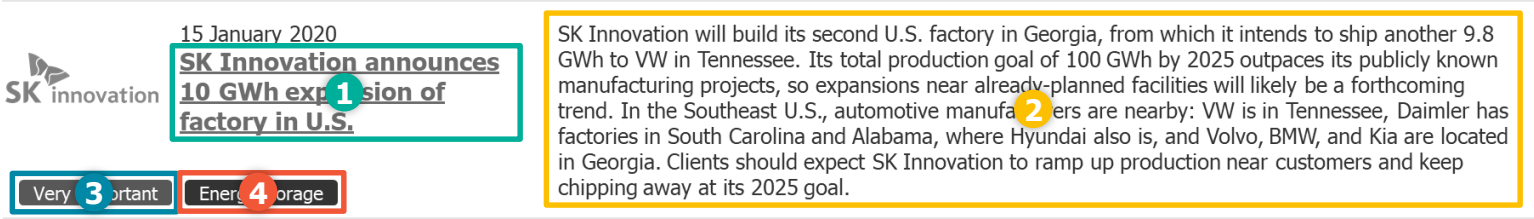
Singapore Battery Consortium

Q3 Newsletter

SINGAPORE BATTERY CONSORTIUM

Understanding curation of recent industry developments and technology news

Recent industry developments and technology news are specifically curated based on the relevance to the progression of the industry. Each news event is categorized based on importance and area of focus (see below for description for both).



1. **Link**: Hyperlink to original news article. Note some news articles may be behind paywall.
2. **Analysis**: Writeup of the news event as it relates to industry development and recommendations for action.
3. **Importance**: Take on the potential importance of the event from "Truly Disruptive" to "Ignore"
4. **Area of Focus**: Category of the news event based on the to the topic.

Importance	Description
Truly Disruptive	A game-changing, landmark development
Very Important	Significant news that will have strong implications
Average Importance	Worth noting, but not likely to be too important or disruptive
Low Importance	An over-hyped development, which is not worth monitoring closely
Ignore	Misleading or irrelevant development, worth being cautious about

Area of Focus	Description
Built environment energy use	Hardware and software technologies for commercial and residential energy consumption
Business models and regulations	Novel business models for energy production, consumption, and distribution, as well as policies with transformational impact on new energy technology development
Energy for mobility	Energy sources for powering road, rail, aviation, and marine – includes movement of goods and people
Energy storage	Various forms electrochemical energy storage, such as Li-ion and solid-state batteries
Stationary storage	Utility-scale and long-duration energy storage for grid services, renewables integration and backup, and microgrid support

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Shipping electrification gains traction as major manufacturers explore battery-powered vessels

2 July 2020

Ampcera announces new solid electrolyte technology for Li-ion batteries

Low Importance | Energy storage

Ampcera has experience selling various Li-ion solid-state electrolytes but has recently focused on a specific formulation using inorganic-organic composites. The solid electrolyte can achieve a thickness of 25 µm and a conductivity greater than 1 mS/cm. Ampcera now plans to scale up the technology and integrate it into more cells. The company can already produce its electrolyte powders at the kilogram scale. Ampcera's solid-state electrolyte performs similarly to competitors' technologies, but it claims to have collaborations with large corporations underway. Clients should favorably view Ampcera's experience selling various other solid-state electrolytes.

2 July 2020

Wärtsilä to design and equip two battery-powered ferries in Norway

Average Importance | Energy for mobility

Boreal Sjö selected Wärtsilä to design two custom ferries to be built at Holland Shipyards. One will be 30 meters long with a 10-car and 100-passenger capacity, and the other will be 50 meters long with a 35-car and 149-passenger capacity. Wärtsilä will supply the thruster motors, batteries, charging equipment, backup generators, and electrical systems. The ships will begin operations by autumn 2021. Electrifying local routes with batteries is a straightforward way to future-proof vessels. Clients should note that converting diesel engines to electric or alternative fuels will continue to be a cost-effective strategy, and ferries are the biggest target for electrification.

9 July 2020

Portland General Electric to trial 4 MW virtual power plant with hundreds of residential customers

Average Importance | Stationary storage

Portland General Electric's (PGE) pilot program intends to incentivize the installation of 525 residential energy storage systems to be aggregated into a 4 MW virtual power plant (VPP). PGE plans to launch its program this fall as part of its Smart Grid Test Bed, where participants are eligible for rebates and monthly bill credits. This announcement comes only a few weeks after Sunrun and Southern California Edison announced their own VPP with 300 residential solar-plus-storage systems. Projects like these are key to taking full advantage of the growing number of residential distributed energy resources (DERs) while delivering additional value for residential consumers in terms of resiliency and economic incentives.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Electric vehicle funding reaches all-time high with strong investor enthusiasm in the market

16 July 2020

Rivian raises $2.5 billion, as one of the few EV startups to do so without going public

Very Important | Energy for mobility

With three vehicle launches slated for 2021, the funding should be enough to see Rivian reach production with its SUV, truck, and delivery vehicle for Amazon. Unlike its peers in the EV space, Rivian has chosen not to go public looking for funds. A surge in investor enthusiasm for EV stocks has led to all-time high valuations for Tesla and Nio, tempting others – such as Nikola Motors, Li Auto, and Fisker – to pursue raising funds through the stock market. With strong strategic backers and adequate funding required to reach commercialization, Rivian is one of the few startups likely to survive consolidation.

16 July 2020

Several U.S. states entertain banning emissions from the trucking sector

Very Important | Business models and regulations

California's initial announcement to ban any polluting trucks after 2045 was quickly followed by another multistate agreement to ban polluting trucks no later than 2050. Momentum to electrify the medium- and heavy-duty vehicle space has been accelerating of late, with many looking at the long-haul trucking sector as a promising fit for hydrogen fuel cell technology, while many logistics companies, such as UPS, are focusing on integrating larger numbers of low- and zero-emission vehicles. Clients should expect this agreement to add to momentum in the space and expect more fleet operators to begin integrating zero-emission vehicles into their fleets by 2024.

17 July 2020

BMW signs $2.3 billion battery supply deal with Northvolt

Average Importance | Energy for mobility

Many automakers are diversifying cell suppliers as a way to protect against battery shortages some automakers have faced. BMW initially used mostly Samsung SDI cells, but more recently, it announced contracts with CATL and now Northvolt. Its choice of Northvolt is unsurprising, given that BMW invested in the company in 2019 and the EU has pushed to develop a local battery supply chain. This supply agreement doesn't come into effect until 2024, reflecting that fact that Northvolt is still building its production capacity and very much in a growth stage. Clients should expect electric vehicle manufacturers to continue diversifying supply chains with future announcements.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Automakers are doubling down on their electrification strategies post-COVID

12 August 2020

Hyundai launches dedicated BEV brand Ioniq, underpinned by new platform

Low Importance | Energy for mobility

We cited many examples of automakers launching dedicated battery electric vehicle (BEV) platforms in the next two to three years in the recent inflection tracker, but Hyundai has now taken its efforts a step further and is launching an electric vehicle brand under the name "Ioniq." Similar to VW's launch of its "ID" sub-brand, the brand launch coincides with the release of the new dedicated BEV platform "e-GMP," on which the vehicles will be built. Clients should note that this announcement is solely focused on the branding of Hyundai's vehicles and is not a change to previous timelines or investments in electrification.

12 August 2020

GM's changes its tune and invests in fast-charging infrastructure with EVgo

Very Important | Energy for mobility

GM had previously partnered with several charging companies to integrate different networks into its driver app, but it had stated it wouldn't invest in the infrastructure. Although the company did not disclose how much it would invest in the network, it notably focused less on highway travel and more on retail locations like grocery stores, where drivers spend 15 to 30 minutes – a strategy focused on making electric vehicles more accessible to drivers who can't charge at home or work. It will likely result in lower profitability than deploying along highways, where fast-charging is needed to enable long-distance travel, as most drivers will opt for lower-cost home charging when possible.

13 August 2020

Battery swapping expands in China, with first stations built in Hainan

Very Important | Energy for mobility

Battery swapping for electric taxis continues to grow in China, as the first station was built on the island province of Hainan to support a fleet of taxis where 200 are already battery swapping compatible. The announcement sheds some light on how these stations are operated, with EDF China and CF Energy building, financing, and operating the stations through a joint venture after the former signed an exclusive agreement with vehicle manufacturer BAIC and station hardware provider Blue Valley (a BAIC Group subsidiary). Clients should note that BAIC's partnerships should allow for faster expansion than vertically integrated operations like Nio, as it can leverage external investment and guaranteed demand through its fleet of taxis.

Next-generation battery materials remains in the early stages, but continues to pick up momentum

20 August 2020

Oxis Energy and Texas Aircraft to manufacture all-new fully electric aircraft

Very Important | Energy for mobility

The high-wing, all-metal aircraft will be based on the design of an existing Texas Aircraft airplane. The two-seater will target flight training and regional transportation in Brazil, with a flight time of two hours and approximate range of 370 km. Oxis will supply a 90 kWh battery system using its high-power cells achieving 400 Wh/kg. While small fixed-wing aircraft is a good first target for electrifying aviation, less developed battery chemistries can be difficult to certify for flight and narrowing the battery choice at an early stage could limit aircraft performance.

20 August 2020

EnergyX and ProfMOF partner up to commercialize MOFs for energy storage

Very Important | Energy storage

Through this partnership, both ProfMOF and EnergyX are more likely to successfully commercialize MOF technologies. ProfMOF has the manufacturing knowledge to produce the materials effectively, while EnergyX has a unique application for a membrane system to extract lithium from brine. Success for MOF technologies will require close collaboration between MOF developers and product manufacturers. Product companies that can use MOFs for different applications should collaborate with MOF manufacturing companies like MOF Technologies and ProfMOF to determine whether MOFs are viable and produce MOFs at scale.

26 August 2020

Kaluza provides grid flexibility services using residential batteries and electric vehicles

Very Important | Stationary storage

Kaluza claims it will become the first provider of grid flexibility services to Western Power Distribution (WPD) by optimizing dispatch of residential Sonnen batteries and electric vehicles (EVs) using a combination of smart EV charging and vehicle-to-grid (V2G). This is part of WPD's IntraFlex project, which intends to "develop learnings on the operability of short term flexibility markets." The project will test the flexibility market developed by Nodes, a joint venture between Agder Energi and Nord Pool. Kaluza's flexibility platform integrates into Nodes' marketplace, aiming to trade flexibility close to real time. Clients should closely monitor this project, which taps into the vast residential energy flexibility.

RECENT INDUSTRY DEVELOPMENTS AND TECHNOLOGY NEWS

Battery-as-a-service business model likely a key driver in reducing overall EV costs

26 August 2020

Nio's "battery-as-a-service" model is the most promising battery leasing model yet

Truly Disruptive | Energy for mobility

Attempts to decouple the costs of the battery and the costs of the vehicle are not new, as Renault has offered a similar battery leasing option on its Zoe. The two reduce the vehicle cost by roughly $10,000 and are leased for between $100 and $150 per month. However, Nio's battery swapping network offers more flexibility to introduce new battery chemistries and allows customers to change their battery size while owning the vehicle. For these reasons, and the fact that it is bringing in partners to help finance the business, clients should view Nio's announcement as favorable.

3 September 2020

QuantumScape goes public via SPAC at $3.3 billion valuation as EV bubble continues to grow

Low Importance | Business models and regulations

QuantumScape is the latest startup to go public via a special purpose acquisition company (SPAC); while most have been electric vehicle companies, this marks the first battery company to jump on the trend. There are a number of red flags about the announcement. The CEO claims the company has eliminated the "science risk," but further examination of investor presentations suggests the company still has yet to make a multilayer cell – a crucial step for commercializing its technology. The company does not appear to be on track to meets its aggressive targets, which include an incredible 91 GWh of production capacity by 2028 at 30% gross margins.

24 September 2020

LG Chem to spin out battery business, likely in an effort to capitalize on investor enthusiasm for EVs

Average Importance | Business models and regulations

LG Chem has consistently ranked in the top three battery suppliers globally measured by GWh of storage delivered, but the business includes segments that look at life sciences and petrochemicals. Although LG Chem noted in its press release that it had not decided if it would go pubic with the new entity, named LG Energy Solution, Lux believes one of the key benefits of such a move would be taking advantage of investor enthusiasm in the electric vehicle space to build out manufacturing capacity. The razor-thin margins associated with battery manufacturing make it challenging to use profits to do so. Clients should note that this does not materially change the outlook or technology roadmap for LG's battery business.

ADVANCED BATTERY ANALYTICS

The Next Frontier for Battery Management Systems

Hundreds of millions of dollars are spent on battery testing and development; any means of expediting that process is advantageous. In battery manufacturing, monitoring systems can speed up formation cycling, which can take weeks. BMS solutions in BEVs and stationary storage can offer crucial predictive maintenance cycles for extended lifetime. Battery analytics solutions use a combination of hardware, such as current, voltage, and temperature sensors, and software, often using cloud computing and machine learning, to improve battery performance. While most OEMs have their own system that monitors battery health, third-party BMS startups add value through advanced capabilities. Current technology is limited by software engineering and incomplete models. Predictive features depend on battery test data, which inhibits smaller companies from developing robust systems for large battery packs in BEVs or stationary storage. Integration into existing battery packs can prove difficult, which software-only solutions can bypass.

LUX TAKE

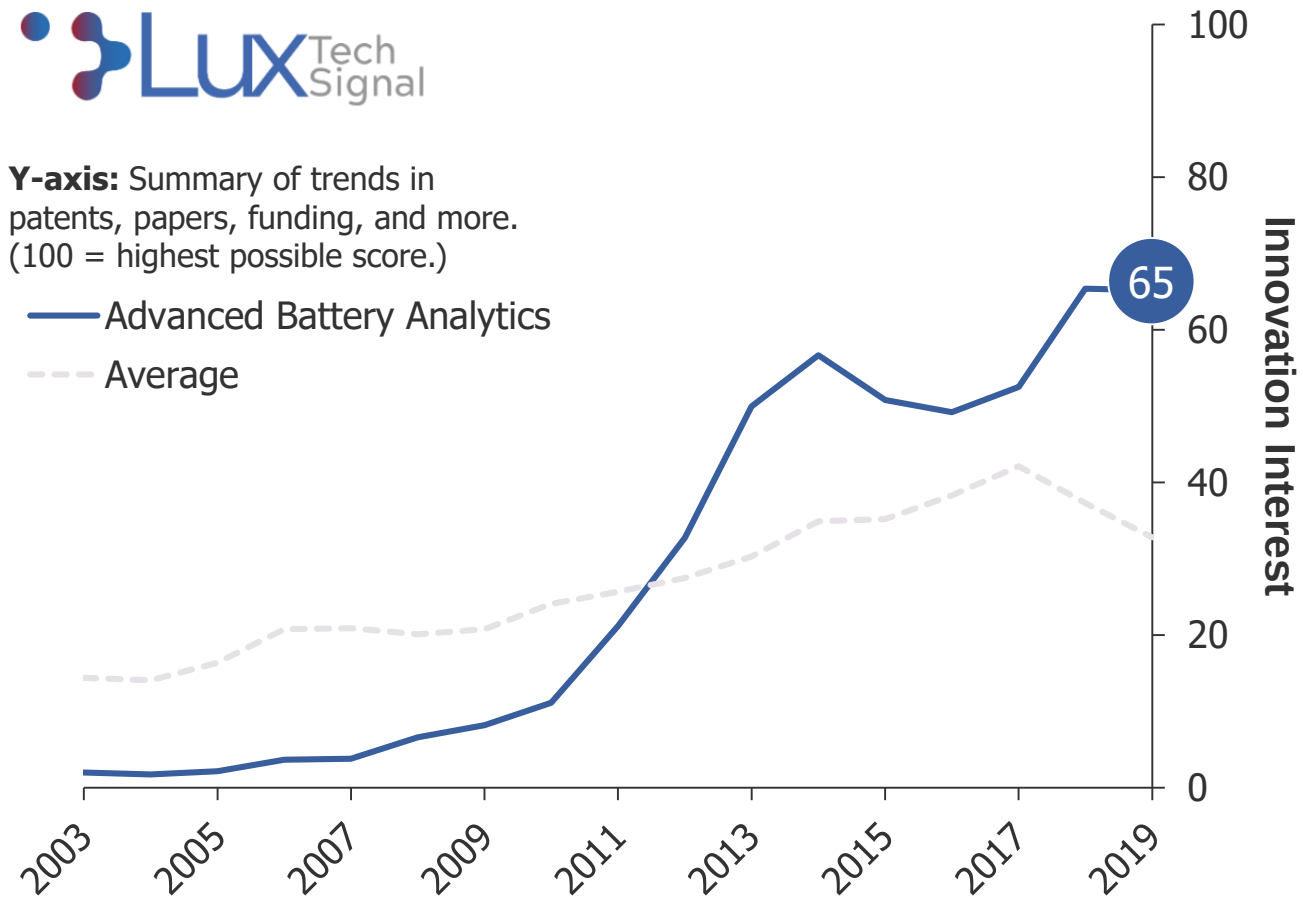
Advanced battery analytics offers solutions across all points of the battery industry. Battery development tools offer accelerated materials discovery and test data handling. Manufacturing-focused technologies can detect defects and speed up formation cycling times. Battery management systems in BEVs and stationary storage offer asset owners wider capacity charge and discharge windows, predictive maintenance features, and fast charging capabilities. Clients interested in maximizing value from batteries have ample opportunities at every step to engage with technologies that can incrementally improve performance without the hefty investment of improving battery chemistry.

LUX TECH SIGNAL

Steady increase in innovation interest for advanced battery analytics over the past decade

The Lux Tech Signal is a composite score, combining data in patents, papers, and funding, plus our own proprietary data. It quantifies the progress of each technology, against a maximum innovation interest score of 100. Changes over time indicate growing (or shrinking) innovation interest, while inflection points may point to commercial opportunities or challenges ahead.

Lux Research independently tracks more than 5,000 technologies, topics, and related concepts. These are chosen based on our taxonomy and possible future research interests, and are automatically monitored using the Lux Intelligence Engine. The averaged Lux Tech Signal performance of this long list is shown in the gray line as context for comparison, to show how a particular technology compares against the average.



PATENT TRENDS

Steady increase in innovation interest for advanced battery analytics over the past decade

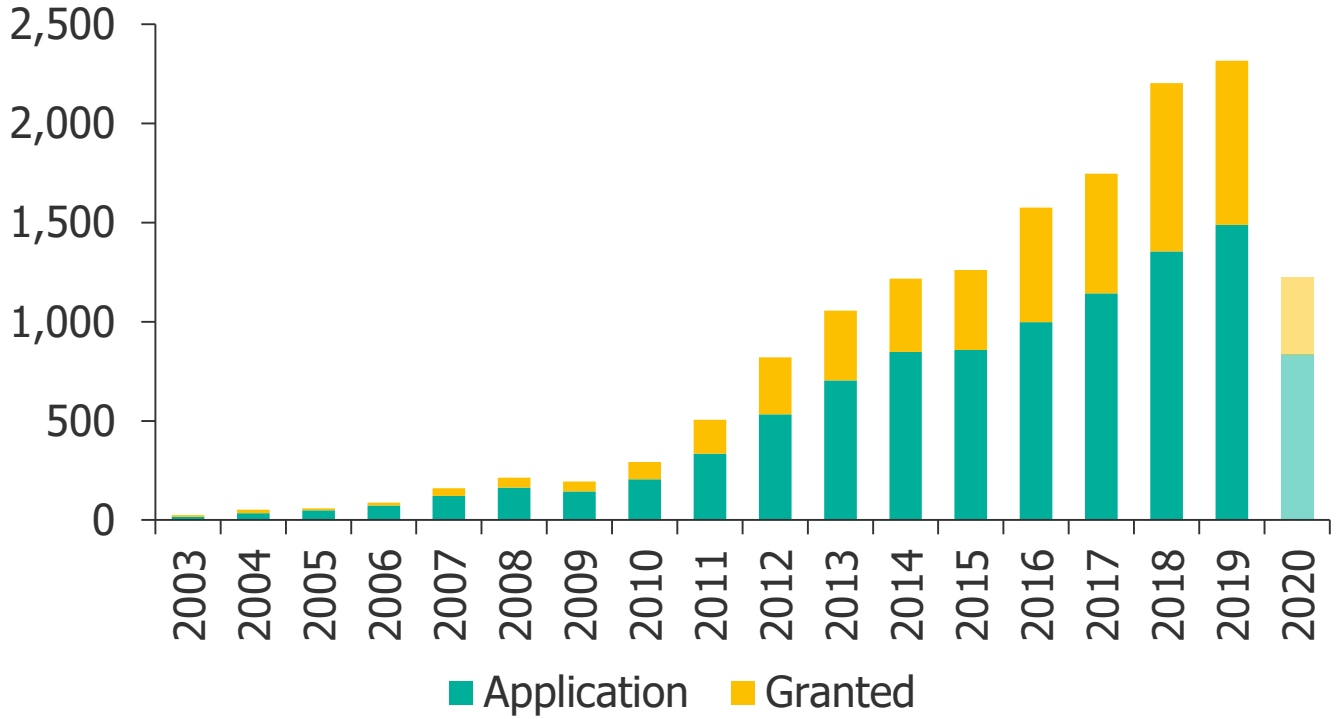
The majority of patents in advanced battery analytics are assigned to battery makers and automotive OEMs, which design hardware and circuitry for large battery packs. The volume of patents speaks to the state of commercialization and maturity of the technology.

Samsung SDI leads in patent activity with 372 granted patents, while LG Chem and Bosch have approximately 300 granted patents each. Battery analytics is necessary for both optimal performance and safety monitoring, and large battery makers have a large lead in IP protection.

With software solutions notoriously difficult to patent, startups in this space will typically have a small amount of IP and depend on trade secrets to protect their technologies.

Advanced Battery Analytics Patents

Total number of applications and grants



INVESTMENT TRENDS

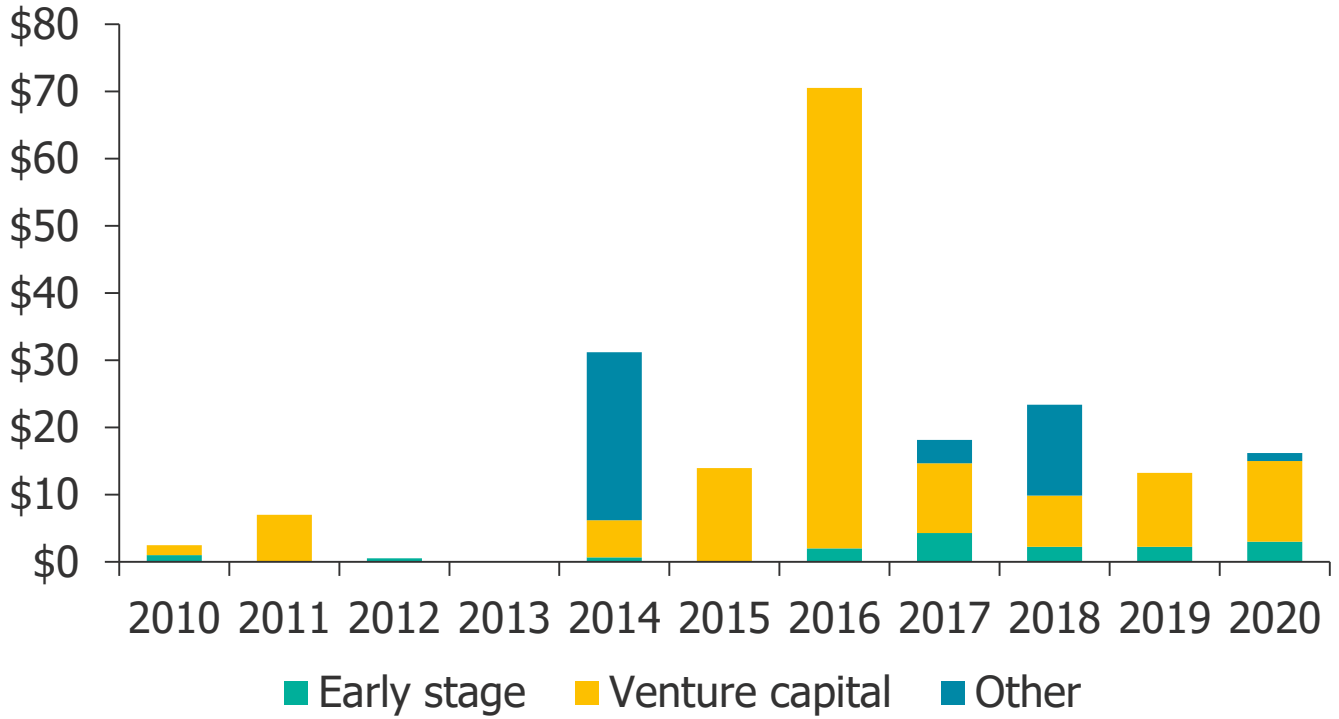
Venture capital firms have invested nearly $200 million in advanced battery analytics startups in the past decade

Almost all advanced battery analytics startups receive funding from VC firms and little investment from strategic partners. One exception to the rule is Qnovo, which has strategic investments from Intel and Qualcomm. In 2016, HyperStrong raised $68 million in a Series B from Qiming Venture Partners, an anomaly in the usually modest BMS industry. Earlier this year, Twaice closed its Series A with almost $12 million in funding from the same pool of investors as its $2 million seed round in 2019. Titan Advanced Energy Solutions closed a similarly sized $10 million Series A from investors like Schneider Electric Ventures and the Massachusetts Clean Energy Center.

The field of battery analytics is capital-light compared to battery development and production, so companies are typically able to exist without the mammoth investments that are typical in other areas of the energy storage industry.

Advanced Battery Analytics Investments

Total funding (US$ millions)



Lux Research

KEY PLAYERS

Advanced Battery Analytics

Using advanced battery analytic tools in the first stage of battery development, researching new chemistries, and building prototypes is typically done by large research institutions or battery makers. IBM and Daimler teamed up to use quantum computing to find optimal electrode materials for lithium-sulfur batteries. Meanwhile, Lawrence Berkeley and Argonne National Laboratory dedicate research teams to building software for battery materials discovery and enhanced performance.

Usage-based battery analytics is where startups have the biggest opportunity. Automotive OEMs and battery makers typically have their own battery management system (BMS) software built into packs, with basic capabilities like state-of-charge and state-of-health monitoring. Third-party BMS software has the advantage of working across manufacturers and systems, with the added value of increased cycle life with active cell charge balancing, fast charging capabilities, or a digital twin feature for usage transparency.

CASE STUDY

Qnovo and GBatteries enable fast charging by advanced battery management systems

INTRODUCTION

While battery developers strive toward increased energy densities, high cycle life, and lower costs, battery management systems (BMS) offer a solution to maximize battery performance and optimize charging times. Electric vehicles have the most to gain from fast charging software that can charge at rates up to 7C. Based on total predicted EV sales, 425,000 fast chargers will need to be deployed globally by 2025, requiring a battery system that can accept the rapid charge rate without deteriorating battery performance or lifetime. Many limitations lie within the battery itself, reflected by Porsche falling short of its 350 kW charging goal with the Taycan. However, BMS software can still deliver fast charging without battery limitations or power requirements while offering better battery health.

USE CASE AND BUSINESS IMPACT

As the demand ramps up for extended driving range and fast charging, battery technology itself cannot be the only answer. Through electrochemical impedance spectroscopy, Qnovo's BMS measures battery health and alters charge and discharge rates for optimal usage. The technology is enabled by vast testing data on lab battery systems under a range of environmental stresses. Then the software uses machine learning to identify optimal charge pulses based on lithium ion diffusion rates inferred from the datasets. GBatteries uses a similar approach to its fast charging software, monitoring impedance at the string level to deliver charge pulses. As a newer startup targeting the EV market, GBatteries is dependent on partnerships with automakers to build the necessary dataset of battery response to its charging method. The key differentiator among companies will ultimately depend on the wealth of testing data available and the complexity of algorithms. BMS adds value for both the battery manufacturer and the consumer by enhancing its current battery technology and unlocking fast charging capabilities independent of power input.

KEY TAKEAWAY

With a focus on fast charging, the right BMS will be able to communicate with existing pack infrastructure to modify charge and discharge patterns for optimal battery life. Lux expects OEMs and third-party BMS developers to complement each other, giving EVs an enhanced cycle life and fast charging capabilities. Both Qnovo and GBatteries have demonstrated their product in single-cell consumer electronics batteries, but the real challenge lies in converting the BMS software to EV battery systems. Clients interested in pursuing fast charging software have an opportunity to step in with partnerships to provide access to more battery data and invest in further development.

CASE STUDY

Powin Energy maximizes value in application stacking via battery analytics

INTRODUCTION

Application stacking in energy storage system (ESS) markets creates multiple revenue streams for a single energy storage system by providing different grid services. While stationary energy storage has historically been more expensive than energy storage for transportation, application stacking favorably changes the economics to create a profitable asset where a singular value stream wouldn't merit deployment. Batteries used in application stacking are subject to a variety of charge and discharge cycles, each of which affect battery health and state of charge differently. Tracking that usage to optimize battery performance across applications has the potential to further reduce the levelized cost of storage (LCOS) by managing battery maintenance across uses for prolonged system lifetime.

USE CASE AND BUSINESS IMPACT

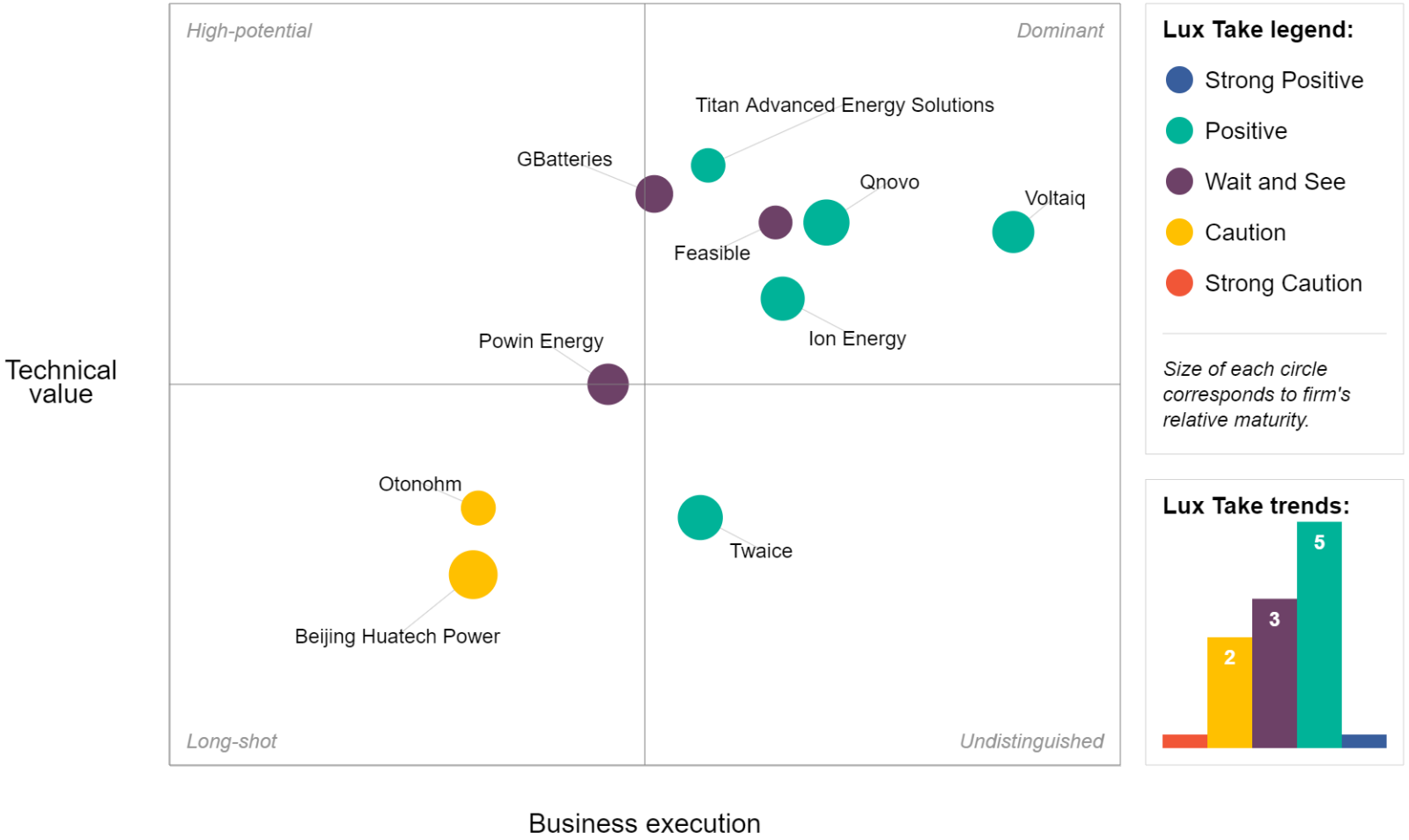
System integrators for ESS add value by integrating battery analytics platforms with a distributed energy resource management system (DERMS). Powin Energy develops a battery management system (BMS) to control power distribution to battery stacks and monitor battery state of charge at the string level. The company offers a platform that analyzes the required usage of a battery for a given application and optimizes charge and discharge cycles to minimize battery degradation. It also does active cell balancing, saving time on maintenance and extending battery lifetime. The BMS can perform front-of-the-meter, behind-the-meter, and microgrid applications while keeping battery usage flexible as priorities shift. The extra analysis done for the battery adds the largest value by extending the system lifetime while engaging with multiple revenue streams.

KEY TAKEAWAY

Application stacking provides a means of decreasing LCOS, but variable demand on batteries can negatively impact their performance. An increased understanding of the battery health in the system, widening the usable capacity window, and lengthening battery life can all drive down the costs of large ESS projects. While monitoring the health and state-of-charge BMS for applications in consumer electronics and transportation are expected to work across an array of battery chemistries, stationary energy storage Li-ion batteries are less likely to be novel. Instead, advanced BMS companies will need to focus on building up an analytics platform capable of processing the complex system infrastructure of a stationary energy storage system. Clients should look for partnerships with companies developing analytics software that minimize cell balancing time requirements and improve battery performance to lower system costs.

LUX INNOVATION GRID

The startup landscape is varied, with each company using its own approach to add value to the battery



Ion Energy

AI-enabled battery management software and hardware

- Ion Energy develops a battery management platform for Li-ion batteries in mobility and stationary applications; the company licenses the management software and circuit board designs to customers, and offers access to its cloud service for device analytics and diagnostics
- Battery management system (BMS) uses conventional electronics components with modified software tailored to specific applications; cloud-based analytics layer uses a digital twin derived from digitized data sheets and algorithms from Ion Energy to estimate state of charge and state of health
- Relies on a licensing model where customers license a BMS board and software suited to a particular application from Ion Energy, partner with a third-party electronics manufacturer for the BMS board, and subscribe to Ion Energy for access to the analytics layer for remote diagnostics or preventative maintenance
- While Ion Energy's business model is unconventional, clients should be encouraged by Ion Energy's traction in the market and favorably view its approach to improving the traditional BMS through analytics

LUX TAKE: Positive

ION ENERGY

Company Website

SUMMARY INFORMATION	
YEAR FOUNDED	2016
LOCATION	Mumbai, Maharashtra, India
REVENUE	$2.25 million (estimate)

Twaice

Digital twin-based battery analytics solution

- Offers a digital twin-based Li-ion battery analytics solution; differentiates in its use of a combination of physics-based and machine learning models to simulate, detect, and predict battery defects
- Additionally, it claims to offer insights at a parallel cell string level as opposed to the module level (a module is made up of many battery cells connected in a specific configuration)
- Its solution is targeted toward electric vehicle OEMs, fleet operators (both utilities and vehicle operators), and insurance companies; claims it has 12 customers across Germany, Austria, Switzerland, France, and China
- While the company's digital twin models are not that differentiated, the market it is entering for offering analytics for better battery fleet management is underserved, with few players standing shoulder to shoulder; clients managing battery assets at scale should engage

LUX TAKE: Positive

TWAICE

Company Website

SUMMARY INFORMATION	
YEAR FOUNDED	2018
LOCATION	Munich, Bayern, Germany
REVENUE	$1.2 million (estimate)

Voltaiq

Performance data analytics of lab-scale and product-level energy storage devices

- Develops a battery data analytics software for global battery OEMs, transportation companies, consumer electronics companies, and energy storage developers and operators; the software imports data across different testing, manufacturing, and operations sources, converts data into a common format, and provides visualization and analytics tools for the data
- The software reduces overall time spent on managing data, visualization and analytics, and battery information like manufacturer, age, and health in order to accelerate new product launch and ensure reliability
- Recently developed a battery digital twin, which tracks the entire life cycle of a battery from build through field operation; also developed an executive dashboard to make relevant testing status and metrics more accessible
- Notable customers include automotive companies like GM, Chrysler, and Ford; Voltaiq also sells its product to battery manufacturers in the consumer electronics industry and industrial energy storage companies
- Clients should view the company positively for its efficient data management, user-friendly platform, analytics to improve decision-making, and developed digital twin of the batteries

LUX TAKE: Positive

voltaiq | Company Website

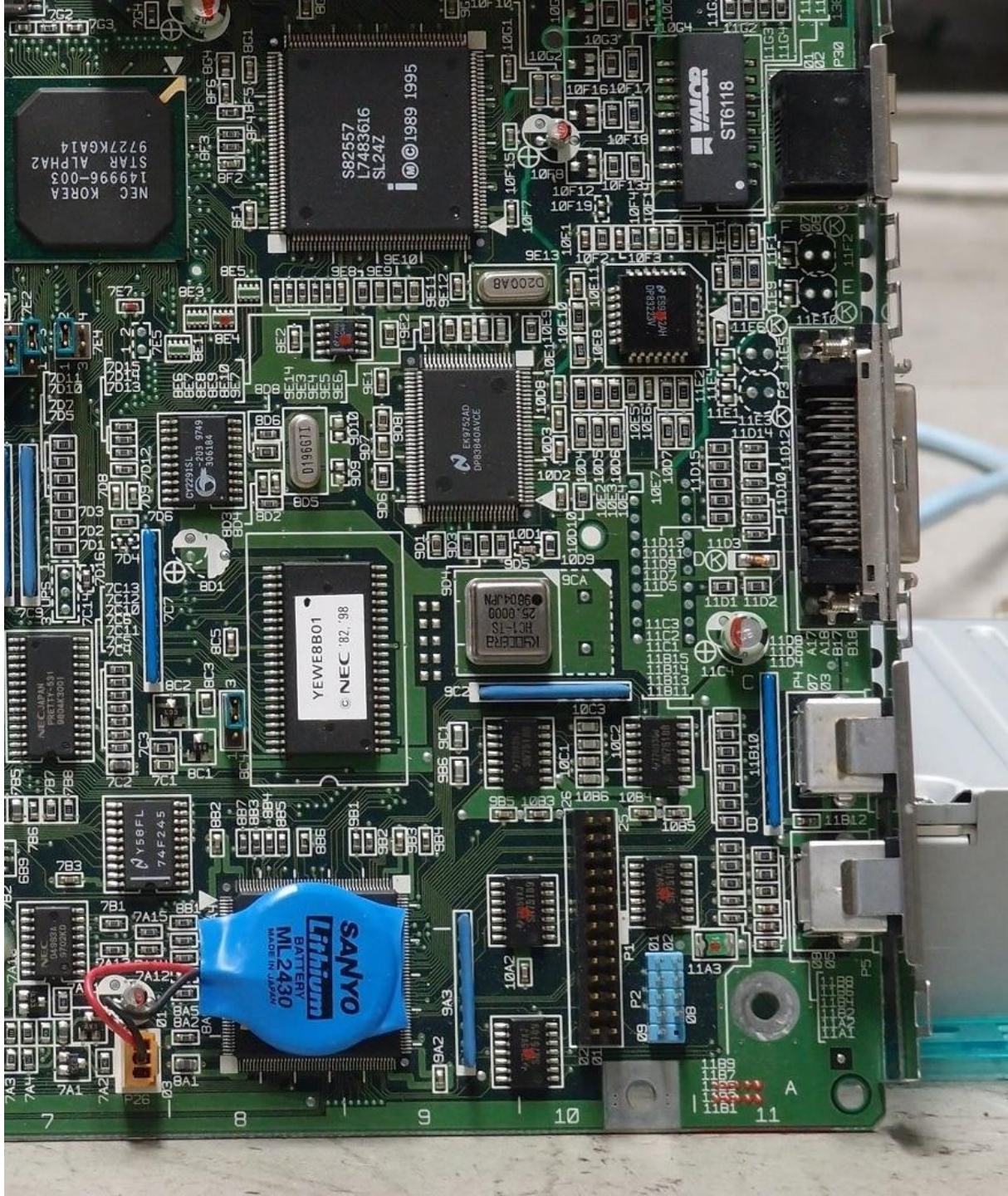
SUMMARY INFORMATION	
YEAR FOUNDED	2012
LOCATION	Berkeley, California, United States of America
REVENUE	$6 million (estimate)

ADVANCED BATTERY ANALYTICS

Key Use Cases

With the battery materials innovation landscape becoming more competitive, startups developing advanced analytics technologies for batteries are now on the rise. These technologies require less upfront capital expenditure than battery material development while still offering improved battery performance, and developers are targeting all segments of the battery industry, including materials research, technology development, commercial manufacturing, and consumer use. There is certainly plenty of room for improvement: Today's battery management systems (BMS) rely on generic lookup tables for battery management, and battery research efforts require extended periods of rigorous study.

In the following sections, we consider the wide range of advanced battery analytics use cases – development, validation, and usage.



ADVANCED BATTERY ANALYTICS

Battery Development

Advances in battery technology require robust tools that can integrate previous experimental results and novel theories for increased performance. Aspects of battery development include data management, materials exploration, and predictive battery behavior:

- **Data Management:** As battery development rapidly evolves, the need to efficiently handle and analyze test data becomes nontrivial. Testing can involve tracking cycle life, behavior leading to battery failure, or performance under variable environments. Battery makers collect large amounts of data during this time, and the appropriate tools can speed the process along. Voltaiq has taken advantage of this need and has become a leading provider of software to ease data aggregation, visualization, and analysis. Companies that recognize the value of effective data management have the opportunity to capitalize on a growing need in the battery development industry.
- **Materials Exploration:** Machine learning and AI have the capacity to compute the performance of numerous battery technologies quicker than labs can build them. IBM has built an AI tool to explore new materials for battery use. While molecular computation is still relatively immature, its potential for modeling the next big battery chemistry holds promise for companies with the requisite tools. Argonne National Laboratory, in conjunction with the Department of Energy, is similarly involved in electrolyte materials research through AI computation. Active players in the materials research space require large interdisciplinary teams, intensive computing resources, and a considerable reservoir of previous experimental results.
- **Predictive Behavior:** One of the biggest overarching industry trends in analytics is the construction of a digital twin (see our tech page on industrial digital twins). Battery digital twins carry information regarding manufacturing origin, chemistry, age, capacity, and usage history. Twaice leverages physics-based and machine learning models to simulate battery behavior and provide simulations of future performance, including defects. While battery analytics companies have come out with their own versions of battery digital twins, Lux is skeptical that these features are useful for novel battery chemistries, as building new models for each unique battery on the market is nontrivial. However, these tools remain useful for evaluating common battery chemistries that have already reached mass production.

ADVANCED BATTERY ANALYTICS

Battery Validation

After batteries are assembled, they go through a quality check and initial charge/discharge cycle. These aspects of battery analytics can be classified as quality inspection for defects and safety testing:

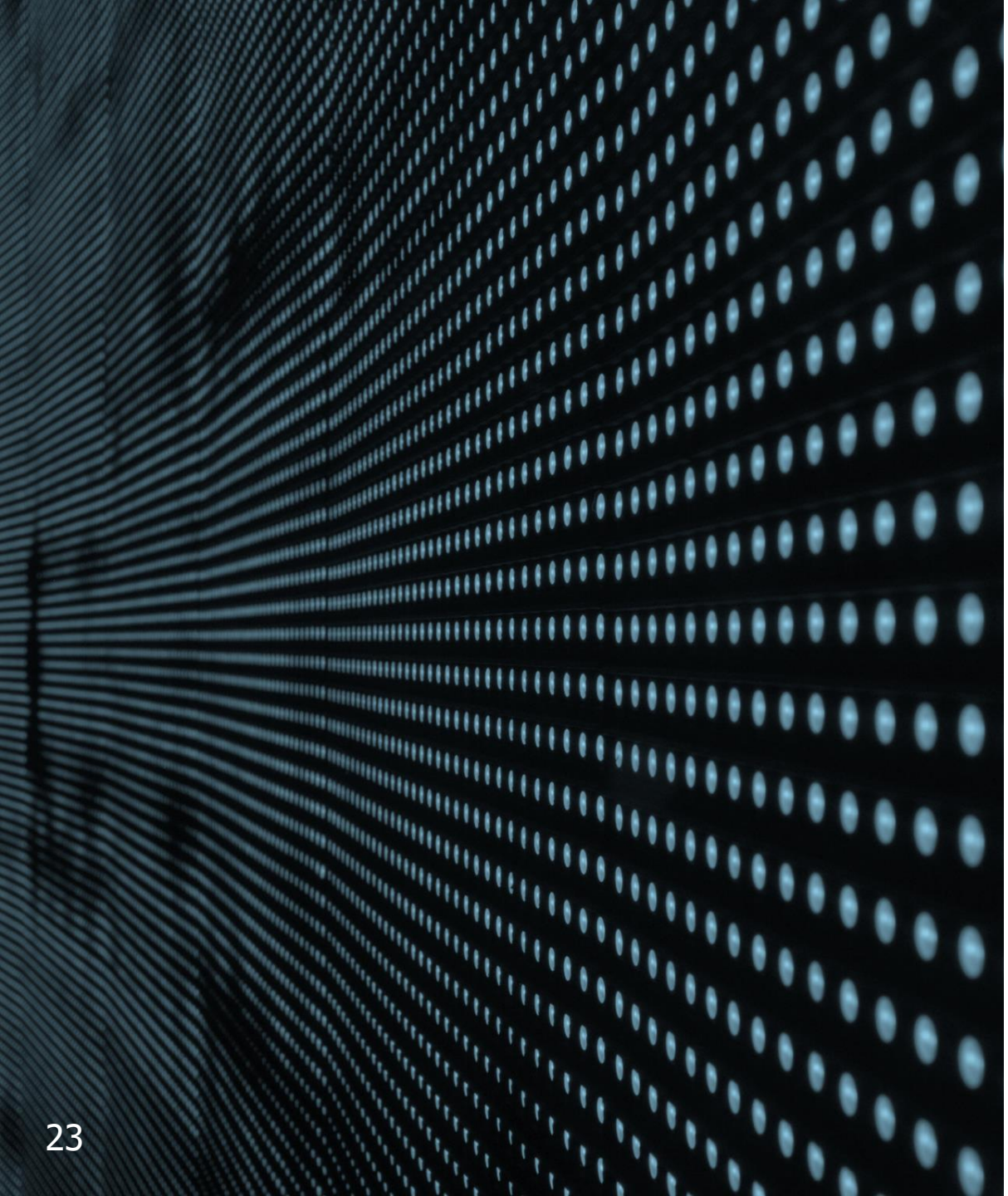
- **Quality Control:** Active battery defect monitoring can minimize the number of malfunctioning batteries before they end up with consumers. Through electrochemical and acoustic spectroscopy, manufacturers can assess previously unmonitored characteristics like lithium plating and uneven solid electrolyte interphase (SEI) layer growth. Feasible utilizes acousto-ultrasonic measurements of batteries to provide insight into a cell's expected lifetime performance and quality of production. Battery producers can use information gained during quality checks to improve their processes and reduce battery failures.
- **Safety Validation:** As batteries become higher-energy, there is an increased need for safety testing validation. The most prominent example, the Samsung battery fires, left Samsung SDI responsible for a reported $3 billion in losses. As a result, the company implemented an eight-step validation procedure for safety measures. It is in battery makers' best interest to have an advanced battery analytics platform that specifically tracks safety and predicts thresholds for safe usage, checks for limitations in cell design, and reports failures accurately.

ADVANCED BATTERY ANALYTICS

Battery Usage

When batteries come into use, optimizing their performance should be a priority to users. Advanced battery analytics that focus on battery usage encompass fleet management, fast charging, and battery monitoring:

- **Fleet Management:** The increased use of shared mobility services provides an opportunity for advanced battery analytics to bring more value to fleet operators. Active monitoring of batteries in the field provides real-time statistics, which can direct appropriate usage. Ion Energy has developed a cloud-hosted BMS that delivers real-time statistics along with predictive maintenance tools. BMS tools that give fleet owners a better understanding of battery performance add value and longevity to their assets.
- **Adaptive Fast Charging:** Fast charging of electric vehicles (EVs) through adaptive BMS remains a hot topic among battery analytics companies. Most platforms depend on a combination of previous performance data and machine learning algorithms to adjust charging. Qnovo uses electrochemical impedance spectroscopy on its test batteries to understand ion diffusion rates during charging and then adapts the charging current accordingly. GBatteries uses algorithms to determine appropriate pulse charging signals for batteries in real time. Companies engaging in adaptive fast charging also promise longer battery lifetimes than normal usage or charging via conventional constant current/constant voltage (CC/CV) methods.
- **Battery Optimization:** Advanced BMS are replacing passive battery monitoring, which depends on generic battery behavior from lookup tables. From small mobile battery packs to large stationary storage systems, BMS take control of appropriate battery cycling and have more control over accessing the full capacity of a battery. This results in active cell balancing, charge and discharge control, environment control, and fleet control. As battery raw material costs begin to plateau, getting the most performance from a battery becomes the next cost-saving step. In the case of BEVs, tapping into the full capacity of a battery can result in fewer cells for an increased driving range. Titan Advanced Energy Solutions claims that its real-time ultrasound-based BMS can provide a 20% improvement in usable battery capacity and a 125% improvement in battery cycle life compared to incumbent voltage/current-based BMS solutions. Of all available battery analytic technologies available, advanced BMS platforms have the best value proposition in optimizing the performance of a battery.



ADVANCED BATTERY ANALYTICS

Driving value across the battery value chain

Across all stages of the battery industry, battery analytics tools are designed to optimize operations and reduce costs. While many cell manufacturers and automotive OEMs already incorporate their own battery analytics, we remain wary of the limitations of current functionalities, and there is still ample room for third-party companies to develop technology across all fields of the battery industry. Battery analytics startups require fewer resources than other battery materials developers, typically only needing a skilled computational team and modest funding. Some startups may face a major roadblock in modeling battery performance without large datasets from battery testing. Therefore, successful companies will have strategic partnerships that provide data on new chemistries, usage patterns, and/or environmental responses.

The field of battery analytics affects all points in the battery industry; clients involved with battery development, manufacturing, or usage are encouraged to leverage these tools to optimize their business operations.

INNOVATE SMARTER & GROW FASTER

About Lux Research

Lux Research is a leading provider of tech-enabled research and advisory solutions, helping clients drive growth through technology innovation. A pioneer in the research industry, Lux uniquely combines technical expertise and business insights with a proprietary intelligence platform, using advanced analytics and data science to surface true leading indicators. With quality data derived from primary research, fact-based analysis, and opinions that challenge traditional thinking, Lux clients are empowered to make more informed decisions today to ensure future success.

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