Extendable Battery Framework

An Open Standard for Modular Energy Storage

Proposed by Modular Battery Technologies Inc. — 2026

Executive Summary

The Extendable Battery Framework (EBF) is an open standard for modular energy storage designed to work across automotive, marine, aircraft, datacenter, and grid applications. Instead of a custom battery pack for every application, EBF standardizes the module: a self-contained, full-voltage, hot-swappable unit with integrated safety and lifecycle tracking. The same module works in a car, a boat, or a building.

Three core technologies make this possible:

- **Charge Node™** — Intelligent full-voltage module with series-only cell connections, integrated BMS, internal isolation, and individual cell monitoring
- **Charge Mesh™** — Adaptive power architecture that configures modules on demand, manages mixed energy sources, and degrades gracefully on failure
- **Linked Context Tokens (LCTs)** — Cryptographic digital twins that track each module through manufacture, deployment, reuse, and recycling with verified provenance

EBF is protected by 13 issued US patents with multiple pending international applications, and is proposed as a royalty-free open standard for manufacturers of certified compliant products. An industry nonprofit, the Safe Battery Alliance, is proposed as the standard's administrator.

Projected outcomes at scale:

Benefit	Estimate
Battery waste reduction	up to 60% (through reuse and standardization)
Greenhouse gas reduction	up to 30% (production + disposal)
Total cost of ownership reduction	20-30% (EVs and grid storage)
Resource utilization improvement	up to 4× EV support from current production

We invite all energy ecosystem stakeholders — policymakers, manufacturers, researchers, investors, and advocacy groups — to review, contribute, and participate.

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1. The Problem

The global energy storage market is growing at over 20% annually, driven by EV adoption, renewable integration, and grid stability demand. Current approaches can't keep up — and create new problems as they scale.

Large monolithic packs lock up resources. Most EVs carry oversized batteries for daily use. A 100kWh pack used for a 30-mile commute wastes 70kWh of capacity every day. That capacity could power another vehicle, a home, or a grid buffer — but it's welded into one car.

Every application requires a custom pack. An EV pack doesn't work in a boat. A boat pack doesn't work in a datacenter. Each new application means a new design, new tooling, new qualification — millions in non-recurring engineering before a single unit ships.

Safety scales with pack size. Conventional battery designs can cascade into thermal runaway. Larger packs mean larger fires. Current mitigation (cooling systems, fire suppression) treats symptoms; the cell connection architecture IS the root cause.

End-of-life is a dead end. Large, model-specific packs are expensive to disassemble, difficult to test at the cell level, and impractical to repurpose. Most end up in recycling streams that recover only a fraction of their value.

Supply chains are brittle. Dependence on specific battery designs and single-source suppliers creates bottlenecks. Lithium price volatility, reshoring pressures under the IRA and CHIPS Act, and geopolitical tensions have made this vulnerability acute.

EBF addresses all five problems with one architectural change: **standardize the smallest unit, not the largest assembly.**

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2. The Solution

2.1 Charge Node™ Modules

The building block. A Charge Node is a standardized, self-contained battery module incorporating:

- **Series-only cell connections** — eliminates the parallel cell configurations that enable thermal runaway propagation. A cell failure in a Charge Node is isolated by physics, not by software.
- **Integrated BMS** — each module monitors its own cells (voltage, temperature, state of charge) independently. No external controller required.
- **Internal relays** — complete electrical isolation when not in use or during fault conditions. Modules self-disconnect.
- **Smart cell circuit** — individual cell-level monitoring via a low-cost ASIC, enabling precise balancing and early anomaly detection.
- **Hot-swappable** — modules can be added, removed, or replaced in the field without system shutdown. No specialized tools or training required.
- **Chemistry-agnostic** — works with any cell type (NMC, LFP, solid-state, sodium-ion). When battery chemistry improves, swap in new modules without redesigning the pack.

Example module: 400V, 1.5kWh, 20kW peak. 3" × 10" × 8", 17 lbs. A motorcycle needs 1-5. A car needs 10-60. A truck needs 50-100+.

2.2 Charge Mesh™ Architecture

The power system that connects modules into working installations:

- **On-demand configuration** — add modules for more capacity, remove them when not needed. A delivery van carries a full complement on long-haul days and half on urban routes.
- **Mixed module support** — different module types (different chemistries, different ages, different capacities) operate in the same system. No homogeneity requirement.
- **Intelligent power management** — real-time load balancing across modules optimizes utilization and extends overall system life.
- **Fault tolerance** — mesh structure allows graceful degradation. One module fails; the rest continue operating. No single point of failure.
- **Cross-sector compatibility** — the same architecture works in vehicles, vessels, aircraft, datacenters, and grid installations. Standardized interfaces ensure interoperability across applications and generations.
- **Scalable** — from a portable tool battery to a grid-scale installation. Same architecture, different scale.

2.3 Linked Context Tokens (LCTs)

The digital identity layer that makes modules trackable, controllable, and accountable:

- **Unique digital twin** — each module is assigned an LCT at manufacture containing specifications, origin, and status.
- **Immutable lifecycle record** — every event (deployment, transfer, maintenance, redeployment, recycling) is cryptographically recorded. The module's history is tamper-evident.
- **Authenticated use control** — modules authenticate when installed, preventing unauthorized use and ensuring compatibility. Stolen modules are identifiable and lockable.
- **Real-time health monitoring** — LCTs continuously update with performance data, charge cycles, and health status. Enables predictive maintenance and accurate state-of-health valuation.
- **Verified provenance for resale** — when a module enters its second life (e.g., from a vehicle to grid storage), its complete verified history travels with it. Buyers know exactly what they're getting.
- **Regulatory compliance** — auditable trail demonstrates compliance across jurisdictions. Critical for cross-border transactions and regulated industries.
- **Multi-stakeholder visibility** — manufacturers, operators, regulators, and recyclers access appropriate information levels through the same system.

2.4 How They Work Together

A datacenter operator needs 500kWh of backup power:

1. **Configure**: install Charge Node modules in a Charge Mesh rack. 334 modules at 1.5kWh each. Takes hours, not months of custom engineering.
2. **Operate**: Charge Mesh manages load, balancing, and health across all modules. LCTs track every module's state.
3. **Maintain**: a module degrades below threshold. Replace it in the field — hot-swap, no downtime. The degraded module's LCT records the transition.

4. **Reuse**: the removed module still has 70% capacity. Its LCT verifies this. It moves to a less demanding application (residential backup) at a fair price based on verified health.
5. **Recycle**: when the module finally reaches end of life, its LCT tells the recycler exactly what's inside, how it was used, and what materials to recover.

No custom engineering. No stranded assets. No mystery modules. One standard, many lives.

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3. Markets

EBF's cross-sector architecture serves every market that uses stored electrical energy:

Transportation

- **Automotive**: flexible range configuration (commuter mode vs road-trip mode), improved safety, reduced OEM development cost
- **Commercial vehicles**: trucks, buses, delivery vans — capacity matched to daily route, not worst-case scenario
- **Marine**: scalable power for vessels from recreational boats to commercial ships; battery swapping at ports
- **Aircraft**: standardized modules for electric aviation; weight optimization through modular design
- **Powersports**: motorcycles, ATVs, snowmobiles — small module counts, easy service

Stationary

- **Datacenters**: backup power and load leveling with no thermal runaway risk at scale
- **Grid storage**: utility-scale installations that grow incrementally as demand requires
- **Renewable integration**: solar and wind buffer storage that adapts to generation capacity
- **Residential**: home energy storage from the same modules used in vehicles

Use Case Scenarios

Urban EV sharing. A city implements EV sharing with EBF vehicles. Users rent cars with capacity matched to their trip. Automated stations swap modules for longer journeys. Resource utilization improves; vehicle availability increases; cost per trip drops.

Off-grid renewable community. A remote community stores solar and wind energy in EBF modules. As the community grows, they add modules. When modules age, they move to less demanding applications (lighting, communications) before recycling. Nothing is wasted.

Electric maritime shipping. A shipping company electrifies its fleet with EBF. Standardized modules swap at ports, minimizing vessel downtime. The same modules provide dockside power storage between loadings. One inventory serves two purposes.

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4. Why This Standard Succeeds Where Others Haven't

Previous standardization efforts have focused narrowly — on form factors, on specific chemistries, or on traceability alone. None have addressed the fundamental architecture.

Existing approach	What it covers	What it misses
EU battery passport	Traceability and sustainability	Modularity, cross-sector compatibility, safety architecture
OEM-specific standards	One manufacturer's product line	Industry-wide adoption, second-life reuse
Battery swapping (e.g., Ample)	Vehicle-specific module exchange	Cross-sector modules, open ecosystem
Cell-level standards (form factor)	Physical dimensions	System architecture, lifecycle management, safety

EBF succeeds because it standardizes the **architecture**, not just the component:

- **Safety by physics, not policy.** Series-only connections eliminate thermal runaway propagation structurally. This isn't a safety feature — it's the absence of the unsafe architecture.
- **Open standard with patent backing.** The standard is royalty-free for compliant products. The 13-patent portfolio ensures architectural coherence — implementers can build on the standard, but the standard itself can't be fragmented by incompatible variants.
- **Network effects.** Every adopter increases the value for every other adopter. Modules manufactured for automotive applications become available for grid storage. Recyclers who handle EBF modules from one sector can handle them from all sectors. The ecosystem compounds.

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5. Environmental Impact

Unit level

- One module serves multiple applications across its lifetime — vehicle → grid → residential → recycling
- Series-only architecture prevents thermal runaway, eliminating battery fire risk and associated toxic emissions
- Chemistry-agnostic design adopts the cleanest available cell technology without system redesign
- Individual cell monitoring enables precise recycling — recyclers know exactly what's inside

At scale

- **Battery waste reduction**: up to 60% through multi-life reuse
- **Greenhouse gas reduction**: up to 30% in battery production and disposal
- **Resource utilization**: up to 4× the number of EVs supported by current battery production
- **Development cost reduction**: 60-80% for OEMs (one module design serves all markets)
- **Lifecycle extension**: ~40% longer useful life through modular repair and repurposing

EBF creates a genuine circular economy for batteries — manufactured once, used many times, recycled with full provenance data.

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6. Adoption Path

Phase 1 (Years 1-2): Standard Finalization and Early Adoption

- Finalize EBF technical standards through industry collaboration
- Establish Safe Battery Alliance industry nonprofit as standard administrator
- Pilot projects across automotive, marine, and stationary applications
- Develop reference designs and supporting documentation
- Engage regulatory bodies on alignment with energy and environmental policy

Phase 2 (Years 3-5): Scaling and Integration

- Large-scale manufacturing of EBF-compatible modules by multiple manufacturers
- ISO-26262 functional safety certification
- Integration into major EV and energy storage products via licensing
- Build-out of module service, exchange, and recycling infrastructure
- Module lifecycle marketplace operational

Phase 3 (Years 6-10): Widespread Adoption

- Significant market penetration across all target sectors
- Mature circular economy for EBF modules
- International standard adoption and cross-border interoperability
- Continuous standard refinement based on real-world fleet data

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7. Regulatory Considerations

Effective EBF adoption benefits from supportive policy frameworks:

- **Standardization mandates** — requiring new energy storage systems to be modular-standard-compatible by a target date
- **Tax incentives** — for manufacturers and consumers who adopt EBF-compatible technology
- **Carbon credits** — where standard adoption contributes to carbon offset programs
- **Public procurement** — requiring EBF compatibility for government and public-sector energy storage
- **Research funding** — grants for further development, testing, and refinement of open battery standards
- **Second-life policy** — frameworks that recognize verified module health data (via LCTs) as sufficient basis for redeployment without full re-qualification

EBF's auditable lifecycle data directly supports compliance with emerging battery regulations including the EU Battery Regulation and US domestic manufacturing requirements.

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8. Stakeholder Engagement

The success of an open standard depends on broad participation:

Manufacturers benefit from standardized production processes, access to multiple end markets with one module design, and reduced per-application engineering cost. Adaptation requires aligning production to EBF specifications and participating in standard governance.

OEMs and integrators gain access to a commodity module supply chain instead of captive battery partnerships. Vehicle, vessel, and installation designs can specify capacity in modules rather than commissioning custom packs.

Utilities and grid operators gain incrementally scalable storage that grows with demand, with verified health data enabling confident capacity planning.

Recyclers gain full visibility into module composition and history, enabling more efficient and complete material recovery. The standardized form factor simplifies disassembly processes.

Regulators gain an auditable framework that demonstrates compliance by construction — the LCT record IS the regulatory trail.

Consumers gain more affordable energy storage, safer installations, and the ability to repurpose or resell modules with verified value.

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9. Participate

The Extendable Battery Framework is an open invitation to the energy storage industry. The standard is designed to be contributed to, not just consumed.

Review the specification. The technical details of Charge Node, Charge Mesh, and LCT architectures are available for industry review and comment.

Join the Safe Battery Alliance. The proposed industry nonprofit will govern standard evolution, certification, and interoperability testing.

Pilot the technology. Manufacturers, integrators, and operators interested in pilot deployments are invited to engage.

Contribute to the standard. Academic and research institutions can participate in refining specifications, testing protocols, and lifecycle analysis.

Contact: dp@modbatt.com
Website: modbatt.com
LinkedIn: linkedin.com/company/modbatt

Appendix: Patent Portfolio

The EBF is supported by 13 issued US patents with multiple pending international applications. The standard is proposed as royalty-free for manufacturers of fully compliant certified products.

Patent	Title	Filed	Issued
US11,380,942	High voltage battery module with series connected cells and internal relays	Nov 2020	Jul 2022
US11,469,470	Battery module with series connected cells, internal relays and internal BMS	Jan 2021	Oct 2022
US11,563,241	Apparatus and methods for removable battery module with internal relay and controller	Feb 2021	Dec 2022
US11,575,270	Battery module — AC coupled comms and methods (CIP)	Feb 2021	Feb 2023
US11,477,027	Apparatus and methods for management of controlled objects	May 2021	Oct 2022
US11,699,817	Apparatus and methods for removable battery module — system, controllers	Mar 2021	Jul 2023
US11,936,008	Electrical power system with removable battery modules — dissimilar modules	Nov 2021	Mar 2024
US11,876,250	High voltage battery module — dissimilar relays, PLC control bus	May 2022	Jan 2024
US12,046,722	Electrical power system — vehicle and stationary installations	Dec 2022	Jul 2024
US12,136,739	Low cost battery cell monitoring circuit — methods	Dec 2023	Nov 2024
US12,142,737	Electrical power system with removable battery modules	Dec 2023	Nov 2024
US12,278,913	Apparatus and methods for management of controlled objects — linking identifiable records	Mar 2022	Apr 2025
US12,405,309	Low cost battery cell monitoring circuit — ASIC	Jan 2023	Sep 2025

Pending: US18/935,265 — High voltage battery module with 1-phase and 3-phase AC output (filed Nov 2024). Multiple PCT applications in national phase internationally.

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dp@modbatt.com