EXTENDABLE BATTERY FRAMEWORK – AN OPEN STANDARD FOR EV BATTERIES

Extendable Battery Framework (EBF) is a comprehensive and readily implemented technological solution to the many problems currently associated with increased EV adoption. With present approaches, vehicles traveling less than 40 miles per day are carrying batteries sized to travel 300+ miles. This practice is not a responsible use of a limited resource and will not scale to support 100% electrification, as discussed below. With a thoughtful approach, we can usher in the next phase of EV adoption by making EV batteries a standardized regulated commodity that is part of a sustainable energy infrastructure. EBF enables this transition.

INTRODUCTION

100% electric transportation is a desirable and achievable milestone. It reduces emissions, addresses geopolitical challenges associated with fossil fuels and improves both the efficiency and robustness of the transportation system. To reach this milestone, over 100M electric vehicles will need to be produced each year; therein lies the problem. Under the current regime we are strained to support 1-2M electric vehicles per year. Whether it's related to availability of raw materials, battery production capacity or supply chain disruption – these challenges today will grow in significance dramatically as we increase production.

The biggest challenge to scaling is the industry convention of building EVs with large, monolithic battery packs. Industry has been driven in this direction by three forces:

- Range-based EV credits and homologation requirements
- A lack of readily accessible rapid charging infrastructure
- Consumer range anxiety

Each of these items contributes to the significant inefficiencies of the current system. At present every EV is homologated and delivered with a large battery to meet a specific range, making vehicle production completely dependent on the battery supply chain. In order to scale to 100% EV adoption, it will be necessary to decouple vehicle production and battery resource.

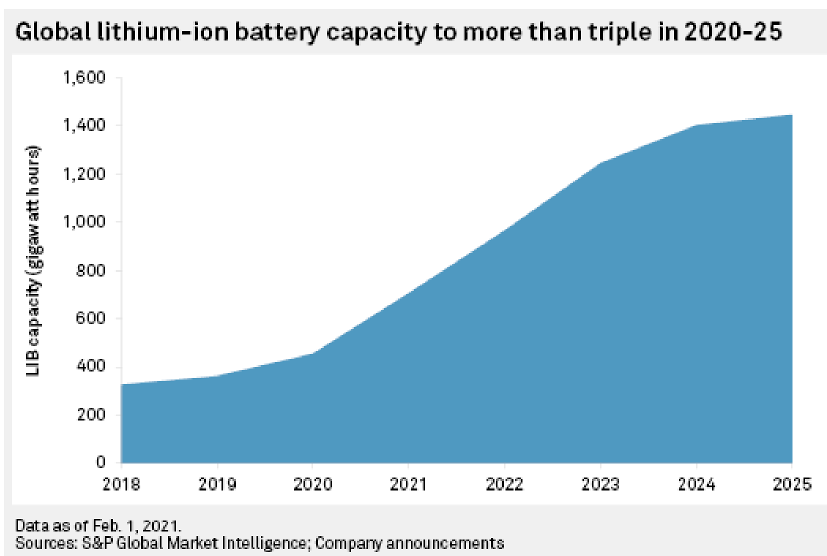
An understanding of the origin of range-based incentives and regulations is helpful here. At industry inception, they were necessary to overcome consumer range anxiety as the biggest barrier to EV adoption. This was needed to jump-start the transition to electric transportation and can be credited with the significant electrification progress made to date. As we move into the next phase, significant investments are now being made into charging infrastructure. Robust charging infrastructure will alleviate much of the range-based narrative and allow us to move forward with a more sustainable approach to EV production. We are now at a transition point where we must look to the future, and where legislative and regulatory decisions made today will have far-ranging impact and consequences as the world transitions to 100% EV transportation.

EBF is a simple and practical technological solution to the scaling problem. It enables optimization and drives the efficiencies essential for future transportation systems. This solution, put forward by Modular Battery Technologies, is available as an open standard that is royalty-free to all manufacturers of vehicles and vehicle batteries. The EBF will transform EV batteries into a lifecycle-managed public energy infrastructure. Together with the investments being made in charging infrastructure, adoption of the EBF standard will enable resilient and efficient transportation systems that are an integral part of a greater circular economy.

RESOURCE UTILIZATION

One of the biggest problems with the current approach is resource utilization. A consumer buying a 300-mile EV will typically use it on 40-mile/day commutes. In doing so, he or she is carrying over 600 lbs of unnecessary battery on every trip. More importantly, the vehicle is locking up a valuable battery resource and thereby keeping several other electric vehicles off the road that could otherwise be utilizing this battery resource. The primary justification is the potential for a longer-range trip. This functionality is desirable, but there is a better way of addressing this contingency – by providing the option to extend the vehicle battery on demand. Adoption of EBF will allow up to 4x as many EVs on the road for a given battery production capacity, as detailed below.

The bottleneck the conventional approach will create is evident when you review production forecasts. Assuming 75-100 KWh for the average battery pack, it will require 75-100 GWh annual production capacity to support every 1 million EVs delivered per year. According to S&P Global Market Intelligence report, the worldwide battery manufacturing capacity is expected to increase from approximately 400 GWh in 2021 to 1,400 GWh in 2025 with vast majority of this production taking place in China.



With current technology and monolithic pack approaches, this capacity will only support 4-6M EVs/year at current rates. It only increases to 14-18M EVs/year worldwide by 2025; far short of the desired 100M vehicles per year necessary for widespread EV adoption. There are further questions raised by reliance on such a critical component sourced from China. The risk of supply chain disruption or difficulty in securing the product is material considering geopolitical uncertainty and the COVID-19 pandemic. We note the EU pushing for $2 billion of investment across 14 projects on the continent to reduce their reliance on China for these same raw material inputs. By more intelligently utilizing this resource, we can enable as many as 4x the number of EVs to come into service for a given battery supply.

Adoption of the proposed EBF open standard is a key component in a robust and resilient transportation system. It allows separation between domestic vehicle production and the battery supply chain supporting it. Sockets to accept standardized battery modules allow for vehicles to be configured on-demand and equipped with only as much battery as is necessary. Vehicles can be manufactured without batteries, which will be added later by the dealer or end-user. This will also reduce the cost of the vehicles, make them more accessible to consumers and reduce or eliminate the need for consumer tax subsidies.

The proposed EBF standard enables this flexibility in a practical, cost effective way. It's compatible with all current and future cell types and chemistries and can be readily implemented now. It can be retrofitted to existing vehicles and will be even more effective in future designs that are optimized to take full advantage of the standard.

SAFETY

There are inherent safety issues with current approaches to building, using and decommissioning EV batteries. Their full consequences are not yet widely apparent due to both the limited number of EVs on the road and the number of EVs reaching end of service life.

The most significant issue is the practice of connecting multiple cells in parallel inside a module. This creates paths for unmonitored and uncontrolled current if one of the parallel-connected cells develops an internal short. When this occurs, all the other parallel-connected cells deliver their full energy into the shorted cell with no means of detecting the condition until a thermal event (fire) occurs. Melting a metal fusible link is the only possibility of stopping thermal runaway in conventional designs. This has been proven to not always be effective, resulting in recent high-profile recalls of EVs.

The proposed EBF open standard eliminates this fundamental safety issue and prevents thermal runaway. This is achieved by requiring that cells inside a module only be connected in series and that each module has two internal relays to fully isolate both terminals when not in use. The configuration assures that there is no unmonitored or uncontrolled current at any time anywhere in the system and that modules are completely safe to handle without specialized equipment or training when removed from vehicle.

SECOND LIFE AND RECYCLING

The large EV battery packs being built today are special use - each designed to fit a specific make, model, and often model year of vehicle. They cannot be used anywhere else. The packs can weigh between 800 and 2,000 lbs and are bulky, requiring specialized equipment to remove from a vehicle. When an EV reaches end-of-life and is retired, removing the pack at the scrap yard is expensive and hazardous due to the fire hazard of parallel-connected cells. It is made even more difficult if the vehicle were crashed or otherwise structurally compromised.

A vehicle designed with a large monolithic battery is also difficult to repair and safely place back into service after minor accidents. This results in unnecessarily scrapping vehicles due to cost and hazards of repair.

Transporting a large, hazardous, potentially damaged battery pack to a recycling center is likewise difficult and expensive. All this means that once millions of EVs start being retired every year, it will become financially impractical to process their large battery packs. This can in turn create an environmental liability that the taxpayer will eventually be forced to fund.

The EBF standard specifies modules that can safely and easily be removed from vehicles, stored and transported. Further, the built-in tracking and condition monitoring features of the modules make them easily convertible to second life in stationary applications once they are too worn for automotive use. The EBF-compliant modules can be sold for residential and commercial power banks, wind farms, solar arrays and the like. After their useful life is exhausted, modules can be safely and economically transported for recycling, with full tracking and confirmation of proper disposal.

CERTIFICATION, COMPLIANCE, USE, AND CHAIN OF CUSTODY TRACKING

One of the challenges in having a commoditized public infrastructure of removable EV battery modules is ensuring safety, interoperability and manufacturer compliance with the standard. The EBF open standard includes a robust, transparent and secure data infrastructure, the Diversified Ledger Architecture (DLA). DLA is comprised of multiple distinct databases operated by private and Government entities, with unique records in each database identifying each module and vehicle for complete and verifiable tracking from manufacture, to use, to recycling.

The data architecture is based on proven open-source designs with secure authentication and authorization levels. The Government-operated database components incorporated in the EBF standard facilitate full regulatory oversight, use tracking, tax assessment and collection. Registrations, chain of custody transactions, safety recalls, trade actions and other Government controls are enabled by the DLA.

PUBLIC INTEREST AND GOVERNMENT ROLE

Today we are on the brink of a fundamental shift in transportation systems, transitioning from fossil fuels to multi-source electric power. The transition promises to reduce and eliminate many harmful emissions and greatly improve efficiency and robustness in the movement of people and goods. However, the existing approaches to building electric vehicles with large monolithic battery packs have the potential to create significant environmental, social, and geopolitical problems. Careful and forward-looking regulatory policy along with strategic investments in public infrastructure are necessary to ensure that the transition to electric transportation fully delivers on its promise while minimizing the potential for negative effects and problems.

The proposed EBF open standard is a comprehensive technological solution addressing the manufacture, use, interoperability, cost-effective recycling, and chain of custody tracking of EV batteries. It gives all levels of Government, from Federal to State and local level, the necessary data, monitoring, and control to enable stewardship over this critical public energy infrastructure component. A transparent and verifiable mechanism is built in to facilitate the assessment and collection of road use, energy use, and other taxes at all levels of Government.

Crafting a regulatory policy that facilitates and incentivizes the adoption of the EBF open standard will help ensure a robust, efficient and environmentally responsible transportation system starting today and long into the future.

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