2018 Global Lithium-ion Battery Technology Innovation Award
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Background and Company Performance

Industry Challenges

The electric vehicle (EV) boom is a global phenomenon. All over the world countries are jumping on the EV bandwagon, planning to ban gasoline cars and switch completely to EVs by specific time frames. Some countries, like China and India, view EVs as a viable solution to their worsening environmental crises, which are due in part to the increase of vehicles on their roads. Others look forward to the economic value EVs can offer. Despite these advantages, however, skepticism in the general public has slowed EV adoption. Mainly, buyers are concerned about how far an EV can travel, how long it takes to charge, and how much it costs.

The battery is the biggest and most expensive component in an EV, essentially making up the entire powertrain, and it plays a significant role in an EV’s overall performance. Frost & Sullivan research observes that manufacturers are racing to develop new electric vehicle battery (EVB) technology that addresses the concerns of apprehensive buyers.

Typically used in consumer electronics, lithium-ion (Li-on) technology provides a promising solution for EVs and currently dominates many recent developments. Additionally, the demand for better and faster performance has caused many Li-on battery manufacturers to switch from conventional graphite cells to silicon, an anode material that offers a higher density and can charge faster than graphite. With their durability and high density, silicon-dominant anodes promise longer lasting EVBs, meaning longer distances, less charging time, and lower costs.

Technology Attributes and Future Business Value of Enevate Corporation

Headquartered in Irvine, CA, Enevate Corporation (Enevate) is a silicon-based battery technology company known for its continuous breakthroughs in energy technology. Stemming from its roots in nano-carbon research at the University of California, the company announced its patented HD-Energy® technology for consumer electronics in 2014 and recently introduced its HD-Energy Technology for EVs using its pure silicon anodes, an extreme fast-charging EVB technology with higher energy density, cold climate operation, and safety benefits, while enabling lower EV and EVB costs. Founder and CTO Dr. Benjamin Park and his team developed a unique pure silicon film that composes of 100% active material and is free of inactive binder additives. Enevate also offers a reference Li-ion cell chemistry that is optimized for the silicon film anode. The company has received global safety and quality certifications such as International Organization for Standardization 9001 (ISO 9001), United Nations 38.3, CTIA/IEEE 1725, UL 1642, UL 2054, and IEC 62133 for batteries using its technology. At present, the company has over 60 patents issued and pending globally.
Shifting the Paradigm

Many consumers are hesitant to switch from gasoline cars to EVs because they are unwilling to invest in what is perceived as an unproven technology. While EVs may promise a return on investment over time, range anxiety, time to charge, and overall upfront costs are often enough to deter consumers from making a purchase. Enevate’s consumer-friendly HD-Energy Technology for EVs presents a seismic shift in EVB technology. With its high-energy density and extreme-fast charging, the battery offers increased driving range, very short charge times, cold-tolerant fast charging and operation, and extra safety due to overcharge resistance that results in a lack of lithium plating or dendrite growth. Specifically, Enevate’s technology allows EVs to add more than 240 miles of range with only a five-minute charge — essentially the same range conventional cars can get with a tank of gasoline. Regenerative braking, which requires high EVB charge rates, enables the car to store more kinetic energy, increasing the range even further, especially in cold climates. With these advantages in place, consumers can use EVs much in the same way they use gasoline cars, have better performance and still have the option of waking up each morning to a "full tank" in the battery.

Dominating with a Superior Performance

While silicon anodes can expand to theoretically absorb over 10 times as much lithium as graphite anodes, this ability is also a problem. After repeated charging and discharging cycles, conventional silicon anodes will begin to deteriorate. Enevate’s technology mitigates this problem. While batteries with Enevate's technology cycle somewhat less than conventional graphite cells, they can still charge and discharge upwards of 1,000 times while maintaining 85% of their capacity and this is sufficient for EVB use. While graphite EVBs only fast charge about 50% in 30 minutes, Enevate’s EVBs can charge up to 10 times faster — test results show it can reach 75% charge in about 5 minutes. Also, graphite EVBs when charged at high rates or cold temperatures experience significant degradation and safety concerns due to lithium plating on the graphite anode and reduced capacities while Enevate's EVBs do not appear to compromise cycle life, energy density, or safety when charged at the same high rates and cold temperatures even down to -20°C.

To remain cost competitive, Enevate avoids expensive manufacturing processes. While some competitors use expensive vacuum deposition, atomic layer deposition, silicon wafers, or synthesis to create their battery electrodes, Enevate realizes these processes are too expensive for the high volume automotive space and instead keeps its line running with low-cost raw materials that are within an established supply chain.
**Pivoting towards EV Growth Opportunities**

When President and CEO Robert A. Rango joined Enevate in 2016, the company was focused on developing and delivering custom battery cells and packs using its HD-Energy Technology for consumer electronics, mainly smartphones and notebook PCs, which entails high volume manufacturing. The difficulty with this approach was that it pitted the company up against large global battery manufacturers with deep pockets and massive production facilities. At that time, the market growth for consumer electronics was beginning to decline, and new investments and technology interest started to shift towards the new and rapidly growing automotive EV market, which because of its massive potential size, will ultimately dwarf the battery capacity and market for consumer electronics. Recognizing this change, Enevate pivoted quickly from smartphones to EVs and modified its HD-Energy Technology to be optimized for EV-chemistries. Rather than manufacturing millions of batteries, Enevate also shifted its business model to licensing the HD-Energy Technology to large EVB manufacturers with giga-factories and EV makers themselves. Meanwhile, its work towards manufacturing commercialization and certifications demonstrates to these new customers how far Enevate has taken the technology towards maturity.

The company enjoys a strong board of directors and advisory board to include renowned industry leaders such as John Goodenough, key inventor of the lithium-ion battery and Mike Lazaridis, co-founder of Blackberry.

Enevate’s technology has caught the attention of some of the leading Li-ion battery and EV companies in the world. The company has four strategic investors. In 2017 alone, Enevate signed deals with multiple strategic partners that represent more than 30% of the global lithium-ion battery production market. Executive Vice President Jarvis Tou and his marketing and business development team are currently engaged with the top 10 companies in the EVB and EV automotive industries worldwide.

One way Enevate differentiates from its competitors is by inviting customers to see its facility. Located in Irvine, California, the company has a complete battery facility dedicated to research and development, engineering, testing, and pilot manufacturing. With a full pilot production line, a dry room facility with automated equipment to build cells, a special area dedicated to chemical testing, and over 2500 battery test channels run by its extensive Enevate Data Management System, Enevate’s facility is well positioned for low volume production to prove out its technologies and to take it as far as possible towards commercialization. Additionally, the company’s proven battery chemistry can be replicated in large scale. At present, the output has reached 2,000 to 5,000 cells a month, a cell production capacity unreachable to most startup competitors.

Among other benefits, extreme fast charging allows for a smaller, less expensive battery than typical EVBs since drivers could recharge with sufficient range in just a few minutes — significantly reducing the overall expense of purchasing an EV. Fleet companies are especially well-positioned to benefit from the technology, as fast charging can improve their charging infrastructure. Because it takes less time to charge, a single charging station can
charge more cars, which means a reduced cost of ownership. Additionally, less time spent charging means the car can spend more time in use, especially with upcoming autonomous EV fleets, which equals increased revenue.

Industry-leading safety is another key differentiator, and comes from a number of different efforts. Enevate was proactive as a startup in pursuing safety certifications such as ISO 9001 and CTIA, which demand regular audits of the company’s facilities and processes. For the company to prove its safety to licensees, it must build a certain number of cells without having any safety issues, and so Enevate Corporation has a One PPM quality effort—meaning, it strives to have less than one defect per million units.

**Conclusion**

Frost & Sullivan observes how Enevate Corporation’s (Enevate) unique concept of using a pure silicon-dominant technology to improve the performance of electric vehicle batteries (EVBs) and lower EVB costs places it ahead of competitors who use graphite-dominant approaches. Moving forward, Enevate also has a roadmap to introduce new technologies, such as silicon-dominant anodes with solid electrolytes in a solid-state battery system. Enevate’s revolutionary technology presents a watershed moment in the evolution of electric vehicles by making them as useable and accessible as conventional gasoline cars, thereby alleviating the concerns of hesitant buyers. Thus, with its innovative approach to lithium-ion EVB technology, Enevate Corporation earns Frost & Sullivan’s 2018 Technology Innovation Leadership Award in the global lithium-ion battery industry.
Significance of Technology Innovation

Ultimately, growth in any organization depends upon finding new ways to excite the market and upon maintaining a long-term commitment to innovation. At its core, technology innovation, or any other type of innovation, can only be sustained with leadership in three key areas: understanding demand, nurturing the brand, and differentiating from the competition.

Understanding Technology Innovation

Technology innovation begins with a spark of creativity that is systematically pursued, developed, and commercialized. That spark can result from a successful partnership, a productive in-house innovation group, or a bright-minded individual. Regardless of the source, the success of any new technology is ultimately determined by its innovativeness and its impact on the business as a whole.
Key Benchmarking Criteria

For the Technology Innovation Award, Frost & Sullivan analysts independently evaluated two key factors—Technology Attributes and Future Business Value—according to the criteria identified below.

Technology Attributes
- Criterion 1: Industry Impact
- Criterion 2: Product Impact
- Criterion 3: Scalability
- Criterion 4: Visionary Innovation
- Criterion 5: Application Diversity

Future Business Value
- Criterion 1: Financial Performance
- Criterion 2: Customer Acquisition
- Criterion 3: Technology Licensing
- Criterion 4: Brand Loyalty
- Criterion 5: Human Capital
Best Practices Recognition: 10 Steps to Researching, Identifying, and Recognizing Best Practices

Frost & Sullivan analyst follow a 10-step process to evaluate Award candidates and assess their fit with select best practice criteria. The reputation and integrity of the Awards are based on close adherence to this process.

<table>
<thead>
<tr>
<th>STEP</th>
<th>OBJECTIVE</th>
<th>KEY ACTIVITIES</th>
<th>OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monitor, target, and screen</td>
<td>Identify Award recipient candidates from around the globe</td>
<td>Pipeline of candidates who potentially meet all best-practice criteria</td>
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<tr>
<td>2</td>
<td>Perform 360-degree research</td>
<td>Perform comprehensive, 360-degree research on all candidates in the pipeline</td>
<td>Matrix positioning of all candidates’ performance relative to one another</td>
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<td>3</td>
<td>Invite thought leadership in best practices</td>
<td>Perform in-depth examination of all candidates</td>
<td>Detailed profiles of all ranked candidates</td>
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<td>4</td>
<td>Initiate research director review</td>
<td>Conduct an unbiased evaluation of all candidate profiles</td>
<td>Final prioritization of all eligible candidates and companion best-practice positioning paper</td>
</tr>
<tr>
<td>5</td>
<td>Assemble panel of industry experts</td>
<td>Present findings to an expert panel of industry thought leaders</td>
<td>Refined list of prioritized Award candidates</td>
</tr>
<tr>
<td>6</td>
<td>Conduct global industry review</td>
<td>Build consensus on Award candidates’ eligibility</td>
<td>Final list of eligible Award candidates, representing success stories worldwide</td>
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<td>7</td>
<td>Perform quality check</td>
<td>Develop official Award consideration materials</td>
<td>High-quality, accurate, and creative presentation of nominees’ successes</td>
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<td>8</td>
<td>Reconnect with panel of industry experts</td>
<td>Finalize the selection of the best-practice Award recipient</td>
<td>Decision on which company performs best against all best-practice criteria</td>
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<td>9</td>
<td>Communicate recognition</td>
<td>Inform Award recipient of Award recognition</td>
<td>Announcement of Award and plan for how recipient can use the Award to enhance the brand</td>
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<tr>
<td>10</td>
<td>Take strategic action</td>
<td>Upon licensing, company is able to share Award news with stakeholders and customers</td>
<td>Widespread awareness of recipient’s Award status among investors, media personnel, and employees</td>
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</table>
The Intersection between 360-Degree Research and Best Practices Awards

Research Methodology

Frost & Sullivan's 360-degree research methodology represents the analytical rigor of our research process. It offers a 360-degree-view of industry challenges, trends, and issues by integrating all 7 of Frost & Sullivan's research methodologies. Too often companies make important growth decisions based on a narrow understanding of their environment, leading to errors of both omission and commission. Successful growth strategies are founded on a thorough understanding of market, technical, economic, financial, customer, best practices, and demographic analyses. The integration of these research disciplines into the 360-degree research methodology provides an evaluation platform for benchmarking industry participants and for identifying those performing at best-in-class levels.

About Frost & Sullivan

Frost & Sullivan, the Growth Partnership Company, enables clients to accelerate growth and achieve best-in-class positions in growth, innovation and leadership. The company's Growth Partnership Service provides the CEO and the CEO's Growth Team with disciplined research and best practice models to drive the generation, evaluation and implementation of powerful growth strategies. Frost & Sullivan leverages more than 50 years of experience in partnering with Global 1000 companies, emerging businesses, and the investment community from 45 offices on six continents. To join our Growth Partnership, please visit http://www.frost.com.