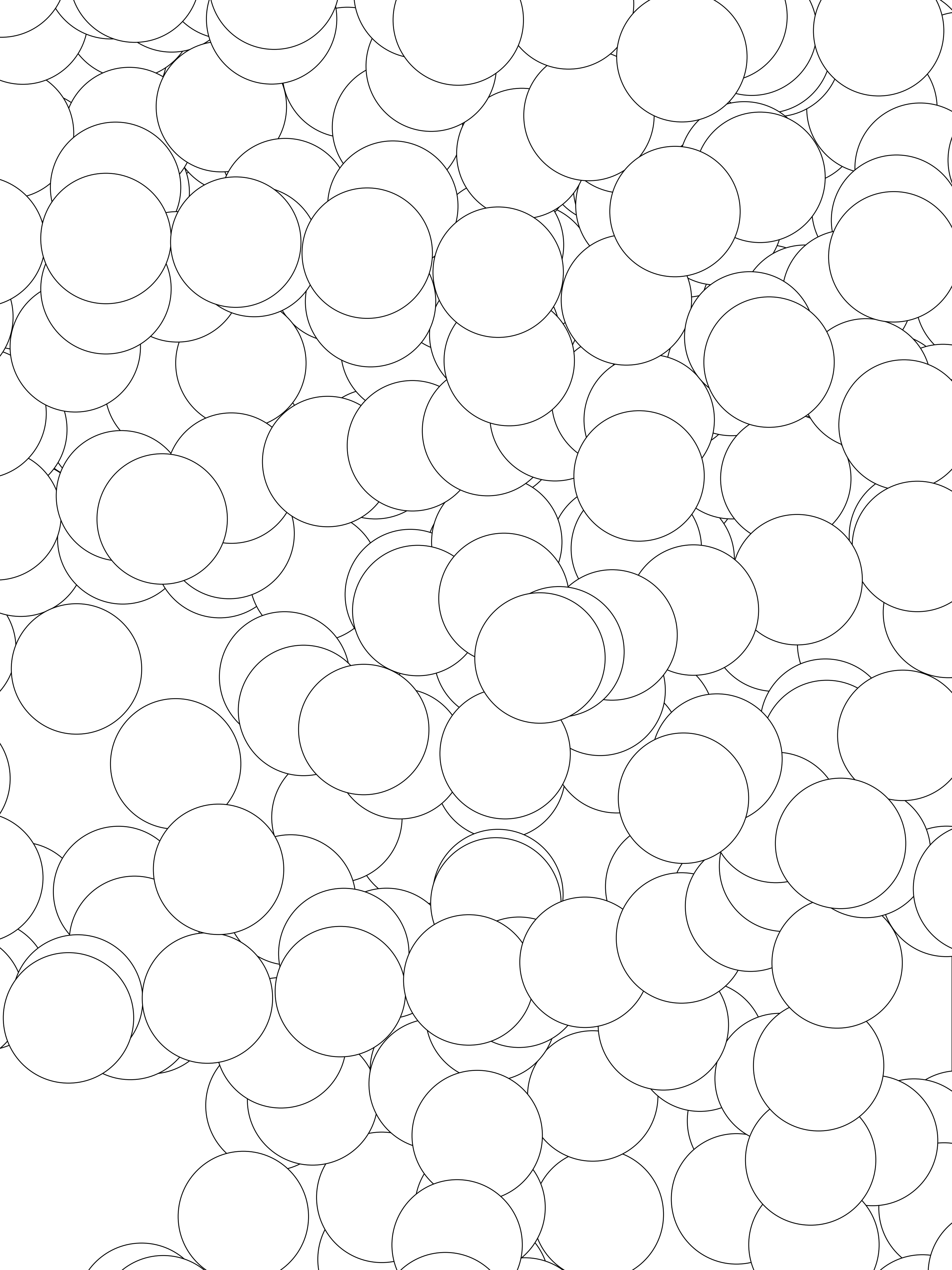
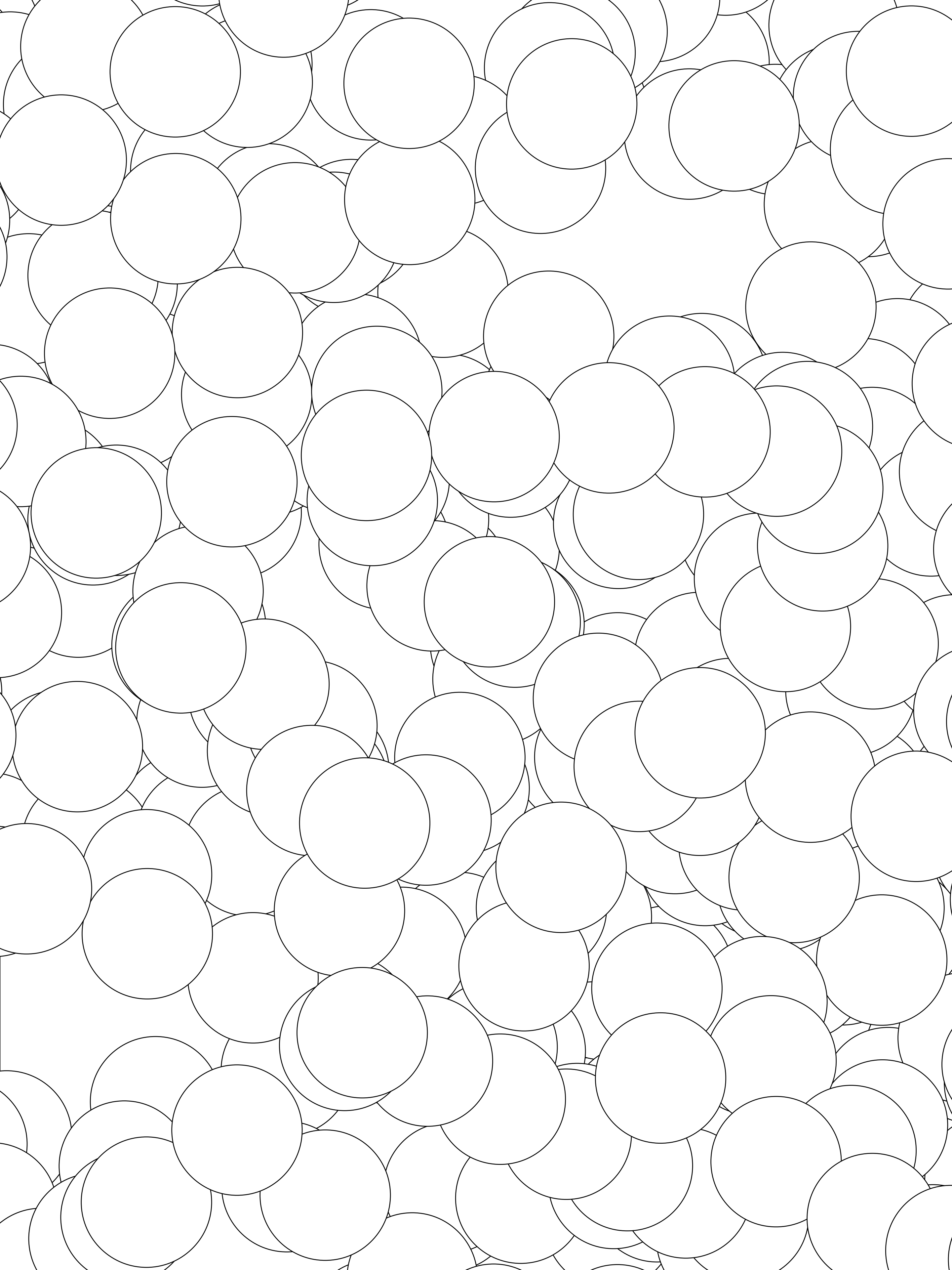
The Voltaiq Effect

Taking Charge in the New
Battery-Powered Economy

VOLTAIQ

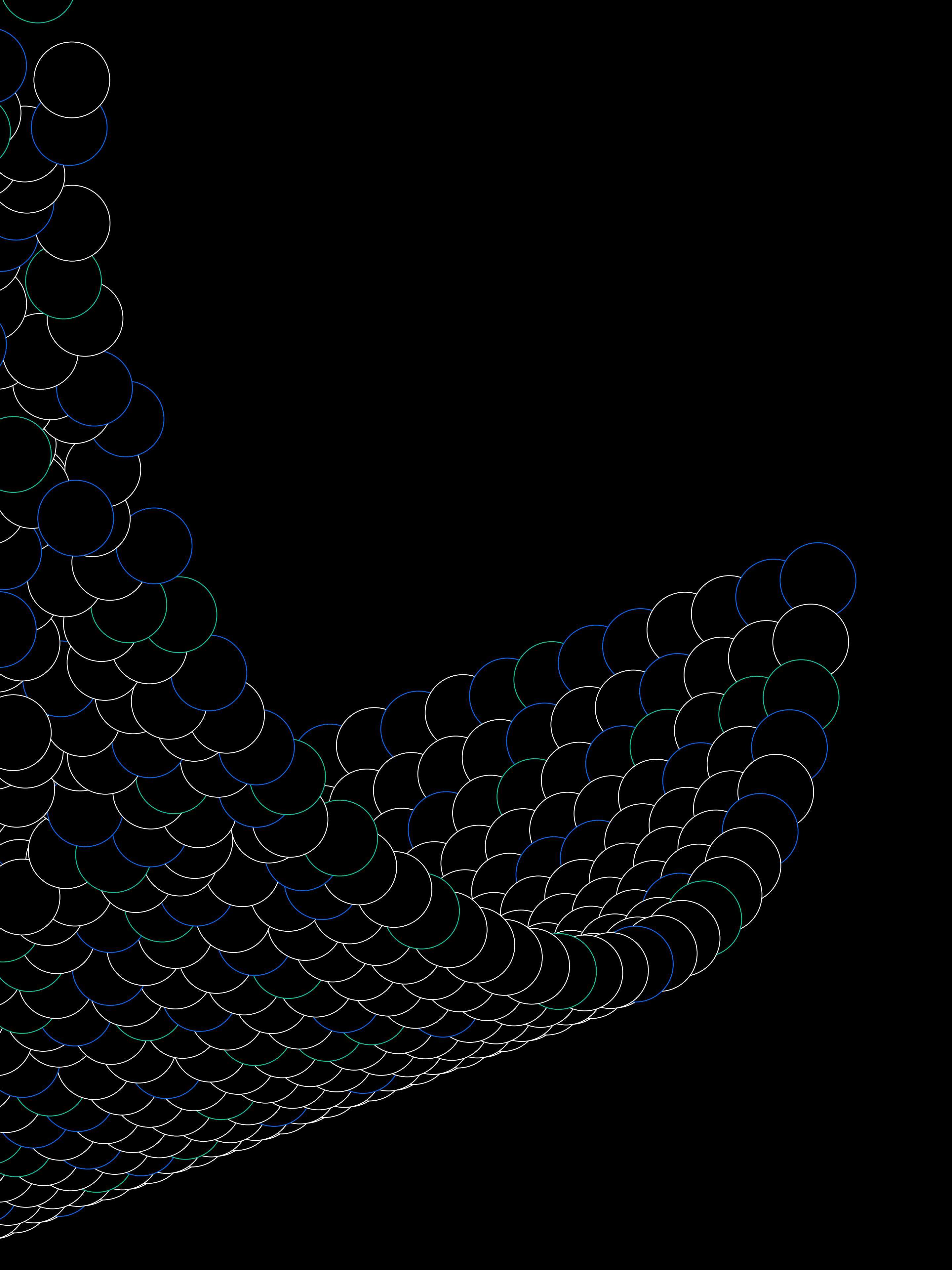




The Voltaiq Effect

by Jeffrey O'Brien

VOLTAIQ



Taking Charge in the New Battery-Powered Economy

Batteries aren't merely unique in the sense that no two are alike. They're distinct from moment to moment. Their performance is influenced by the environment. They react to stress and pressure. They're finicky – even volatile.

Energy pulses less than a millimeter beneath a deceptively calm exterior, the product of a stream of chemical reactions. If they sound biological, they nearly are. Like humans, batteries are assemblies of interdependent, massively complex systems.

Optimizing their safety, assessing their health, and extending their lifespans requires the equivalent of modern medicine. Voltaiq's Enterprise Battery Intelligence (EBI) platform is an analytics solution created with that goal in mind. It automatically gathers and mines data for insights, providing a window into real-time behavior.

EBI identifies malfunctions and offers a detailed vision of future performance. It's a turnkey solution built to help companies take charge in the new battery-powered economy.

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1 | The Rush of Battery Power

Few inventions in recorded history can rival the transistor for its breadth and speed of impact on society. The pace of change has been so fast, especially of late, that it's easy to lose sight of the toil, investment, and adjacent technologies that have enabled the now ubiquitous (and invisible) nerve cells of the Information Age. But Ralph Szygenda knows better. He had a front-row seat in the early days of the transistor and has followed its trajectory from up close for half a century.

Szygenda spent two decades at Texas Instruments, one of the earliest companies to invest in transistor development, where he designed computer systems for military jets before rising to the role of CIO. He later became CIO at Bell Atlantic, the precursor to Verizon, overseeing its transition from phone company to information and entertainment powerhouse. And during 13 years as CIO of GM, he managed a $4 billion annual IT budget devoted to modernizing what was then the world's largest company. So it's worth listening when the 72-year-old semi-retired Szygenda identifies another transistor-scale change afoot. "Think of the way computing has infiltrated our lives," he says. "The same is going to hold true again, but this time it's about electrification."

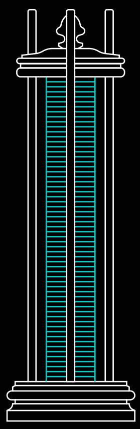
While electricity has been reshaping the world for centuries, its benefits have been largely restricted to the proximity of an outlet. But evermore sophisticated batteries are changing this dynamic and promising to spark a Cambrian explosion of electric devices. The lithium-ion battery in particular – which garnered the 2019 Nobel Prize in Chemistry for its inventors – is leading the way. As these containers of potential energy become smaller, safer, more energy-dense, and faster-charging, Szygenda believes billions of wireless, perpetually connected, location-aware devices will unleash creativity, spur productivity, and unveil unimaginable opportunities while destroying entire industries, just as mobile phones have done. By his reckoning, battery uptake is where the transistor was during the microelectronics revolution of the 1980s, when appliances, watches, and cameras first gained computing ability. And adoption is accelerating. "Everything that we touch will soon be battery-powered," Szygenda says. "It's the same movie. A basic underlying technology goes through a rapid development cycle thanks to enormous investments. A number of cooperating technologies are at play. And the combination changes our world. Manufacturing, transportation, communication, power grids, our homes and offices and cities – everything."

It's not just technology that's driving battery adoption. It's also a matter of saving life as we know it on our planet. Faced with a barrage of climate events – from Category 5 hurricanes to catastrophic floods, forest fires, and droughts – 80 percent of Americans believe the US should place tougher restrictions on carbon emissions, and 79 percent place a priority on developing alternative energy sources. The Biden administration has promised to prioritize efforts to combat climate change. Seventeen countries and California have taken actions to phase out internal combustion engines and encourage the adoption of electric vehicles (EVs), according to the Climate Center. With wind and solar setting new production records, renewable energy is now cheaper to produce than most forms of fossil fuels, ushering in an opportunity for incredible economies of scale related to reducing carbon output, rethinking the power grid, and even unleashing zero-emission transportation systems ranging from scooters and cars to delivery fleets, airplanes, drones, and autonomous tractors.

The cost of producing Li-ion battery systems has dropped 90 percent in the past decade, and government money is pouring in along with investments from the consumer electronics, retail, logistics, energy, and auto industries. "The battery factories today, these are multibillion-dollar investments, on the same order of building semiconductor fabs," Szygenda says. "If you build them efficiently, you will have a profound impact and capture huge upside. But if you do it incorrectly, it's going to cost you a phenomenal amount of money."

Unplugged

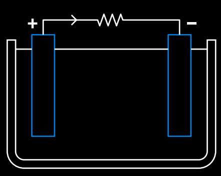
A timeline of batteries and their effects on industry and society



1800

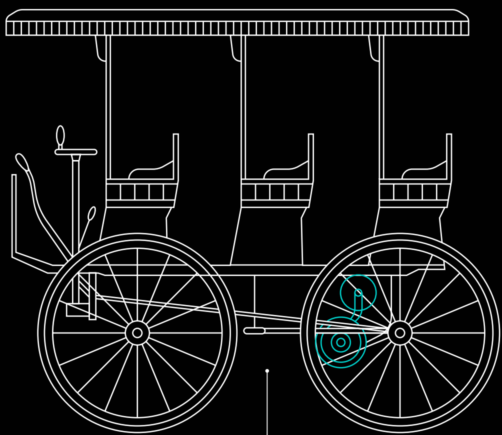
The Voltaic Pile

Italian physicist Alessandro Volta invented the first electric battery after debating with another scientist about the source of stimulus in an experiment involving frog leg contractions. Volta created stacks of alternating copper and zinc discs separated by brine-soaked cloth. He connected the top and bottom discs with a copper wire to increase the circuit's output. Volta's creation became a hit with scientists who used it as a reliable power source for lab experiments.



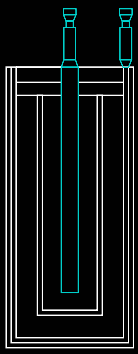
1859
Lead-Acid Battery

The first rechargeable battery, invented by French scientist Gaston Planté, features a lead anode and a lead dioxide cathode immersed in sulfuric acid. The electrodes react with the acid to produce a current; recharging occurs when the current is reversed. “Wet cell” batteries are heavy and bulky but produce large currents, making them useful in automobiles and boats. Roughly 99 million are manufactured every year – with nearly 90 percent recycled for reuse.



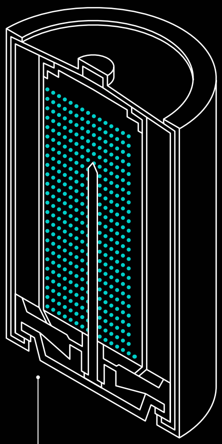
1890
The Morrison Electric

If there’s a battery geek superhero, it’s Scottish American chemist William Morrison. His six-passenger Morrison Electric carriage featured two dozen lead-acid battery cells weighing 32 pounds each. The commercial version had a 100-mile range, traveled up to 12 mph, and recharged in 10 hours. His business partner, Harold Sturgis, exhibited a modified four-passenger model to much acclaim at the World’s Columbian Exposition in Chicago in 1893 – 15 years before the introduction of the Model T.



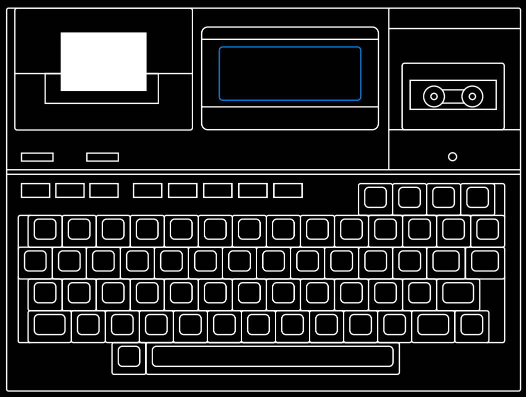
1899
Nickel-Cadmium Battery

Invented by Swedish engineer Waldemar Jungner, the NiCd rechargeable battery uses nickel oxide hydroxide and metallic cadmium electrodes and a potassium hydroxide alkaline electrolyte to boost energy density. NiCd cells became popular after they were packaged into a “jelly roll” design. They were common in consumer electronics and toys until the 1990s, but have been largely replaced by less expensive and more environmentally friendly alternatives.



1959
Alkaline Battery

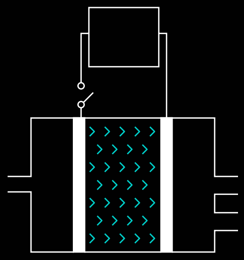
Canadian engineer Lewis Urry improved upon acidic zinc-carbon batteries with zinc-manganese dioxide electrodes and an alkaline electrolyte. He co-patented the first dry-cell, or alkaline, battery on behalf of Eveready. Sales skyrocketed in the 1980s thanks to ad blitzes by Energizer and Duracell, and the total alkaline battery market is expected to approach $8 billion in 2021. Recent awareness campaigns have boosted alkaline recycling – an important development since they’re hazardous waste.



1981

Epson HX-20

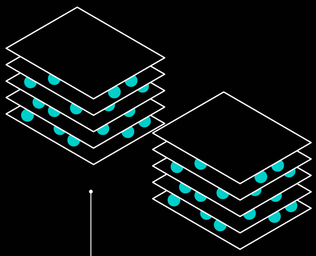
The first laptop computer debuted at Comdex in New York. It featured a calculator-sized LCD screen, a dot matrix printer, a microcassette player, 16 KB of RAM, and 100V rechargeable NiCd batteries. *BusinessWeek* declared it "the fourth revolution in personal computing." The Epson HX-20 has become a collector's item, and while many are still operational, it's a common refrain that "the NiCd batteries need replacing." In 2019, global shipments of battery-powered computers – including laptops, tablets, and smartphones – was just shy of 2 billion units.



1989

Nickel-Metal-Hydride Battery

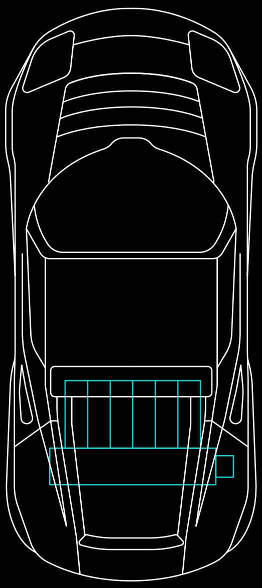
The rechargeable NiMH replaces the cadmium in NiCd with a hydrogen-absorbing alloy. This provides as much as three times the capacity and significantly higher energy density while also being more environmentally friendly. NiMH quickly became a popular choice to power high-drain devices like digital cameras, early electric hybrid vehicles, including the Toyota Prius, and the first fully electric car, the GM EV1. Unlike alkalines, they don't tend to leak, but overcharging can cause hydrogen gas to form, potentially causing the cell to rupture.



1991

Lithium-Ion Battery

The 2019 Nobel Prize in Chemistry was awarded to three scientists for the development of this world-changing battery. Interestingly, they weren't collaborators. Stanley Whittingham, an Exxon chemist, developed an early version that used titanium disulfide and lithium metal as electrodes. It repeatedly caught fire. University of Texas professor John Goodenough swapped in lithium cobalt oxide to double energy density. Akira Yoshino added petroleum coke to create a more stable prototype. Li-ion battery sales are expected to hit $87.5 billion by 2027.



2005

Tesla Roadster

By now, the Model 3 has become the best-selling luxury car in the US and cemented Tesla CEO Elon Musk's place among the world's wealthiest humans. But it was this $90,000 two-seater that paved the way. The Roadster was the first EV to use a lithium-ion battery – 6,831 cylindrical 18650 format laptop battery cells, to be precise. It had a range of 200 miles, topped out at 120 mph, and completely dispelled the perception of alternative-fuel vehicles as pokey and ugly. A new Roadster is scheduled to hit the market sometime in 2022.

"Everyone is trying to figure out how to make batteries better. If you're the first to find the path forward, that's an incredible advantage."

2021

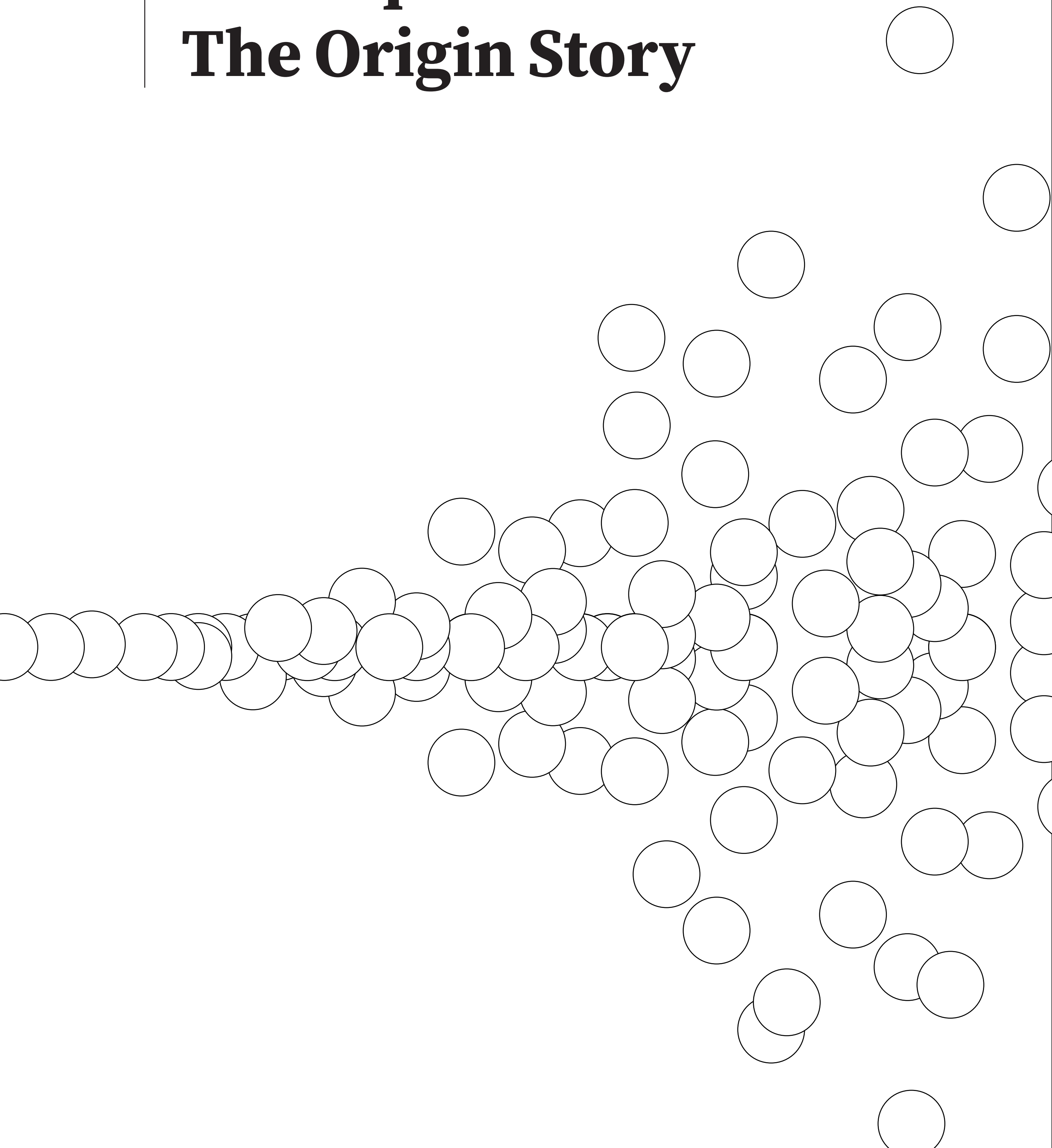
Who Killed the ICE?

In early 2021, GM CEO Mary Barra tolled the bell for ICEs, declaring that GM will stop selling gasoline and diesel-powered passenger cars and SUVs by 2035. Ford quickly followed, announcing it would halt ICE car sales in Europe by 2030. Volvo then vowed to stop selling all automobiles that run on fossil fuels by 2030. And Volkswagen revealed its plans to build six battery "gigafactories" with an annual production capacity of 240 GWh – enough to power more than 4 million of the company's ID.3 EVs.

Szygenda is often approached to provide counsel on industrial disruption. For the most part he's been content to watch his grandchildren grow in the Texas suburbs. But he made an exception to join the advisory board of a San Francisco Bay Area software startup called Voltaiq, which has created an enterprise analytics platform purpose-built for battery development, production, and operation. He believes the platform holds the key to supercharging a battery revolution, and he's hardly alone. In a few years, Voltaiq has gone from a side hustle to amassing a client list that includes Amazon, Facebook, GM, Google, Mercedes-Benz, Microsoft, and dozens of high-profile startups, as well as an advisory board that doubles as a "who's who" in batteries.

"Everyone is trying to figure out how to make batteries better," Szygenda says. "A decade from now they won't even be recognizable. If you're the first one to find the path forward, that's an incredible advantage."

2 | Voltaiq: The Origin Story



In 2007, Voltaiq co-founders Tal Sholklapper and Eli Leland were a couple of brainiac PhD students at UC Berkeley. Sholklapper completed a doctorate in materials science and engineering in 2½ years – a school record. Leland received his PhD in mechanical engineering. They shared a campus during their studies but never actually met.

After graduating, Sholklapper did research in nanoscale materials discovery at Lawrence Berkeley National Laboratory and co-founded a fuel-cell startup. Leland decamped for New York to become technical lead at the CUNY Energy Institute for a new capacitor project, which was funded by ARPA-e, a DARPA for commercializing energy technologies. Sholklapper soon followed, leading a parallel project to commercialize a new type of grid-scale battery. The duo would often share a subway ride after long days at the office, bouncing around ideas and expressing mutual frustrations about their arduous hypothesis-testing routines.

Trying to shine light on the inner workings of a battery system was an excruciating affair that involved months of long-duration testing followed by gathering and importing performance data into Excel spreadsheets, trying to deduce insights from one-off graphs, and starting over. "Battery development isn't just complex. It's also a weird combination of gritty physical work and hurry-up-and-wait," says Leland. "I remember we were mentally and physically taxed a lot but also kind of invigorated, because we felt like we were exploring this new frontier."

Batteries aren't like mechanical devices. Their durability and safety can't be determined by rapidly putting them through the paces until they break. Every time a key variable is changed, the system must be re-tested in all imaginable facsimiles of real-world usage. To accelerate their experiments, Sholklapper, Leland, and their colleague Dan Steingart – now Co-Director of the Electrochemical Energy Center at Columbia University – developed a browser-based data visualization and analytics tool.

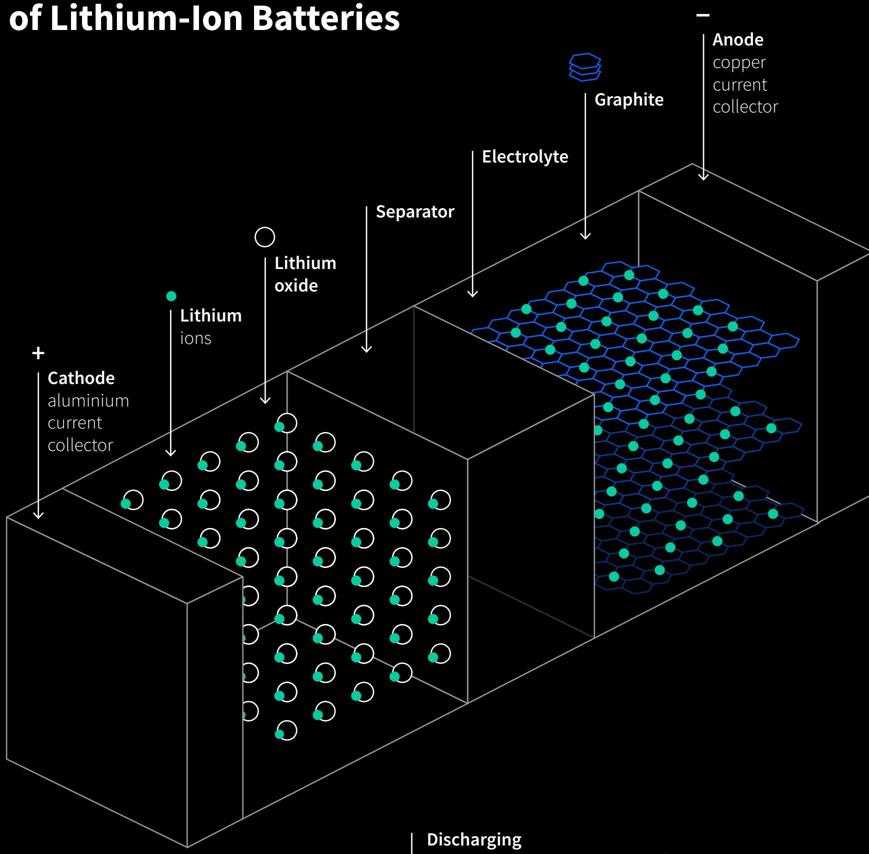
It would periodically open the data files being written by the battery testers, do some basic processing, and serve a text file to a minimalist web page that listed the names of all the battery tests that had ever been run in the lab, each with a link. “You’d click on the link, and the script would create a static black-and-white plot. That’s all,” says Leland. “But everyone was in it all the time, obsessively checking on tests over the course of weeks or months. It was pulled up on the projector in every meeting with VCs and DOE big shots. If it ever went down it was an immediate all-hands fire drill to get it back up.”

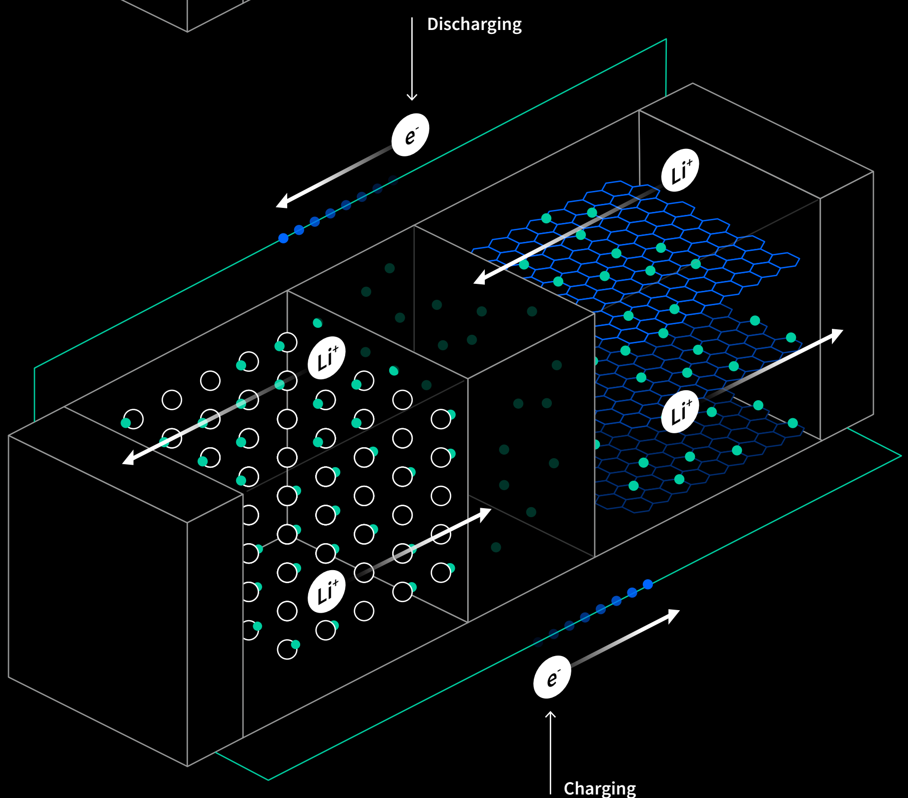
The “crappy little data system,” as Leland now remembers it, infused energy into the engineering team. It relieved the monotony of manually gathering and uploading data from thumb drives and writing Excel macros. But the real excitement came from getting a first glimpse into real-time battery behavior. “I’d have 30 tabs open with all the batteries I was tracking, and the data was continually updating,” Sholklapper says. “From there we just started dreaming up all kinds of different experiments, just to see what might happen.”

In an early test, Sholklapper placed some AA batteries on the testing rig and began monitoring charging cycles. At dinner with his wife one night, he scribbled a charging algorithm on his hand; it was a formula for how to turn single-use, off-the-shelf batteries into rechargeables lasting more than a thousand cycles. It would later become the basis for a patent. “That’s when the light bulb went on,” recalls Sholklapper. “If we could figure out in a few months how to make a AA cycle thousands of times, we knew a more robust platform could have a huge impact on the battery industry.”

The duo began surveying friends and former colleagues to see whether anyone had a similar tool. None did. They were all mired in the thumb-drive-and-Excel routine. “Look at every other vertical, whether it’s semiconductors, biotech, CRM. Everything was being digitized, everyone was into Big Data. But batteries were a couple

Tapping the Potential of Lithium-Ion Batteries





The Key Components

Each Li-ion battery consists of anode and cathode electrodes, which store lithium at different energy states. The positive and negative current collectors provide conducting metal pathways for electrons to enter and exit the battery, while the electrolyte provides a medium for Li-ions to shuttle between the electrodes. A porous separator permits ions to pass through it, but provides electrical separation between the electrodes and prevents shorting.

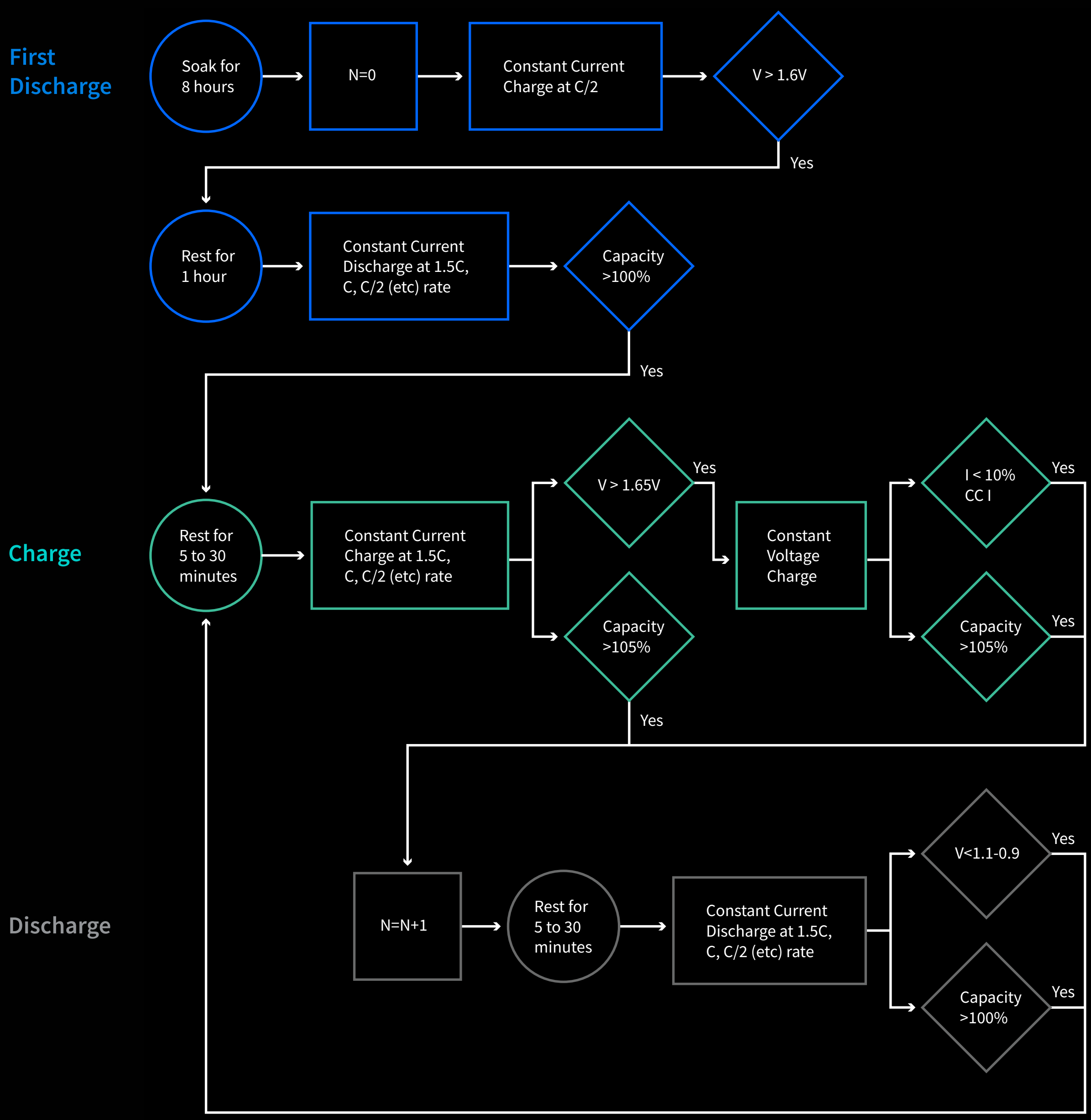
How Does It Work?

Charging
When the battery is charging, a charger pulls (negative) electrons from the cathode and pushes them through an external circuit toward the anode. In response, (positive) lithium ions travel inside the battery from the cathode, through the separator, to reunite with the electrons in the anode. When the graphite in the anode is full of lithium ions, the battery is fully charged.

Discharging
When the battery is providing power, electrons cascade from the anode, through the device being powered, back to the cathode. The ions in turn flow back from the anode, through the separator, to the cathode. When the anode is depleted of ions, the battery is fully discharged.

How to Extend the Life of a AA Battery to 1,000 Cycles

Tal Sholklapper's scribblings became the basis for US Patent 9,419,289 B2.



"Look at every other vertical being digitized. Batteries were a couple of decades behind. Electrification has the potential to be as big a market as fossil fuels – and it has to be driven by data."

of decades behind," Leland says. "And everyone was hitting the same walls. There's a real shortage of talent. Everyone wastes way too much time wrangling data, and models don't work because the systems are far too complex. It all led us to this now-obvious conclusion. Electrification has the potential to be as big a market as fossil fuels – and it has to be driven by data. It's why we built Voltaiq, and it's what drives us every day."

Leland and Sholklapper figured they could bring their analytics platform not just to battery manufacturers and developers but also to any company with an increasing interest in sourcing batteries to expand their business opportunities through increased mobility and to reduce carbon footprint – which was fast becoming just about everyone. With his previous startup experience, Sholklapper took the CEO role; Leland became CTO. As of early 2021, they had raised more than $15 million largely on the strength of Voltaiq's technology and the size of the addressable market. They now have a couple dozen employees and an impressive roster of clients.

Among them: Jeff Bruce, Director of Battery Technologies for Microsoft. He signed on because he was feeling the same pain that the co-founders were experiencing at CUNY. "You cycle batteries to charge and discharge and then repeat. We do it quickly. We do it slowly – in heat and in cold," says Bruce, whose primary interest involves extending the battery life of Surface devices. But Microsoft also has an increasing stake in backup power for its burgeoning cloud computing business, Azure. "Emulating a projected five-year lifecycle will take us about nine months of testing and thousands of batteries."

A Surface device will typically use a battery with two to four cells. By contrast, an EV battery pack has anywhere from several hundred to several thousand cells, making it geometrically, if not exponentially, more complex. "Batteries are like living organisms. You've got billions of particles packed together in electrode sheets. The layers keep getting thinner, and everyone is trying to pack in more energy, making systems more and more difficult to predict," Leland says. "Tiny variations, whether it's nano-structural defects or contaminants, are going to have enormous, often counterintuitive effects. And it's even worse when you're thinking about behavior over a lifespan. The way that batteries are operated, and even stored, can determine how they behave down the road. That's why batteries need to be tested for so long under so many different conditions."

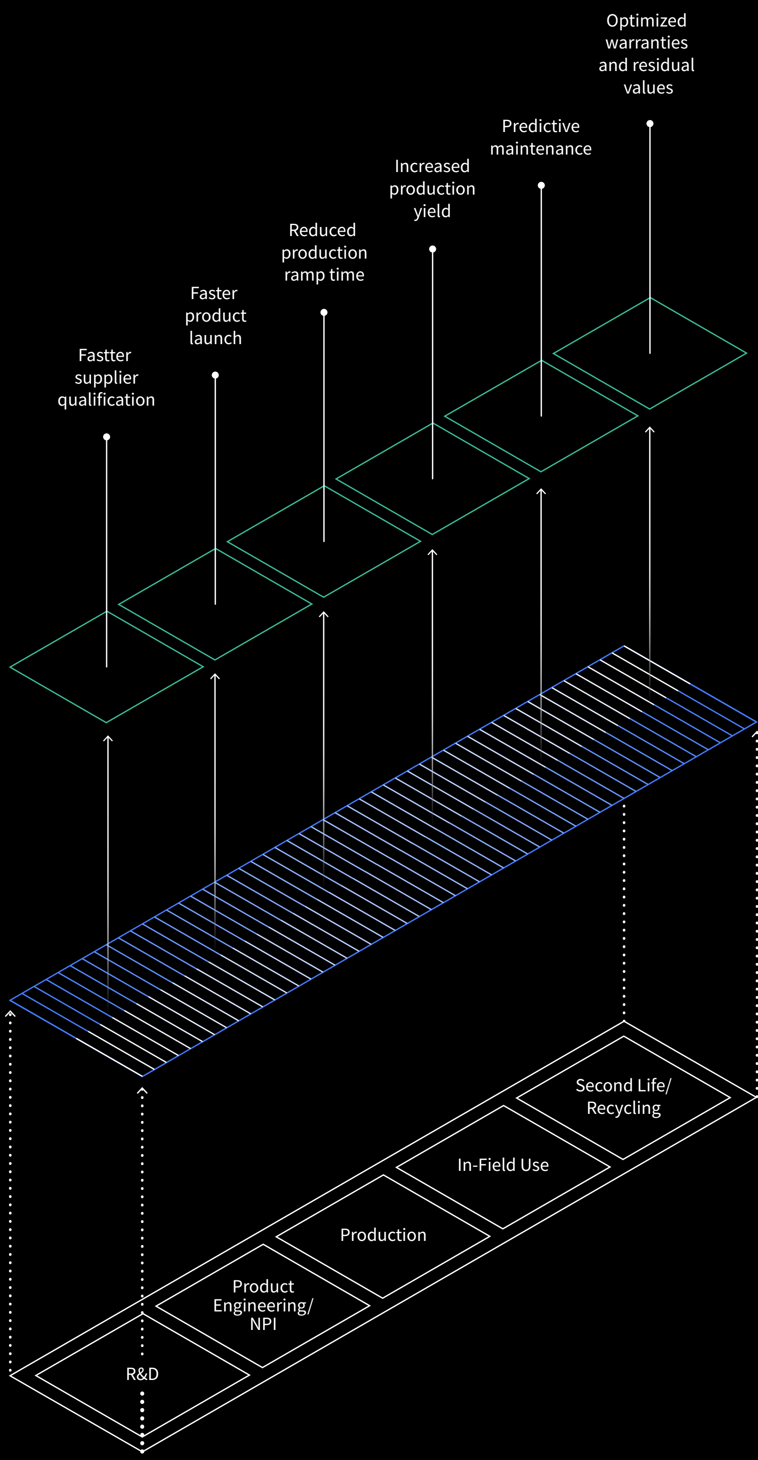
Pre-Voltaiq, Bruce's team would spend upwards of 30 percent of their time wrangling data, and at least one team member always had to be on location. The Voltaiq Enterprise Battery Intelligence platform has allowed the team to offload the process of gathering and analyzing data, and it enables them to work remotely. "The engineers can be in Atlanta or Taipei or Shanghai and still access the data," says Bruce.

While cost savings are always nice, Bruce considers Voltaiq's biggest value to be the way it removes the friction from experimentation and testing. "When the constraints aren't there, it changes your attitude," he says. "With Voltaiq, you don't have to limit yourself to testing five variables or 10 variables, so we get more discovery and learning in a rapid amount of time. That's going to lead to better designs, safer designs, and batteries that just serve the customer better."

Bruce's ultimate goal is to develop batteries that recognize usage patterns. As things stand, a lack of insight

A Purpose-Built Battery Analytics Platform

Converting battery lifecycle data to business outcomes



The Voltaiq Effect

The outcomes matter most, and this is where the platform shines. Call it the Voltaiq Effect. OEMs can quickly stress-test internal/supplier innovations, launch products, and ramp up production. Usage data can be mined for predictive maintenance and to determine fair market value.

Enterprise Battery Intelligence Platform

Using status quo processes, it takes hours, days, or even weeks to make sense of test data. Voltaiq provides a real-time view of behavior. Clients can correlate design tweaks to performance variations, enabling them to instantly see the impact of modifications.

Battery Lifecycle

The platform's baseline activity is the automated collection and processing of performance data and metadata across all phases of development, manufacturing, and usage. The cloud-based solution allows every business function to collaborate and share analyses in a single, unified system.

Battery-Enabled Industries

The Enterprise Battery Intelligence platform was purpose-built to analyze batteries across industries and use cases. Voltaiq works with the biggest EV and consumer electronics firms as well as battery manufacturers, materials developers, and medical device suppliers.

How Will You Acquire Enterprise Battery Intelligence?

Every battery-enabled business needs an infrastructure to properly develop, produce, operate, maintain, and finance battery products. Here's a look at the advantages of building versus buying.

Build Your Own →	Who?	What?	Where?	When?	Why?	How much?
What you need to know about developing an internal battery data solution	It'll be up to your own overworked IT teams, battery engineers, or perhaps expensive consultants whose expertise leaves the building when the project ends.	They'll design and create a solution tailored to your specific needs. Of course those needs will change – updates and maintenance are expensive and time-consuming.	It'll be siloed in the parts of your organization feeling the most pain, meaning there will be little integration or collaboration across the organization.	It'll take anywhere between two and five years to assemble a team, design and implement a system, and begin to see results, assuming on-time delivery.	Most companies choose this route because they don't trust any service provider to truly understand their particular needs.	Total cost is a moving target. Unpredictable personnel and equipment costs spanning design, development, and maintenance cycles tend to bloat budgets. Modifications and improvements will cost extra.

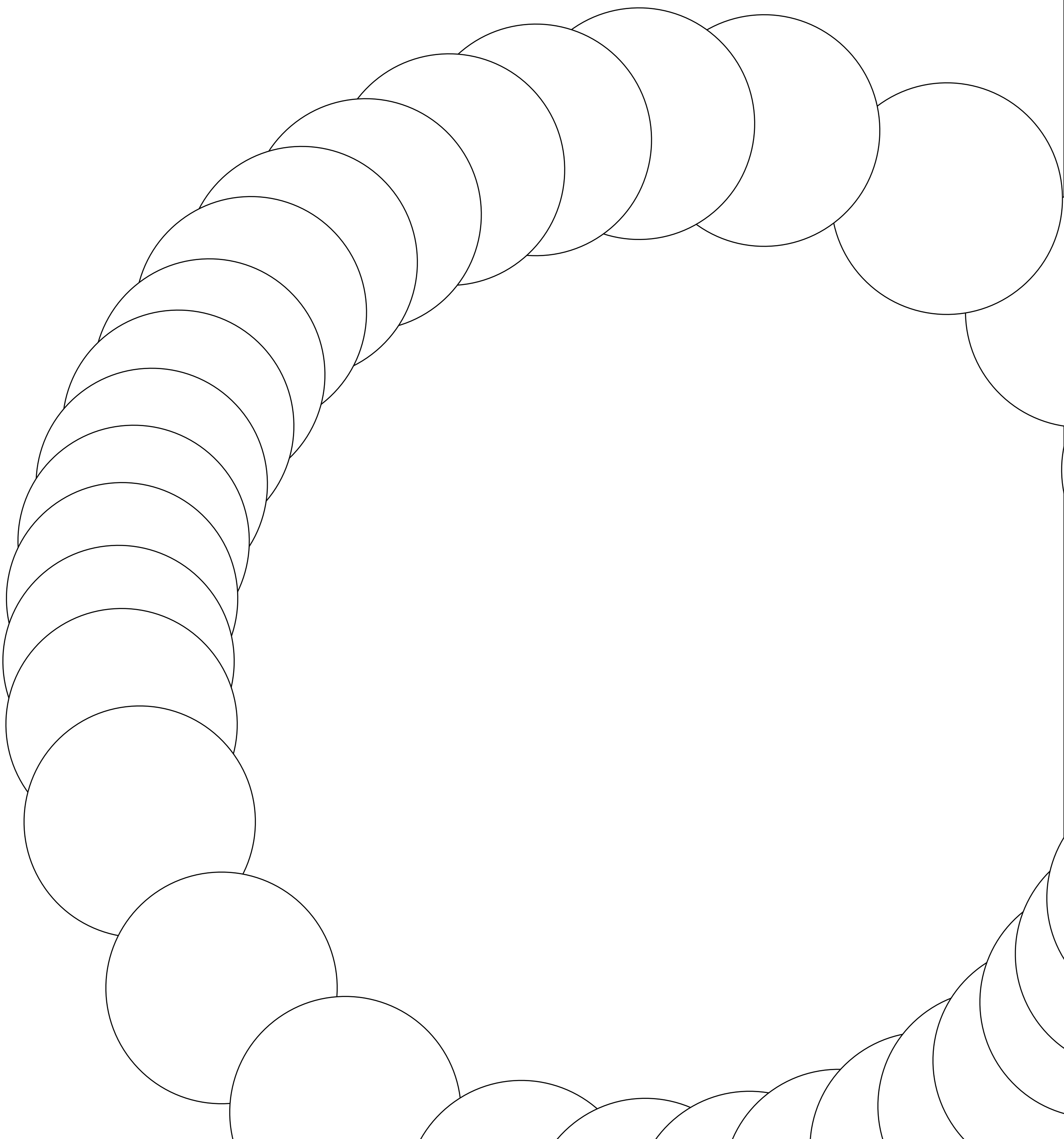
Buying Expertise →	Who?	What?	Where?	When?	Why?	How much?
What you need to know about subscribing to the Voltaiq EBI SaaS Platform	The Voltaiq EBI platform is built by a team of battery industry veterans, PhD battery scientists, and experts in product design and large-scale enterprise data platforms.	It's the only commercial EBI platform. It's continuously enhanced with best practices from market leaders across battery sectors (EVs, CE, battery suppliers, academic research, etc.).	Voltaiq is hosted in the cloud (public or private), to serve the whole enterprise. Built with the entire battery lifecycle in mind, it enables collaboration across R&D, product development, manufacturing, in-field use, and finance.	Voltaiq can be up and running inside your enterprise in as little as a week. Typical onboarding takes 30 days, including user training. Organizations realize almost immediate value.	Battery issues are costing your organization billions. Every day you hesitate to implement a best-in-class solution from the company that invented EBI is a costly decision.	Annual costs are fixed. The EBI platform features a transparent subscription pricing model, which lowers the total cost of ownership.

"Batteries used to be all about electrical engineering and mechanical engineering mixed with materials science and chemical engineering. Now we're starting to build in behavioral sciences."

into how user behavior affects performance forces companies to develop batteries for the lowest common denominator. So users are forced to modify their own behavior for the sake of the battery. Bruce wants to flip that dynamic. "You're going to see more AI control so the battery can learn how it's being used and adapt itself," he says. "Batteries used to be all about electrical engineering and mechanical engineering combined with materials science and chemical engineering. Now we're starting to build in behavioral sciences."

Such ambition is typical of Voltaiq's customer set. "When our clients gain confidence that they can handle the data problem, they start looking beyond product launch windows and toward the bigger picture – and that's what's going to drive the next wave of battery power," Leland says. "In EVs, where the pace of change is so fast and the pressure is so great, battery insights could be the difference between life and death. The fact that auto companies try to do development without scalable, dedicated infrastructure is, frankly, insane. And the results are the delayed launches and recalls that you're always seeing in the news."

3 | Welcome to the EV Age



In 2006, the American filmmaker and environmental activist Chris Paine was nominated for an Academy Award for the documentary *Who Killed the Electric Car?* The film explored the culpability of a series of "suspects," ranging from oil syndicates to car companies, consumers, and the US government. While Paine may have erroneously tolled the bell for EVs, he proved prescient in one regard. He granted batteries a full acquittal, arguing that a new class of lithium-ion systems would emerge to extend EV range to more than 300 miles on a single charge.

Fast-forward 15 years, and the prediction has more than played out. Market leader Tesla has surpassed the 400-mile range, and CEO Elon Musk recently predicted that batteries will soon be six times more powerful, with a 16 percent increase in range, and cost less. "It's absolutely critical that we make cars that people can actually afford," Musk said at a Tesla event. "Affordability is key to how we scale."

It wasn't long ago that Musk was nearly alone on the road toward an all-EV future. Today it's a frantic race and everyone's in. There are many well-capitalized startups, including Rivian – which received a $700 million investment from Amazon, along with a commitment to buy 100,000 electric delivery vans – and many Chinese ventures, like Nio, which recently completed a $1.8 billion IPO. Volvo has its all-electric brand, Polestar, and Hyundai, Jaguar Land Rover, Nissan, and Porsche have several all-electric models in production.

Volkswagen has pledged to invest nearly $86 billion into its digital and electric vehicle technologies program over five years, which will include roughly 70 electric vehicles by 2025 and an electric version of 300 models across the brand portfolio by 2030. Ford has committed $22 billion to bring 40 electrified (including 16 fully electric) vehicles to market by 2023, including the Mach-E, which began shipping in late 2020. It's the first extension of the Mustang brand, meaning Ford is betting one of its strongest brands on its electrification strategy. The F-150 Lightning isn't far behind. The electrified version of the best-selling pickup has Wall Street, Ford insiders, and the marketplace buzzing. Reservations for the 2022 model surpassed 100,000 within months of the unveiling. "The electric vehicle market overall is accelerating at an exponential rate," wrote Darren Palmer, Team Edison Global Product Development Director at Ford, in a blog post. "All of us here have unknowingly prepared for this our entire careers."

General Motors CEO Mary Barra has pledged $27 billion, with plans to launch 30 EVs by 2025. That's in addition to the $2.3 billion GM co-invested with lithium-ion supplier LG Chem to build a new battery cell assembly plant. The company claims its Ultium battery architecture will achieve a range of 450 miles. In early 2021, Barra announced plans to halt the sale of all gasoline- and diesel-powered passenger cars and SUVs by 2035.

"As one of the world's largest automakers, we hope to set an example of responsible leadership in a world that is faced with climate change," she said in a statement. (Ford followed with its own declaration to sell only EVs in Europe beginning in 2030. Volvo countered with: No more ICEs anywhere by 2030.)

"The EV market overall is accelerating at an exponential rate. All of us here have unknowingly prepared for this our entire careers."

Lifting the Veil on Battery Performance

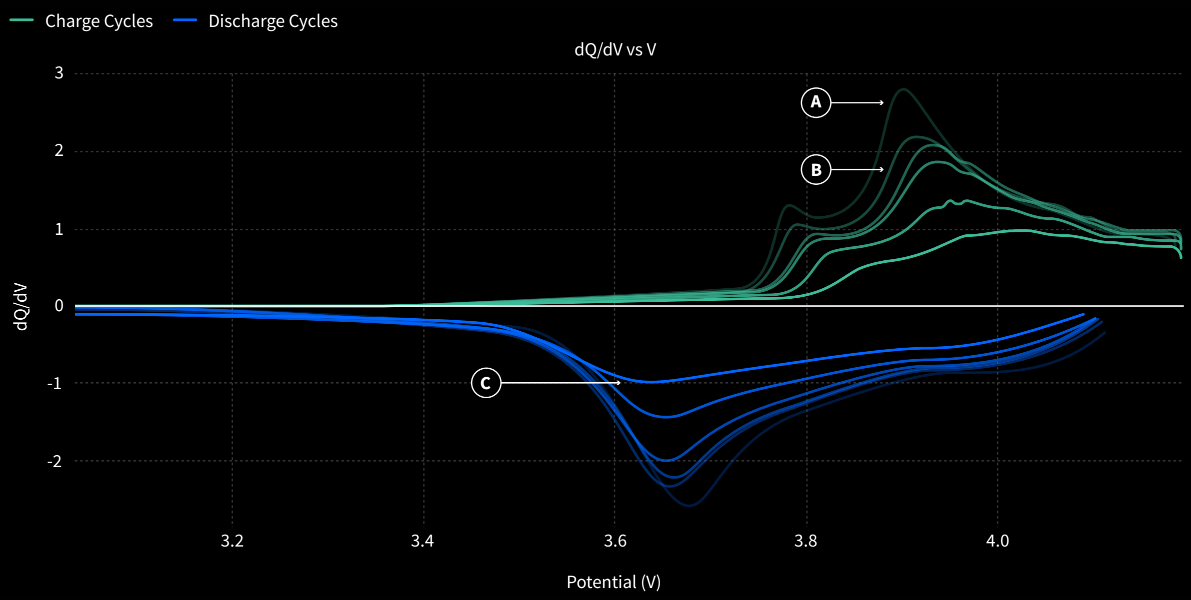
Three charts showing how Voltaiq instantly analyzes chemical composition, age, health, and behavior across a battery's lifecycle

The Life (and Loss) of Energy

- **A** The outermost peaks represent the stored energy of a new battery.
- **B** Each subsequent trajectory represents the same battery after completing an additional 100 charge-discharge cycles.
- **C** The cycles flatten and shift due to increased electrical resistance, which causes the battery to generate more heat and accelerates degradation.

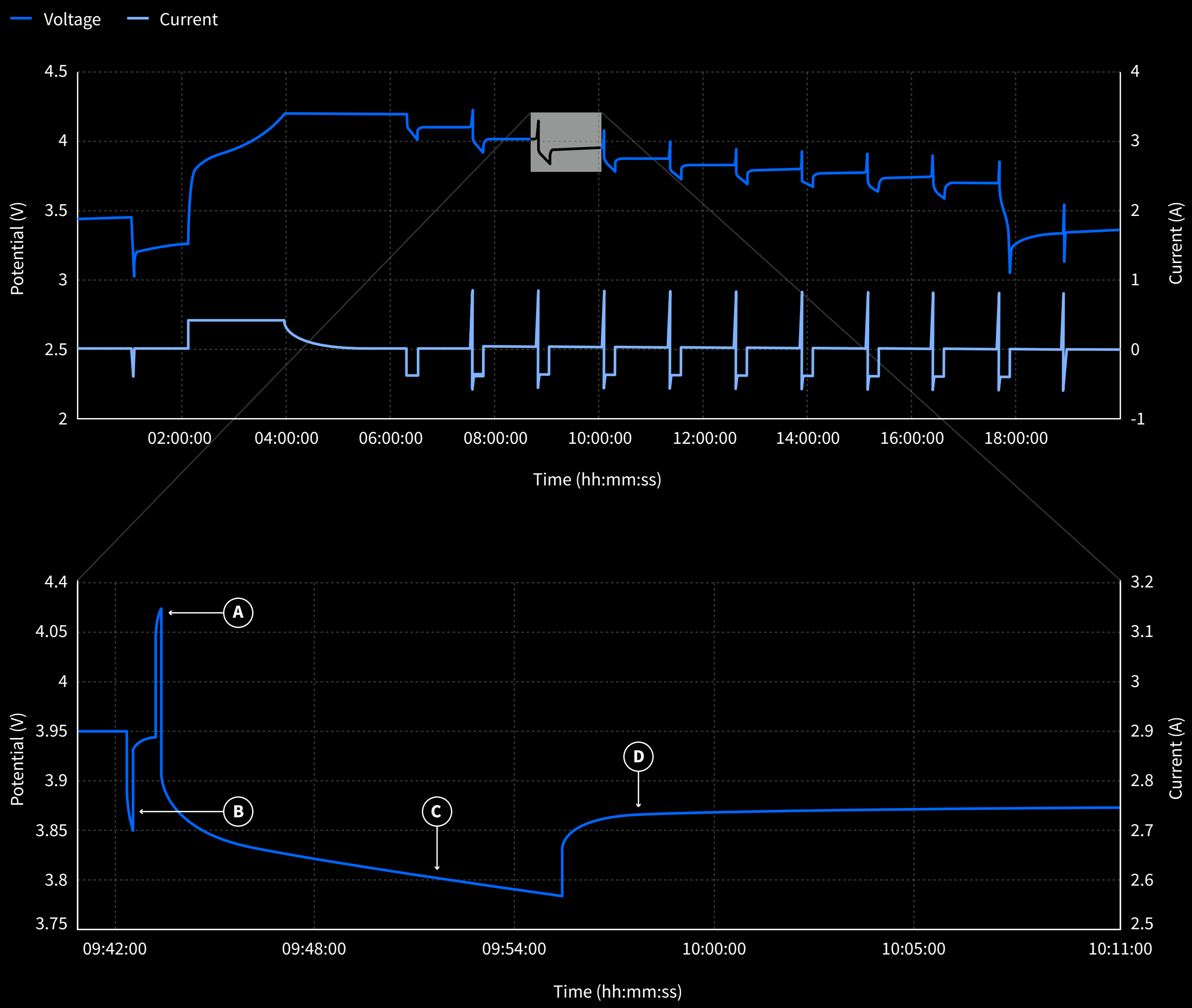
1. Battery Fingerprinting

Voltaiq can reveal battery chemistry and age by analyzing standard charge-discharge data without cutting the battery open. In this graph, charge and discharge cycles feature peaks whose height and location correspond to a battery's constituent materials. As the battery ages, peaks flatten and diverge. Voltaiq automatically generates such graphs for every battery in its system, providing highly useful insights during R&D and supplier qualification, and for predictive maintenance.



2. Hybrid Pulse Power Characterization

Battery performance is mapped using the HPPC protocol. This technique discharges the battery in increments and applies pulses to determine how much power can be practically pulled out or put in at each charge level. Repeating this analysis at various temperatures and charge rates reveals the battery's behavior over its entire operating range. Voltaiq processes this data in seconds, generating valuable analysis in EV battery pack and battery management system (BMS) development.



Analyzing Performance at Various States of Charge

A Charge pulse is analyzed to see how quickly energy can be put back into the battery at this State of Charge (SOC). This is helpful in determining, for example, how well an EV can recharge through regenerative braking.

B Discharge pulse is analyzed to see how quickly energy can be pulled out of the battery at this SOC. This is useful in determining how fast an EV can be accelerated at a given SOC without overheating and damaging the battery.

C Here the battery is discharged another 10 percent to begin the next round of pulses at the next phase of SOC

D Here the battery is at rest, allowing the voltage to relax back to an equilibrium for the next SOC

In late 2020, the German luxury automaker Daimler, corporate parent of Mercedes-Benz, announced an $85 billion investment aimed at advancing electrification. Daimler CEO Ola Källenius said in a statement that the company tripled sales of all-electric and plug-in hybrid vehicles in 2020 over the year prior. In 2019, such vehicles represented roughly 2 percent of sales for the company. In 2020, it was 7.4 percent. For 2021, Mercedes is targeting 13 percent.

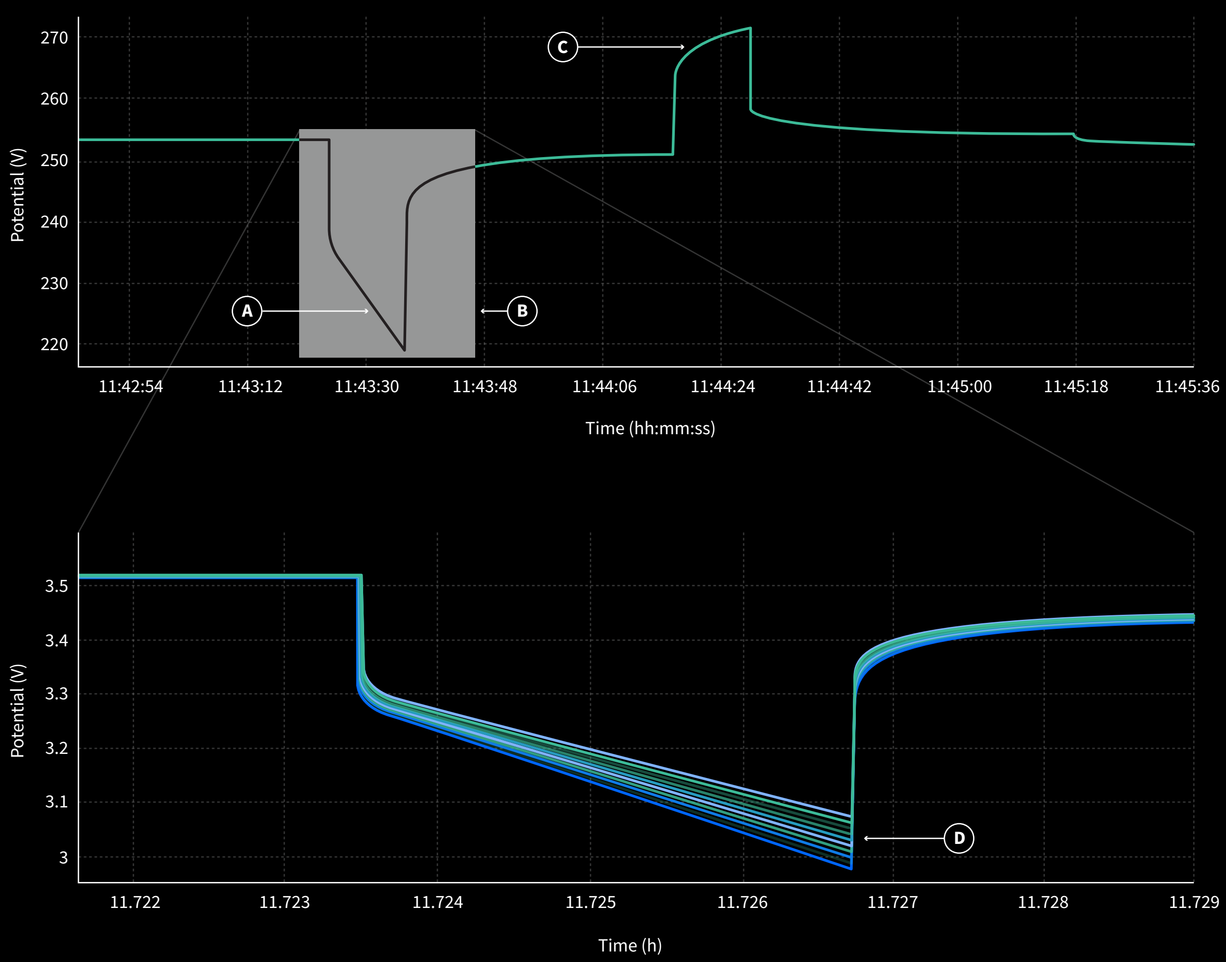
One Voltaiq customer, the head of research and development for a European luxury automaker, says the market signals are aligned toward an all-EV future and his employer, which asked not to be named for competitive reasons, is all-in. “We’re not in the early-adopter space, but our customers know when we get into a market, we get it right. We’re transforming the business not only in terms of the end product, but also in the way we adapt internally. We have to get the battery right.”

This Voltaiq customer scours the marketplace for novel approaches to batteries, which puts the onus on his team to do much of the vetting and testing. “A lot of what we do is cutting the wheat from the chaff. Every week, there are, like, 10 new game-changing ideas, so

“Every week, there are, like, 10 new game-changing ideas, so it becomes very important to screen and benchmark these companies on all kinds of metrics very quickly.”

3. EV Pack and Grid Storage System Diagnostic

Large-scale EV pack and grid storage systems are tested with charge and discharge pulses during design validation, on the manufacturing line, and in the field. System-level behavior may appear normal while concealing divergent voltages and temperatures at the cell or module level. Voltaiq can automatically identify these anamolies, uncovering faulty design, poor assembly, or imminent catastrophic failure.



Finding a Weak Link in the Battery System

- **A** Diagnostic discharge pulse
- **B** System-level analysis indicates that everything seems fine.
- **C** Diagnostic charge pulse
- **D** Individual cell voltages show significant divergence at the bottom of the discharge pulse, indicating major potential problems.

"Voltaiq isn't just a data company trying to pivot to this space. The platform was built with an understanding of batteries right from the start."

it becomes very important to screen and benchmark these companies on all kinds of metrics very quickly," the customer says. Which is where Voltaiq comes in. "They're not just a data company trying to pivot to this space. The platform was built with an understanding of batteries right from the start."

One of the EV researcher's major goals revolves around sustainability. The team is placing a premium on removing cobalt and other difficult-to-source materials from its battery architectures to both reduce costs and address ethical concerns associated with mining. And while today's lithium-ion batteries are highly recyclable, the goal is to make them fully compostable.

In the shorter term, like Microsoft's Bruce, the EV researcher wants to put an end to the dynamic where consumers must alter their behavior for the sake of EV batteries. No owner of a luxury automobile should have to limit a road trip or sit for an hour at a charging station. The vision is for them to only think about the fact that they're driving an EV when they're marveling at its acceleration.

"You shouldn't have to alter what you want to do for the sake of your transportation," the researcher says.

4 | The High Cost of Failure

In an October 2019 ceremony held by the Royal Swedish Academy of Sciences, the Nobel Prize in Chemistry was awarded to John B. Goodenough, M. Stanley Whittingham, and Akira Yoshino for their roles in creating lithium-ion batteries and for "making possible a fossil fuel-free society." Around the same time, Amazon co-founded The Climate Pledge, a vow to achieve net-zero carbon emissions by 2040. Several signatories have joined, including Best Buy, IBM, Mercedes-Benz, and Verizon. Microsoft has pledged to go carbon free and reverse all emissions since the company's founding. And Google has stated it will operate on carbon-free energy 24/7 by 2030 as part of an initiative, according to CEO Sundar Pichai, "to spur more than $5 billion in clean energy investments, take more than 1 million cars off the road each year, and create more than 8,000 clean energy jobs."

Renewable energies are clearly driving the trend. Wind and solar technologies have made great progress in recent years, increasing efficiency while driving down costs. But that's only half of the equation. Turning these corporate pronouncements into reality will require a massive uptake in energy storage – that is, battery systems – and the money is pouring into this arena as well. According to Wood Mackenzie Power & Renewables, grid-scale storage is projected to increase thirteen-fold between 2018 and 2024. In large markets like China, Germany, the US, and South Korea, deployments are doubling and tripling every year.

The massive battery systems being deployed at large-scale solar projects – in Colorado, Hawaii, Texas, and elsewhere – have the potential to disrupt the energy industry in much the way that mainframes revolutionized financial services. As more investments stream into materials and manufacturing, form factors and costs will shrink, lifecycles will extend, energy density will improve, batteries will power everything from IoT devices to entire city blocks. "Electricity is why we have cities," Sholklapper says. "It gave us elevators and skyscrapers and high-density housing.

How a Battery Fails

What makes a silent object with no moving parts so apt to swell, degrade, and combust?

Swelling

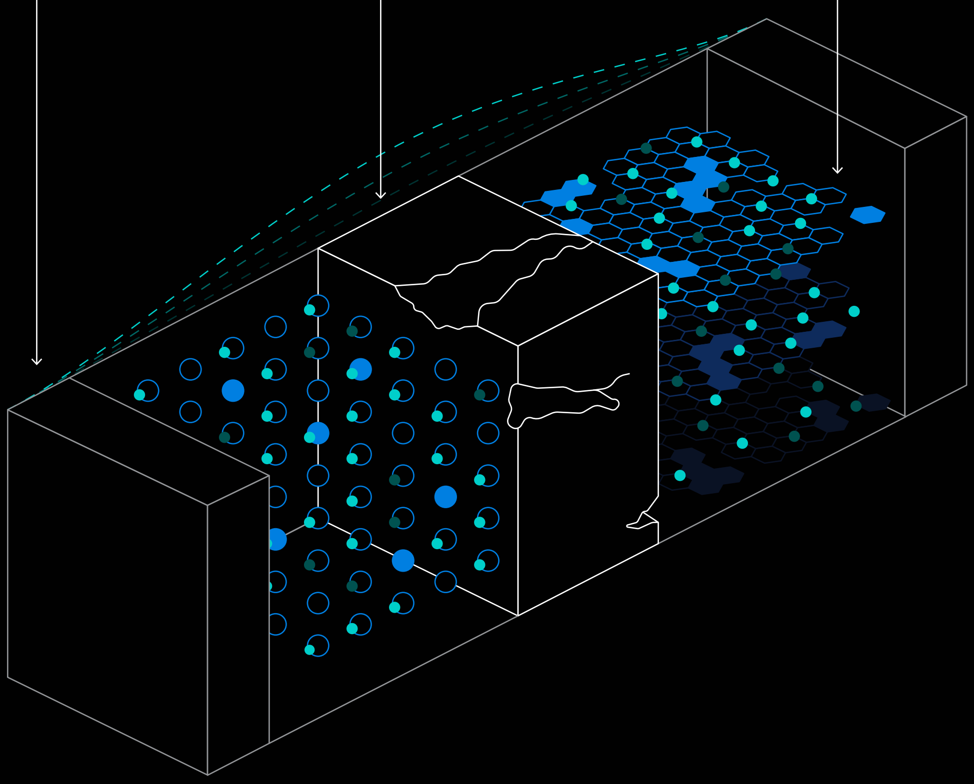
Poor cell quality and/or design, overcharging, faulty charging equipment, and internal mechanical damage can all cause lithium-ion cells to swell. Deep discharging can also trigger decomposition and, as a result, gas formation that leads to bloat. A device should not be operated with a swollen battery. It must be discharged and replaced.

Explosions

The cathode and anode aren't meant to come into contact, so if the separator degrades, the cell can go *boom*. "Thermal events" can also occur due to overheating (don't leave your phone in the car on a hot day), overcharging, poor design, or shoddy construction. Cheap headphones and hoverboards are highly susceptible – but $100,000 EVs are certainly not immune.

Degradation

As lithium ions travel between cathode and anode, they cause physical damage to the electrode structures, breaking them apart over time. The faster you charge and discharge, the quicker the battery loses capacity. EVs face another dilemma: They're exposed to extreme weather, fast charging, and highly variable user behavior – all of which can make battery health and lifespan difficult to predict.



How Battery Development Fails

It takes a ton of money, time, organization, and talent to master testing and development. There are no shortcuts.

Talent Shortage

There's a frenetic competition to hire battery engineers. Worse, highly compensated talent is often wasted. Battery engineers can spend as much as 30 percent of their time gathering data, writing Excel macros, and analyzing spreadsheets. Such work slows innovation and saps morale.

Pack and Cell Testing

Cell quality and performance vary widely, even within the same manufacturing lot – and pack life is limited by the worst cell. Battery packs require novel, complex cooling systems. And the diagnostic process is arduous. Cell testing takes years to simulate real-world use and conditions; there are no shortcuts.

Organization and Culture

Every EV model represents a billion-dollar bet on the battery. Relying on battery manufacturers or external labs is risky. An OEM properly organized around battery mastery is more likely to reduce late-stage failures, ensure product safety and performance, and drive innovations in the marketplace.

What happens when you remove the requirement to be connected to the grid? It's sort of like imagining a few decades ago how mobile phones would affect the world. That's the order of change we're going to see."

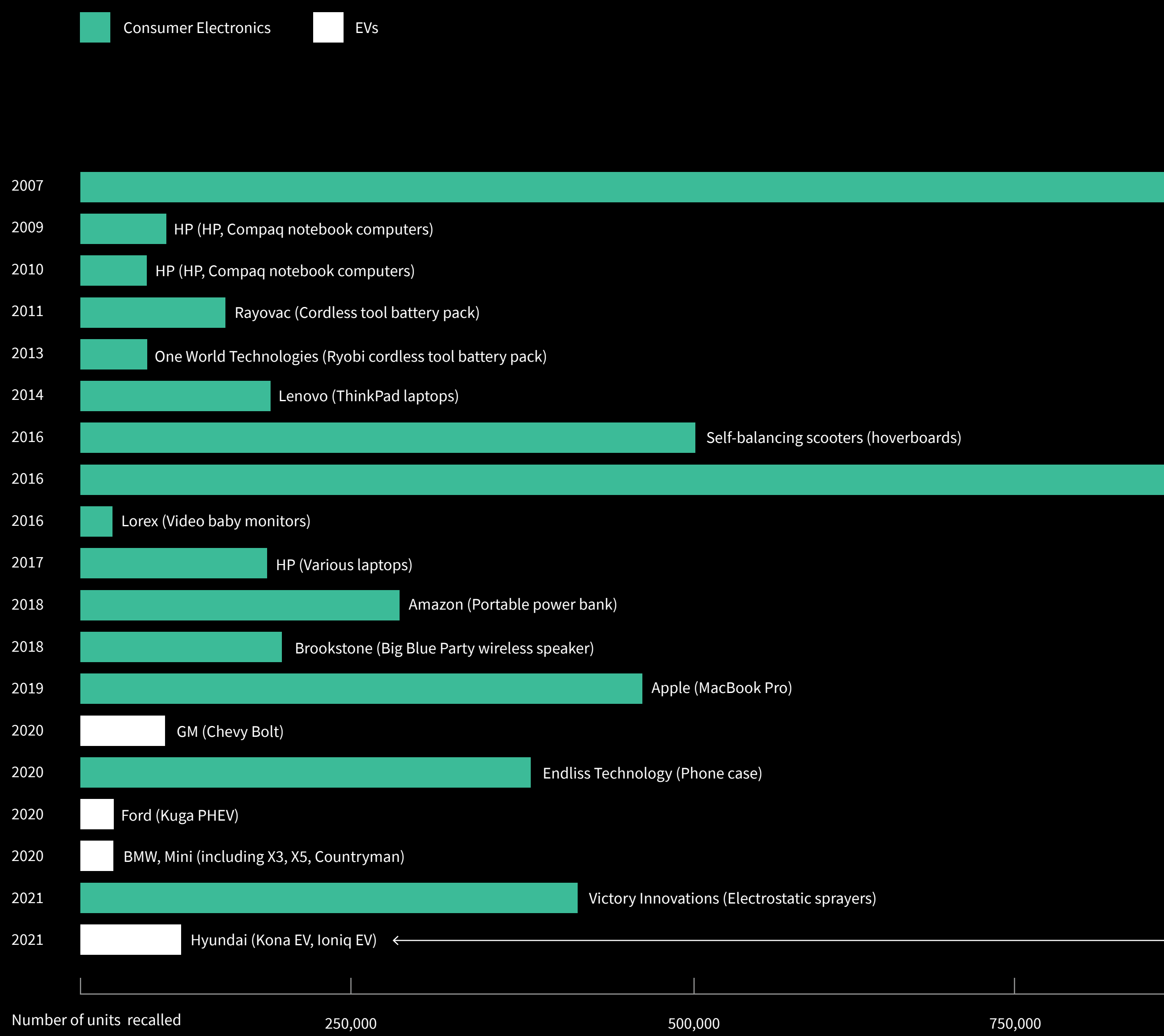
Of course, there's an obvious barrier to realizing such ambitions, and anyone with a passing interest in batteries knows what it is. Fire. Exploding laptops and phones. Combustible cars and headphones and hoverboards and home energy storage units. These adverse events have been happening for decades because no one has been able to sufficiently untangle the enormous complexity of battery systems. Not Amazon or Apple, Best Buy, Dell, Samsung, Microsoft, Nvidia, Panasonic, LG, or dozens of Fortune 500 companies. They've all implemented costly product recalls due to battery quality issues.

Such actions are hugely expensive. Sony recalled 9.6 million laptop batteries at a cost of $429 million. GM called back nearly 70,000 EVs for an estimated $500 million. Ford recalled its Kuga plug-in for $400 million. And Hyundai is spending an estimated $900 million to recall the Kona EV – roughly $11,000 per vehicle. Even worse, such recalls can do long-term brand damage. Think about when Samsung's Galaxy Note phones were banned from airplanes. "The company is still living with that," says Sholklapper. "In the EV space, recalls are actually stunting growth. When early-adopter consumers are being told not to park a car in the garage because it might explode that creates a lot of fear, uncertainty, and doubt for anyone considering going electric."

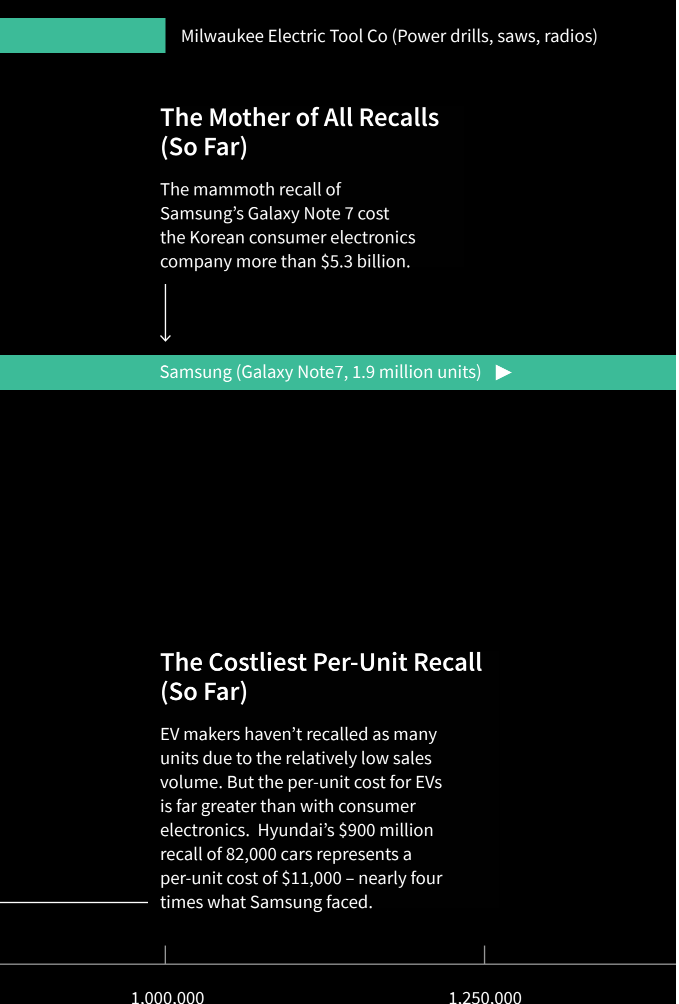
Why does this keep happening? Here's the easy, unsatisfying answer: a lot of reasons. Highly charged (positive and negative) materials sit mere microns apart in a battery's housing. When everything is properly aligned, the combination seems almost magical – providing silent, efficient, instantaneous power. But the smallest misalignment or minor abuse can cause the energy in the materials to combine – and go *boom*!

The Long, Sordid History of Battery Recalls

It’s not just EV batteries that are overheating, exploding, and catching fire. The same thing has been happening in laptops, cars, headphones, and power tools for decades.



"Every EV represents a billion-dollar bet on the battery. If you can identify a faulty batch of batteries, that can make all the difference, whether that means hitting a product launch or avoiding a costly recall."



"Good engineering and process control can help, but when you look at the rapid expansion of production, materials innovation, and supply chain developments, there are bound to be problems," says Sholklapper. "There are just so many unknown unknowns, and none of the old tools, systems, or skills apply. There's a pressing need for a better data analysis infrastructure."

Voltaiq greatly reduces this risk. The platform sheds light on variations or misalignments – without having to open the battery – months or even years before they're detectable through traditional methods. It's almost akin to a CT scan or an MRI, laying bare the battery's underlying chemistry during normal operation to identify cell degradation, conduct root-cause analysis, and perform competitor benchmarking. "It takes time-series charge and discharge data, combines it with analytics about the inner electrochemistry, and matches behavior against known profiles that can lead to failure," Leland says. "The most important thing to understand is the effect. If you can identify a faulty batch of batteries, that can make all the difference, whether that means hitting a product launch or avoiding a costly recall after you've gone to market."

5 | The Untethered Future

Bob Galyen is as close to royalty as they come in the battery world. Over the course of decades at GM, he did formative research that led to the development of the General Motors EV1 and went on to become CTO of the world's largest battery company, Contemporary Amperex Technology Company Limited (CATL), which is based in China. He first encountered Voltaiq at CATL, and he was so impressed that he joined the advisory board.

He's in good company. Along with Szygenda, the board includes the former global managing partner of automotive at Accenture; the former chair and CEO of GM; former board members of BMW, Geely, and Volvo, and two former CEOs of Tata Motors, among others. "We all recognize that the opportunities are enormous. Agriculture is going to be huge. Think about drones – for industry, for health care. Submarines, airplanes, eVTOLs, and probably other types of transportation that we can't even think of yet," Galyen says. "And Tal and Eli and their team are going to bring it all to light. Voltaiq is becoming a clearinghouse for battery intelligence, a source for best practices, and anyone who works with them benefits. It's what makes the platform so much more powerful than anything any company could do by itself." Call it the Voltaiq Effect.

Sholklapper and Leland are quick to point out that every customer retains full control over its own data, but they agree with Galyen that customers benefit from a network effect as the platform becomes more highly tuned across use cases, form factors, and materials.

Moreover, the Voltaiq platform enables clients to change the way they work. Rather than waiting for the end of a testing cycle to gather data and iterate in a waterfall development manner, they monitor real-time data and iterate on the fly, in a model that's closer to Agile software development. "When you have the data you need, it speeds up the entire workflow," Sholklapper says. "It cuts out the waiting and lets high-value engineers do what they're being paid to do."

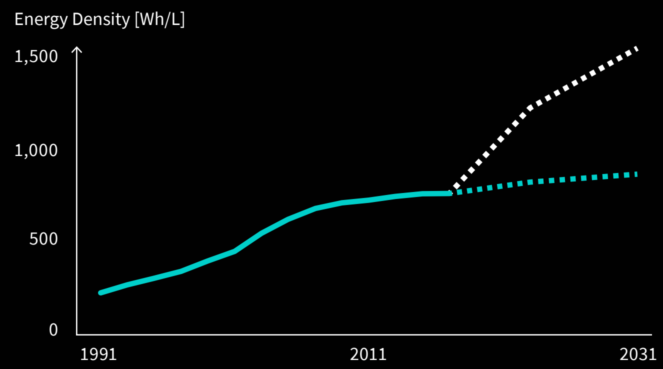
Every Company Is a Battery Company

Over the past 50 years, semiconductors have yielded more power at less cost, digitizing every company as a result. Now, lithium-ion batteries are tracking a similar path.

Energy Density Keeps Rising

Investments across industries are driving materials discovery and performance enhancements, leading to batteries that hold more energy and last longer.

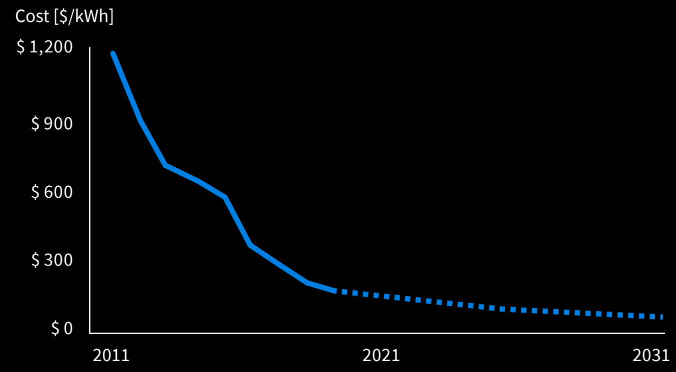
- Limits of basic Li-ion chemistry and design
- With novel chemistry and manufacturing



Prices Keep Falling

Prices of mass-market cells have fallen off a cliff, and they're expected to decrease further over the next 10 years due to economies of scale.

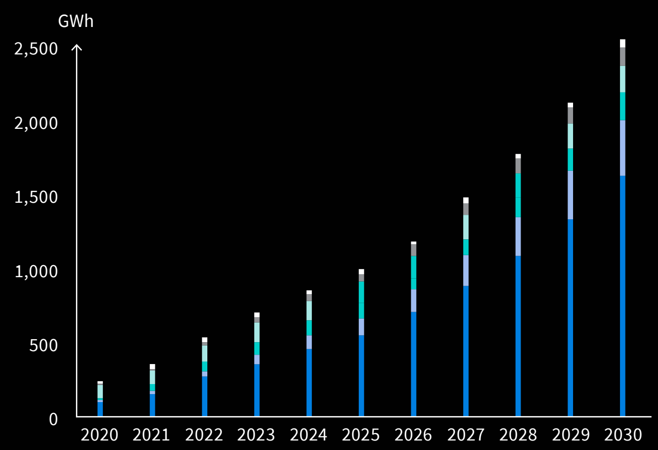
- Observed prices
- 18% learning rate



Demand Is Surging in New and Emerging Markets

When power goes up and prices go down, new use cases emerge. Consumer electronics dominated the battery market for years. Now it's all about the EVs.

- Passenger EVs
- Commercial EVs
- Stationary storage
- Consumer electronics
- Electric two-wheelers
- E-buses



Voltaiq is also helping customers create a digital twin of their batteries, combining data from cell suppliers, OEMs, and end users to provide full traceability across the lifecycle. “Understanding battery makeup and usage is important so that you can make good engineering decisions and de-risk your products,” Sholklapper says. “But the ripple effect is that it helps you understand any battery’s remaining value. This is going to be so important for EV companies trying to accurately price their leases, for logistics companies trying to manage their fleets, and for recyclers and second-market players.”

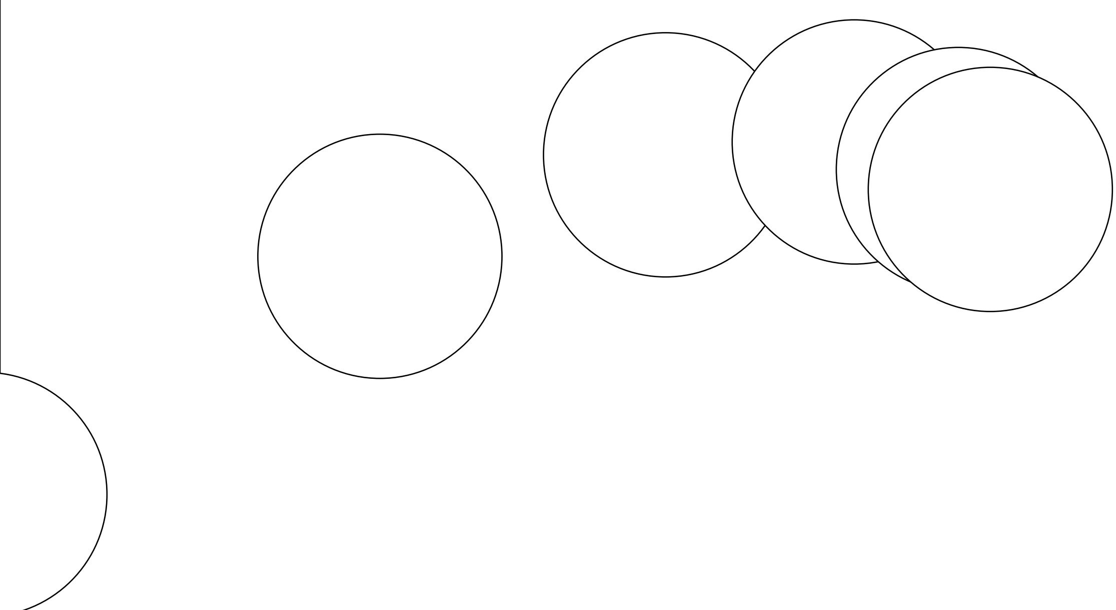
This 360-degree vision plays into how the co-founders see Voltaiq evolving. If the market follows the trajectory that Szygenda anticipates, batteries will become part of everything. And in many cases, like EVs, they’ll be a product’s most valuable component. “A lot of what you hear in the media is about the cost of recalls. But how can you run a business and plan for the future when you don’t even know the true value of your product?” Sholklapper says. “That has massive financial implications.”

It’s been almost a decade since Sholklapper and Leland had their epiphany on a subway ride down Manhattan’s west side. At a time when solar remained a costly fringe energy source and EVs were still a novelty, they saw that a combination of electrification and mobility could change the world. Perhaps more importantly, they also realized that the battery industry was well behind other industries when it came to using data. They understood implicitly what everyone else would soon find out: Batteries are hard. So they built a platform to help.

Given how long they’ve been toiling in labs, elbow-deep in grime, teaching themselves to code, scratching out algorithms, it’d be tough to call their rise an overnight success story. It’s more a tale of true grit.

“It was completely obvious to us back then how this was going to play out,” Leland says. “Maybe it didn’t happen as fast as we thought. Maybe we didn’t do everything perfectly. But the market has shifted. And there’s no turning back.”

6 | About Us



About Us

Executive Summary

There's a historical precedent for the meteoric rise that lithium-ion batteries are experiencing across industry and society. Semiconductors traveled a similar path. In retrospect, computing may seem like it infiltrated our world in a blink, but the progression of semiconductors from a curious lab project to the linchpin of modern life occurred in stages. Anyone around in the 1980s remembers when computing first appeared in digital watches, microwave ovens, and washing machines. That's roughly where batteries are today. Their trajectory from here is undeniably up and to the right.

Many of the same forces that propelled semiconductors are at play: massive industrial investment, steady technological improvements, and economies of scale. But battery development and usage are also being accelerated by a unique confluence of external factors. The specter of climate change has spurred public alarm and triggered national governments to mandate reduction of greenhouse gas emissions. The cost of renewable energy has plummeted to the point where it's cheaper to build new solar and wind facilities than to maintain fossil fuel plants. Car manufacturers have declared EVs the future of transportation. Wall Street is rewarding companies focused on zero-carbon futures. And consumers are embracing the benefits of an increasingly wireless lifestyle. It's no exaggeration to say that nearly every company has become, to an extent, a battery company.

But achieving semiconductor-style escape velocity will require overcoming significant hurdles. Batteries are highly complex, on the order of biological entities, making them highly unpredictable. Unlike semiconductors, they can't be rapidly stress-tested until they break. Rather, they must endure time-consuming charging/discharging routines that simulate real-world usage and environments.

They're finicky to the point of being volatile; they can explode. And when it comes to digitization, battery development is a decade or more behind industries that have risen up around, say, CRM or predictive maintenance. Without a purpose-built analytics engine, battery manufacturers and their customers have been hampered by a hodgepodge of custom tools and industrial-age processes as well as an acute shortage of engineering talent.

Overcoming these hurdles is a high-stakes affair. With so many firms racing to market, any edge could translate into untold rewards. But the penalties for cutting corners are significant. Battery-related recalls can easily cost hundreds of millions of dollars and do lasting damage to brand reputation – as many of the world's largest companies can attest.

Enter Voltaiq with its Enterprise Battery Intelligence platform. Created by a couple of UC Berkeley PhDs named Tal Sholklapper and Eli Leland, Voltaiq's software offers a real-time view of battery behavior, instantly correlates material and process changes to

"It was obvious that batteries were going to play an increasingly important role across industries. But our real insight was understanding how data would become the key to unleashing their potential."

– Eli Leland, Voltaiq CTO

performance, and streamlines battery testing and development workflows. It speeds up product development, reduces the risk of failure and recalls, and enables companies to track batteries through their lifecycles to determine health and residual value at any given time.

Sholklapper and Leland came up with the idea for the company while working on government-funded energy research projects at the CUNY Energy Institute in Manhattan. Frustrated with the highly manual and analog nature of battery behavior analysis, they created an automated tool to gather data, analyze it in the cloud, and instantly present insights in a browser-based tool. Voltaiq has since attracted some of the world's biggest companies – including Amazon, Facebook, Microsoft, and many carmakers and battery manufacturers – as well as an A-list board of advisors. "We saw this all coming in our days at CUNY," says Leland. "Even back then, it was obvious that batteries were going to play an increasingly important role across industries. But our real insight was understanding how data would become the key to unleashing their potential."

Adds Sholklapper, "Some of the world's most successful companies were born out of a novel idea to break a systemic bottleneck or relieve a pain point. That's exactly how it happened with us. Now the plan is to get the solution into as many hands as possible to unlock the incredible potential of batteries to change our world for the better."

About Us

Tal Sholklapper

The first time Voltaiq Co-Founder and CEO Tal Sholklapper graduated early from UC Berkeley, it's probably fair to say he was tricked. He and a friend agreed to carry an extra class every semester so they could spend their final spring traveling together across Europe. Sholklapper made good on the pact, earning a BA in physics and applied mathematics in 3½ years – but the friend botched the plan and had to complete the full term. So Sholklapper put that extra few months into doing energy research at Lawrence Berkeley National Laboratory.

The next time he graduated early from UC Berkeley, with a PhD in materials science and engineering, his only pact was with himself. "I guess you could say I'm the kind of person who's always looking for an angle," Sholklapper says. "I realized from undergrad that you could shortcut the experience, and once I got rolling, well, it just happened even more quickly than I thought possible." He received his doctorate in 2½ years – a school record – while still working at Berkeley Lab.

The son of Israeli immigrants who settled in Los Angeles, Sholklapper has always been a voracious learner. When he was in preschool, a psychologist encouraged Sholklapper's parents to speak Hebrew and English interchangeably to help slow their young son's mind.

He recalls being a "perpetual A-/B+ student" who was far more motivated to grasp the essence of a subject than to achieve full mastery. "I'm not a perfectionist by any stretch," he says. "Once I've figured out how a system works, my mind tends to move elsewhere. I've always got a million ideas going."

More often than not, "elsewhere" means the hardest challenge he can find. He chose UC Berkeley because it has the finest physics program in the nation. At Berkeley Lab, he plunged into understanding the immense complexity of fuel cells. He found a kindred spirit and mentor who encouraged him to harness his prodigious intellect and pursue his own research. He took the guidance and ran, authoring 10 scientific papers in just over two years and channeling the prolific streak.

"I just sort of stitched everything together, put on a nice little intro section, and that became my dissertation," he says. "I had no interest in the shackles of academia. I wanted to develop things and get them into people's hands."

He followed his fascination with energy and co-founded a fuel cell startup, Point Source Power, funded by Khosla Ventures. After a few years, he headed east to the CUNY Energy Institute, which is where he met Voltaiq Co-Founder and CTO Eli Leland. They were both following the same calling.

"The world was already moving toward renewables," he says. "And we both realized the shift would reveal large opportunities because of how energy ties

Tal Sholklapper, PhD
Chief Executive Officer, Voltaiq

into big businesses and the overall economy. It was all coming together in a way that made me think, this is an area where I could spend my life and do something meaningful."

Sholklapper and Leland would spend long days at CUNY and collaborate into the night writing code for what would become the Voltaiq platform. "Going from hardware development cycles into software was thrilling. It was like, oh shit, I can code something up over the weekend and get it out there by Monday," he says. "Of course, first we had to teach ourselves to code – and I didn't even know how to freaking type!"

These days, Sholklapper doesn't have to search out his next great challenge; it's finding him. Companies are investing billions into de-carbonization. Renewables are at a tipping point – and batteries are the linchpin. But, as evidenced by the stream of reports about battery-related recalls and fires, they're extremely complex. And everyone needs help. "The tiniest variances or contaminants – I'm talking atomic level, small parts per billion – have huge effects on batteries, and often well down the road," Sholklapper says. "That's our opportunity, making sense of enormous amounts of data to erase the time lag and immediately show customers how millions of variables will affect a battery over its lifespan."

It's perhaps the grandest challenge of energy today – and incredibly meaningful work. Which means Sholklapper is, finally, precisely where he wants to be.

About Us

Eli Leland

Voltaiq Co-Founder and CTO Eli Leland has been working toward reimagining the world's energy system for his entire life. Which is not to suggest he's had a one-track mind. Far from it. The son of a doctor (dad) and a mixed-media artist turned documentary filmmaker (mom), he inherited a broad appreciation for science, the arts, and world cultures.

He performed in the opera *Orpheus in the Underworld* as an 8-year-old and went to theater camps and on mountain-biking retreats. He was on the math team, wrote and directed a comedy show in high school, and joined an a cappella group in college. "My parents encouraged me to do everything. They wanted me to play sports – T-ball and karate," he recalls of growing up in Evanston, Illinois. "My mother had a fascination with the Caribbean and would pull me out of school for a couple months at a time to live in St. Vincent while she was working on her MFA."

He also demonstrated a tinker's tendencies, starting with Legos and radio-controlled cars. "I loved crashing them, breaking them, and getting new parts to put them back together. And then I'd do the same with appliances, then cars," he says. He'd pore over *MotorTrend*, memorizing auto dimensions, drag coefficients, engine variants, and body specifications. "I would walk my dog and try to name every car by looking at the taillights from a block away. I was obsessed. That came from my father's father. He wasn't formally educated, but he was a fixer. He always wanted to understand how a system works, and he gave me my first car, a 1978 Oldsmobile with a rusted-out floor covered in plywood. That's how he rolled."

Leland wasn't especially studious, but he was an eager learner and dove into AP chemistry and advanced mathematics in high school while learning how to "represent points in space through both Cartesian and polar coordinates." Accepted at a number of top-flight schools, he chose Princeton and graduated with a degree in mechanical engineering and no idea of what to do next. The car companies were recruiting graduates to Detroit. The big industrials wanted them in Ohio. Many grads opted for investment banking, but that didn't feel right – especially since Leland skipped the perfunctory Wall Street internship the previous summer to spend his saved bar mitzvah money while backpacking around Europe.

He had a short, unsuccessful stint in management consulting and then a longer run leading a deployment team at an Austin enterprise software company, Trilogy Software. Around that time, the first "green tech" movement drew his attention. "I decided I wanted to spend the rest of my career in energy, and it felt like batteries were going to be super important," he says. So he went to UC Berkeley to get his PhD.

Despite attending Berkeley at the same time as Voltaiq CEO Tal Sholklapper, they didn't meet until they were spearheading parallel projects at CUNY Energy Institute in Manhattan. Leland was technical lead for a new capacitor project. Sholklapper was trying to

Eli Leland, PhD
Chief Technology Officer, Voltaiq

commercialize a new grid-scale battery. They bonded over a common problem – the frustrating, slow, and highly manual process of collecting and organizing battery data.

While commuting on the subway after long days in the lab, they'd hash out ideas for possible solutions – and hone their collective vision for how new energy systems could change the world. "There's a global imperative to de-carbonize the world economy. We're facing the catastrophic effects of climate change," he says. "Tal and I never accepted the notion that it's actually going to cost anything to address the challenge. There's an enormous opportunity to create substantial economic wealth here by de-centralizing energy, and any suggestion otherwise is complete bullshit. It was obvious to us back then, and it's even more obvious today."

As Voltaiq's CTO, Leland draws upon his unique combination of skills and interests – an engineer's penchant for deconstruction plus a storyteller's instincts – to communicate technical complexities. "I never wanted to make a better TV display for rich people. I want to build a great American company to help us all transition into a new, more sustainable future," he says.

"It's a big, hairy problem. I can't think of anything more daunting. But we have to figure it out," he adds. "I've been working my entire life to get here, even if I didn't always know it. It's what I'm meant to do."

Advisory Board

Carl-Peter Forster

Formerly the CEO of GM Europe and CEO of Tata Motors (responsible for Jaguar Land Rover), Forster has held board and senior management positions at Volvo Cars, Geely Automotive Holdings, and Rolls-Royce, among others.

Robert Galyen

Chair of Galyen Energy, Galyen has more than four decades of experience in batteries. In two decades at GM, he helped develop the EV-1. He later became the CTO of the world's largest battery manufacturer, CATL.

Peter Haeussermann

The GM of Mitsubishi Electric, Haeussermann has more than 40 years of experience in automotive technology development. In addition to his role at Mitsubishi, he's the Senior Expert at Hanselmann & Compagnie, GmbH.

David Park

Vice President of Marketing for PDF Solutions, Park was formerly Vice President of Worldwide Marketing for the business intelligence and analytics firm Optimal+. He was also Director of Marketing for Synopsys.

Prof. Dr. V. Sumantran

Sumantran has more than 35 years of automotive experience. He was CEO of Tata Motors' car division and a member of the board. He was Vice Chair of Ashok Leyland and currently serves on the advisory boards for several Fortune 500 firms.

Ralph Szygenda

CEO of RJS Solutions, Szygenda has more than 50 years of IT experience. He spent two decades at Texas Instruments, rising to the role of CIO. He was also the Group VP and CIO of GM, where he oversaw the world's largest IT budget.

Martin Thall

President of Auto Tech Partners, Thall has 30-plus years of IT, automotive, and telecom experience. He's held leadership posts at Visteon and Verizon and was Microsoft's VP and GM of Automotive and Embedded Operating Systems.

Rick Wagoner

Formerly Chair and CEO of GM, Wagoner is a director at ChargePoint, Excelitas Technologies, and Graham Holdings. He's also the Chair of Invesco, an advisor to Jefferies and Riverwood Holdings, and a startup investor and advisor.

Chris Perry

Chief Innovation Officer at Weber Shandwick, Perry has been the agency's lead for GM for more than 20 years. He's worked to modernize marketing and PR at many leading brands, including IBM, Novartis, PepsiCo, and Verizon.

Richard Spitzer

A VC and PE investor with deep knowledge in the automotive space, Spitzer is Founder and Managing Partner at Escavel Capital. Previously, he was Global Managing Partner at Accenture Automotive, and Senior Partner at A.T. Kearney Automotive.

Dan Steingart

Steingart is Co-Founder of the machine learning battery inspection startup Feasible and Co-Director of the Columbia Electrochemical Energy Center. He's researching ways to exploit traditional failure mechanisms and interactions in batteries.

Kevin Whalen

President of Rohrich Automotive Group, Whalen has 40-plus years of automotive retail experience. A founding member of Group One Automotive and Ascent Automotive, he was also on Toyota's Product Advisory Committee.

Luke Wilhelm

Wilhelm is Chief Product Officer at the IoT startup Very and the former Director of Hardware Engineering at Uber Elevate. Previously he held senior engineering leadership positions at Apple and QuantumScape.

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