BATMAX: unleashing the power of AI and digital twins for Europe's next-gen battery manufacturing

How the BATMAX project accelerates gigafactory readiness and drives the digital transformation of Europe's battery industry.

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As the global demand for electric vehicles (EVs), grid-scale storage and portable electronics continues to soar, the pressure to innovate in battery manufacturing intensifies. Europe is at the epicentre of this technological revolution, striving to reduce its dependence on imported batteries while meeting its ambitious climate goals. At the heart of this transformation lies the Horizon Europe-funded BATMAX project—Battery Management by Multi-Domain Digital Twins.

Launched in May 2023, BATMAX aims to set a new standard in digitalised battery production by integrating artificial intelligence (AI), digital twins and real-time data analytics in every stage of the battery value chain. Its core mission is clear: to enhance productivity, efficiency, sustainability and quality of European gigafactories—making them globally competitive and future-ready.

Batteries are critical—but so is how we make them

Battery manufacturing is a complex, multi-step process involving material preparation, electrode coating, cell assembly, electrolyte filling, formation, ageing and testing. Even slight deviations in humidity, slurry viscosity, coating thickness or drying speed can have a significant impact on battery production yield, safety and performance.

Traditional battery plants rely heavily on human oversight, trial-and-error optimisation and offline quality testing. As a result, today's gigafactories often experience:

- low first-pass yields (often below 70%)
- high material and energy waste
- delays in process calibration and scale-up
- difficulty in predicting and preventing defects.

The BATMAX project addresses these challenges by building a robust digital framework that enables predictive quality control, self-optimising processes and closed-loop manufacturing systems—all of which are powered by AI and fed by massive, real-time dataflows.

The BATMAX vision

Funded under Horizon Europe, BATMAX is coordinated by VTT Technical Research Centre of Finland Ltd and brings together 12 partners from nine European countries. The project is strategically designed to deliver three key outcomes:

1. **Digital twin-driven manufacturing:** developing physics-based digital twins for the entire battery manufacturing line—these are dynamic, virtual replicas of real-world processes that allow simulations, predictions and real-time optimisations.
2. **AI-powered decision-making:** deploying advanced machine learning algorithms that adapt and learn from historical and real-time process data to prevent faults, fine-tune parameters and increase first-pass yield.
3. **Human-centric automation:** integrating intuitive interfaces, decision support tools and digital dashboards to empower factory operators and engineers to collaborate effectively with AI systems.

In doing so, BATMAX lays the foundation for Battery Manufacturing 4.0, a new paradigm in which factories are smart, self-aware and resilient—capable of adapting to product changes, supply fluctuations and sustainability targets on the fly.

What makes BATMAX unique?

Unlike isolated R&D projects, BATMAX spans the full value chain and is embedded within real industrial production environments. Four use cases—waterborne, non-road mobile machinery, heavy-duty vehicles and stationary storage—are being developed to validate BATMAX's innovations under real-world conditions.

Let's explore the project's pillars:

1. Digital twins for every step of the battery line

Digital twins are a core feature of BATMAX. These virtual representations of physical assets allow engineers to simulate, predict and optimise processes without physical trial-and-error.

In BATMAX, digital twins are being developed for key stages of battery production, including electrode fabrication (slurry mixing, coating, drying), cell assembly (stacking, electrolyte filling, sealing), formation and ageing (voltage, temperature, current profiling), and end-of-life testing (capacity, impedance, internal resistance). Each digital twin is calibrated using multi-physics models and enriched with data from inline sensors and industrial IoT systems. This fusion of modelling and real-time data enables precise process control, significantly reducing ramp-up times and enhancing production output. Digital twins provide manufacturers with a digital sandbox for testing different process conditions, significantly reducing the reliance on trial-and-error adjustments. By simulating different material compositions, environmental conditions, and manufacturing speeds, engineers can fine-tune operations without incurring unnecessary costs or waste.

The use of digital twins also facilitates the integration of next-generation battery materials. As the industry transitions towards more sustainable chemistry, digital twins can model the effects of different materials in the manufacturing process, ensuring a smooth transition and mitigating the risks associated with new formulations.

2. AI meets process engineering

The AI systems developed in BATMAX go beyond simple pattern recognition. They are designed to learn the physics behind battery production and recommend corrective actions for optimal settings.
Key AI use cases include:

- **Anomaly detection:** automatically identifying defects in coating, alignment or electrolyte filling before failures occur
- **Predictive maintenance:** forecasting equipment wear and scheduling interventions to avoid downtime
- **Yield optimisation:** adjusting process parameters in tandem to maximise output without sacrificing quality
- **Sustainability metrics:** reducing energy usage, emissions and scrap through intelligent process adjustments
- **Real-time process correction by leveraging AI:** enabling proactive adjustments to significantly reduce waste and improve battery quality—the ability to anticipate and address deviations before they impact production is a game-changer for the industry.

3. Empowering people, not replacing them

A key principle in BATMAX is human-centric design. Rather than replacing human expertise, the project is focused on augmenting it with digital tools.
Through intuitive dashboards, operators receive alerts, decision support and twin-model visualisation that explain, not just what is happening, but why it's happening. This increases trust in automation and fosters a collaborative environment between AI and human experts.

Moreover, BATMAX is creating training modules and skill frameworks to equip Europe's battery workforce with digital manufacturing competencies. The training initiative will help ensure that Europe retains a globally competitive workforce, skilled in both conventional manufacturing and emerging digital production techniques.

Aligning with Europe's battery strategy

BATMAX is more than a technological project—it's a strategic enabler of Europe's broader industrial and environmental goals.

The project supports key objectives of the European Battery Alliance (EBA) and the Strategic Action Plan on Batteries, including:

- achieving battery production sovereignty in Europe
- supporting the emergence of green gigafactories
- enhancing the competitiveness of European battery players
- developing a skilled and digital-ready workforce.

By enabling more productive, sustainable and flexible battery manufacturing, BATMAX contributes directly to Europe's leadership in clean mobility, renewable energy and climate-neutral industry.

A strong European consortium

The BATMAX project is powered by a diverse and highly skilled consortium combining expertise in battery technology, AI, digital twins and industrial manufacturing. The consortium includes leading research institutions, battery manufacturers, technology providers and software developers. This strong collaboration ensures that BATMAX's innovations are not just theoretical but are deeply embedded into actual European battery production facilities, making them highly scalable and impactful.

Looking ahead

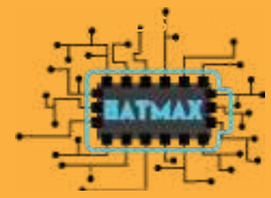
As the world races towards electrification, BATMAX is positioning Europe at the cutting edge of smart, scalable and sustainable battery production. By 2026, the project aims to deliver:

- fully functional digital twin platforms integrated into pilot-scale battery lines
- AI algorithms capable of reducing manufacturing waste by up to 30%
- scalable architectures ready for deployment in commercial gigafactories
- a trained workforce fluent in digital tools and ready to operate factories of the future.

The long-term ambition is to establish Europe as the global leader in AI-driven battery production, ensuring a steady supply of high-quality, sustainably manufactured batteries for generations to come.

Through this, BATMAX is not only helping Europe build better batteries but also building the digital infrastructure that will define the future of clean manufacturing.

For more information on the BATMAX project, visit: www.batmaxproject.eu



PROJECT SUMMARY

BATMAX is an EU-funded project that aims to pave the way for advanced, next-generation data-based and adaptable battery management systems (BMS), capable of fulfilling the needs and requirements of mobile and stationary applications and use cases. The main objective of the project is to contribute to improving battery system performance, safety, reliability, service life and lifetime cost.

PROJECT PARTNERS

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PROJECT LEAD PROFILE

VTT is one of Europe's leading research institutions, owned by the Finnish state. They advance the utilisation and commercialisation of research and technology in commerce and society. Through scientific and technological means, they turn large global challenges into sustainable growth for businesses and society. They bring together people, business, science and technology to solve the biggest challenges of our time.

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