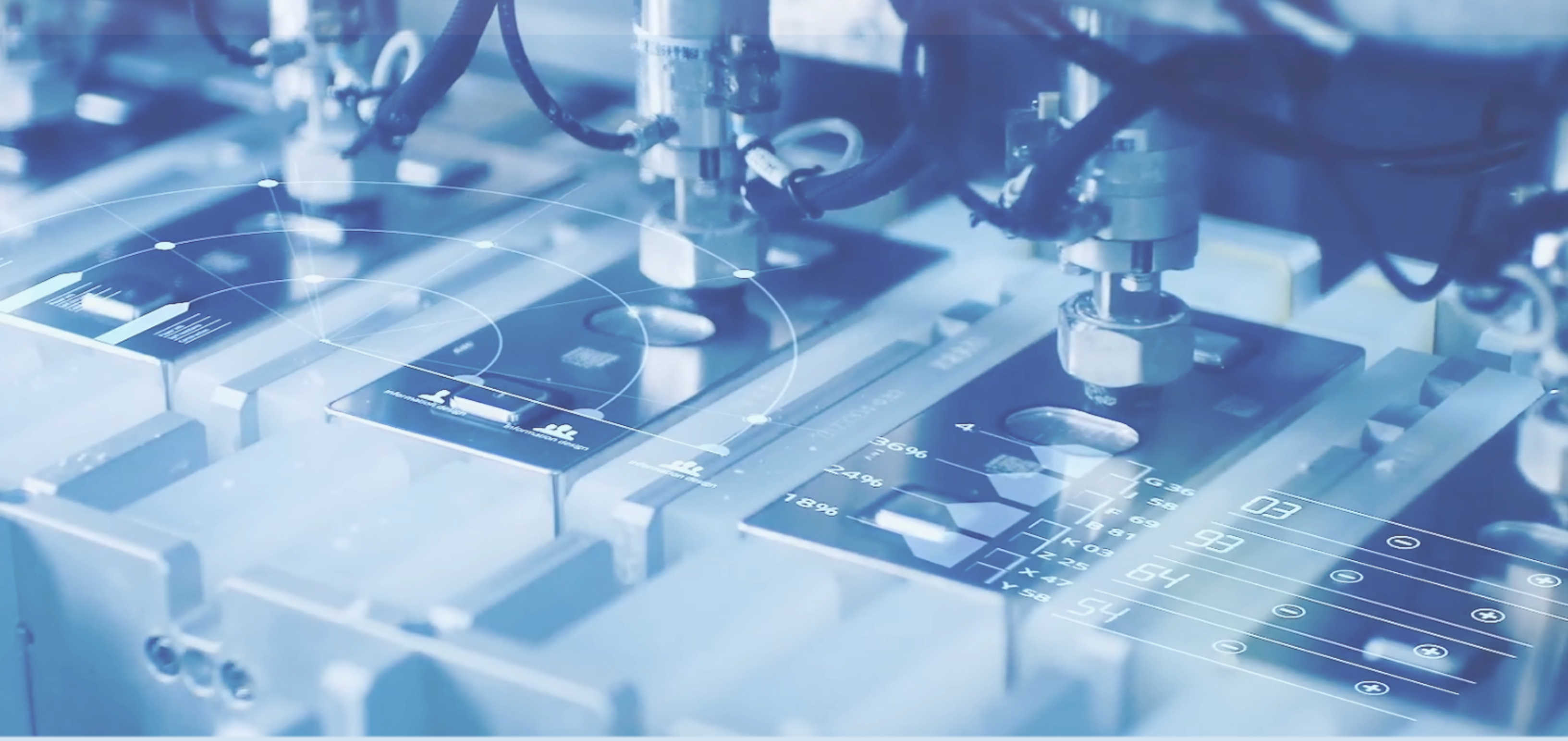

Becoming Globally Competitive: The Challenge of Battery Research in the US

BM Proto
Research

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About Us

BM Proto was founded to specifically support and accelerate battery research and development efforts by both academic and industry institutions by contracting research efforts and prototyping work. Work was historically done domestically but recent advances internationally in facilities and operations expertise have allowed for faster and cheaper prototyping capabilities internationally. BM Proto is also able to facilitate interactions between suppliers of battery components as well as sourcing production-grade quality batteries or battery modules for testing or distribution. For additional questions or discussions on addressing these issues, please contact us at info@bmproto.com.

Executive Summary

This white paper strives to highlight major challenges and opportunities behind the development of the battery research industry in the US. Battery research is both a slow and expensive process that requires highly specialized equipment. Academic labs are severely limited in the scope of their research due to the equipment available and industry research is limited by the throughput of existing facilities. Construction, operation, and baseline knowledge coupled with managing shareholder expectations on investment returns exacerbate challenges to scaling research which also impedes speed and efficacy of commercializing current and future technology.

Introduction

Recent technological and economic improvements have improved the performance and cost of lithium-ion batteries, allowing new innovations in transportation, utilities, and electronics. Successful integration and adoption of electric passenger vehicles have disrupted the largely mature internal combustion engine (ICE) vehicle industry as electric vehicles (EV) have the potential to become cleaner, more efficient, and provide better performance than the incumbent ICE vehicles. Such a change, mainly occurring in the last decade, has caused significant re-evaluation of corporate strategy and widescale investment as vehicle manufacturers, energy companies, and countries assess the impact in the coming years. Adoption of new energy generation such as wind and solar similarly creates stress on utility companies to balance fluctuating supply and demand more than the constraints from traditional fossil fuel power plants. Significant cost reductions and mature supply chains have allowed battery powered energy storage systems (BESS) to be implemented at great volume at every level from institutional grid storage to residential systems. Increased stationary storage capabilities allows more tolerance when balancing power loads while also acting as backup reserves when standard operations are affected by demand spikes, inclement weather, or issues with power generation facilities. With both EV and BESS markets poised to grow by at least 25% CAGR until 2030[1], production of critical energy storage devices also becomes tantamount to meet this new demand. As countries pivot to implement these new technologies, geopolitical issues also become inevitable. The speed and efficacy of battery research and development programs are closely tied with each country's energy policy and as a result, countries develop a competitive edge. Companies can leverage these differences to accelerate their development timelines.

Academic Research

Research is primarily conducted in two settings - academic and industry. While each field has a clear niche, an effective research environment within a country is best created with strong collaboration between the two. Government policy and funding is especially critical as researchers look to substantiate theories with compelling data.

Academic research groups are normally interested in pursuing fundamental understanding of intrinsic properties of materials or electrochemical behavior. Research is generally less time-sensitive so researchers are more free to explore topics that they find scientifically interesting. As a significant part of the workforce consists of graduate or post-graduate students, salaries of academic researchers are generally lower and workforce development pathways are more variable as researchers learn from a variety of sources to develop both subject-specific and general critical thinking skills. Industry partners will usually fund grants to perform important but non-critical research as it is often more cost-effective and frees their employees to focus on more urgent deliverables.

[1] Source, Source

Between researcher salaries, equipment purchases, and university fees, professors in US universities are often limited in their breadth of their research interests. Battery research is a time-intensive and capital-intensive effort. Many new materials are highly sensitive to water or air oxidation thus requiring specialized environments like gloveboxes. Cyclers, used to test batteries, can cost as much as $1,000 per channel. To study cycle life, a researcher might require concurrently running dozens of channels for months at a time. Other metrology equipment such as ICP-MS, SEM, XRD, TEM, and CT machines can cost hundreds, if not millions of dollars and doesn't include the modifications to the facilities to house these expensive instruments. Luckily, interdisciplinary collaboration and user facilities can shift much of the onus off the individual research group, but limited resources often mean papers do not have rigor for reproducibility or experiment designs may consistently omit time consuming but important experiments. Moreover, if a research group decides to study mature lithium-ion technologies, it may be limited by access to large scale manufacturing equipment needed for highly tuned and precise battery components. Some of these limitations can be turned into constructive learning experiences. Researchers are forced to design and build every part of the process using less than ideal equipment and gain a deep understanding of failure diagnoses, process optimization, and ultimately, the key principles underlying the test article.

Conversely, research done in Chinese universities is done at significantly larger scale. Researchers are accustomed to working in shifts around the clock to maximize lab utilization. Strong collaboration with industry means access to industry standard labs, equipment, and knowledge. This research output is reflected in the output; the Australian Strategic Policy Institute reported Chinese institutions account for 65.4 percent of the high-impact publications for electric batteries compared to the United States' 11.9 percent. Patents in electric mobility from Chinese entities have increased by 1100% from 2010 to 2020 to account for 26.9% of all patents globally[2].

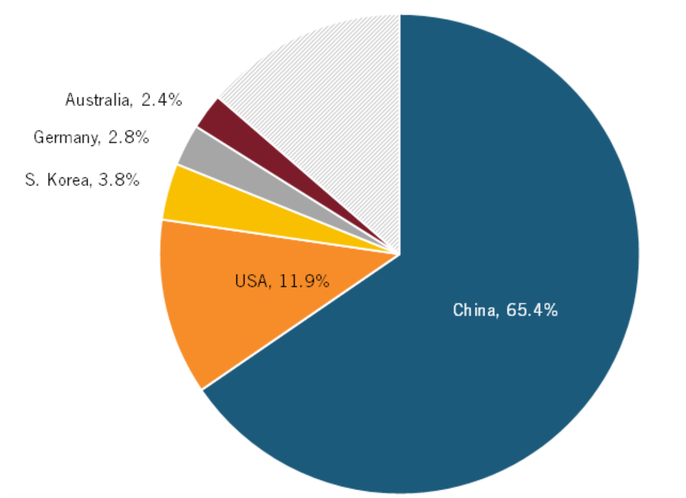

Figure 1. Top five countries for high-impact publications about electric batteries in the ASPI Critical Technology Tracker dataset[3]

[2] Source
[3] Source

Contract Research

The gap in research capabilities is now being addressed by construction of both public and private battery prototyping facilities such as the ones at Argonne National Laboratory, Spectra Power, Battery Innovation Center, and the University of Michigan. Despite a surplus of demand for facility usage, many prototyping facilities struggle to remain profitable primarily citing depreciation, labor, utilities, among others as primary factors. In response to these economic pressures, private companies such as Novonix and Wildcat Technologies have both begun pivoting away from contract research business models and focusing more on raw material production[4]. Nonprofit facilities located in universities or national laboratories also can continue to operate via academic or government assistance. To alleviate financial pressures, contract research facilities will often be located away from areas with expensive real estate and high cost of living. However, finding and retaining a critical mass of skilled technicians and engineers can be difficult so the reliability and quality of work product may suffer over time. In addition, the high operating costs and high demand means contract research is often expensive and requires reservations from the customers weeks, if not months in advance. Despite all this, contract manufacturing remains in high demand, notably with startups or research groups lacking their own capabilities or research teams at major corporations looking to increase their throughput while being constrained by headcount.

For startups looking to target the electric mobility sector, it is clear that manufacturers are increasingly trending towards larger hard shell batteries such as Tesla's 46800 cylindrical, BYD's blade cell, and CATL's Qilin designs. For stationary storage, nearly all cell manufacturers are based in China and the primary cell offering are large (50+ Ah) prismatic cells. In its Powerwall 3, Tesla is replacing cylindrical cells used in its previous design with large LFP prismatic cells. As the size of the battery increases, the complexity of manufacturing also scales accordingly. Equipment costs increase as well - larger cell jelly rolls mean tighter tolerances for winding machines and hard can require expensive lasers to perform precise laser sealing on edges. As of present, it appears no independent prototyping services exist in the US capable of producing any large cylindrical or prismatic cells let enough for a prototype pack whether for use in grid or vehicle applications.

Industry Research

Given the challenges around doing contract manufacturing, it's natural that many companies begin building out dedicated facilities for their own research teams. Control over lab settings, reduced risk for intellectual (IP) loss, and speed to perform experiments are highly valued in industrial research as for-profit companies to strive to reach profitability and create competitive advantages. Over time, companies can build up a deep base of IP and lab operation experience to remain competitive in the battery landscape. Companies may also require dedicated facilities to work on problems around optimization and scaling for manufacturing that might not be suitable for academic labs. Building out a research facility, however, is significantly more complex and expensive than many might expect. Initial CAPEX

[4] Source

expenditure at minimum several million dollars. Careful consideration must be given to identify equipment needed and the scale of the research facility. One example is a dry room. Since battery performance is acutely related to water, oftentimes ultralow humidity rooms will be constructed to handle battery components before the battery is assembled. However, this will require a sizeable investment in the dry room buildout as both the dehumidication equipment and custom flooring will have to be prepared to support the dry room. The time to complete a dry room will be at minimum two years between construction, installation, and permitting. In addition, OPEX expenditure also begins at onset as building leases and employee salaries need to be paid even during planning so as timelines become longer, the financial burden becomes greater and greater. Battery labs are highly scrutinized as the nature of research can be dangerous from the reactive chemicals such as lithium used in development and battery testing. As a result, permitting, particularly in California, is time-consuming as environmental, safety, and facilities are reviewed by the local municipality. It is not uncommon to expect lab buildouts to double or triple their initial time and cost estimates. Even after the facilities are fully constructed, it is expected to take almost a year for the facility to operate as intended as equipment needs to be tuned and adjusted, operations need to be documented and validated, and maintenance needs to be codified. Facilities buildouts pose a major risk to the survival of companies, especially those funded by venture capital firms expecting returns in 5-7 years.

A novel method for research throughput

Financially, the prospect to offshore or outsource research or development work remains resolutely compelling. Given the complexity of research manufacturing and cost of doing business particularly California, it's no surprise that some companies in Silicon Valley have begun quietly outsourcing the more laborious part of prototyping to countries with lower costs of living and high levels of expertise in manufacturing. Of course, these ventures do come with their own risks such as communication barriers, expectations around work quality, and time zones differences. Without a proper system and dedicated oversight, research projects may stall as confidence in experiment results and data integrity are impacted.

Offshoring research can reduce the cost and time by an order of magnitude and leveraging the expertise of local labor force can vastly reduce the time and cost needed to reach operating capability. Long-term operations may also be financially appealing. The discussion focuses primarily in California as it is the largest hub for battery related research in the US. In 2024, the minimum wage of hourly workers in California is $16 and many cities imposed their own higher minimum wage. Due to a shortage in skilled labor, many battery technicians command a premium, usually 2-3x the minimum wage and engineering salaries are even higher. Due to the supply of battery talent, companies usually choose to locate research centers in California and pay the premium to conduct research. While this model is tenable at a small scale, the scale of work required to advance battery research increases the likelihood that labor will likely be a major hindrance to being competitive within the field. Other critical operational expenditures such as utilities and cost of commercial space can be more than twice as costly in California when compared other states. These concerns increase the cost battery testing while stringent environmental and safety regulations limit the feasibility of performing abuse or safety tests in California. For these reasons among others, it is entirely possible that the US battery research may never be competitive with China's unless drastic changes are made.

Last year, CATL, the largest battery manufacturer in China and the world, spent nearly $2.6 billion USD on just battery R&D. The company aggressively develops its IP portfolio and performs its own manufacturing equipment design and construction to increase its competitive advantage. CATL retains almost 20,000 employees dedicated to R&D staff and actively hires the best researchers from top Chinese academic institutions[5]. Like Tesla, when CATL develops a new technology, it can scale them smoothly to pre-existing manufacturing lines while drawing on the experience of the associated production teams. To remain competitive, many other battery OEM's in China also utilize similar models of scale as they seek to improve their offerings both on cost and performance. Government support has also centralized a large part of the battery supply chain in China, facilitating strong supplier-customer relationships. As a result, companies can test and request new material samples while vendors adjust to developments to create new product offerings. Due to major language and working styles between China and western countries, many technological developments are not well publicized in the English-speaking portion of the global battery industry. Consequently, it is not uncommon to discover technologies that non-Chinese startups are hoping to develop proprietary IP around have already scaled into full production by their Chinese counterparts. At times, companies based in the US might be hesitant to outsource due to fear of IP theft. Several mitigation strategies can be used to minimize IP leakage and obfuscate key development from vendors. Overall, given the US lags years, if not decades behind China in terms of both battery research and manufacturing, it is far more likely that IP would flow from China to the US rather than the reverse[6].

Level-setting expectations for technology commercialization

It is clear that China has been aggressively developing their battery and EV industries; it is estimated that it has dedicated over $230 billion USD in subsidies dating back to 2009[7] to allow these companies to control the global market. While US government is starting to open funding opportunities such as the recent $3 billion USD DOE funding round spread across 25 entities[8], there needs to be far more support at every level as companies scale their research efforts to be competitive. Support from investors for ventures looking to simply replicate, not leapfrog, current technology is needed to build the knowledge base for future technology to truly succeed.

While the battery industry aspires to replicate the success the software industry has enjoyed, batteries and battery manufacturing will be significantly more constrained by physical limitations. Simply having the technology is only half the battle – scaling that technology so it can be used widely may prove even

[5] Source, Source
[6] Additional Reading
[7] Source
[8] Source

more difficult. By 2030, it is expected that battery demand will reach 4.1 TWh with LFP and NMC being the dominant chemistries[9]. At that scale, battery markets will start to resemble commodity markets where margins are low and volumes are high. In the last few years, both NMC and LFP have begun dipping as low as $70/kWh. Detractors say that this is a result of strong government subsidies and is ultimately unsustainable but similar examples in the solar industry suggest that price do stabilize only marginally higher after government subsidies expire as economies of scale come into play. Niche or smaller applications such as defense or consumer electronics may command higher margins but the total sales and manufacturing volume will be less and overall have less impact on global trends. As of now, Tesla is the only US-based company able to conduct battery manufacturing at scale in the US and remain competitive in pricing in large part due to vertical integration and strong demand for both electric vehicles and stationary grid. Much of their initial expertise was gained by partnering with Panasonic at the Gigafactory in Nevada. We expect almost all large-scale battery manufacturing done in the US to follow this model.

Conclusion

It is our opinion that the US battery industry is severely hampered by a lack of research equipment and facilities. Research in both academic and industry settings must be done faster, cheaper, and at greater volumes to unlock new technologies. Given the surplus of low-cost skilled labor internationally, companies stand to benefit by outsourcing research and testing as a force multiplier. Conducting research internationally naturally carries some level of risk but these can be mitigated with the proper systems in place. Accessing these resources can allow American startups to accelerate research and development activities and ultimately become profitable.

[9] Source

Additional Reading

CATL – The Battery Giant Leading Innovation in China A-Shares

Friendshoring the Lithium-Ion Battery Supply Chain: Battery Cell Manufacturing