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From Idea to Impact

A CLIMATE TECH STARTUP STORY

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Executive Summary

Clean energy technology commercialization is critical to U.S. climate and competitiveness goals.

The United States is a global leader in clean energy research, investing $9.2 billion in energy research, development, and demonstration (RD&D) in 2020—more than Japan, the European Union, and China combined.[1] But the U.S. has historically struggled to commercialize and domestically manufacture new technologies, thus missing important opportunities to strengthen U.S. competitiveness and create domestic jobs.[2]

With more than 100 new clean energy manufacturing projects announced since the passage of the Infrastructure Investment and Jobs Act (IIJA) in November 2021 and the Inflation Reduction Act (IRA) in August 2022, there is an urgent need for both public and private-sector stakeholders to understand the unique challenges involved in commercializing clean energy technologies.[3] These challenges include long R&D periods, strict product safety standards, workforce issues, complex permitting requirements and infrastructure needs, and the significant funding required to achieve commercial scale.

Addressing these challenges will be vital as the United States works to drive broad-based decarbonization, strengthen its manufacturing sector, and ensure that the benefits of early-stage innovation accrue to U.S. workers and businesses as companies scale. Private investments are key to driving commercialization, but federal programs also offer vital support for de-risking emerging technologies, especially during periods of private investment volatility and when technology development timelines do not match private investment horizons and risk profiles. This is often the case for clean energy technologies, many of which require large pools of patient capital to support long development timelines and face unique policy uncertainties when going to market.

Challenges also exist in the private sector funding stack: there is a lack of patient private capital to support the long development timelines needed for many clean energy technologies, and few funding mechanisms will readily support first-of-a-kind commercial-scale operations. While solutions are emerging to fill these gaps, such as advanced market commitments and purpose-built first-of-a-kind funding, they are not yet widespread.

The roles of public and private funding in clean energy technology commercialization.

This paper examines the complementary roles of public and private funding in addressing common challenges faced by clean energy technology companies as they move from R&D to industrialization, with specific examples from battery technology innovator Sila Nanotechnologies and sustainable manufacturing pioneer Monolith as case studies in successful clean energy technology commercialization.

Sila Nanotechnologies has developed and commercialized a next-generation battery material used in electric vehicles (EVs) and consumer electronics. Robust federal and private support has supported Sila's growth and continues to help Sila successfully navigate the challenging dynamics commonly faced across the clean energy ecosystem, including:

- Long timelines for technology development and validation
- Major capital investment decisions and commitments for first-of-a-kind commercial-scale manufacturing equipment and facilities, which in some cases must be completed before the relevant customer supply contracts are finalized
- Major infrastructure upgrades, permitting requirements, and skilled labor needs

With the IIJA and IRA sparking a wave of investment in clean energy manufacturing, this paper identifies the challenges that must be overcome to accelerate clean energy commercialization and revitalize the U.S. manufacturing space.

Sila's and Monolith's journeys from lab to market provide several key lessons as private investors and government actors seek to support and accelerate clean-tech commercialization. In the public sector, these lessons include:

- **The commercialization journey is long and capital intensive.** In Monolith's case, the transition from an R&D organization to a deployment organization with a large-scale facility will likely cost over $2 billion and take over ten years.
- **Early-stage federal programs offer vital support for startups.** Such programs not only gave Sila essential financial and technical support, but also helped Sila hit development milestones and attract private investors.
- **Mid- to late-stage federal support is improving with new funds.** The key challenge now is to ensure these funds are accessible on commercially relevant timelines.
- **Non-financial federal support is valuable to companies.** Department of Energy's Loan Program Office (LPO) provided Monolith with deep expertise and comprehensive due diligence that not only mitigated technology risk but also helped to establish technical credibility to other investors.

- **Key barriers remain to revitalize U.S. manufacturing.** The challenges these companies have overcome are common to many clean energy manufacturers in the U.S., including procuring sufficient quantities of clean power and accessing skilled labor.

Their experience also highlights lessons in the private funding ecosystem, including:

- **The cyclicality of private markets can slow startup growth.** The fundraising environment for Sila to raise private funding in the early days was challenging as a consequence of the "Cleantech 1.0" boom-and-bust cycle.
- **Patient capital can be critical but is in short supply.** Patient capital with longer investment horizons can help hard-tech startups like Sila to navigate extended development cycles. Unfortunately, relatively few pools of patient capital are currently available to support new clean energy commercialization.
- **New solutions are needed to support first commercial operations.** Domestically produced next-generation clean energy technology companies such as Sila must overcome unique challenges around raising capital for first-of-a-kind commercial scale facilities. The timing mismatch between capital commitments, advanced market commitments, and concessional capital poses a particular challenge.

Introduction

Two long-term transformations are now reshaping the U.S. economy: broad-based decarbonization aimed at achieving net-zero emissions by 2050, and a major focus on manufacturing renewal that has seen U.S. businesses commit over $200 billion to new projects since 2022.[4] Effective public and private sector engagement at the intersection of these trends is needed to accelerate the commercialization of clean energy technologies, promote decarbonization, and grow domestic manufacturing while supporting local economies and bolstering international competitiveness.

While the United States has long led the world in clean energy research and intellectual property generation, it has historically struggled to commercialize and domestically manufacture novel technologies. Over the past decade, the United States accounted for ~20% (ranked #2 globally) in total patents for clean energy technologies, including solar, fuel cells, wind energy, and geothermal.[5] However, as of 2022 the United States accounted for only ~1% of the world's total installed solar PV manufacturing capacity, ~8% of global wind manufacturing capacity, and ~6% of global lithium-ion battery production capacity.[6]

Clean energy technologies are characterized by multidecadal RD&D periods, high capital intensity for commercial-scale production, and the need to sell into commodity-like end markets. This creates significant challenges for commercialization: the first viable solar photovoltaic cell, for instance, was invented and demonstrated at Bell Labs in the 1950s, but it took over 50 years for the technology to be deployed at a commercial scale.[7] Closing the gap between innovation and commercialization will require careful attention to the challenges faced by companies commercializing new clean energy technologies to enable them to scale at the pace needed to achieve U.S. climate goals.

Startups play a critical role in spurring clean energy innovation by developing new technologies that larger players perceive as too risky, or by targeting emerging markets initially too small for larger companies to consider. The rise of electric vehicles offers a stark example: in 2013, the year that Tesla launched the Model S, only ~0.3% of global passenger vehicles were electrified, and the cumulative announced EV investment was less than $10 billion globally.[8] By the end of 2022, 14% of passenger vehicles sold globally were electric, and large automakers had driven the cumulative announced EV investment worldwide to $860 billion.[9] Tesla's journey to profitability was long and difficult: the company had to raise ~$14 billion from private investors, public investors, and government loans before finally achieving positive cash flow in 2019, 16 years after it was founded.[10] Direct federal support in the form of a federal loan from the Loan Programs Office accounted for ~3% of Tesla's total funding from founding to 2019, but the funding came at a pivotal time in Tesla's growth journey in the aftermath of the 2008 financial crisis when private funders were less willing to invest.

This paper sheds light on the challenges faced by clean energy startups as they bring new technologies from the lab to the marketplace. Key findings are illustrated with reference to the commercialization journeys of Sila Nanotechnologies and Monolith, two clean-tech leaders that have benefitted from both federal government and private sector support, while also facing significant challenges as they have brought their core technologies from lab to market.

With U.S. businesses investing over $80 billion in new clean energy manufacturing projects since the passage of the IIJA in 2021 and the IRA in 2022[3], and the federal government launching multiple programs to encourage clean energy innovation and manufacturing, Sila's and Monolith's journeys offer important lessons for both public and private sector stakeholders. Understanding the challenges faced by clean energy companies is essential as U.S. leaders seek strategies to accelerate both the commercialization of new clean energy technologies and the broader revitalization of the U.S. manufacturing ecosystem.

The Five Stages of Clean Energy Technology Commercialization

New clean energy technologies typically evolve through five major stages on the road to commercialization. Each requires step changes in product scale, investment, and commercial success:

1. **Basic Research:** Foundational scientific discovery to identify the core principles and physical processes underlying a novel technology.
2. **Proof-of-Concept:** Elaborating on basic research to demonstrate viability with laboratory-scale versions of new products or manufacturing processes. Early product-market testing to validate business opportunity.
3. **Pre-Commercial Demonstration:** Proving the technical feasibility of production beyond lab scale to secure initial commercial contracts.
4. **First Commercial Operation:** Scaling production of a proven technology into a larger manufacturing facility, opening the door to larger commercial contracts.
5. **Large-Scale Commercial Growth:** Replicating processes from first commercial deployments across multiple other manufacturing facilities.

As new technologies go through each stage—from initial research, to validation and commercial demonstrations, to large-scale commercial operations—the investment needed grows exponentially. Most private investors, however, focus on supporting specific phases of the lab-to-market journey. To effectively scale even the most promising new technology, a startup must therefore continually seek new funding from a patchwork of private and public sources. Inefficiencies or gaps at any step in that process can critically impair a startup's ability to manufacture and commercialize a new clean energy technology at scale.

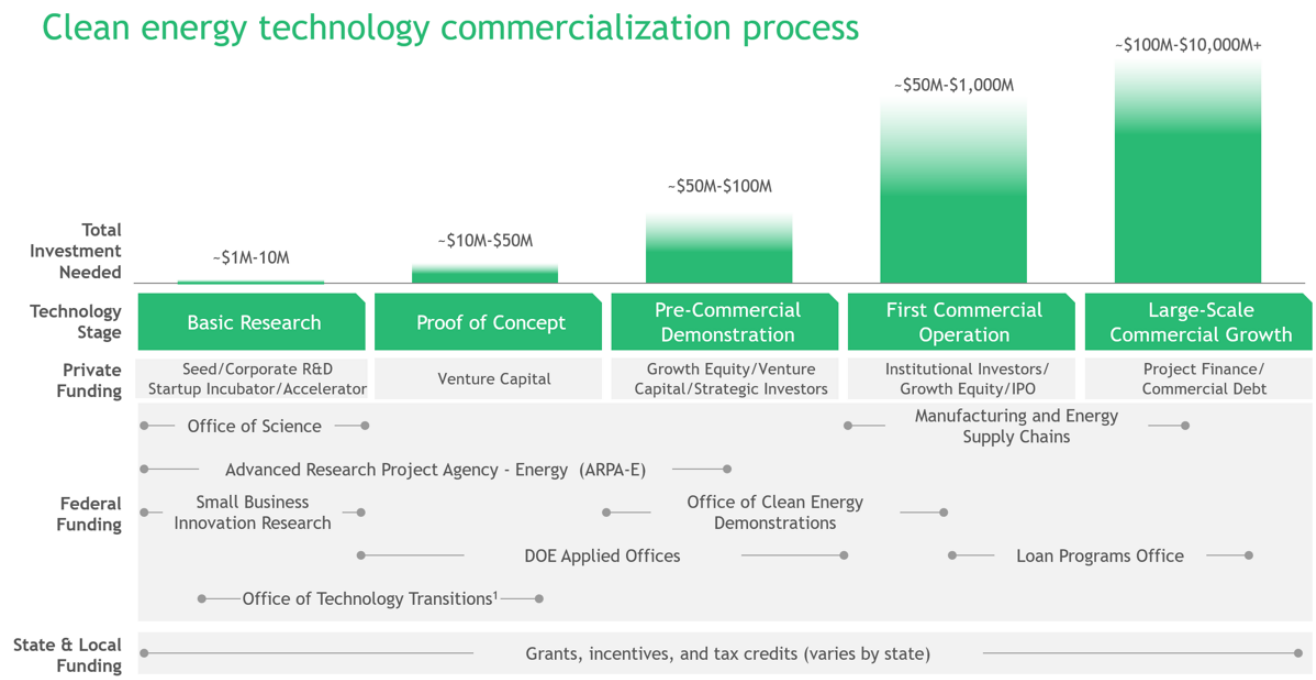

Figure 1. Clean energy technology commercialization process

1. OTT provides non-financial support throughout the commercialization lifecycle.
Note: Investment needed and funding sources for each stage are representative and can vary by industry and technology. Funding offered by federal programs may not match exactly with “total investment needed” bar amount due to funding availability from other sources.

Source: BCG experience

Clean energy innovators can seek support from a variety of private funding sources, depending on the technology stage and amount of funding needed:

Table 1. Approximate investment amount by funding type for clean energy startups

Funding type	Approximate investment amount	Description
Seed investors	$5,000–$1M	Invests in early stages of a company in exchange for equity.
Startup incubators	$5,000–$50,000	Provides mentorship and resources in the initial stage of a company to help them grow, typically does not take equity.
Startup accelerators	$20,000–$150,000	Invests in early stages of a company that has passed incubation phase in exchange for equity, typically provides intense mentorship and education for 3-6 months.
Corporate R&D departments	Various	Invests in internal R&D projects to develop new products or technology that could one day be commercialized by the parent company.
Venture capital (VC) firms	$50,000–$100M	Invests in high-growth, high risk companies in exchange for equity, with aims of generating above-market returns. Typically involves multiple venture capital firms with one firm leading the investment for each “round” of funding.
Strategic investors	Various	Invests in a wide range of stages, typically aims for access to new markets and technologies with less focus on financial returns.
Growth equity investors	$10M–$100M	Invests in later-stage companies with a more proven business models, less technical risk, and higher investment needed than venture capital firms can offer to scale operations and accelerate growth.

Institutional investors	Millions to billions	Invests large amounts of money on behalf of others in companies that have achieved first commercial operation or later for portfolio diversification.
Initial public offerings (IPOs)	Various	Allows companies to be listed on public financial markets to broaden capital access; typically occurs once companies demonstrate growth and a path to profitability.
Project finance/ commercial debt investors	$100M–$1B	Invests in large projects using proven technologies to generate stable, long-term contracted cash flows with minimal risk. Typically uses assets as collateral to invest in a specific project but not in a company directly.

The federal government complements private investments in a number of ways, including:

- Offering additional validation of technical credibility for emerging technologies through federal technical experts (complementary to private sector technical diligence)
- Building community ecosystems (e.g., conferences) to support companies as they grow
- Funding early-stage startups whose risk profile is not yet appropriate for private investors
- Providing consistent support, helping startups to weather private-sector investment cycles or shifting investor preferences

U.S. federal government spending on clean energy commercialization has historically targeted the “Basic Research” and “Proof of Concept” phases of commercialization. Recent changes have sought to broaden federal support, however, with Congress’ passage of the bipartisan IIJA Act directing the Department of Energy to establish the Office of Clean Energy Demonstrations (OCED) in 2021 and the Office of Manufacturing and Energy Supply Chains (MESC) in 2022. Since 2021, the Loan Programs Office (LPO) has also grown in significance, with the IRA of 2022 increasing LPO’s lending authority from $40 billion to $400 billion.

Key funding programs across the clean energy innovation lifecycle include:

Table 2. Approximate investment amount by federal government entity for clean energy startups

Federal government entity	Approximate investment amount	Description
Office of Science	$5,000–$5M	Provides funding and resources for foundational research, experiments, and innovation across various scientific fields to support breakthrough discoveries and technological advancements.
Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR)	$50,000–$2M	Multi-agency programs intended to stimulate innovation and commercialization at startups and small businesses.
DOE Applied Offices	$100,000–$30M	Provides technology-specific grants aligned to DOE offices (e.g., Fossil Energy & Carbon Management, Nuclear Energy, Energy Efficiency & Renewable Energy).
Advanced Research Project Agency - Energy (ARPA-E)	$500,000–$20M	Focuses on supporting basic research and proof of concepts for early-stage technologies. However, ARPA-E also offers select grants for later stage funding.
Office of Clean Energy Demonstrations (OCED)	$35M–$500M	Provides funding to support first-of-a-kind technology demonstrations and commercial deployments.
Office of Manufacturing and Energy Supply Chains (MESC)	$25M–$500M	Funds onshoring domestic supply chains for key sectors (e.g., batteries)
Loan Programs Office (LPO)	$100M–$10B	Provides loans and loan guarantees to support the construction of facilities ranging from first-of-a-kind demonstrations to Nth-of-a-kind facilities.
Office of Technology Transitions (OTT)	$500,000–$5M	Supports startups, small businesses, and industries in the transition from research into practical use and commercialization through grants, partnerships, and licensing opportunities.

In addition to federal funding, many states and localities incentivize clean energy and local manufacturing with tax credits, rebates or incentives, and grant programs targeting specific sectors. While these incentives vary by state, they can provide substantial support in addition to federal and private funding sources.

Taken together, these options mean there is now significant federal, state, and private sector support available for clean energy companies as they progress through each stage of their commercialization journey. In practice, companies need to tap into each of these sources in unique ways throughout the commercialization process, depending on their specific funding and operational needs.

Case Study: How Sila Nanotechnologies is Scaling Domestic Innovation

Founded in 2011 and headquartered in Alameda, California, Sila Nanotechnologies is a next-generation battery materials company that employs almost 400 people and holds over 200 patents. From its origins in a Georgia Institute of Technology (Georgia Tech) research lab, Sila has grown to become a major player in the next-generation battery materials space.

Sila's flagship product is the Titan Silicon™ anode, which increases the amount of energy that can be stored in a given weight or volume of lithium-ion batteries. The anode is an essential component of the battery and is the negative electrode that lithium ions are stored in when the battery is fully charged. Compared to battery cells with traditional graphite anodes, Sila's anode enables battery cells to be 20-40% more energy dense by volume. One of the most promising use cases for this higher energy density is allowing electric vehicles to travel longer distances on a single charge.

The commercialization of domestic anode technologies such as the Titan Silicon anode is a strategic priority for U.S. automakers and lawmakers. The graphite supply chain is currently heavily concentrated in China, with around 60% of natural graphite mined in China and around 90% of all graphite anode materials refined in China.[11]

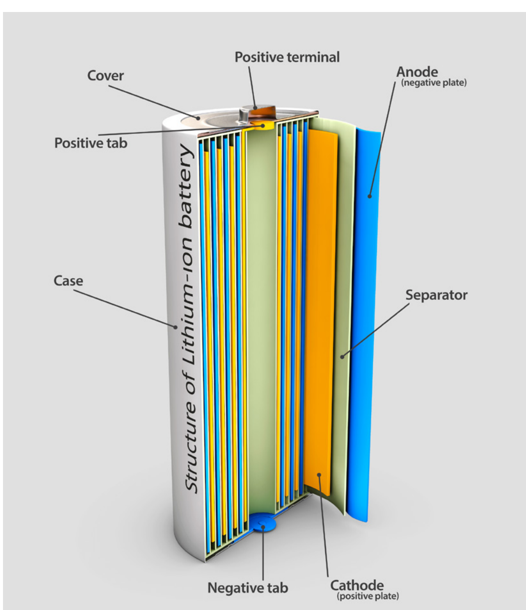

Figure 2. Structure of a lithium-ion battery

Sila's growth story demonstrates the opportunities and challenges commonly faced by clean energy companies as they scale U.S. manufacturing capabilities to commercialize first-of-their-kind technologies.

Sila has benefited from robust federal and private support, with eight federal awards totaling $123 million across Sila's lifecycle plus $925 million in private funding raised across seven rounds, an ~8:1 ratio of private capital to taxpayer resources.[12] Federal funding proved crucial at key points in Sila's lifecycle, with SBIR and ARPA-E supporting the company's basic research and development when the technology stage didn't match with typical private investment risk appetite. A $10 million ARPA-E SCALEUP grant and access to a valuable technical community helped Sila to develop efficient at-scale manufacturing processes, and a $100 million selection from MESC supported the development of Sila's first automotive-scale manufacturing facility.

Sila's product currently appears in the battery powering the Whoop 4.0 fitness tracker and the product's first automotive launch will be in the electric version of the Mercedes Benz G-Class SUV.[13] At present, Sila is developing its first auto-scale manufacturing facility and preparing for larger-scale growth. The company's path to commercialization, like those of many companies in the clean energy technology ecosystem, was complex and required a blend of public and private funding.

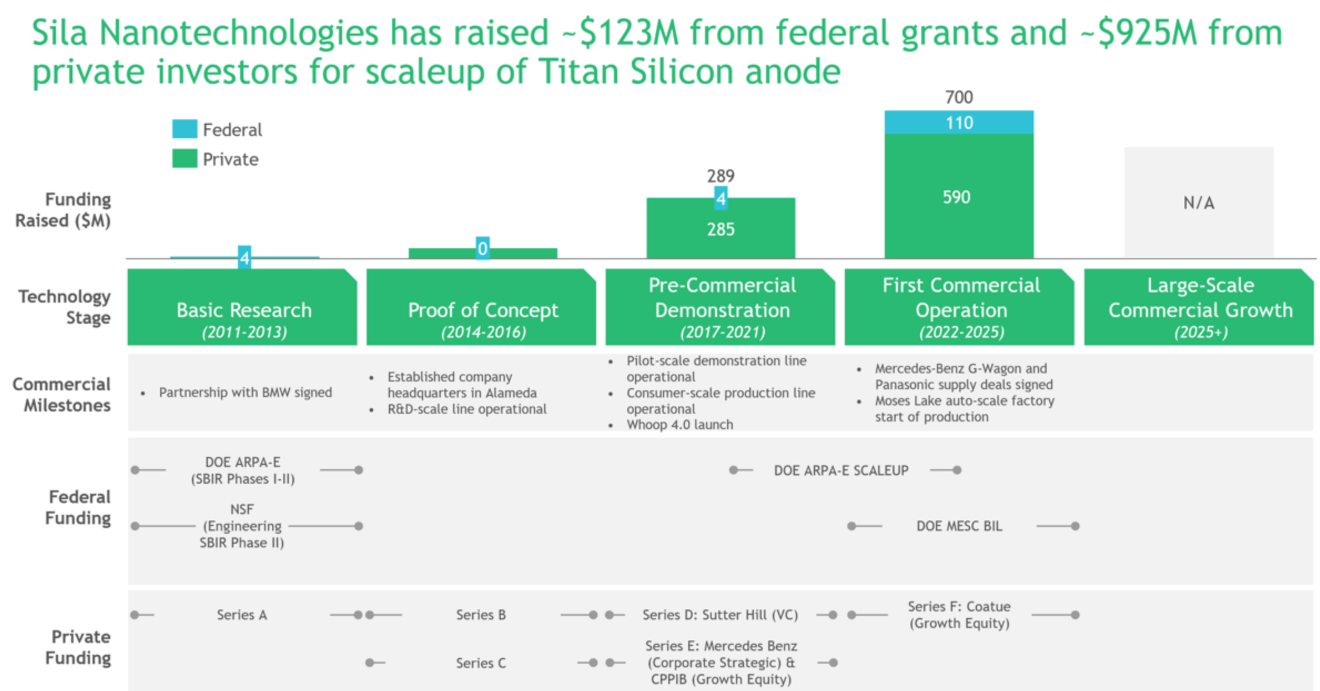

Figure 3. Commercialization process for Sila Nanotechnologies

Note: Only lead investors are shown for private funding reounds with publicly available data. Graph does not show ~$4.5M in ARPA-E grants and $1M in grants from DOE (Office of Energy Efficiency and Renewable Energy) for non-anode products.

STAGE 1: BASIC RESEARCH (2011–2013)

Sila was founded in 2011 by former Tesla engineers Gene Berdichevsky and Alex Jacobs, and Georgia Tech materials science professor Gleb Yushin. Berdichevsky had been the seventh employee at Tesla, helping engineer the Tesla Roadster battery, while Jacobs had designed battery packs for the Tesla Roadster. After leaving Tesla, Berdichevsky became Entrepreneur-In-Residence at Sutter Hill Ventures, a venture capital firm, where he explored ideas for new startups in the battery space and connected with Yushin over his research into silicon anodes. For its first three years, Sila was headquartered in Atlanta at the Advanced Technology Development Center, the State of Georgia's flagship science and business incubator, and used shared lab space at Georgia Tech. The University proved a helpful location for Sila's incubation, providing a breadth of resources including support in patent licensing and an encouraging administration.

Support from private and federal partners

Many clean energy companies face challenges during the basic research phase because of long and uncertain timelines for research and development, less definable science risk, and the need to access expensive state-of-the-art scientific equipment. During this basic research stage, Sila was fortunate to find private venture capital investors willing to accept the risk profile and investment time horizon required for fundamental materials science development, as well as having access to equipment at Georgia Tech. During his time as an Entrepreneur-in-Residence at Sutter Hill Ventures, Berdichevsky was introduced to Andrew Verhalen, a General Partner at Matrix Partners. Though neither Sutter Hill nor Matrix typically invested in materials science or battery companies, both firms took a chance on the founding Sila team and on the growth potential of the still-nascent EV market. The two firms joined together to fund Sila's Series A in September 2011.

Despite Sutter Hill and Matrix's early backing, the Sila team knew that relatively few VC investors were prepared to fund foundational research. To preempt potential funding challenges, Sila sought federal support. In fall 2012, Sila won two major federal grants providing additional funding: a $3.2 million grant from ARPA-E's SBIR program and a $0.5 million grant from the National Science Foundation (NSF) SBIR. Sila became aware of these opportunities through Yushin's network as a Georgia Tech professor and was able to successfully progress from concept paper to full application with a small team of Sila employees and minimal input from an outside grant advisory firm.

Sila also formed an early development partnership with the automaker BMW in 2012, thanks to a connection through Yushin's lab. The partnership helped bolster Sila's early credibility and presented an opportunity to get early feedback on Sila's product from a potential future customer.

The combination of private and federal funding gave Sila the time and resources needed to reach technical milestones that investors wanted to see before completing a new round of funding. Capital was scarce for Sila's first five to six years, according to Berdichevsky, so receiving $3.7 million in federal grants was crucial in fueling Sila's early growth.

Joining the ARPA-E ecosystem brought additional benefits, with program managers offering programmatic guidance and making introductions to technical collaborators and additional investors, including In-Q-Tel, the venture arm of the U.S. intelligence community, which later invested in Sila's Series D. The ARPA-E program managers were tough and to-the-point, but also very supportive, according to Yushin, helping Sila's first-time founders sharpen the company's technical and commercial approach.

STAGE 2: PROOF OF CONCEPT (2014–2016)

Clean energy companies in the "Proof of Concept" phase are typically focused on scaling up from lab to pre-commercial production, validating product-market fit with early customers, continuing to raise funding, and attracting talent to join an early-stage company.

In 2014, Sila sought to raise a Series B to fund further expansion. The fundraising environment was brutal at the time, Yushin says, with the dust still settling from "Cleantech 1.0," the 2006-2011 period during which VC firms invested over $25 billion in clean energy startups but saw poor returns.[14] With Sila outgrowing its Georgia Tech incubator space, the company would soon need additional capital to fuel growth—but most venture investors were still reluctant to consider anything related to clean energy hardware. Sila approached over 50 investors to try to raise additional funding in the private markets, but few were willing to invest on favorable terms. Sila was somewhat insulated from the cyclicality of private markets by its SBIR awards from 2012, which helped extend the company's runway. By April 2014, Sila closed their Series B funding round from venture capital investors with the total funding around three times larger than their Series A.

Achieving pilot-scale production

Armed with new funding, Sila relocated its headquarters to Alameda, California, in 2014, building a small R&D-scale line and soon after starting construction on a larger pilot-scale demonstration line. As is the case with many other clean energy technologies companies, the Bay Area was attractive to Sila because of the concentration of investors and technical talent, as well as easier access to battery manufacturing partners in Asia. Sila selected Alameda, a small city across the bay from San Francisco, for its early manufacturing facilities because it was one of the few localities in the San Francisco Bay Area able to quickly process permits for key input materials used in Sila's manufacturing process.

By 2016, Sila was making accelerated progress in product development through engagement with customers from the pilot-scale demonstration line. Thanks both to Tesla's increasing success and broader government incentives and programs, the EV space was seen as a major opportunity, leading investors to seek exposure to EV and battery-related investment opportunities. Due to this ground shift, driven by both public and private investments and support, Sila was able to successfully complete their Series C round in June 2016, helping to fund their next phase of growth.

STAGE 3: PRE-COMMERCIAL DEMONSTRATION (2017–2021)

In the pre-commercial demonstration phase, clean energy companies typically further scale production, prove the technical feasibility of their product, and form strategic partnerships with buyers.

By 2017, Sila's pilot-scale demonstration line was fully operational and Sila was able to start manufacturing at a larger scale to demonstrate the Titan Silicon anodes' potential in commercial products. In contrast to Sila's early days, when capital was limited, by 2017 it was becoming clear to Wall Street that the electric vehicle industry was growing exponentially, and investors were looking to place bets in companies that could drive the transformation. Private funders again approached Sila looking to invest, and in August 2018, Sila raised a $70 million Series D funding round led by Sutter Hill.[15] Also participating in the round were Siemens-backed venture firm Next47, Samsung, In-Q-Tel, and Amperex Technology Limited (ATL), a subsidiary of the Japanese firm TDK Corporation.[16] The presence of strategic investors including ATL and Samsung—two of the largest battery cell makers in the world—helped provide credibility to Sila's technology.

However, Sila faced a challenge: its two most promising end markets—consumer electronics and electric vehicles—required batteries and production capacity at massively different scales. In fact, the battery in an electric vehicle has a capacity 5,000 to 10,000 times greater than that of a typical smartphone. While the pilot-scale demonstration line production volume sufficed for early testing of batteries for consumer electronics applications and small-scale automotive testing, it could not produce enough anode material for automakers to fully complete the extensive safety testing needed for a mass-produced vehicle. To enable pre-commercial demonstration in the automotive space, a third production line on an order of magnitude larger—and more costly to build—than the pilot-scale demonstration line was needed.

Thanks to its recently completed Series C and Series D rounds, Sila had secured enough funding to proceed with building its third production line.

By 2019, investor interest was still high. Capitalizing on the momentum from its Series C and D rounds, Mercedes-Benz (formerly known as Daimler) led Sila's $170 million Series E round in 2019 as a strategic investor, with the Canadian Pension Plan Investment Board (CPPIB) providing an additional $45 million about seven months later as a growth equity investor.[17] The Mercedes-Benz investment also came with a commitment to jointly drive research and development for electric vehicle batteries, a partnership that culminated in Sila's first automotive contract in 2022.

In 2019, Sila also won a $10 million ARPA-E SCALEUP grant, which helped past ARPA-E awardees to translate high-risk new technologies from lab scale to commercial scale production. The award provided Sila with continuing access to ARPA-E's technical experts, with a specific focus on helping Sila efficiently scale the production process from the pilot-scale demonstration line to the consumer-scale production line. Yushin notes that the SCALEUP grant was so useful that he wished it had come even earlier in Sila's scaling process, since it provided funding and technical support to help establish the most efficient way to scale Sila's process.

Following the ARPA-E SCALE-UP grant, in 2020 Sila won a $3.6 million Advanced Vehicle Technologies Research Grant from the Department of Energy. The team was encouraged to apply while at a DOE workshop and submitted the application themselves with some external legal support. This funding enabled them to experiment with and better understand the calendar life and cycle life of their anodes, important metrics for regulators and Sila customers. With this research, they were able to shorten their time to market and improve their product overall.

Generating commercial traction

The completion of its third production line in 2021 enabled Sila to begin commercial production for consumer electronics customers. In 2021, Sila signed its first customer contract with Whoop, a producer of fitness trackers, which used Sila's anode technology to shrink the Whoop 4.0 fitness tracker by 33% without reducing battery life. The contract established Sila as one of the first next-generation battery companies to bring a product to market, demonstrating the viability of both Sila's product and its production capabilities.

Establishing a consumer-scale production line also enabled Sila to produce enough anode material to continue the rigorous automotive battery qualification process, which requires the delivery of multiple tons of material per automaker for testing in pre-production EVs over a three-to-five-year period. Only by committing to this lengthy process, while also fostering auto industry relationships such as its Mercedes-Benz partnership, could Sila lay the groundwork to later secure automotive-scale supply agreements.

Despite these commercial successes, Sila also faced roadblocks during this demonstration phase. There are no producers of lithium-ion battery cells for consumer electronics in the United States, so Sila needed to work with cell-making partners in Asia, adding significant complexity to the testing process. These challenges were compounded when the COVID-19 pandemic hit, making cross-border travel impossible. Still, technical progress continued, and soon after the consumer-scale production line was up and running, planning began for another still larger facility.

STAGE 4: FIRST COMMERCIAL OPERATION (2022–2025)

As clean energy companies shift to the “First Commercial Operation” stage, they will typically build a larger commercial-scale facility and sign offtake contracts with larger customers. Federal support can be critical in this phase, as there may still be a small amount of technical and market risk for new technologies, and investment requirements typically grow into the hundreds of millions of dollars.

By 2022, Sila’s consumer-scale production line was delivering materials for the Whoop fitness tracker and providing test materials to automakers for the battery safety validation process. However, any automotive contract would require a factory far larger than the consumer-scale production line to supply enough material for production vehicles.

Selecting a large-scale manufacturing base

In January 2021, Sila raised a $590 million Series F led by Coatue, a growth equity fund, to support construction of its first automotive-scale commercial production facility. Sila was also selected for an additional $100 million in funding from the Department of Energy’s Office of Manufacturing and Energy Supply Chains (MESC), funded under the IIJA, to help finance the facility. The award, while significantly larger and more complex to apply for than past federal awards Sila had received, helped provide another source of non-dilutive funding for the Moses Lake facility.

In March 2022, Sila selected Moses Lake, a town in eastern Washington State, for the facility site. The factory will start initial production in early 2025 and have 20 gigawatt-hours (GWh) of capacity by 2026, producing enough materials for 200,000 electric vehicle batteries. Sila expects the Moses Lake facility to employ 150–300 people and is partnering with local community colleges and vocational programs to train workers.[18]

Moses Lake has a number of attractive characteristics for Sila, including access to Washington State's abundant low-cost hydropower, which will help lower the carbon footprint of Sila's product and of the electric vehicles in which it is used. Importantly, too, the only U.S. producer of silane, a silicon-rich gas used as an input for Sila's production process, is located in Moses Lake across the street from Sila's chosen site. The silane factory, owned by REC Silicon, has been offline for many years due to weak domestic demand, but is slated to reopen at the end of 2023 thanks to federal domestic manufacturing incentives such as the Section 45X Advanced Manufacturing Production Credits, enacted under the IRA, which provide incentives for domestically produced polysilicon. Surging demand from solar panel manufacturers and silicon anode players such as Sila, which helped bolster the case for reopening the plant, was also driven in part by domestic manufacturing incentives such as 45X and the Section 48 investment tax credit for renewable energy projects with domestic content.[19]

One month after announcing the Moses Lake factory, Sila also announced their first automotive supply contract: Sila's anode material would be used to increase the range of the electric version of the Mercedes-Benz G-Class SUV, colloquially known as the G-Wagon. The strategic partnership with Mercedes proved beneficial for both companies: Mercedes gained early access to a novel technology that differentiated its vehicles, while Sila secured an early customer for its product.

In December 2023, Sila announced another major milestone: Panasonic would purchase Titan Silicon anode materials from Moses Lake for use in high-performance automotive applications.[20] The Panasonic deal gave Sila another avenue to market, with agreements signed with both a major battery cell manufacturer and a major automotive OEM.

Bigger investments, greater scale

Sila is now at a stage that proves critical for many clean energy technology companies: shifting from foundational R&D and demonstration to at-scale manufacturing. Clean energy companies at this stage frequently encounter challenges that correspond to those faced by U.S. manufacturers more broadly. These include complex federal, state, and local permitting requirements, long wait times for power grid upgrades, and the need to reskill local workforces to support new processes and advanced manufacturing methodologies.

Managing access to the power grid is a common challenge. Clean energy manufacturing ventures generally require reliable access to abundant clean and low-cost energy in order to scale. In areas with limited power grid capacity, a large new manufacturing facility could require upgrading the local power grid, which can take years to deliver. This can potentially delay factory construction and limit economic benefits to local communities.[21]

New federal programs targeted at supporting later stage clean energy technologies provide welcome support, but efficiently accessing federal funding can be complex—especially for companies with first-of-a-kind processes. For example, many federal funding programs provide awards through cost-share agreements, where the federal government will pay for a pre-defined portion of a fixed total project cost. However, early-stage cost estimates, such as those typical for large capital projects and especially first-of-a kind facilities, may have wide margins of error and may not fully reflect the final cost of construction.[22] As companies receive more exact quotes from vendors, required expenditures can increase, even as contracting terms of the initial federalaward require that the total project cost remains constant. This can force companies to consider other cost-reduction measures such as reducing the size of the plant. This trend has been exacerbated in part, ironically, by the IIJA and IRA: by triggering a surge in new industrial construction, these laws drove up costs for existing projects by increasing demand for construction materials and labor faster than suppliers could respond.[23]

In addition to navigating technical risk around first-of-a-kind processes, clean energy companies producing novel products that do not yet have established markets can face challenges when seeking late-stage federal funding. For example, DOE's Loan Programs Office, which provides loans and loan guarantees for mature and near-mature technologies that cannot yet access commercial debt from the private sector, requires that a credit-worthy buyer has committed to purchasing a large portion of the project output, or that there be reputable market projections for the project output that has not been purchased in advance.[24] For novel products, this creates a complex situation: there may not be enough historical data from which to develop a detailed market forecast. To secure funding from LPO, clean energy companies must therefore sign additional supply contracts with buyers prior to project construction. However, customers operating in industries with strict safety standards may want to be able to test novel materials from a fully operating factory before committing to large purchases, potentially requiring clean energy companies to build large-scale manufacturing facilities in advance of having contracted sales.

Such challenges underscore the fact that while the last three years have brought numerous new federal programs to support the later stages of commercialization, in some cases gaps still remain for companies scaling first-of-a-kind technologies.

Monolith's experience with DOE's Loan Program Office (LPO)

While some challenges may remain in accessing late-stage federal support for companies selling into novel markets, LPO has provided crucial late-stage support to companies in selling into more established markets. One such example is Monolith, a company founded in 2012 and headquartered in Lincoln, Nebraska which utilizes low emission feedstocks to decarbonize major industrial processes. Monolith's two primary products, hydrogen and carbon black, are key materials used in hard-to-abate industrial sectors like tire and ammonia fertilizer production. Monolith initiated their LPO application in 2019 and successfully completed the process at the end of 2021, receiving a conditional commitment for a $1.04 billion loan guarantee to expand its Olive Creek facility in Hallam, Nebraska.

Monolith's original Nebraska facility, Olive Creek 1, was the first of its kind in the world to utilize methane pyrolysis at a commercial scale. Although Monolith is built to grow without government incentives, this facility's planned expansion, called Olive Creek 2 or "OC2," would have been significantly more challenging and taken longer to achieve without LPO support. Monolith would likely have had to look to private credit markets, which have a very limited history of investing in technology like methane pyrolysis, or to have funded OC2 entirely with equity, which would have had a substantial impact on the project's returns.

In addition to financial support, the LPO process provided Monolith with:

- Deep technical expertise through its access to specialists at DOE, helping Monolith to navigate the challenges associated with a new technology.
- A rigorous, nonpartisan, and consistent review process, providing further validation of Monolith's technical credibility and economic value.

Once completed, OC2 will create over 800 direct and indirect jobs in the region, while producing approximately 194,000 tons annually of carbon black.[25] Hydrogen from the manufacturing process will additionally be converted into 300,000 annual tons of anhydrous ammonia to provide a vital local fertilizer supply to the Corn Belt.

Lessons from the Journey from Lab to Market

Sila's and Monolith's journeys from lab to market provide several key lessons as private investors and government actors seek to support and accelerate clean-tech commercialization. In the public sector, these lessons include:

- **The commercialization journey is long and capital intensive.** In Sila's case, it will likely take around 14 years and require over $1 billion in funding to go from a Georgia Tech lab to full commercial scale production in Moses Lake. In Monolith's case, the transition from an R&D organization to a deployment organization with a world-class facility will likely cost over $2 billion and take over ten years. Consistent federal support across this lifecycle is critical to ensure that domestic innovations are commercialized in the United States.
- **Early-stage federal programs offer vital support for startups.** In the early stages of Sila's growth, federal SBIR funding from ARPA-E and NSF played a key role. Such programs nearly doubled Sila's total funding and gave them the financial and technical support needed to develop its core product, provided important stage-gates to hold Sila accountable to hitting specific development milestones, and helped Sila attract private funders for future growth.
- **Mid- to late-stage federal support is improving.** Recent changes at DOE have broadened federal support to include later stages of commercialization that were previously not well covered (e.g., the creation of the Office of Manufacturing and Energy Supply Chains and the Office of Clean Energy Demonstrations, as well as increased lending authority for the of Loan Programs Office). For example, the expansion of LPO's loan authority under the IIJA in 2021 played a key role in enabling Monolith's conditional loan, and that authority has been furthered expanded under the IRA. The key challenge now will be for these offices to ensure newly created funds are accessible to companies on agreeable contractual terms and on commercially relevant timelines.
- **Non-financial federal support measures are valuable.** For Sila, there were many non-financial benefits to being awarded federal grants. ARPA-E provided the opportunity to partner with program managers, attend technical conferences, and connect with federal investors like In-Q-Tel. For Monolith, the LPO program provided deep expertise and comprehensive due diligence that not only mitigated technology risk but also helped to establish technical credibility to other investors.
- **Key barriers remain to revitalize U.S. manufacturing.** The challenges

Sila and Monolith have faced are common to many clean energy manufacturers in the United States, including procuring sufficient quantities of clean power and accessing skilled labor. Concerted federal and state efforts to streamline access to the supporting infrastructure underpinning clean energy manufacturing and to unlock additional demand for clean energy through market-based mechanisms could help address these challenges, spurring decarbonization while boosting local economies.

Their experience also highlights lessons in the private funding ecosystem, including:

- **The cyclicality of private markets can slow startup growth.** In Sila's early days, raising private funding was difficult due to a widespread reluctance to invest in clean energy hardware after "Cleantech 1.0". Federal funding, although also cyclical depending on political priorities, can provide complementary support to technologies when private markets are slower to invest, as demonstrated by the additional $3.7 million in SBIR grants raised after Sila's Series A.
- **Patient capital can be critical but is in short supply.** Sila has been fortunate to work with Sutter Hill Ventures, one of the few "evergreen funds" that has no fixed end date for investors to exit. This "patient capital" contrasts with typical venture capital funds which aim for funds to last between 8–12 years, potentially creating pressures for companies to optimize for short-term results or to pursue exits sooner in the technology development cycle than would otherwise be optimal. Only ~100 evergreen funds have been raised in the past 20 years (compared to ~10,000 traditional VC investors) with most primarily focused on software and life sciences.[26] Creating new clean energy commercialization funds with longer investment horizons and the ability to blend multiple sources of capital (e.g., corporate capital, venture capital, philanthropic capital, etc.) could help hard tech startups navigate extended development cycles.
- **New solutions are needed to support first commercial operations.** As Sila builds its first automotive-scale commercial plant in Moses Lake, it has had to overcome a common problem for first-of-a-kind clean energy facilities: the capital required to build a commercial-scale facility increases into the tens or hundreds of millions of dollars. Investors that can provide that scale of funding typically are willing to take significantly less risk than venture capital investors and will want most of a factory's production to have a guaranteed buyer before it is financed. This challenge is often addressed through advanced market commitments (groups of buyers that commit to buy new clean

energy products before manufacturing is established to provide a clear demand signal) and concessional capital (blending private capital and philanthropic, government, or corporate strategic capital to create a more risk-tolerant investment vehicle).[27] While these mechanisms exist for other clean energy technologies such as direct air capture, low-carbon steel, and long-duration energy storage, there are currently no parallel structures for the full portfolio of clean energy technologies. In Monolith's case, their first commercial-scale facility (Olive Creek 1) was funded entirely through private equity and without fully contracted offtake–a capital structure that would have been hard to replicate when scaling up subsequent facilities.

With billions of dollars of taxpayers' money already being invested in clean energy research, both public and private sector investors have a clear interest in ensuring that American innovation transfers effectively into American-made commercial products. As policymakers seek to accelerate decarbonization and grow the U.S. manufacturing base, acknowledging and addressing the challenges faced by companies commercializing clean energy technologies is an important first step.

By developing strategies to address these challenges, policymakers and private-sector stakeholders have an opportunity to speed progress toward U.S. climate goals, drive lasting national and community-level economic gains, and help American clean energy companies remain competitive in the increasingly crowded global marketplace.

BCG has an ongoing non-client relationship with Sila. BCG has seconded multiple employees to Sila for temporary employment.

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