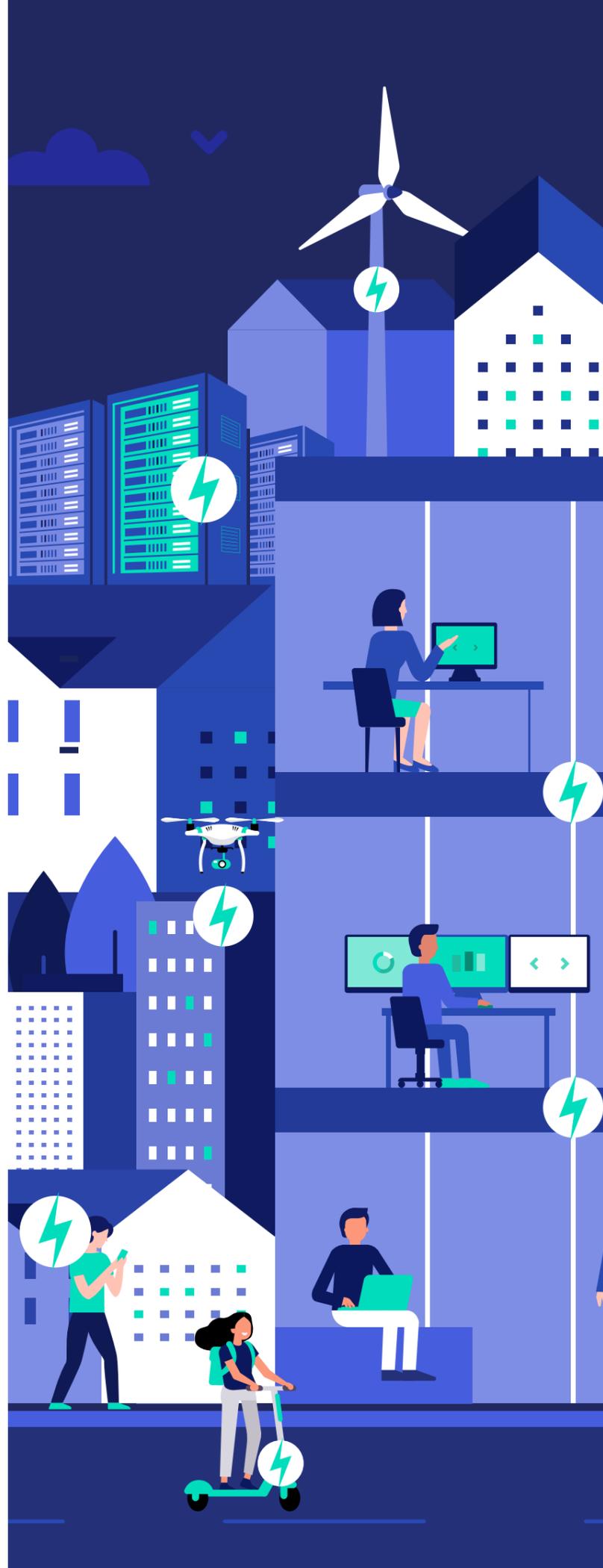# BattGenie.

BattMaaS

Accelerating Battery Innovation Through
Advanced Modeling as a Service

White Paper 2025

Welcome to,

A Comprehensive Battery Modeling Platform for the Energy Storage Industry

## Contents

01

Executive Summary

The battery industry's quest for optimal performance, safety, and longevity demands sophisticated modeling capabilities that can accurately predict cell behavior across diverse operating conditions. Yet organizations face a fundamental challenge: developing and maintaining high-fidelity battery models requires deep electrochemical expertise, significant computational resources, and continuous validation efforts that few can afford.

BattMaaS

BattMaaS (Battery Models as a Service) transforms this landscape by democratizing access to state-of-the-art battery modeling through a comprehensive platform that delivers validated, parameter-agnostic models in formats that integrate seamlessly with existing workflows. Built on years of battery modeling expertise and validated against real-world data,

> **BattMaaS provides a complete spectrum of battery models—from rapid equivalent circuit models to detailed physics-based simulations—all accessible through flexible deployment options. Whether deployed as Functional Mock-up Units (FMUs) compatible with over 150 simulation tools, executed through cloud APIs, or run as licensed binaries on customer infrastructure, BattMaaS enables organizations to leverage advanced battery modeling without the overhead of model development and maintenance.**

What sets BattMaaS apart is its parameter-agnostic architecture: a single model can simulate any battery chemistry, capacity, or form factor simply by updating external parameters. This revolutionary approach means organizations no longer need different models for different cells—one BattMaaS model adapts to all, accelerating development cycles and reducing costs while maintaining unprecedented accuracy.

Cloud API's — Battery R&D

Battery Models — Licensed Binaries — Battery Storage

FMU's — Electric Vehicles
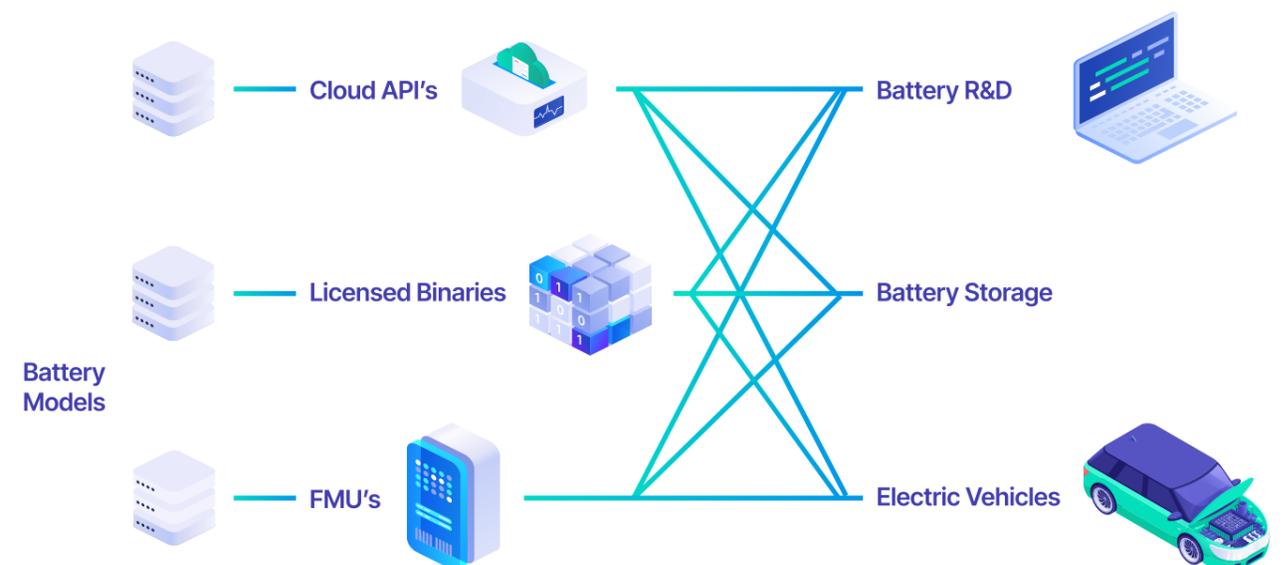
02

The Modeling Gap in Battery Development

Battery development has reached an inflection point. As applications diversify from consumer electronics to electric vehicles to grid storage, the demand for accurate battery models has never been greater. Engineers need models that can predict performance across temperature extremes, forecast degradation over thousands of cycles, optimize charging strategies in real-time, and ensure safety under abuse conditions. Yet the complexity of modern battery systems makes developing such models a formidable challenge.

Traditional approaches force organizations into difficult compromises:

- **Simple equivalent circuit models** execute quickly but lack the fidelity to capture complex electrochemical phenomena
- **Physics-based models** provide accuracy but require specialized expertise to develop and computational resources to run
- **Commercial modeling packages** offer pre-built solutions but lock users into rigid workflows and proprietary formats
- **Custom model development** demands teams of electrochemists, months of development, and extensive validation

The result is a modeling gap that constrains innovation across industries. Automotive OEMs struggle to optimize battery pack designs without accurate thermal models.

Consumer electronics manufacturers cannot predict runtime under varying usage patterns. Energy storage providers lack the tools to forecast degradation and warranty costs. Battery manufacturers need months to validate new chemistries. What the industry needs is accessible, accurate, and adaptable modeling that accelerates rather than constrains innovation.
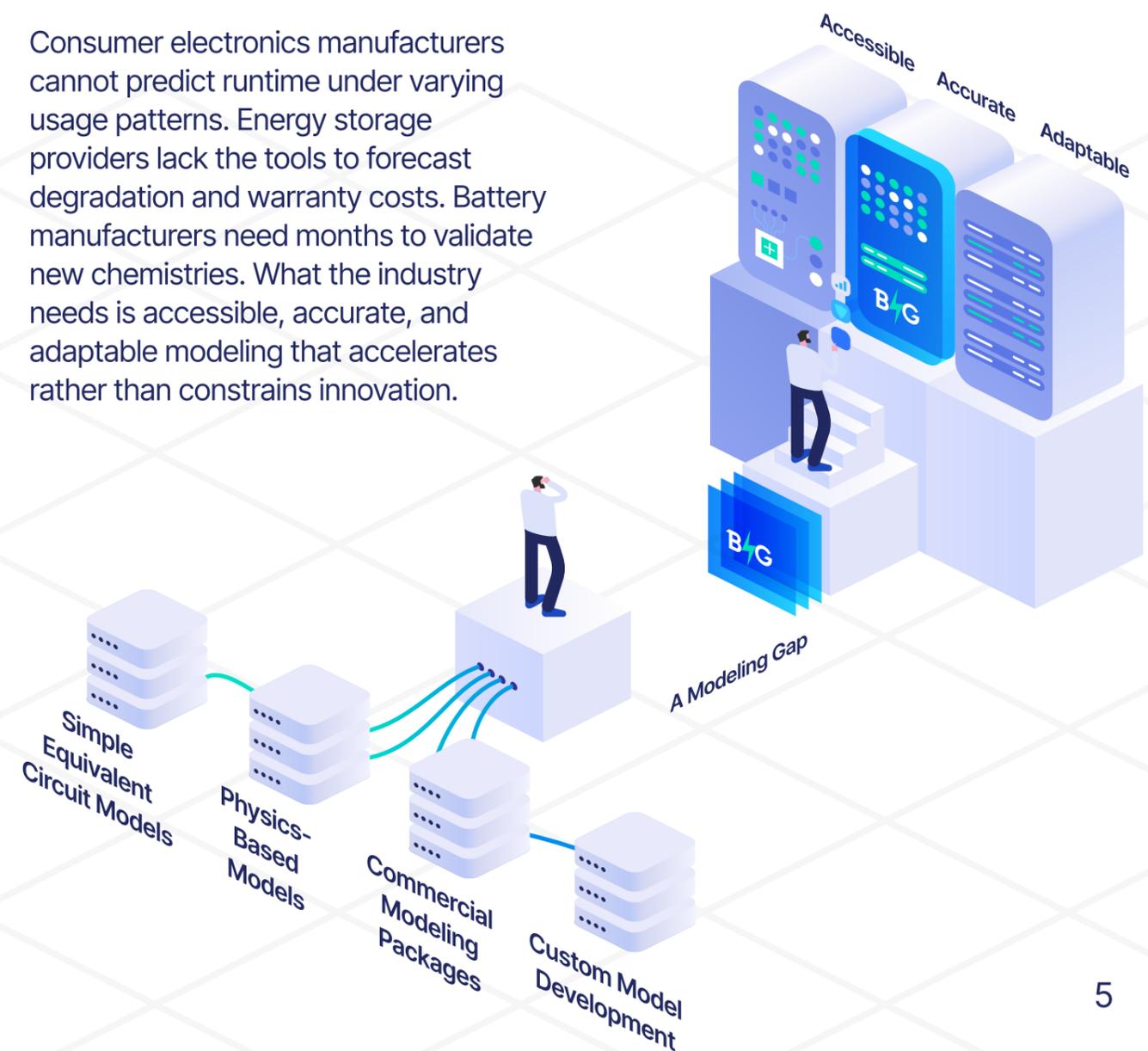
03

BattMaaS: Architecture for Universal Battery Modeling

BattMaaS represents a paradigm shift in battery modeling—from ownership to access, from development to deployment, from rigid to adaptable. At its core, BattMaaS provides a comprehensive library of validated battery models that can be deployed instantly across any simulation environment, scaled to any computational resource, and adapted to any battery chemistry through parameter configuration.

Comprehensive Model Library

BattMaaS offers the industry's most complete battery model portfolio, each optimized for specific use cases while maintaining compatibility across the platform:

Equivalent Circuit Models (ECM): Rapid execution for real-time applications and BMS development, capturing essential electrical behavior through networks of resistors, capacitors, and voltage sources with millisecond response times suitable for embedded systems.

Single Particle Models (SPM): Balance fidelity and speed for design optimization, capturing lithium diffusion in electrode particles while maintaining computational efficiency ideal for rapid design iteration.

Tank Model: Specialized thermal-electrochemical coupling for pack design, treating the battery as interconnected thermal and electrochemical reservoirs to predict temperature distributions and thermal runaway scenarios.

Pseudo Two-Dimensional (P2D) Model: The crown jewel of our library, also known as the Doyle-Fuller-Newman model, which solves the complete set of electrochemical equations across electrode and separator domains. This model simulates lithium particle and lithium-ion transport in both the solid particles of the electrodes and the surrounding electrolyte, capturing concentration gradients, reaction kinetics, and transport phenomena through coupled partial differential and algebraic equations.

Machine Learning Models: Complement physics-based approaches by leveraging neural networks to capture non-linear relationships and predict behaviors that physics-based models struggle to represent, excelling at interpolation within trained conditions.

Custom Models: Tailored solutions for specific chemistries, form factors, or applications including emerging technologies like solid-state batteries.

All models incorporate comprehensive degradation mechanisms and thermal effects:

- SEI growth, lithium plating, mechanical stress, particle cracking, calendar aging
- Heat generation, temperature-dependent parameters, thermal runaway
- Hysteresis effects and intercalation-induced stresses (critical for silicon anodes)

The Power of Parameter-Agnostic Modeling

The revolutionary parameter-agnostic architecture of BattMaaS fundamentally changes how organizations approach battery modeling. Instead of maintaining separate models for each cell type, chemistry, or application, users work with a single, adaptable model that can be instantly reconfigured through external parameters.

External Parameter Configuration. All model parameters can be modified externally without touching the model code. This means a single FMU can simulate:

An 18650 NMC cell for a power tool in the morning

A large-format LFP pouch cell for grid storage in the afternoon

An experimental silicon-anode cell for R&D evaluation in the evening

Chemistry Independence

- Open-circuit voltage curves for different cathode materials (NMC, LFP, NCA, LCO)
- Diffusion coefficients for various anode compositions (graphite, silicon, blended)
- Electrolyte properties for different salt concentrations and solvents
- Particle sizes and porosities for different electrode designs

Real-World Scenarios

EV Manufacturer: An automotive OEM evaluating battery suppliers uses a single BattMaaS model to compare cells from multiple vendors. By simply loading each vendor's parameters, they simulate pack-level performance without developing vendor-specific models.

Battery Manufacturer: A cell manufacturer optimizing a new chemistry explores thousands of parameter combinations using the same model, completing in hours what previously required months of model development.
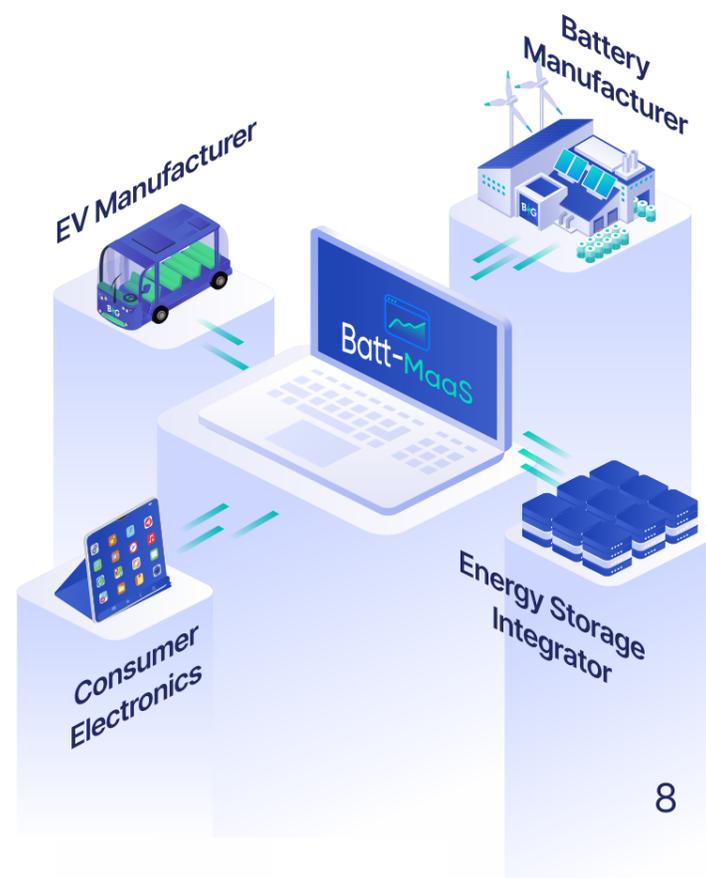
Consumer Electronics: A smartphone manufacturer evaluates how different battery options affect device runtime by adjusting capacity and chemistry parameters, predicting performance across their entire product line using one model.

Energy Storage Integrator: A BESS developer models different cell configurations for a grid project, comparing high-energy versus high-power cells and evaluating thermal management strategies through parameter updates.

Flexible Deployment Architecture

BattMaaS eliminates the traditional trade-off between capability and accessibility through multiple deployment options designed for specific use cases.

Functional Mock-up Units (FMU) - The Industry Standard

Our FMUs represent the most advanced battery models available in the FMI standard. Built to FMI 3.0 specifications with FMI 2.0 compatibility, they integrate seamlessly with over 150 simulation tools:

- MATLAB/Simulink for control design and system simulation
- Dymola, SimulationX, and other Modelica platforms
- ANSYS Twin Builder for digital twin applications
- GT-Suite and AVL CRUISE for automotive powertrain simulation
- IPG CarMaker for vehicle dynamics and ADAS testing
- dSPACE and ETAS for hardware-in-the-loop applications
- Python environments via FMPy for custom workflows

What makes BattMaaS FMUs unique:

- **Co-simulation Mode:** Includes BattGenie's proprietary solver optimized for battery equations
- **Guaranteed Convergence:** Patented numerical methods ensure convergence even for regenerative braking
- **Minimal Interface:** Only two inputs required (current and ambient temperature)
- **25+ Configurable Outputs:** Voltage, SOC, temperature, power, internal states, and more
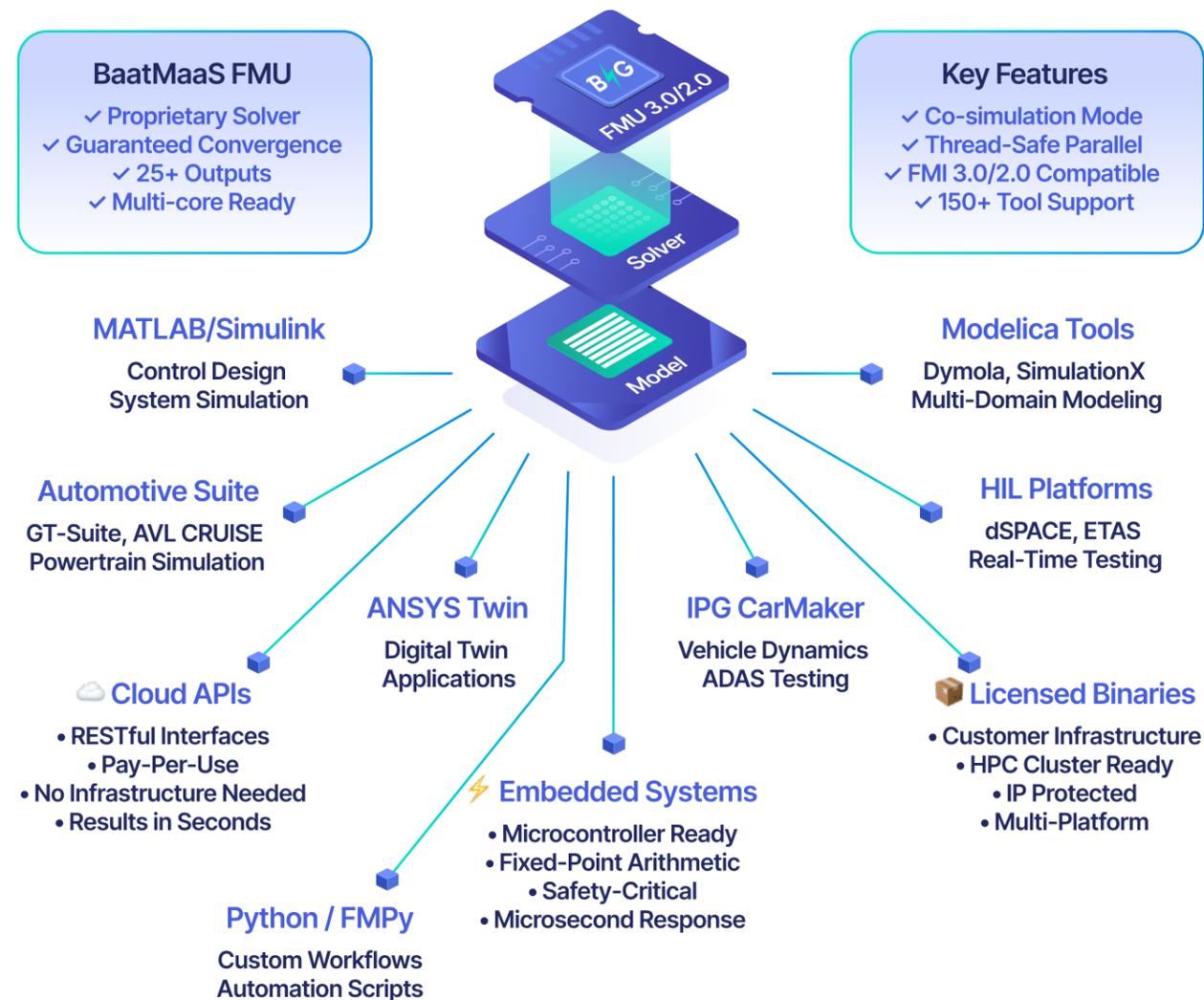- **Multi-core Support:** Parallel execution for multiple parameter sets

Cloud APIs

- RESTful interfaces for on-demand execution without local resources
- Web-based applications and automated testing pipelines
- Collaborative workflows with pay-per-use access
- Results in seconds without infrastructure investment

Licensed Binaries

- Standalone executables for customer infrastructure
- Platform-optimized for Windows, Linux, and embedded systems
- Thread-safe parallel execution on HPC clusters
- Encrypted to protect IP while maintaining functionality

Embedded Deployment

- Reformulated models for microcontroller implementation
- Fixed-point arithmetic for processors without FPUs
- Deterministic execution for safety-critical applications
- Real-time capable with millisecond response times

BaatMaaS FMU
✓ Proprietary Solver
✓ Guaranteed Convergence
✓ 25+ Outputs
✓ Multi-core Ready

FMU 3.0/2.0
B|G
Solver
Model

Key Features
✓ Co-simulation Mode
✓ Thread-Safe Parallel
✓ FMI 3.0/2.0 Compatible
✓ 150+ Tool Support

MATLAB/Simulink
Control Design
System Simulation

Modelica Tools
Dymola, SimulationX
Multi-Domain Modeling

Automotive Suite
GT-Suite, AVL CRUISE
Powertrain Simulation

HIL Platforms
dSPACE, ETAS
Real-Time Testing

ANSYS Twin
Digital Twin
Applications

IPG CarMaker
Vehicle Dynamics
ADAS Testing

Cloud APIs
• RESTful Interfaces
• Pay-Per-Use
• No Infrastructure Needed
• Results in Seconds

Licensed Binaries
• Customer Infrastructure
• HPC Cluster Ready
• IP Protected
• Multi-Platform

Embedded Systems
• Microcontroller Ready
• Fixed-Point Arithmetic
• Safety-Critical
• Microsecond Response

Python / FMPy
Custom Workflows
Automation Scripts

Performance That Transforms Workflows

BattMaaS revolutionizes modeling workflows through unprecedented performance that makes detailed simulations practical for everyday engineering:

10x Faster Than Traditional Solvers

- COMSOL: Hours for thousand cycles → BattMaaS: Minutes
- Optimized numerical methods specifically for battery equations
- Efficient memory management with vectorized operations
- Adaptive time-stepping maintaining accuracy while maximizing speed
- Compiled implementations eliminating interpretation overhead

Superior Accuracy

- 99.9% accuracy in voltage prediction across full SOC range with self-convergence
- >99% accuracy in capacity fade forecasting over thousands of cycles
- <1% error in temperature prediction under dynamic loads
- Validated against data from leading manufacturers and national labs

Scalable Execution

- Single-cell simulations: Milliseconds on standard laptops
- Parameter sweeps: Thousands of combinations using cloud resources
- Pack-level simulations: Thermal coupling on workstations
- Fleet-scale digital twins: Distributed computing infrastructure

Real-Time Capable

- Electrochemical models execute in milliseconds
- Hardware-in-the-loop testing at kHz update rates
- BMS algorithm validation with actual control hardware
- Embedded implementation in production systems

18 Mins
BaatMaaS
Optimized Solver

10x Faster

180 Mins
COMSOL
Traditional Solver
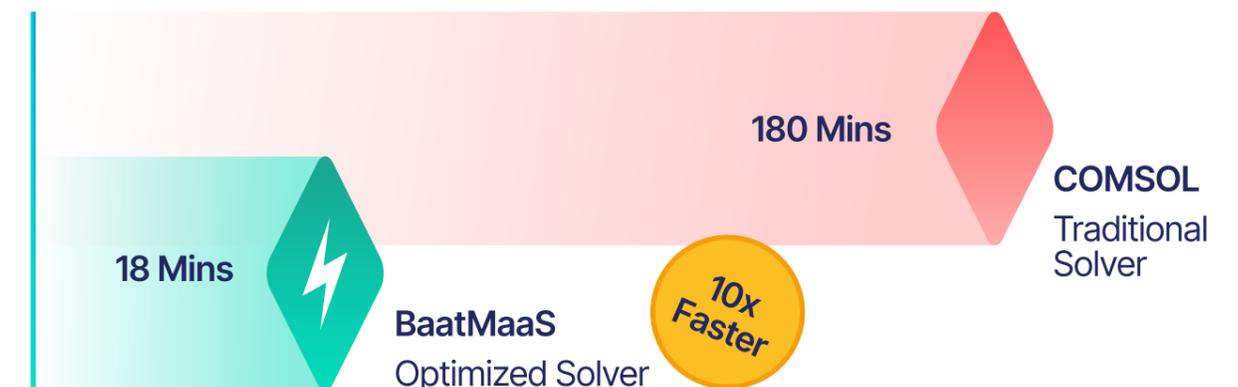
04

What Can You Do with BattMaaS Models?

BattMaaS models enable transformative capabilities across the entire battery value chain. From initial cell selection through end-of-life prediction, organizations use BattMaaS to answer critical questions and optimize key decisions.

Electric Vehicle Applications

Battery Pack Design Optimization

- Compare series/parallel arrangements for voltage and capacity targets
- Optimize cell placement for thermal uniformity
- Evaluate cooling strategies (air, liquid, immersion)
- Predict pack-level performance from cell-level data
- Simulate worst-case scenarios for safety validation

BMS Algorithm Development

- Design state estimation algorithms (SOC, SOH, SOP)
- Develop cell balancing strategies for pack longevity
- Create adaptive charging profiles for different temperatures
- Implement safety monitors for thermal runaway prevention
- Validate algorithms through HIL testing before vehicle integration

Thermal Management & Fast Charging

Engineers ensure safe operation across all conditions by predicting temperature distributions during fast charging, optimizing cooling system sizing, and simulating thermal propagation. Fast charging protocols balance speed with battery health through multi-stage profiles, temperature-dependent current limits, and adaptive protocols that adjust to aging.

Consumer Electronics

Device manufacturers leverage BattMaaS to enhance user experience by accurately forecasting battery life under various usage patterns, developing dynamic power allocation strategies, and implementing predictive throttling to prevent shutdowns. Thermal safety validation ensures compliance by simulating device heating under maximum load, verifying thermal limits, and evaluating cooling needs.

Battery Energy Storage Systems (BESS)

Grid Integration & Economics

- Model battery response to grid frequency events
- Simulate provision of ancillary services
- Optimize round-trip efficiency under various cycles
- Forecast capacity fade over project lifetime
- Calculate levelized cost of storage

Degradation & Revenue Optimization

Energy storage developers predict long-term performance through capacity fade forecasting, warranty evaluation, and augmentation planning. Economic optimization maximizes returns through charge/discharge scheduling, use case combination evaluation, and sensitivity analysis to electricity price variations.

Manufacturing and R&D

Battery manufacturers and research institutions accelerate innovation:

Cell Development

- Screen electrode materials through simulation
- Predict performance of new chemistry combinations
- Optimize electrode compositions and structures
- Reduce physical prototyping requirements

Quality Control

- Develop acceptance criteria from model predictions
- Identify outliers through model-based analysis
- Optimize testing protocols for efficiency

IC Manufacturers

Semiconductor companies developing battery management ICs validate gauge accuracy across chemistries, test protection circuits under fault conditions, optimize fuel gauge algorithms, and create reference designs with accurate battery models.
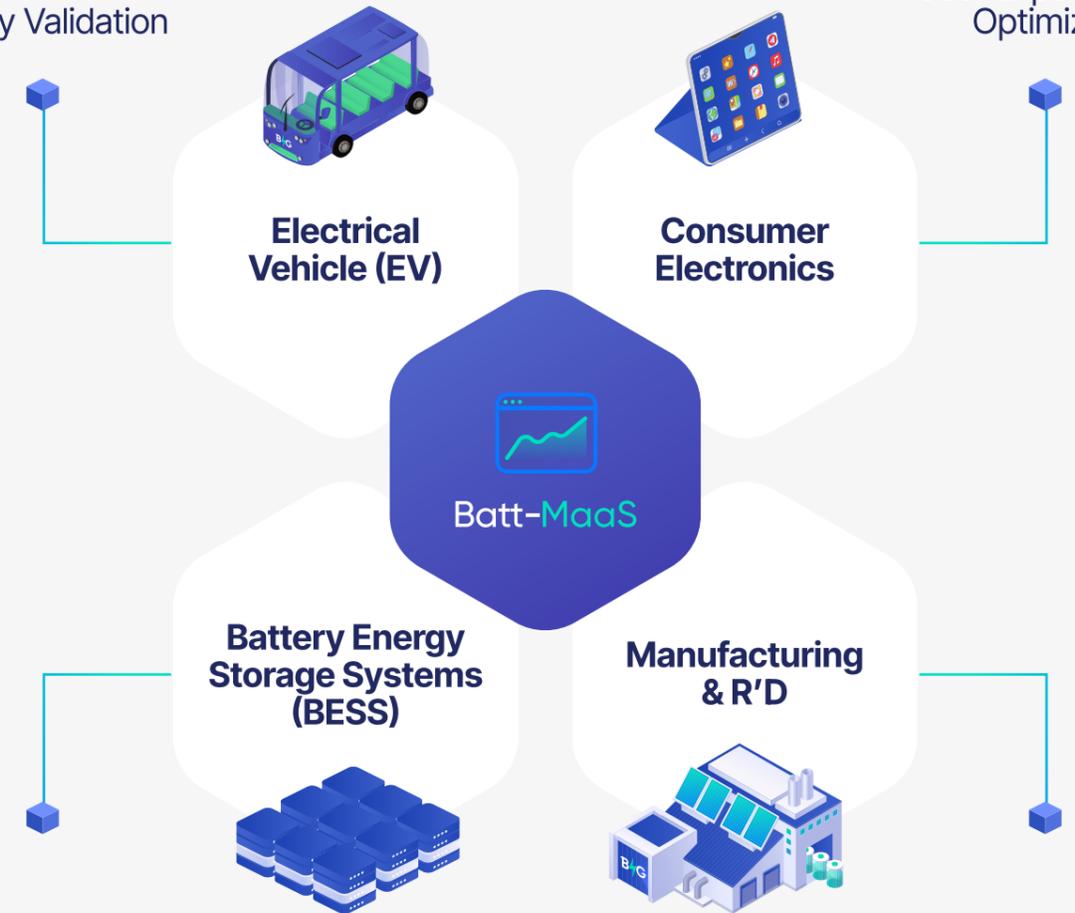
Use Cases:

10x Faster Development

Pack Design Optimization

BMS Algorithm Development

Thermal Management Strategy

Fast Charging Protocols

Safety Validation

Improved User Experience

Runtime Prediction

Adaptive Power Management

Thermal Safety Validation

Battery Selection

User Experience Optimization

Electrical Vehicle (EV)

Consumer Electronics

Batt-MaaS

Battery Energy Storage Systems (BESS)

Manufacturing & R'D

90% Prediction Accuracy (20 years)

Grid Integration Studies

Degradation Forecasting

Revenue Optimization

Ancillary Services Modeling System Sizing

Reduced QC Time

Cell Chemistry Evaluation

Quality Control

Accelerated Testing Protocols

IC Validation

Process Optimization

05

Deep Integration with BattStudio Ecosystem

While BattMaaS delivers standalone value, its integration with the broader BattStudio ecosystem multiplies its impact through synergies that transform isolated modeling efforts into comprehensive digital twin workflows.

Seamless Data-Model Pipeline with BattDaaS

The combination of BattMaaS modeling and BattDaaS data management creates a closed-loop system:

Automated Parameter Extraction

- Open-circuit voltage curves from slow cycling
- Resistance and capacitance from pulse tests
- Diffusion coefficients from rate capability data
- Thermal parameters from temperature measurements

Continuous Validation & Digital Twins

Models improve continuously through operational data with automatic comparison against test results, parameter refinement based on fleet statistics, and validation report generation. Real-time data streams enable living digital twins that update parameters based on observed behavior, predict remaining useful life, identify anomalies, and enable predictive maintenance.

Unified Workflow Management

BattStudio orchestrates complex modeling workflows:

- **Automated Testing:** Specify test matrices, distribute simulations, generate reports
- **Multi-Scale Simulation:** Propagate cell models to pack level with thermal coupling
- **Optimization:** Combine models with algorithms to find optimal strategies

BattStudio

BattMaaS

BattDaaS

Automated Testing

Multi-Scale Simulation

Optimization
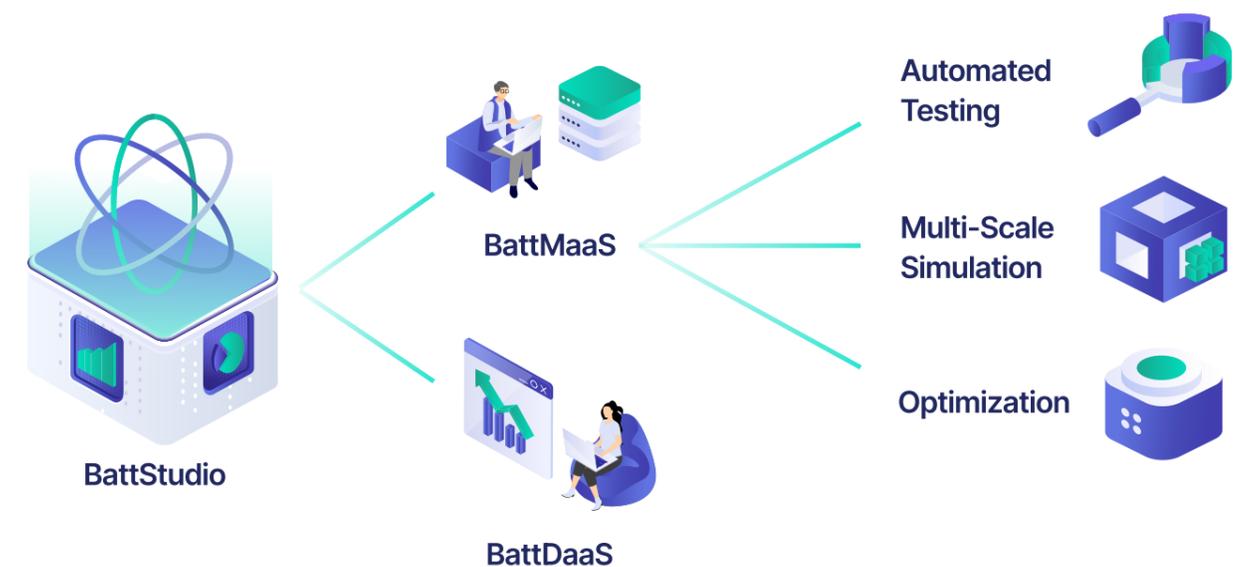
06

Unique Advantages of BattMaaS FMUs

Beyond Traditional FMUs

BattMaaS FMUs represent a new generation of Functional Mock-up Units specifically engineered for battery applications:

One Model, Any Chemistry

Unlike traditional battery FMUs hard-coded for specific chemistries, BattMaaS FMUs feature:

- Fully external and configurable parameters
- Instant switching between chemistries via parameter files
- Evaluation of emerging chemistries without model changes
- Instant comparison of cells from different manufacturers

Dynamic Capabilities

- Parameter updates during simulation for adaptive control
- Aging simulation through parameter drift
- Real-time model tuning based on observations
- Manufacturing variation studies

Build Once, Deploy Everywhere

- No recompilation for different operating systems
- Consistent results across all simulation tools
- Unified model management across organizations
- Simplified version control and updates

Advanced Numerical Features

- Guaranteed convergence for stiff battery equations
- Robust handling of discontinuities (CC-CV transitions)
- Adaptive time-stepping for efficiency
- Consistent initialization for any starting condition
- Numerical stability across entire operating range

Licensing Flexibility

Our flexible licensing adapts to evolving needs:

Usage-Based Options

- Pay-per-use for exploration and pilots
- No upfront investment
- Access to entire model library
- Transparent pricing by compute hours

Seat-Based Licenses

- Unlimited simulations for power users
- Predictable annual costs
- Priority support and training included
- Volume discounts available

Enterprise & Academic

- Customized agreements for large organizations
- On-premise deployment options
- Special academic pricing for education and research
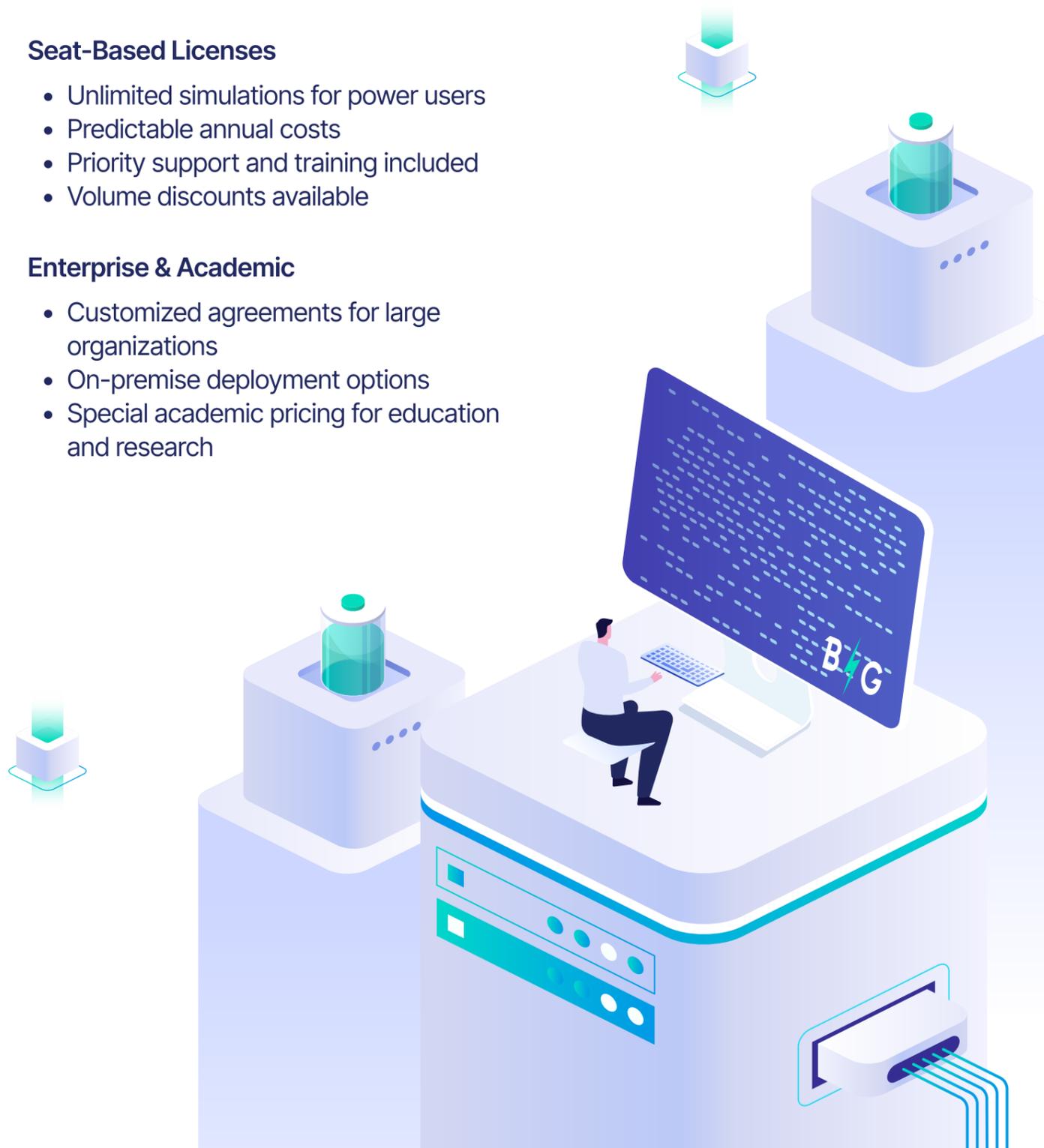
BattMaaS FMUs vs Traditional Battery FMUs

Next-Generation Functional Mock-up Units

	Traditional Battery FMUs	VS	BattMaaS FMUs
Chemistry Support	Hard-coded for single chemistry New model per chemistry type		✅ External configurable parameters ✅ Instant chemistry switching via files
Deployment	Recompilation for each platform Version management complexity		✅ Build once, deploy everywhere ✅ Unified model management
Dynamic Capabilities	Fixed parameters during simulation Limited aging representation		✅ Build once, deploy everywhere ✅ Unified model management
Dynamic Capabilities	Fixed parameters during simulation Limited aging representation		✅ Real-time parameter updates ✅ Aging simulation via parameter drift
Numerical Robustness	Convergence issues common Discontinuity handling problems		✅ Guaranteed convergence (patented) ✅ Robust CC-CV transition handling
Licensing Model	Rigid perpetual licenses		✅ Pay-per-use / Seat-based / Enterprise ✅ Flexible scaling to your needs

Conclusion: Democratizing Battery Innovation

BattMaaS represents more than a collection of battery models—it embodies a vision for how advanced modeling can accelerate the transition to sustainable energy storage. By removing barriers to sophisticated battery modeling, BattMaaS enables every organization to make better decisions, develop superior products, and bring innovations to market faster.

The platform's revolutionary parameter-agnostic architecture means accurate battery modeling is no longer exclusive to large corporations with dedicated modeling teams.

> **Startups can access the same advanced models as major OEMs. Battery manufacturers can evaluate new chemistries without months of model development. Energy storage developers can optimize system economics with confidence in long-term predictions.**

The combination of comprehensive model coverage, unmatched performance, and flexible deployment options makes BattMaaS the definitive modeling platform for the battery industry. Whether designing next-generation electric vehicles, optimizing grid-scale storage, or developing cutting-edge consumer electronics, BattMaaS provides tools to simulate, optimize, and validate with unprecedented speed and accuracy.

> **The future of energy storage depends on batteries that are safer, more efficient, and longer-lasting than ever before—with BattMaaS, that future is here today.**

Client Testimonial

> **BattMaaS has fundamentally transformed how we approach battery system development at Lucid Motors. The parameter-agnostic architecture means we can evaluate cells from multiple suppliers using a single model, dramatically accelerating our selection process. The 10x performance improvement over traditional solvers allows us to run comprehensive design space explorations that were previously impossible. What used to take weeks of simulation now completes overnight. The seamless integration with our existing toolchain through FMUs meant we were productive from day one. BattMaaS isn't just another modeling tool—it's a competitive advantage that allows us to deliver industry-leading range and performance.**

Brian Spatocco, Senior Director of Energy Storage Systems, Lucid Motors

LUCID

BattGenie.

About BattGenie Inc.

BattGenie Inc. stands at the intersection of battery science and advanced computing, creating software solutions that accelerate the development and deployment of next-generation energy storage systems. Founded by leading researchers from the University of Washington and University of Texas at Austin, BattGenie has developed the fastest and most robust battery simulation algorithms in the industry. Our patented numerical methods guarantee convergence where traditional solvers fail, while our optimized implementations achieve order-of-magnitude performance improvements over conventional tools.

BattMaaS exemplifies our commitment to making advanced battery technology accessible to all, enabling organizations of any size to leverage the same sophisticated tools that power the world's leading battery programs.

Batt-MaaS

24-25