactured domestically.

The Scaling Challenges Faced by Battery Material Manufacturers

The cautionary tale for a new lithium-silicon battery materials manufacturer revolves around two factors: first, production cost, and secondly, commercial scalability. The latter challenge pertains to turning a lab product into a commercially viable product. As has been seen with many energy storage and renewable energy manufacturing businesses, focusing on performance and creating the best product available on the market often means not creating cost-oriented solutions and innovations, which ultimately ends up knocking out many companies with great ideas.

Many players in today’s battery sector make an error similar to the above, racing to announce what are essentially great academic results for lab projects, but with inadequate considerations to the cost and process development necessary to successfully commercialize the innovation. This can be a recipe for disaster when it’s time for the product to move out of the lab because it remains fundamentally too expensive to produce at scale and/or is too complex to scale. Over complexity can be a death-blow to a product when attempting to scale for global market demand.

So, what's the takeaway? Performance is important, but the cost to produce the product and the scalability of the product are critical. By lowering the cost for silicon battery innovations and avoiding overly complex processes, we open the door to a commercial scale technology.

The second challenge for silicon battery technologies is transitioning the business into market leadership. Many teams can be overly optimistic and eager to claim quick success, but commercial success often takes multiple ideas, possibly thousands of iterations, and hard lessons learned to finally achieve real success on a larger scale. One of the most important steps in overcoming this challenge is to integrate process development from the very beginning of the company’s founding. If companies are not developing processes at the lab scale, teams will be forced to not only address potential complications at the commercial scale but will also likely find they haven't accounted for full scale processes and thus face the unintended consequences of driving up cost and complexity.

Overcoming this challenge typically requires that the leadership team has experience scaling technologies to even understand why it’s critical to allocate often-stretched resources to this step early on. Nailing this down is an unskippable step in scaling a business to a commercial manufacturer.

Even if a team has the experience and forethought to prioritize scaling during product development, it’s impossible to avoid all missteps during the commercial manufacturing process. The companies that will find success in this era of lithium-silicon battery innovation need to remain focused on optimizing their technology to the highest performance to meet the needs of customers and partners. As consumers increasingly acknowledge that climate change must be addressed through rapid electrification of traditionally gas-powered systems, and electronics continue to proliferate across sectors, demand will continue to rise. A company that can efficiently produce its battery product at scale and in regional, domestic markets to meet demand without sacrificing cost, performance, quality, and safety will find a substantial place in the market. When a company has a refined process development to begin manufacturing a silicon-based battery innovation at scale from the get-go, they will be able to reach commercial success efficiently and economically.

Commercial success necessitates that new entrants make product adoption as seamless as possible. For example, the overwhelming demand for energy storage means that battery manufacturers cannot make dramatic changes to battery cell assembly lines, slow down at all, and/or adopt new materials that do not drop into existing manufacturing lines. It is precisely for this reason that lithium-silicon batteries with scalable innovations are the only advanced battery technologies available today that can drop-in and deliver the performance needed for the price desired, and at the scale necessary for industries across sectors. The needs of today will only be met by companies that have drop-in materials and plug-and-play factories that can break the cycle of geographic and/or state controlled battery material resources, enabling a seamless transition to better batteries.

Group 14's Modular Manufacturing to Meet Global Scale

At Group14, we intentionally built our company with the right footholds to scale quickly. We designed our entire manufacturing process for both today's step-change product, SCC55™, and all of our roadmap products to be at commercial scale on day one.

To confidently reach commercial scale quickly, we worked closely with our partners to design a modular blueprint for manufacturing, developing what we have coined Battery Active Material (BAM) modules. Each BAM module is self-contained with a 2,000 t/y capacity. This modular design enables plug-and-play expansion anywhere on earth, ensuring that we can place multiple BAM modules together to make a BAM factory of any size. These modules ensure we can scale rapidly and globally. Further, all our products use essentially the same manufacturing processes which means guaranteed consistent scaling for years to come. Our BAM modules and

BAM factories break the vicious cycle of batteries being dependent on graphite, a largely geographic and state controlled resource.
Our BAM module strategy for the rapid scaling and manufacturing of SCC55™ and all of our roadmap products has three important traits that it enables:

1. Reduced build time (*we have the blueprint, now it's a case of repetition*)
2. Cost efficient production (*we use conventional equipment that is available globally and our process has two relatively simple steps*)
3. Rapid scale with configuration flexibility and complete location independence (*since each module is identical, we can assemble as many modules as needed*)

We call our approach to manufacturing plug-and-play manufacturing. Plug-and-play manufacturing enables global scale rapidly because each 2,000 t/y capacity BAM module is:

- 100% identical, significantly reducing EPC schedules
- Truncates commissioning and qualification cycles
- Shovel-ready for global deployment today
- Can be placed anywhere on earth quickly and with relative ease
- Enable outstanding production uptime and manufacturing reliability at every factory, regardless of location.

Group14 is committed to being a world leader for energy storage innovations that have global scale built-in. Our BAM module and BAM factory strategy will ensure that we can deliver as many BAM factories as are needed to meet market demand for the electrification of everything. BAM factory deployments alongside other manufacturing innovations like gigafactory deployments will help ensure that the tsunami of demand can be met and met domestically.

The Importance of Strategic Partnerships and Dual Source Manufacturing

While a modular approach to manufacturing is critical for rapid scale, it doesn't happen overnight. Our template for scale is ready and it works. But in order to begin the process of meeting global demand today requires leveraging strategic partnerships to manufacture for key regional markets from the get go. Our strategic partnership and joint venture (JV) with SK Group (who has tremendous manufacturing experience and capabilities) helped to validate and finalize the BAM module design and ensures that dual sourcing is mechanically included in all joint efforts. This partnership and others like it are critical early steps for any advanced battery materials company to achieve early on to eliminate supply chain risks for large volume customers across all sectors.

Not only have we eliminated supply chain risk for our customers through dual sourcing, Group14 has also highly leveraged our manufacturing and engineering capabilities further by collaborating with key European battery suppliers and automotive OEMs. These strategic partnerships when brought together ensure that SCC55™ production and all roadmap energy storage innovations are safely established in each key market, globally–North America, Asia Pacific, and Europe–significantly mitigating the global supply chain constraints affecting those markets, and allowing for the rapid transition away from our global dependence on graphite. If we can transition from graphite for li-ion batteries at speed and at scale, we can advance the electrification of everything today while ushering in a new era of possibilities for electrified technologies across all sectors, like: electric and autonomous vehicles, edge computing, AI advancements, robotics, AR/VR, powered prosthetics, electric flight, mobility in all its forms, super computing, IOT, and much more.

The battery demands of today and tomorrow require the global mass adoption of lithium-silicon batteries that are produced through scalable and modular commercial manufacturing techniques. Transitioning the energy storage industry away from an over-reliance on li-ion batteries using graphite anodes (with no more potential) to lithium-silicon batteries with silicon-based SCC55™ anodes that can be made anywhere on earth quickly and affordably is critical for reaching the electrification of everything. We are committed to creating an all-electric world and have built the right scaling processes into all of our innovations so that we can deliver on this commitment.

We hope that this paper helps our stakeholders better understand why it is so critical that we transition from graphite powered li-ion batteries to SCC55™ powered lithium-silicon batteries, and sheds light on the importance of scalable domestic manufacturing practices.