

## **Extendable Battery Framework—Commoditizing Energy Storage Across Markets**

The Extendable Battery Framework (EBF) is a comprehensive, open standard designed to transform energy storage across multiple sectors, including automotive, marine, aircraft, and stationary applications. By standardizing and commoditizing battery modules, the EBF addresses critical challenges in safety, supply chain management, resource utilization, and sustainability. This whitepaper outlines the urgent need for such a standard, the technical innovations that make it possible, and the far-reaching benefits of its adoption.

We invite all energy ecosystem stakeholders—Policy Makers and Regulators, Manufacturers and Industry Players, Academic and Research Institutions, Investors and Financial Institutions, Environmental and Consumer Advocacy Groups—to review, contribute, and participate.

EBF comprises a comprehensive suite of patented technologies:

- Charge Node: Intelligent, self-contained full voltage module with series-only cell connections, built-in BMS, and internal isolation
- Charge Mesh: Adaptive, resilient power system architecture that collaboratively manages energy sources and loads safely and efficiently
- Digital Twin Linked Control Tokens (LCTs): Secure, transparent and enforceable control tokens for precise tracking and use control

The global energy storage market is experiencing unprecedented growth, driven by the rapid adoption of electric vehicles (EVs), the integration of renewable energy sources, and increasing demand for grid stability. According to recent industry reports, the global EV market is expected to grow at a CAGR of over 20% in the next decade, while grid-scale energy storage installations are projected to triple by 2030. This explosive growth is putting immense pressure on battery supply chains, highlighting the urgent need for standardized, efficient, and sustainable energy storage solutions.

The COVID-19 pandemic and recent geopolitical tensions have further underscored the vulnerabilities in global supply chains, particularly in the battery sector. As countries and companies seek to build resilience and reduce dependencies, the time is ripe for innovative approaches that can transform how we produce, use, and manage energy storage systems. EBF has the potential to serve as the technical basis for this transformation.

## Executive Summary

The Extendable Battery Framework (EBF) presents a transformative approach to energy storage, addressing critical challenges in safety, supply chain management, resource utilization, and sustainability across multiple sectors including automotive, marine, aircraft, and stationary applications.

Key features of the EBF include:

- Standardized, interchangeable Charge Node™ modules
- Adaptive Charge Mesh™ architecture for flexible power management
- Blockchain-based lifecycle tracking and control via Linked Control Tokens

The EBF offers significant benefits:

- Enhanced safety through series-only cell connections and individual cell monitoring
- Improved resource utilization, potentially quadrupling EV support from current battery production
- Facilitation of a circular economy for batteries, simplifying recycling and second-life applications
- Reduction in total cost of ownership for energy storage systems by an estimated 20-30%
- Potential to reduce battery-related greenhouse gas emissions by up to 30%

Implementation of the EBF requires collaboration between government, industry, and other stakeholders. A phased approach over 6–10 years is proposed, starting with standard finalization and pilot projects, progressing to large-scale manufacturing and integration, and culminating in widespread adoption across all target sectors.

The EBF represents a paradigm shift in energy storage, offering a path to a more resilient, efficient, and sustainable energy future. By taking a leadership role in establishing and promoting the EBF, the United States has the opportunity to drive innovation, strengthen domestic manufacturing, and lead the world in creating a truly sustainable circular economy for energy storage.

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## 1. Introduction: The Need for a Universal Energy Storage Standard

As the world accelerates its transition to clean energy, the demand for efficient, safe, and sustainable energy storage solutions is skyrocketing. However, current approaches to battery production and utilization, particularly in the electric vehicle (EV) industry, are creating significant challenges:

- Resource inefficiency: Many EVs carry oversized batteries for daily use, locking up valuable resources.
- Supply chain vulnerabilities: Dependence on specific battery designs creates bottlenecks and geopolitical risks.
- Safety concerns: Conventional battery designs can lead to thermal runaway and other safety issues.
- End-of-life management: Large, model-specific battery packs complicate recycling and second-life applications.

The EBF addresses these challenges by introducing a modular, standardized approach to energy storage that can be applied across various industries.

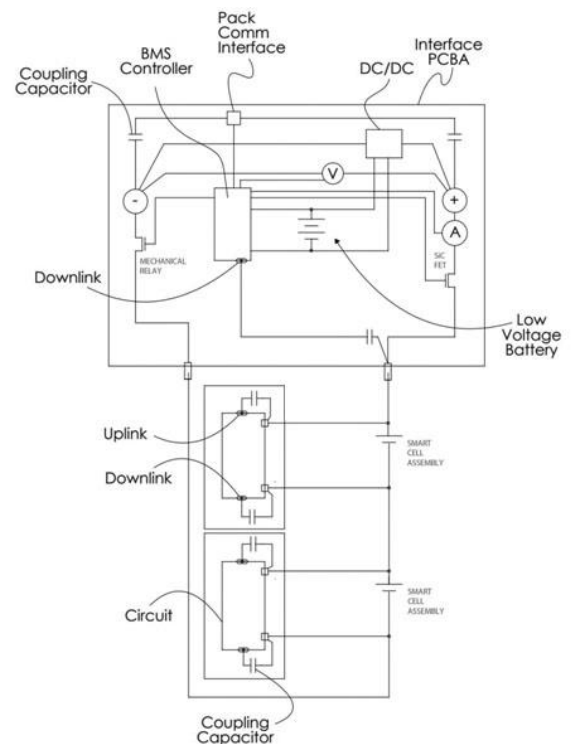
## 2. The Extendable Battery Framework: Core Technologies

The EBF is built on a suite of innovative technologies, protected by nine issued US patents and multiple pending applications. Key components include:

### 2.1 Charge Node™ Modules

Charge Node™ modules are the building blocks of the EBF system. These standardized, self-contained units incorporate:

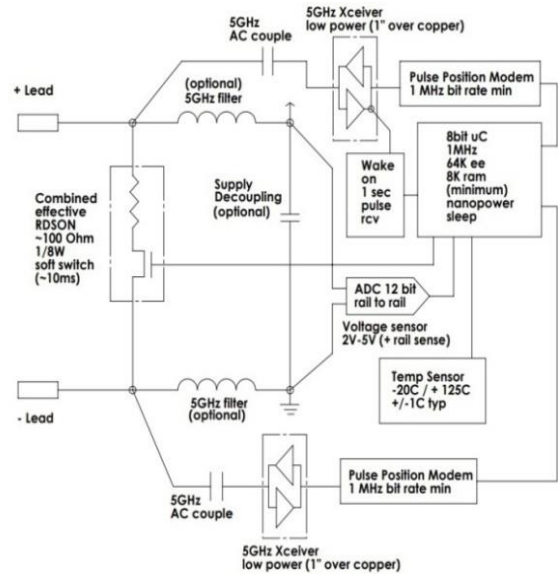
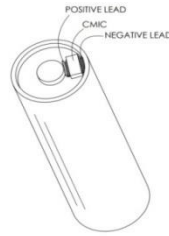
- Series-only cell connections for enhanced safety
- Integrated Battery Management System (BMS)
- Internal relays for complete isolation when not in use
- Control and tracking via Linked Control Tokens (LCTs) for seamless integration, provenance, chain of ownership, prevention of unauthorized use, verified State Of Health (SOH) and lifecycle management



## 2.2 Smart Cell Circuit

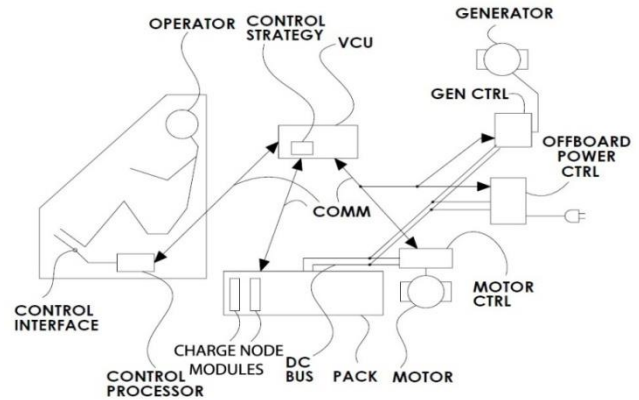
Each cell within a Charge Node™ module is equipped with a smart monitoring circuit that provides:

- Real-time voltage and temperature monitoring
- Individual cell balancing
- Direct communication with the module's BMS



## 2.3 Charge Mesh™ Architecture

The Charge Mesh™ architecture allows for flexible configuration of Charge Node™ modules to meet diverse energy storage needs across different applications. It is a cornerstone of the Extendable Battery Framework, providing a flexible and scalable approach to energy storage. This innovative system allows for dynamic arrangement of Charge Node™ modules to meet diverse energy storage needs across different applications.



Key features of the Charge Mesh™ Architecture include:

### *Adaptive Configuration*

- On-demand pack configuration allows precise tailoring of energy capacity and power output to specific use requirements.
- Modules can be easily added or removed to adjust capacity as needs change, optimizing resource utilization.

### *Cross-Sector Compatibility*

- The architecture is designed to work across automotive, marine, aircraft, and stationary applications, enabling true commoditization of energy storage.
- Standardized interfaces ensure interoperability between different module types and generations.

### *Intelligent Power Management*

- Advanced algorithms optimize power distribution among modules, enhancing overall system efficiency and longevity.
- Real-time load balancing ensures even utilization of modules, extending battery life and improving performance.

### *Fault Tolerance and Redundancy*

- The mesh structure allows for graceful degradation in case of individual module failure, maintaining system operation.

- Redundant communication pathways ensure reliable control and monitoring even in challenging environments.

#### *Scalability*

- From small portable applications to large-scale grid storage, the Charge Mesh™ Architecture scales seamlessly.
- Modular design facilitates easy system expansion or contraction as energy needs evolve.

#### *Safety Enhancement*

- Distributed architecture limits the impact of any single point of failure, enhancing overall system safety.
- Intelligent isolation of modules in case of detected anomalies prevents cascading failures.

#### *Efficient Thermal Management*

- The modular structure allows for more effective cooling strategies, crucial for high-performance applications.
- Distributed heat generation reduces hotspots and improves overall thermal efficiency.

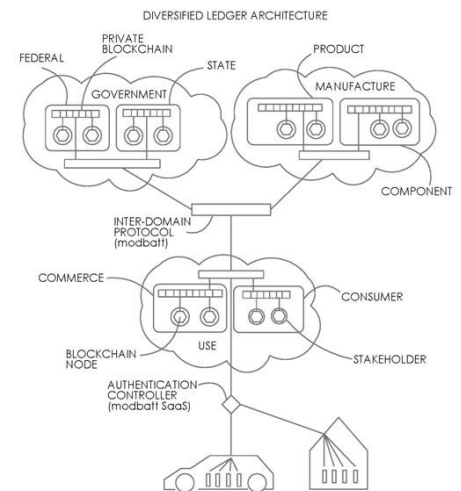
#### *Future-Proofing*

- The architecture is designed to accommodate future advancements in battery technology without requiring a complete system overhaul.
- Software-defined functionality allows for continuous improvement and feature updates.

The Charge Mesh™ Architecture represents a paradigm shift in energy storage system design. By providing a flexible, scalable, and intelligent framework for module integration, it enables the true commoditization of energy storage across multiple sectors. This approach not only optimizes current applications but also paves the way for innovative energy solutions in the future.

## 2.4 Diversified Ledger Architecture and Linked Control Tokens (LCTs)

The Diversified Ledger Architecture is a crucial component of the Extendable Battery Framework, providing a robust system for tracking, controlling, and managing battery modules throughout their entire lifecycle. At the heart of this architecture are Linked Control Tokens (LCTs), which serve as digital twins for each physical battery module.



How LCTs Enable Lifecycle Management:

#### *Unique Digital Identity*

- Each battery module is assigned a unique LCT upon manufacture.
- This digital twin contains critical information about the module's specifications, origin, and current status.

#### *Secure Tracking*

- LCTs use blockchain technology to create an immutable record of each module's history.
- Every transaction, from initial deployment to recycling, is securely logged and verified.

#### *Authenticated Use Control*

- LCTs enable secure authentication when modules are installed in vehicles or other applications.
- This prevents unauthorized use and ensures modules are only used in compatible systems.

#### *Real-time Status Monitoring*

- LCTs continuously update with performance data, charge cycles, and health status of their associated modules.
- This real-time information enables proactive maintenance and optimized performance.

#### *Efficient Transfers and Redeployment*

- When a module changes ownership or is redeployed to a new application, its LCT is securely transferred.
- This streamlines the process of repurposing modules for second-life applications.

#### *End-of-Life Management*

- LCTs facilitate proper recycling by providing a complete history of the module.
- Recyclers can access critical information about the module's composition and use history.

#### *Multi-stakeholder Visibility*

- Different stakeholders (manufacturers, users, regulators) can access appropriate levels of information.
- This transparency enhances trust and enables efficient collaboration across the ecosystem.

#### *Regulatory Compliance*

- LCTs provide an auditable trail that can demonstrate compliance with regulations.
- This feature is particularly valuable for cross-border transactions and in highly regulated industries.

The Diversified Ledger Architecture, powered by LCTs, creates a comprehensive system for managing the entire lifecycle of battery modules. This approach not only enhances the security and efficiency of battery use but also enables new business models and facilitates the creation of a true circular economy for energy storage.

By providing a secure, transparent, and efficient means of tracking and controlling battery modules, the Diversified Ledger Architecture and LCTs play a pivotal role in realizing the full potential of the Extendable Battery Framework across multiple sectors and applications.

While there have been various efforts to standardize battery technologies, the Extendable Battery Framework (EBF) stands out for its comprehensive, cross-sector approach. Unlike proposals that focus solely on form factors or specific chemistries, the EBF provides a flexible architecture that can accommodate diverse battery technologies and applications.

For instance, initiatives like the EU's proposed battery passport focus primarily on traceability and sustainability but do not address the fundamental issues of modularity and cross-sector compatibility. Similarly, EV-specific standards proposed by some automakers lack the broader applicability to other sectors that the EBF offers. The EBF's unique combination of standardized modules, intelligent power management, and blockchain-based lifecycle tracking provides a more holistic solution to the challenges facing the energy storage industry.

### 3. Benefits Across Multiple Sectors

The EBF's standardized approach offers significant advantages across various industries:

#### 3.1 Automotive

- Flexible range configuration
- Improved vehicle performance and efficiency
- Enhanced safety through thermal runaway prevention

#### 3.2 Marine

- Scalable power solutions for various vessel sizes
- Easy battery swapping for extended journeys
- Improved safety for maritime applications

#### 3.3 Aircraft

- Standardized modules for electric aviation
- Weight optimization through modular design
- Enhanced safety for airborne applications

#### 3.4 Stationary Power

- Scalable solutions for grid storage and backup power
- Easy integration with renewable energy systems
- Improved lifecycle management for large-scale installations

#### 3.5 Use Case Scenarios

To illustrate the practical applications and benefits of the EBF, consider the following scenarios:

##### Scenario 1: Urban EV Sharing

A city implements an EV sharing program using EBF-compatible vehicles. Users can rent cars with just enough battery capacity for their needs, swapping modules at automated stations for longer trips. This optimizes resource use, reduces costs, and improves vehicle availability.

##### Scenario 2: Off-Grid Renewable Energy

A remote community uses EBF modules to create a scalable energy storage system for their solar and wind installations. As energy needs grow, they easily add more modules, and when modules degrade, they're repurposed for less demanding applications before being recycled.

##### Scenario 3: Electric Maritime Shipping

A shipping company adopts EBF for its fleet electrification. Standardized modules are swapped at ports, minimizing downtime. The same modules are used for dockside power storage, creating a highly efficient, integrated energy ecosystem.

These scenarios demonstrate the versatility and efficiency of the EBF across different sectors and use cases.



## **4. Addressing Current Industry Challenges**

### **4.1 Supply Chain Resilience**

By decoupling vehicle production from battery supply, the EBF enhances supply chain resilience and supports domestic manufacturing.

### **4.2 Resource Utilization**

The modular approach allows for more efficient use of battery resources, potentially quadrupling the number of EVs supported by current production capacity.

### **4.3 Safety**

The EBF's series-only cell connections and individual cell monitoring significantly reduce the risk of thermal runaway and other safety issues.

### **4.4 Circular Economy**

Standardized modules facilitate easier recycling, second-life applications, and overall lifecycle management.

### **4.5 Environmental Impact**

The environmental benefits of the EBF are substantial and far-reaching. By enabling more efficient use of battery resources, the framework could potentially reduce battery waste by up to 60% compared to current practices. The modular design facilitates easier repairs and replacements, extending the overall lifespan of energy storage systems by an estimated 40%.

Furthermore, the EBF's support for a circular economy could significantly reduce the carbon footprint of battery production and disposal. Preliminary lifecycle assessments suggest that widespread adoption of the EBF could lower the greenhouse gas emissions associated with battery production by up to 30%, primarily through improved resource utilization and simplified recycling processes. These environmental benefits align closely with global sustainability goals and could play a crucial role in mitigating the ecological impact of the rapidly growing energy storage sector.

### **4.6 Economic Implications**

The economic implications of widespread EBF adoption are profound and multifaceted. By standardizing battery modules and enabling a more efficient, circular economy for energy storage, the EBF has the potential to create numerous new job opportunities and business models.

In the manufacturing sector, the shift towards standardized modules could lead to the creation of tens of thousands of new jobs in domestic battery production and related industries over the next decade. The framework's support for easier battery swapping and second-life applications could give rise to new service-based business models, potentially generating billions in new economic activity.

Moreover, by reducing dependency on specific suppliers and enabling more flexible supply chains, the EBF could lead to significant cost reductions in energy storage systems. Early economic models suggest that these efficiencies could result in a 20-30% reduction in the total cost of ownership for EVs and large-scale energy storage installations, making clean energy technologies more accessible and accelerating their adoption.

## 5. Implementation and Industry Adoption

Successful implementation of the EBF will require:

- Government leadership in establishing the standard
- Industry collaboration forums
- Regulatory frameworks to incentivize adoption
- Investment in supporting infrastructure

### 5.1. Regulatory Considerations

Effective implementation of the EBF will require supportive regulatory frameworks. Policymakers could consider several approaches to encourage adoption:

- Standardization Mandates: Regulations requiring new energy storage systems to be EBF-compatible by a certain date.
- Tax Incentives: Offering tax breaks for manufacturers and consumers who adopt EBF-compatible technologies.
- Carbon Credits: Implementing a system where EBF adoption contributes to carbon offset credits.
- Public Procurement: Requiring EBF compatibility for all government and public sector energy storage purchases.
- Research Funding: Allocating grants for further development and refinement of EBF technologies.

These regulatory tools could significantly accelerate EBF adoption and help realize its benefits on a larger scale.

### 5.2. Implementation Roadmap

The implementation of the EBF can be envisioned in several phases:

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

- Finalize EBF technical standards through industry collaboration
- Implement pilot projects in various sectors
- Develop and test supporting infrastructure

*Phase 2 (Years 3–5): Scaling and Integration*

- Begin large-scale manufacturing of EBF-compatible modules
- Integrate EBF into major EV and energy storage products
- Establish a network of module swapping and recycling facilities

*Phase 3 (Years 6–10): Widespread Adoption and Ecosystem Development*

- Achieve significant market penetration across all target sectors
- Fully develop the circular economy for EBF modules
- Continuous refinement of standards based on real-world data

This phased approach allows for iterative improvement and helps manage the complexities of such a significant shift in energy storage paradigms.

### 5.3. Stakeholder Engagement

The success of the EBF relies on active engagement from various stakeholders:

*Manufacturers* will benefit from standardized production processes and more flexible supply chains. They'll need to adapt their production lines and product designs to EBF standards.

*Consumers* will enjoy more flexible and cost-effective energy storage solutions. They'll need to be educated about the benefits and usage of EBF-compatible products.

*Regulators* play a crucial role in creating supportive policies and ensuring safety standards. They'll need to work closely with industry to develop appropriate regulations.

*Recyclers* will see new opportunities in the circular economy created by EBF. They'll need to develop processes specific to EBF module recycling.

*Utilities* will benefit from more flexible and resilient grid storage options. They'll need to adapt their systems to integrate EBF-based storage solutions.

By fostering collaboration among these stakeholders, we can create a robust ecosystem that maximizes the benefits of the Extendable Battery Framework.

#### **5.4. Challenges and Mitigation Strategies**

While the EBF offers numerous benefits, its implementation is not without challenges. Some potential obstacles and their mitigation strategies include:

- **Initial Costs:** The transition to EBF may involve significant upfront costs for manufacturers. This can be mitigated through phased implementation and government incentives.
- **Legacy System Compatibility:** Ensuring compatibility with existing systems could be challenging. Developing adapter solutions and providing clear upgrade paths can address this issue.
- **Stakeholder Alignment:** Getting all industry players to agree on standards could be difficult. Regular stakeholder forums and clear demonstration of benefits can help build consensus.
- **Cybersecurity Concerns:** The connected nature of EBF systems may raise cybersecurity issues. Implementing robust security protocols and regular audits will be crucial.
- **Consumer Education:** Educating consumers about the new system will be vital. Comprehensive marketing campaigns and clear labeling can help increase understanding and adoption.

By proactively addressing these challenges, we can smooth the path for EBF implementation and maximize its benefits.

## **6. Conclusion: A Path to Sustainable Energy Storage**

### **6.1. Future Developments**

The Extendable Battery Framework is designed to evolve with technological advancements. Future developments could include:

- **AI Integration:** Incorporating artificial intelligence for predictive maintenance and optimal module allocation.
- **Vehicle-to-Grid (V2G) Optimization:** Enhancing EBF's capability to support advanced V2G applications.
- **Novel Materials:** Adapting the framework to accommodate emerging battery chemistries and materials.
- **Space Applications:** Extending EBF principles to energy storage solutions for space exploration.

- Quantum-Secure Encryption: Updating the blockchain component to be resilient against quantum computing threats.

These potential advancements ensure that the EBF will remain at the forefront of energy storage innovation for years to come.

## **6.2. Impact and Action**

The Extendable Battery Framework represents a paradigm shift in how we approach energy storage. By standardizing and commoditizing battery modules across multiple sectors, we can address critical challenges in resource utilization, safety, and sustainability. The EBF offers a path to a more resilient, efficient, and environmentally responsible energy future.

As global demand for energy storage continues to grow exponentially, the time to act is now. By taking a leadership role in establishing and promoting the EBF, the United States has the opportunity to drive innovation, strengthen domestic manufacturing, and lead the world in creating a truly sustainable circular economy for energy storage.

## **6.3. Next Steps: Get Involved with EBF**

For Policymakers and Regulators:

- Review the EBF proposal and consider its alignment with current energy and environmental policies.
- Engage in discussions about potential regulatory frameworks to support EBF adoption.
- Contact us to arrange briefings or consultations on the technical and policy aspects of EBF.

For Manufacturers and Industry Players:

- Explore how EBF could integrate with your current and future product lines.
- Participate in upcoming industry forums and working groups on EBF standardization.
- Reach out to discuss potential pilot projects or collaborations.

For Researchers and Academic Institutions:

- Consider research opportunities related to EBF technologies and their potential impacts.
- Engage with us for access to technical specifications and data for academic study.

For Investors and Financial Institutions:

- Evaluate the market potential and investment opportunities presented by EBF technologies.
- Contact us for detailed market projections and business model analyses.

For Environmental and Consumer Advocacy Groups:

- Assess the potential environmental and consumer benefits of EBF adoption.
- Collaborate with us on public education and awareness campaigns.

For All Interested Parties:

- Visit our website at <https://www.modbatt.com> for more detailed information and regular updates.
- Connect and follow us on LinkedIn at <https://www.linkedin.com/company/modbatt/>
- An electronic copy of this document can be found at <https://www.modbatt.com/EBF.pdf>

## **APPENDIX A: Glossary of Key Terms**

**Extendable Battery Framework (EBF):** A comprehensive, open standard designed to transform energy storage across multiple sectors by standardizing and commoditizing battery modules.

**Charge Node™:** Intelligent, self-contained full voltage module with series-only cell connections, built-in BMS, and internal isolation. The building blocks of the EBF system.

**Charge Mesh™:** Adaptive, resilient power system architecture that collaboratively manages energy sources and loads safely and efficiently across various applications.

**Linked Control Tokens (LCTs):** Secure, transparent, and enforceable digital twins for precise tracking and use control of battery modules throughout their lifecycle.

**Battery Management System (BMS):** An integrated system within each Charge Node™ that monitors and manages the battery cells, ensuring optimal performance and safety.

**Diversified Ledger Architecture:** A blockchain-based system that provides robust tracking, controlling, and managing of battery modules throughout their entire lifecycle.

## APPENDIX B: List of key patents

EBF is a broad suite of technologies based on the research and development work carried out by Modular Battery Technologies, Inc. (ModBatt) starting in 2019. It is being proposed as an open industry standard that is royalty-free to manufacturers of fully compliant certified products. An industry non-profit organization Safe Battery Alliance is proposed as the administrator of the EBF standard.

1. US11,380,942 PCT/US21/50518 HIGH VOLTAGE BATTERY MODULE WITH SERIES CONNECTED CELLS AND INTERNAL RELAYS Filed 02-NOV-2020 - ISSUED 7/5/2022
2. US11,469,470 PCT/US21/53798 BATTERY MODULE WITH SERIES CONNECTED CELLS, INTERNAL RELAYS AND INTERNAL BATTERY MANAGEMENT SYSTEM Filed 04-JAN-2021 - ISSUED 10/11/2022
3. US11,563,241 APPARATUS AND METHODS FOR REMOVABLE BATTERY MODULE WITH INTERNAL RELAY AND INTERNAL CONTROLLER Filed 10-FEB-2021 - ISSUED 12/14/2022
4. US11,575,270 PCT/US21/55047 BATTERY MODULE WITH SERIES CONNECTED CELLS, INTERNAL RELAYS AND INTERNAL BATTERY MANAGEMENT SYSTEM Filed 22-FEB-2021 (CIP) - ISSUED 02/07/2023
5. US11,699,817 PCT/US21/54434 APPARATUS AND METHODS FOR REMOVABLE BATTERY MODULE WITH INTERNAL RELAY AND INTERNAL CONTROLLER Filed 31-MAR-2021 ISSUED 07/11/2023
6. US11,477,027 PCT/US21/55813 APPARATUS AND METHODS FOR MANAGEMENT OF CONTROLLED OBJECTS Filed 11-MAY-2021 - ISSUED 10/18/2022
7. US11,936,008 PCT/US21/60860 ELECTRICAL POWER SYSTEM WITH REMOVABLE BATTERY MODULES Filed 17-NOV-2021 - ISSUED 3/19/2024
8. US17/710,759 PCT/US22/24797 APPARATUS AND METHODS FOR MANAGEMENT OF CONTROLLED OBJECTS Filed 31-MAR-2022
9. US11,876,250 PCT/US22/xxx HIGH VOLTAGE BATTERY MODULE WITH SERIES CONNECTED CELLS AND INTERNAL RELAYS Filed 31-May-2022 - ISSUED 1/16/2024
10. US12,046,722 ELECTRICAL POWER SYSTEM WITH REMOVABLE BATTERY MODULES Filed 12-DEC-2022 - ISSUED 7/23/2024
11. US18/092,806 LOW COST BATTERY CELL MONITORING CIRCUIT Filed 3-JAN-2023