

COMPANY PROFILE

Paraclete Energy

Manufactures layered silicon particles for silicon anodes in Li-ion batteries. Founded in 2007 and based in Chelsea, United States of America. Currently in introduction stage.

➔ **LUX TAKE: Positive**



New Content Last Added: April 2, 2019
Coverage: Owning the Energy Transition
Topics: Energy storage

What You Need to Know

- Paraclete Energy manufactures surface-modified silicon nanoparticles that the company claims address a number of challenges in silicon anodes, such as first-cycle efficiency, cycle life, and capacity
- Produces a version of silicon powder that features three layers – an inner artificial solid-electrolyte interphase, a middle conductive matrix, and an outer functionalized layer – to enable a silicon anode that reaches 500 to 1,000 cycles with 3,590 mAh/g of capacity
- Aims to produce low-cost, functionalized silicon powder that battery manufacturers can purchase and blend with their preferred graphite and binder to ease the supply chain challenges of silicon anodes
- Clients should engage with Paraclete Energy given its promising data and validate its performance, but still note that given the wide variety among silicon anode systems, some development effort will still be necessary

Overview

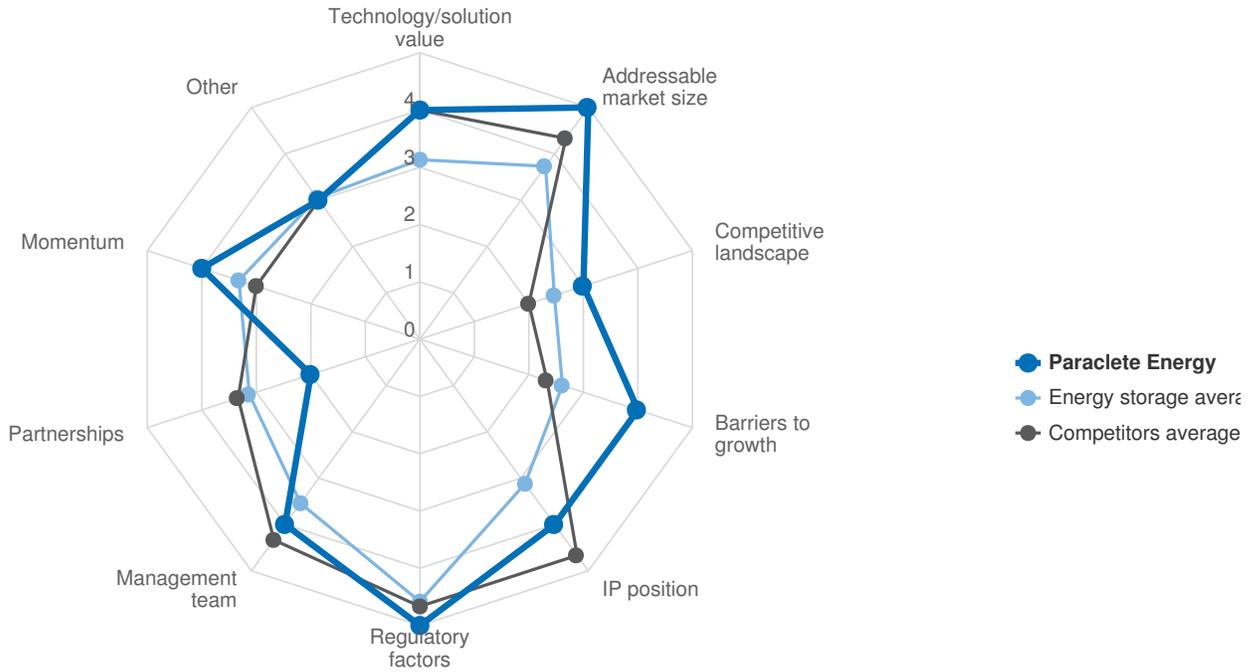
HEADQUARTERS: Chelsea, Michigan, United States of America	FOUNDED: 2007	CASH: <i>\$5.5 million</i>
WEBSITE: www.paracleteenergy.com	EMPLOYEES: 37	REVENUE: <i>\$1.5 million</i>
BUSINESS MODEL: Sells Product	PHONE: +1 734 288 4120	PROFITABLE: No

Italics indicate Lux Research estimated value

Scorecard

TECHNOLOGY/SOLUTION VALUE  4	While many startups and large companies are working to commercialize silicon anodes, Paraclete Energy is offering a solution that addresses major concerns around cost, cycle life, and supply chain
ADDRESSABLE MARKET SIZE  5	The market for high-capacity anodes for consumer electronics will be approximately \$4 billion by 2025, while high-capacity anodes for passenger EV will be \$6 billion by 2025
COMPETITIVE LANDSCAPE  3	The silicon anode space is quite crowded, with more than a dozen startups and an equal number of large companies all competing to develop solutions to enable silicon anodes; Jeff does say that Paraclete Energy offers leading capacity and cycle life metrics at competitive costs
BARRIERS TO GROWTH  4	Paraclete Energy is already demonstrating its manufacturing process at scale and has validated its performance metrics with the Department of Energy; the challenge will be securing large-volume customers and developing its supply chain to reduce costs
IP POSITION  4	The company has filed 90 patents, with nine granted to date covering the process, composition of matter, and article of manufacture
REGULATORY FACTORS  5	Recent regulations in China are offering significant subsidies for higher-energy-density electric vehicle packs, which may be enabled by silicon anodes
MANAGEMENT TEAM  4	Paraclete Energy's management has significant technical expertise and has been developing this specific technology for more than a decade; the company could benefit from direct customer experience in the automotive or battery manufacturing field
PARTNERSHIPS  2	Jeff declined to name current customers due to nondisclosure agreements, but did highlight Paraclete Energy's partnership with the Department of Energy's Vehicle Technology Office as the benchmark silicon material in the Advanced Battery R&D program
MOMENTUM  4	Paraclete is finishing its first venture funding round and is further expanding its 25-ton production line to 50 tons by the end of the year, with plans for 750 tons by the end of 2020
OTHER  3	Paraclete Energy keeps the nature of its partnerships and funding history undisclosed, which makes challenging to verify the financial health of the company; clients should engage to learn details under a non-disclosure agreement

SCORECARD COMPARISON



Lux Research Company Profile: Paraclete Energy

Key Metrics

METRIC	VALUE	COMMENT	DATE
Specific energy	12,385 Wh/kg	Calculated specific energy of silicon anode powder from company's capacity metric of 3,590 mAh/g	
Price	<i>\$12/kWh</i>	Estimated silicon particle price given company's claim of cost parity with graphite on \$/kWh basis; assumes \$15/kg graphite, resulting in \$125/kg silicon particle cost	
Cycles	500-1,000# of cycles	Cycle life of surface-modified silicon particles cycled at 3,590 mAh/g capacity	

Italics indicate Lux Research estimated value

History

Paraclete Energy was founded in 2007 by Jeff Norris and others, originally focusing on developing functionalized silicon inks for low-cost printable photovoltaics. The company pivoted to batteries starting in 2012. Jeff said the company has to date relied on angel funding, but did not disclose the total amount raised; he did add that he himself has invested \$3 million into the company. As of April 2019, Paraclete Energy is working to close its first venture round, but Jeff did not name investors, only that they're strategic and institutional investors.

Technology

Paraclete Energy manufactures surface-modified silicon nanoparticles for silicon anodes in high-capacity Li-ion batteries. The company sells a variety of nanoparticles, but in its most sophisticated product, Paraclete Energy chemically alters the surface of its 99.8% silicon metal particles in three 3 nm to 5 nm layers. The inner layer is a dielectric artificial solid electrolyte interphase that is ionically conductive and protects the silicon from further passivation from interactions with the electrolyte and is produced by reacting the silicon with various organic and inorganic solutions in a solvent. Jeff says it is covalently cross-linked with the silicon active material, adding the cross-linking between surface modifier layer, silicon, and graphite imparts the mechanical strength necessary to accommodate swelling and improve cycling, swelling that Jeff claims would otherwise damage other coated carbon systems. The middle layer is a carbonaceous matrix that further shields the silicon from the electrolyte, provides electrical conductivity to the particle surface, and is manufactured during comminuting and sphericalization. The outer layer is a tunable layer that can offer a variety of properties (e.g., hydrophilicity, prelithiation, fast charging) depending on the desired functionalization. Jeff said the layers are added at room temperature in a closed-loop, inert process that reduces silicon oxide formation, and a review of patent literature indicates that the layers are added at different steps in the manufacturing process.

Jeff said the resulting layered silicon particles can offer up to 3,590 mAh/g of capacity and can cycle for 500 to 1,000 cycles before experiencing 20% capacity fade. The layers also help address first-cycle efficiency loss, where capacity is lost during the first charge. Particle swelling still occurs at this high capacity, but Jeff claimed this is mitigated by the particle layers and covalently cross-linking the surface-modified particles to the graphite, providing a stronger mechanical framework. Jeff said the layers impart air stability for improved handling, and the nonexotic manufacturing process means the silicon particles can be manufactured cheaply. Paraclete Energy sells its particles on a \$/kWh basis equivalent to graphite; by Lux's estimate, this is priced between \$125/kg and \$250/kg.

Strategy and Markets

Paraclete Energy aims to manufacture and sell its layered silicon particles and already has 25 tons of production capacity today, with plans to expand to 750 tons by the end of 2020. The company's target customers are anode materials companies and cell manufacturers, providing what Jeff calls a drop-in-ready silicon product that cell manufacturers can pair with their preferred graphite, binder, and electrolyte options. By separating the silicon from the graphite, Jeff said Paraclete Energy offers greater flexibility and sourcing options to cell manufacturers. Jeff did not disclose which cell manufacturers Paraclete Energy is working with, but did say that some are developing semisolid electrodes and others are developing hybrid electrolytes. Paraclete Energy was chosen by the Department of Energy Vehicle Technology Office as the benchmark silicon technology for others participating in its Advanced Battery R&D program. Paraclete Energy is not targeting any specific application, but is developing products that can enable the use of silicon anodes for higher-energy-density Li-ion batteries.

Partnerships

PARTNER	TYPE	IMPORTANCE	COMMENT
 <p>U.S. Department of Energy (DOE)</p>	Customer	Major	The Department of Energy Vehicle Technology Office is using Paraclete Energy's silicon as the benchmark silicon in its Advanced Battery R&D program

Competitive Landscape

INDIRECT COMPETITORS



Last Update: April 10, 2019

Key Issues

CHALLENGE TO CLAIMS OF A DROP-IN SOLUTION

What They Said

Jeff Norris said that Paraclete Energy's surface-modified silicon nanopowders can serve as a drop-in solution providing both good cycle life and high capacity. Improved cycle life comes from a variety of features: a flexible artificial solid-electrolyte interphase, high-purity silicon metal without oxides, and a covalently bonded network through the silicon particles to the binders and other carbon particles for improved mechanical strength. This network can be tuned by the outer surface modification layer. Because Paraclete Energy only provides the silicon powders, it allows cell manufacturers to use whatever binder, graphite, and electrolyte it prefers.

What We Think

Given the variety of carbons, graphites, and binders used across the Li-ion battery industry, it is unlikely that Paraclete Energy has a single surface modification that is optimized for everyone, independent of electrode manufacturing parameters.

This is largely an argument of semantics, though, because every major cell manufacturer develops and validates new electrode formulations prior to adoption all the time; development is expected. Lux's conversations with cell manufacturers have indicated that cell manufacturers rarely believe "drop-in solutions" are exactly that, and they don't need to, as long as there are available production variables that can be changed without significant rework or compromise of the product. Paraclete Energy has these production variables available in the form of an outer surface modifier and thus presents an opportunity over other silicon anode developers that require special carbon nanostructures, electrolytes, or binder polymers to work effectively. Clients should focus on development opportunities with Paraclete Energy, but ignore some of the marketing claims that may not matter in the broader picture.