SIEMENS

ACCELERATE DIGITAL TRANSFORMATION

Power the world of tomorrow with faster battery material innovation

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Battery material production by 2030

Powering the world of electrification

The world is electrifying at an unprecedented pace. From powering electric vehicles that transform mobility to storing renewable energy for a sustainable planet, batteries are a cornerstone of our future. Yet, this rapid transformation comes with significant challenges that the battery materials industry must overcome to keep pace with demand and innovation.

To meet evolving needs, manufacturers must develop next-generation battery chemistries with doubled energy density, rapid charging, enhanced safety and improved recyclability. However, achieving these breakthroughs requires breaking down engineering silos and reducing reliance on lengthy physical testing cycles – an imperative underscored by a 15x increase in battery-related patents since 2000.

Simultaneously, the battery materials market is projected to grow at a 19 percent CAGR through 2030, driving the urgent need to scale existing facilities and rapidly establish new ones. Flexible production planning and agile strategies are essential to navigate emerging competitors and increasingly complex global supply chains.

The stakes couldn't be higher. Success requires not just innovation, but the ability to accelerate development cycles, optimize manufacturing processes and ensure cost-effectiveness at scale.

+19%

Annual growth rate (CAGR) to 2033

Source: McKinsey

$100 bn

In revenue by 2033

Source: FMI

200 k

New jobs by 2030 just in the U.S.

Source: CAR Report

15x

Increase number of patents since 2000

Source: FPA

>2 kWh

Capacity of battery to have battery passport from 2027

Source: Council of the EU

Power the world of tomorrow with faster battery material innovation

Pioneering battery materials: innovate faster, scale smarter, operate efficiently

Repeatable battery material innovation

The challenge
Innovating and validating new battery materials is an arduous and resource-intensive process. Development cycles often span *5 to 10 years, with only 1 in 10,000 discovered materials successfully reaching commercial production*. Compounding this challenge, over 70 percent of R&D costs are consumed by testing and process validation. These hurdles make it imperative to accelerate the discovery and development of advanced battery materials while ensuring scalability and efficiency.

The solution:
Innovate and validate new battery materials efficiently with AI.

AI-powered material discovery
Utilize molecular simulation tools and AI-driven material science platforms significantly reduce material screening time and minimize the need for costly experiments. These technologies enable faster identification of viable materials and streamline the innovation process.

Streamlined research collaboration and data management
Deploy the research which integrates formula development, specification management and laboratory information systems (LIMS). This ensures smooth collaboration across lab stakeholders, efficient test execution and accelerated learning, creating a unified workflow from research to development.

Ensure repeatability and scalability of material innovation processes
A collaborative platform unifies multi-level specification management for all disciplines and product elements, while allowing version-controlled lifecycle and tracking material composition for compliance – facilitating concurrent access to accurate, comprehensive product information for all stakeholders.

The impact
This transformative approach redefines battery material innovation. By leveraging AI, simulations and digitalized workflows, organizations can dramatically shorten R&D cycles, reduce costs and deliver high-performance battery materials to market faster. These advanced solutions don't just improve efficiency – they unlock new possibilities for scalable, repeatable and sustainable innovation.

Digital production for battery materials

The challenge
Scaling battery material innovation from lab to large-scale production is a complex journey fraught with challenges. *Laboratory processes often fail to scale linearly, with yield reductions of up to 30 to 50 percent during production scale-up*. Even slight variations in material composition – sometimes as small as 1 to 2 percent – can cause significant performance drops. Additionally, the iterative testing, validation and customization of production lines often lead to extended delays and inflated costs.

The solution:
Engineer and validate your battery materials production processes virtually.

Centralized recipe management with a PLM data backbone
A robust PLM data backbone captures and manages detailed battery materials production recipes. This ensures consistency, traceability and compliance across the development and production lifecycle, enabling seamless collaboration between R&D and manufacturing teams.

Automated digital recipe transformations
Automating recipe transformations eliminates manual errors, accelerates scale-up and ensures consistent application across production sites while meeting regulatory requirements.

Digital Twin process simulation for validation and scale-up
A digital twin simulates and validates product performance, process designs, verifies control strategies and facilitates technology transfer, reducing risks and optimizing process parameters for scalable production.

Plant optimization with digital twin and event simulation
Plant digital twins and event simulation tools optimize plant layout, material flow and resource utilization. These simulations empower data-driven decisions to enhance operational efficiency and minimize costs.

Integrated plant engineering solutions
Advanced plant engineering tools streamline equipment design, installation and maintenance, ensuring assets are optimized for specific processes and adaptable to changing market demands.

Seamless collaboration across workflows
By integrating PLM and digital twin solutions, organizations create a unified ecosystem where R&D, engineering and production teams work in harmony. This alignment bridges the gap between lab-scale experimentation and mass production, ensuring consistent quality and faster time to market.

The impact
With these solutions, businesses can overcome the most pressing scale-up challenges. By maintaining consistency, reducing costs and streamlining workflows, companies can deliver high-quality battery materials more efficiently. These innovations not only accelerate production but also establish a competitive edge in the fast-evolving battery materials market.

+15%
Production efficiency

-50%
Design time

-5%
Electricity consumption

-10%
Nitrogen consumption

Siemens solutions accurately simulates the output, energy consumption, labor and production cost, helping us transfer from lab scale to industrial scale. The system also helped us analyze manufacturing bottlenecks and improve the energy consumption and cost, which addresses the core value of the EV industry – reducing carbon emissions."

William Chen
Assistant Vice President
Production technology and quality control
HCM Material Business

Smart battery materials production

The challenge
Battery material production is a highly complex process where even small fluctuations in raw material composition can impact up to 10 to 15 percent of a battery's final electrochemical performance. Precise control is required across multiple manufacturing steps, including mixing, precipitation, drying and calcination. Additionally, *60 to 70 percent of production issues originate from a lack of traceability, requiring the integration of process, equipment and supply chain data to ensure problems are solved and not repeated*.

The solution:
Enable paperless, traceable production with enhanced operations visibility.

Open and robust manufacturing operations management (MOM)

Implement MOM solutions, which acts as a production orchestrator, ensuring seamless, traceable execution with instant visibility into operations. This solution provides:

- Holistic traceability across the production process
- Digital planning, execution and quality tracking
- IT/OT convergence for faster response times and greater operational flexibility

Optimized plant process design and engineering

Leveraging model-based simulations and predefined engineering workflows, battery material producers can optimize process design, reduce variability and enhance production efficiency. Automated process optimizations help eliminate manual errors, prevent over design and accelerate scale-up, ensuring consistent quality and regulatory compliance while reducing operational costs.

Integrated plant-wide automation

Leverage standardized automation systems, including flexible integration, IT/OT convergence and enhanced security and safety across the production lifecycle.

The impact
By combining advanced manufacturing execution systems with best-in-class automation, businesses can:

- Achieve complete traceability across production and supply chain operations
- Enhance visibility into processes for better decision-making
- Minimize disruptions, improve quality and ensure production consistency

This comprehensive approach empowers battery manufacturers to deliver higher-performance materials with greater precision, efficiency and reliability while staying ahead in a competitive market.

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Using Siemens MOM allowed us to weave a digital thread across the entire production process. Using end-to-end digitalization reduced the batch production time by 5 to 10 percent. In addition, it relieved our production supervisors of five days per month.”

Dr. Moritz Hofherr
Automation Engineer, BASF

Data driven plant operation

The challenge
Battery material plants generate massive amounts of data from sensors, systems and operational logs. However, *many complex operations involve parameters that cannot be measured directly with sensors, posing a challenge for real-time monitoring and optimization*. For brownfield plants, retrofitting advanced connected equipment adds significant costs, making it difficult to modernize operations effectively.

The solution:
Maximize efficiency combining data and simulation models.

Industrial IoT and advanced analytics
Use the Industrial IoT in combination with MES and automation systems to structure and collect plant data efficiently. This enables:

- Descriptive, predictive and prescriptive analytics for actionable insights
- Integration of real-time data into simulation models to improve accuracy and enable closed-loop optimization

Executable Digital Twins (xDT)
Deploy xDTs to calculate non-measurable parameters in real time and immediately apply corrections. These digital twins can be:

- Process-based for operational optimization
- Physics-based for applications requiring 3D simulations

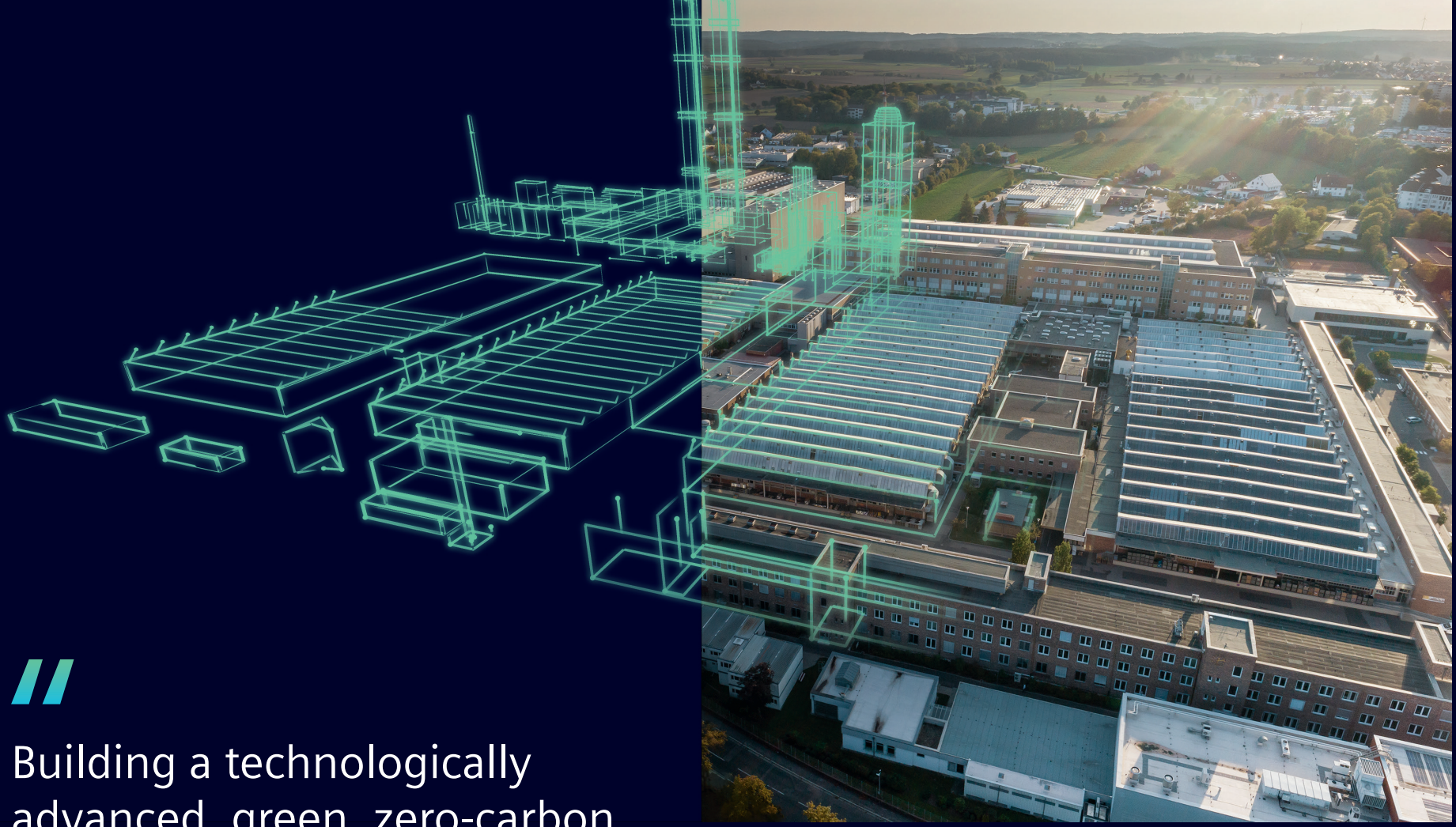
Data-driven optimization
Leverage data and simulation models from the engineering phase to optimize plant efficiency, enable real-time performance monitoring and proactively avoid production issues using predictive analytics.

Continuous improvement practices
Implement continuous improvement strategies by using data-driven insights to refine processes, reduce inefficiencies and foster innovation.

The impact
By integrating IoT platforms, digital twins and simulation models, battery material plants can:

- Enhance operational efficiency in both greenfield and brownfield facilities
- Leverage data and simulation for more informed and accurate decision-making
- Drive continuous improvement and innovation in plant operations

This approach not only improves plant performance but also ensures future-readiness, enabling businesses to stay competitive in an increasingly data-driven industry.



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Building a technologically advanced, green, zero-carbon and intelligent 'Lighthouse Factory' in Panzhihua requires strong support from Siemens.

Deputy GM
From one of the largest Asian battery materials producers

-50% Decreased scrap rate

+10% Improved efficiency

+80% Improved business analysis efficiency

Are you ready to lead the charge toward a sustainable future?

As the demand for cleaner energy and sustainable solutions grows, battery material innovation stands at the forefront of this transformation. By leveraging advanced technologies, embracing digitalization and fostering collaboration, manufacturers can overcome today's challenges and seize tomorrow's opportunities.

This is not just about adapting to change – it's about driving it. Together, we can power the world of tomorrow with battery material innovation, shaping a smarter and more sustainable future.

Are you ready to lead the way together with Siemens?

Siemens Digital Industries (DI) is an innovation leader in automation and digitalization. Closely collaborating with partners and customers, DI drives the digital transformation in the process and discrete industries. With its Digital Enterprise portfolio, DI provides companies of all sizes with an end-to-end set of products, solutions and services to integrate and digitalize the entire value chain. Optimized for the specific needs of each industry, DI's unique portfolio supports customers to achieve greater productivity and flexibility. DI is constantly adding innovations to its portfolio to integrate cutting-edge future technologies. Siemens Digital Industries has its global headquarters in Nuremberg, Germany, and has around 72,000 employees internationally.

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