

Revolutionizing the Global Electricity System through Multi-Day Battery Storage

Editor-in-Chief's Interview with Form Energy CEO Mateo Jaramillo



Form Energy is a trailblazing American company in the energy storage sector, specializing in the development and commercialization of an innovative iron-air battery. The battery stands out for its ability to store electricity for up to 100 hours, offering a cost-effective solution comparable to traditional power plants. CEO Mateo Jaramillo is co-founder and CEO of Form Energy. He was formerly Vice President of Products and Programs for Tesla's stationary energy storage program, an effort he started. In that role, he was responsible for Tesla Energy's product line and business model definition, as well as global policy and business development. Mateo joined Tesla in 2009 as the Director of Powertrain Business Development, serving as commercial lead on over \$100M in new development and \$500M in production contracts signed for electric powertrain sales. Prior to Tesla, Mateo was Chief Operating Officer and part of the founding team at Gaia Power Technologies, a pioneering distributed energy storage firm. He serves on the Board of the American Clean Power Association. He earned his A.B. in Economics from Harvard University and a Masters in Theology from Yale Divinity School.

Krieg Long Duration Energy Storage (LDES) systems seem poised to revolutionize energy system decarbonization, offering bulk power benefits and resilience to behind-the-meter applications. Given the increasing prevalence of extreme weather events, these technologies may become pivotal in enhancing local and regional grid resilience and reducing grid expansion costs. Can you delve deeper into their significance and potential?

Jaramillo “Long duration” is an imprecise term which, as used today in the industry, currently covers everything from 6 to 1,000+ hours of rated dis-

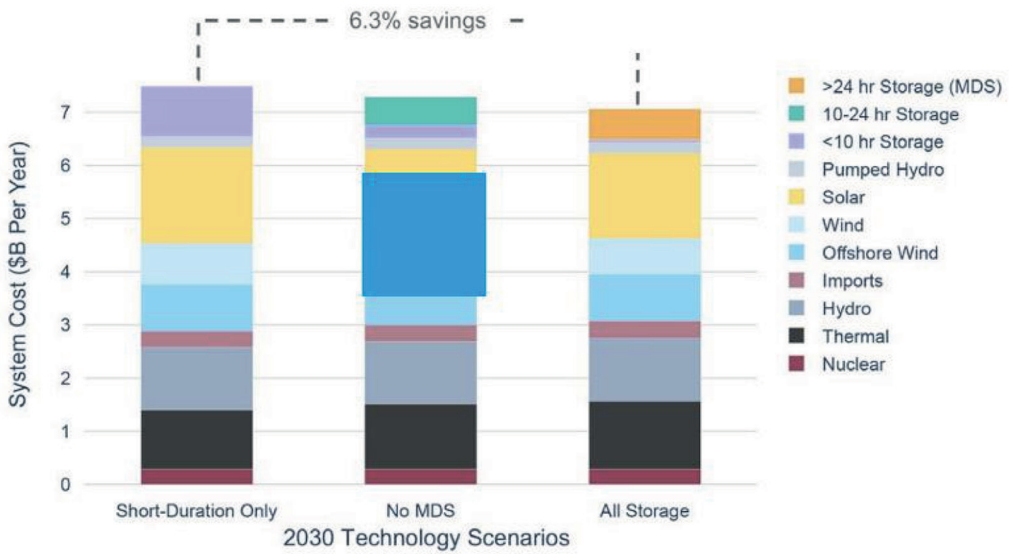
charge. The term “long duration” typically refers to storage systems that can discharge for longer periods than the most deployed lithium-ion systems today, which are usually designed to discharge for 2-4 hours at full capacity and in practice, “long duration” is used today to refer to storage systems ranging from lithium-ion batteries that can provide 6-8 hours of storage capability, to 10-hour flow batteries, to 12-hour mechanical or thermal storage systems. Form’s electrochemical battery can discharge energy continuously for 100+ hours and solves a different problem from other “long duration” storage technologies; we prefer to use the term “multi-day” storage (MDS) to refer to our approach.

MDS is an essential part of a reliable, cost effective, decarbonizing grid. Multi-day weather events such as extreme cold, extreme heat, and prolonged cloudy doldrums present the primary reliability challenge to present day and future grids. This fact was tragically demonstrated by the four-day outage that Winter Storm Uri inflicted on Texas. MDS can harness low-cost clean energy during periods of abundance and use that energy to provide a low carbon backstop to the grid during these prolonged periods of grid stress. But MDS isn’t just a “rainy day fund.” While catastrophic events like Winter storm Uri happen relatively infrequently, grid operators are tasked with managing the more minor heat waves and winter storms that occur many times each year—MDS presents an economic solution to these challenges. Further, MDS complements today’s storage technologies to support renewable energy firming, providing flexible power as the sun sets and as the breeze dissipates. In that light, the U.S. Department of Energy noted that the grid will need between 225 and 460 gigawatts of LDES to enable decarbonization, with 180 – 200 GW coming from MDS.¹

Krieg With growing reliance on solar and wind for energy generation, the challenge of seasonal fluctuations in electricity supply becomes prominent. A low-carbon power system needs to provide clean energy even during non-peak solar and wind periods. How can long-term energy storage reshape grid dynamics in such scenarios?

Jaramillo Seasonal fluctuations in clean energy present an economic opportunity for MDS. During spring and fall months, demand for electricity tends to be relatively low due to mild weather. However, clean energy supply tends to be strong as days are often long, clear, and breezy. As a result, energy tends to be clean and inexpensive—an ideal opportu-

¹ U.S. Department of Energy, 2023. Pathways to Commercial Liftoff: Long Duration Energy Storage. https://liftoff.energy.gov/wp-content/uploads/2023/10/Pathways-to-Commercial-Liftoff-LDES-May-5_UPDATED-v10.pdf



nity for MDS. In our modeling we see MDS taking advantage of this abundant, low-cost clean energy during spring and fall months to shift energy seasonally—as shown in the chart below, taken from a recent study Form Energy published focused on supporting New England’s clean energy goals.² The figure shows how MDS charges throughout spring and fall months, followed by discharges throughout summer and winter grid stress periods. The result of this economic behavior is that MDS dramatically increases the utilization of renewable energy, cutting renewable energy waste—curtailment—by up to 83% in our modeled scenarios.

Krieg It would be hard not to view your senior management group as a “dream team.” Each member is a respected veteran in his or her specialty. It strikes me as providential that you’re working together rather than competing in the LDES development and implementation space. Could you describe Form Energy’s core leadership team as well as your mission and shared values?

Jaramillo Thank you, Richard. Form Energy was created when two early-stage companies working on breakthrough energy storage battery technologies joined together. Our teams combined because everyone valued having the best shot at making a meaningful impact on climate change more than their particular company achieving singular success. As

² Form Energy, 2023. Clean, Reliable, Affordable: The Value of Multi-Day Storage in New England. <https://formenergy.com/wp-content/uploads/2023/09/Form-ISO-New-England-whitepaper-09.27.23.pdf>

co-founders, we knew it made good business sense to join forces, but it was our mutual respect and ability to connect as human beings that sealed the deal. The Form Energy origin story is an unusual one, free of the egotism that can often accompany venture-funded tech startups. Our company was founded on human connection, mutual respect, and deep motivation and inspiration to create a better world.

Krieg The federal and state governments are vigorously promoting LDES system development. DOE, under Secretary Granholm, has scoped out multiple pathways for commercial liftoff of these technologies. With funding in the Inflation Reduction Act and through other means, the agency wants to improve critical certainty for private investment. Construction of your first battery factory in West Virginia relies in part on asset-based performance financing from the State. And in New York, you received a sizable grant from the state's Research and Development Authority (NYSERDA) to deploy a 10 MW/1,000 MWh pilot battery project by 2026. How has the supportive public policy environment impacted the company's trajectory?

Jaramillo We are racing against the clock to commercialize an entirely new battery chemistry for grid-scale multi-day storage. It took about 30 years from when the first lithium-ion battery was used in a camcorder to becoming the mainstream battery that powers all the electric cars in the world. We have about $\frac{1}{3}$ of the development time to get our product to market, and this will only be possible with a supportive public policy environment at the federal, state, and local levels.

The Inflation Reduction Act supports the U.S. manufacturing sector broadly, and the entire domestic battery manufacturing industry specifically, in addition to other industries such as solar and wind, with manufacturing credits for the production of PV cells, wafers, inverters, and wind components, especially in the case of offshore wind. Although we have not yet received any IRA funding, it is already having a positive impact. For instance, when the IRA passed last summer, we had already received an executed term sheet for a Series E funding and were well underway in our site selection process for our first high-volume manufacturing facility. With the passing of the IRA, it became clear the entire electric industry was about to shift into high gear. Our investors soon grasped the impact; our in-process funding round doubled in size, and we all pushed forward to close quickly and finalize our site selection process. West Virginia state officials, as well as the local county and city officials, stepped up to bring the revitalization of the old Weirton Steel site to fruition by offering a substantial state incen-

tive package, a pro-business landscape, streamlined processes, and a serious commitment to workforce development.

Across the country, more and more states are setting targets for LDES. For instance, in a first among states, California approved \$126 million in incentives to demonstrate new long-duration storage technologies. Massachusetts came out with its 2022 Massachusetts Climate Bill, which recognized the potential of long-duration and other storage technologies to enable the state's ambitious climate goals. And, as you mentioned New York State has a long-duration energy storage grant program, a \$17 million fund intended to expedite commercialization of promising technologies offering 10 to 100+ hours of energy storage.

We believe that the demonstrated leadership at the local, state, and federal level will result in meaningful climate impact and will allow us to meet our country's energy goals: enhancing grid resilience and security, increasing grid reliability and safety, creating well-paying jobs and economically benefiting local communities, and ensuring the inventions that secure our energy future are built right here in the United States. However, to do this in a relevant timeframe, there must be a new focus on coordination and alignment between the federal level and the local level to provide greater certainty and expediency around clean energy and infrastructure deployments. For instance, there will need to be dedicated efforts to streamline permitting processes, enhance grid modeling and planning tools, create new market structures, and provide the necessary support to scale up domestic manufacturing.

Krieg It's noteworthy that in New York and West Virginia, you're on the ground in the nation's 4th and 40th largest states. I'm particularly interested in West Virginia because Form Factory One is a historic facility—both in terms of the iron-air batteries to be produced there and its impact on West Virginia's economy. Am I correct that the Weirton WV site was selected from a slate of some 500 locations? What led you to select this site, and what do you think the facility's economic impact might be?

Jaramillo Yes, you are correct. We led a year-long, robust nationwide selection process for the site of our first full-scale battery manufacturing plant. Our team started by identifying over 500 candidate locations across 16 states, narrowing the search to three locations. After evaluating several promising manufacturing site locations, we landed on a great site in Weirton, West Virginia. We appreciated the proximity to our existing pilot manufacturing facility in Eighty-Four, PA and were also impressed with West Virginia's pro-business landscape, streamlined processes, and commitment to workforce development.

As we look to our future, when we are receiving hundreds of thousands of tons of iron every year by rail or barge and turning it into electrodes in batteries, there were only a few places in the United States that made sense to build these batteries because the infrastructure and know-how is already there. Weirton is a historic steel community—sits on a river—has direct access to rail and hardened highways —and has the know-how to make great things out of iron.

Regarding economic impact, our first commercial production line in Weirton will result in the creation of over 750 good-paying jobs when it is in full operation by 2028. We have already hired more than 20 West Virginians and will ramp up hiring for Form Factory 1 later this year and into next year. The majority of factory employees will be machine operators, assemblers, material handlers, maintenance and repair technicians, lab technicians, and shipping and receiving associates. We will also be looking to hire leadership positions at all levels—manufacturing associate leads up through supervisors, managers, and directors. In addition, we'll also be hiring employees to support the finance, human resources, engineering, environmental health and safety, supply chain, and logistics teams.

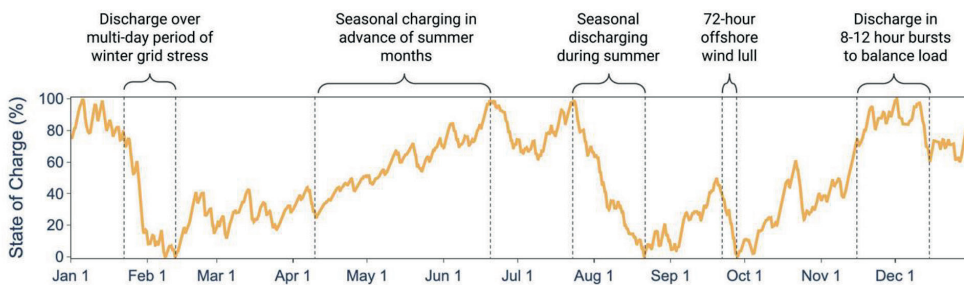
There will also be indirect economic benefits to the community, and in fact we are already seeing this, as we construct the factory. Many of the subcontractors working on the construction of the factory are within the region and hire local tradespeople. We now have teams of employees who are in Weirton regularly for work, staying at the local hotels, eating at the local restaurants, and supporting the community through their patronage; this will only increase as we begin to hire more employees to work at Form Factory 1.

Krieg Turning attention to New York, a recent analysis by a Stanford University team highlighted the critical role of various energy storage solutions, including LDES and multi-day storage (MDS), to effectively decarbonize the State's electric grid. These solutions were shown to be the least cost approach to meeting New York's needs for dispatchable, emissions-free resources. What else did the study show?

Jaramillo I am not familiar with this specific analysis but Form Energy also studied the decarbonization of New York's power grid in line with the Empire State's goals.³ Our research shows that investing in a diversity

³ Form Energy, 2023. Modeling Multi-Day Energy Storage in New York Storage Portfolios that Can Enable a Reliable, Zero Carbon Grid. <https://formenergy.com/wp-content/uploads/2023/09/Form-Modeling-Multi-Day-Energy-Storage-in-NY-whitepaper-8.8.23.pdf>

of storage resources—including short duration (<10 hour), medium duration (10 - 24 hour) and multi-day (>24 hour) storage—presents the least cost, most reliable path for New York to meet its goals. Our study shows that a technology pathway that supports all storage types can save the state hundreds of millions of dollars per year by 2030 and roughly \$9 billion dollars per year by 2030, relative to a path that focuses exclusively on today’s lithium-ion technologies. These savings are primarily driven by the ability of multi-day storage technologies to provide dispatchable, emissions free power; without multi-day storage, the State would need to “over build” other types of storage resources in order to ensure reliability during extreme weather conditions and prolonged renewable energy lulls. In fact, in 2030, one megawatt of multi-day storage reduces the need for roughly 2.33 megawatts of other resources, including wind, solar, and storage. The resulting impact is a lower cost, lower land use, more efficient system.



Krieg Nationally, DOE estimates suggest a potential cumulative benefit of up to \$530 billion in the next 25 years, provided LDES technologies gain sufficient market traction by 2030. This includes over 2 million job years in engineering and construction. Do these projections align with your own expectations and vision for LDES?

Jaramillo The stability of the electric grid is increasingly important as we electrify more and more of society. However, recent severe weather events—ranging from heat waves to cold snaps to thousand-year rains—have highlighted the weakness of our electric grid, which is increasingly reliant on low-cost—and weather driven—renewable energy. Energy storage would be an obvious solution to this, however while we have cost-effective batteries for up to a few hours, in order to run the grid reliably and affordably, we need new, transformative energy storage technologies capable of cost-effectively storing electricity for longer durations, and specifically multiple days.

We believe there is tremendous potential for LDES to gain market traction in the U.S. and beyond. The global market for these systems is expected to grow tremendously in the coming years. A [study](#) by the nonprofit LDES (Long Duration Energy Storage) Council pegs the long-duration energy storage market at between 80 and 140 terawatt-hours by 2040.

Krieg Form Energy has operated in one of the most scientifically challenging corners of the rapidly evolving energy sector. Over the past five years, I've been impressed that unlike many startups—in energy, water supply and in other critical infrastructure sectors—you've consistently avoided the exaggerated claims that investors sometimes hear. Reflecting on your journey over the past half-decade, how would you characterize Form Energy's current position and accomplishments?

Jaramillo Form Energy has progressed quickly since our founding in 2017. We now have more than 650 employees working across the United States. Our mission and focus from the very beginning has been on impact, and until we are manufacturing at scale, we know we haven't achieved our goal. All of our progress to date is viewed by the company in that context.

We are headquartered in Somerville, MA, where our team is focused on electrochemical research and development, innovation, and continuous learning and improvement. We have facilities in Berkeley, CA, where our team is focused on product engineering and design, assembly development, as well as full scale battery validation and testing. Eighty-Four, PA is home to our manufacturing engineering team, where we operate a pilot manufacturing line to test our manufacturing processes and prepare for the scale up and broad commercialization of our iron air battery systems. And as noted above, we are constructing our first high-volume manufacturing facility in Weirton, WV, where we will begin manufacturing iron air battery systems for broad commercialization starting in 2024.

We continue to make tremendous progress on the commercial front. We partnered with Minnesota's second-largest electric utility, Great River Energy, to jointly deploy a 1.5 megawatt/150-megawatt hour pilot project to be located in Cambridge, MN. We announced a partnership with Xcel Energy to jointly deploy a 10 megawatt / 1,000 megawatt-hour multi-day storage system at the Sherburne County Generating Station in Becker, Minnesota and a 10 megawatt / 1,000 megawatt-hour multi-day storage system at the Comanche Generating Station in Pueblo, Colorado. Both projects are expected to come online as early as 2025.

We are also collaborating with Georgia Power, the largest electric subsidiary of Southern Company, to deploy a 15 megawatt/1500-megawatt hour energy storage system in the utility's service area. This project is expected to come online in 2026. We were awarded a \$12 million grant from the New York State Energy Research and Development Authority to accelerate the deployment of a 10 megawatt / 1,000 megawatt-hour iron-air battery system in New York State, expected to come online by 2026. And most recently, we announced a partnership with Dominion Energy to provide a 5 megawatt / 500 megawatt-hour iron air battery storage system as part of the Darbytown Storage Pilot Project in Virginia. We have several other commercial negotiations underway and will have more news to share later in the year.

Krieg Looking a decade ahead, considering the possibilities and economic viability in the long-term energy storage industry, where would you like Form Energy to be?

Jaramillo Iron-air batteries can cost-effectively facilitate access to renewable energy sources, boost the stability and reliability of power grids, and ultimately accelerate grid decarbonization. Our internal analytics predict that over the next decade, achieving Form's cost and performance targets will unlock tens of gigawatts of demand for multi-day storage in the U.S. and accelerate the country's trajectory towards a more reliable and resilient grid. At such levels of deployment, Form's technology will catalyze billions of dollars in savings to American electricity consumers.