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Battery Electric Bus Disposal Strategies: Challenges, Opportunities, and Recommendations

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Issue

Transit agencies across the United States have begun transitioning their bus fleets to zero-emission technology to support climate goals, and California is leading the way. In 2019, the California Air Resources Board enacted the Innovative Clean Transit rule requiring that all transit agencies in the state transition to a 100% zero-emission fleet by 2040 and that all transit bus sales be zero-emission starting in 2029. Massachusetts has similar legislation, and Oregon, Indiana, Vermont, and Rhode Island are considering passing comparable laws.

Many agencies have chosen battery electric buses (BEB) as their zero-emission technology to replace aging internal combustion engine buses. BEBs run on large lithium batteries: A single BEB battery pack can weigh more than a ton (2,205 lbs), which is similar to the average size of battery pack for a personal electric vehicle (EV). However, BEBs typically have multiple battery packs found in the rear, bottom, and roof of the bus. Given the tight deadline to transition to zero-emission bus fleets, state governments have offered little guidance to agencies on how to retire BEBs after their 12-year life spans.

To examine this issue, the researcher conducted interviews with different stakeholders in the BEB ecosystem to answer the following questions:

- What assumptions and concerns do transit agencies have about the retirement of BEBs?
- How are BEB manufacturers planning to adapt to the needs of transit agencies?
- What are the future prospects of the U.S. EV battery recycling and reuse market?
- What new policies can be implemented to better prepare stakeholders for the unique challenges of BEB retirement?

Study Approach

The researcher gathered content for this project through interviews with subject matter experts from transit agencies and BEB manufacturers. The transit agencies interviewed included the San Francisco Municipal Transportation Agency (SFMTA), LA Metro, and the Los Angeles Department of Transportation (LADOT). The researcher selected California transit agencies for this study because they have the most experience operating BEBs in the U.S. The researcher also interviewed three of the top BEB manufacturers with influence on the future of North American BEB manufacturing. The researcher also conducted an extensive review of current academic literature, market reports and industry whitepapers about the battery recycling and reuse market.

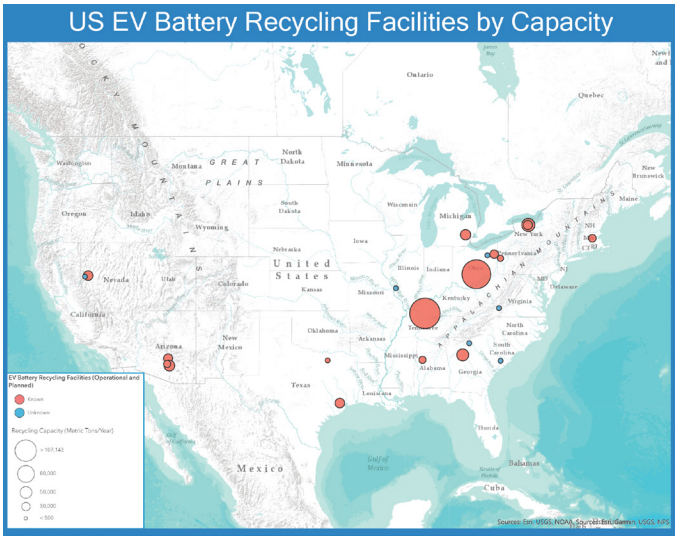

Figure 1. Map of planned and operational U.S. EV battery recycling facilities

Key Findings

Transit agencies assume that disposal strategies for BEBs will mirror those for internal combustion engine buses. In the past, buses have been auctioned off whole, sold for scrap metal, or donated. The researcher identified challenges with those strategies unique to BEB technology. These include high capital infrastructure costs required to operate a used BEB, high transportation costs associated with shipping BEB batteries due to their classification as hazardous waste and the low auction value of recently retired hybrid electric buses.

Transit agencies are enthusiastic about the benefits of battery electric storage systems for BEB fleets. Storage systems at bus depots increase charging efficiencies and backup operational capacity by charging stationary batteries during low-demand periods. The researcher identified used BEB batteries as a potential cost-effective feedstock for storage systems due to their large capacity, even after substantial capacity degradation.

BEB manufacturers showed mixed enthusiasm for providing secondary battery services to transit agencies. The BEB market has experienced significant consolidation in recent years. Due to limited profitability, BEB manufacturers' willingness to offer battery buybacks or construct battery reuse projects varies. In addition, proprietary battery technology and supply chain issues may make future reuse projects difficult.

The EV battery recycling and reuse market is poised to grow significantly due to major private and public investments. Recent domestic sourcing requirements for EV tax credits are also driving this growth. Battery electric storage system projects are also slated to grow in popularity; however, the decreasing costs of new EV batteries reduce the appeal of used batteries as a feedstock. The distribution of recycling centers is not uniform throughout the United States. Most facilities are concentrated in the eastern states, with some facilities in Nevada, Arizona, and Texas (Figure 1).

Recommendations

Transit agencies operating BEBs in their fleets must develop comprehensive battery disposal plans prior to the retirement of their first BEBs. Such a plan should:

- Establish standard levels of capacity degradation for determining reuse or recycle pathways.
- Identify local recycling centers to minimize transportation costs.
- Establish safe storage locations for used batteries.
- Identify internal/external opportunities for battery electric storage systems that could utilize used batteries.
- Select storage technologies that allow for swapping in larger-capacity batteries as technology continues to improve.

Transit agencies with excess used BEB batteries could also transfer ownership to other public agencies interested in establishing storage systems.

National-level standardization of BEB battery technology could facilitate a circular battery economy, reducing disposal concerns. Establishing standardized open-source software for battery management systems (BMS) that allows communication between batteries from different manufacturers would make reuse projects significantly easier to implement. BMSs are essential for managing the recharging and discharging of the multiple battery modules found inside a battery pack. Ideally, standardized BMS software would allow for communication at the battery module level; battery pack-level communication would suffice. Lastly, current battery construction necessitates tedious manual labor during recycling in order to maximize recovered materials. Standardization of screw connections and module junctions, as well as mandating water-soluble adhesives inside the battery, would make recycling these batteries significantly easier.

Criboli, M. (2024). Where Do Batteries Go When They Die? An Assessment of Battery Disposal Strategies for Battery Electric Buses. (Master's capstone, UCLA). Retrieved from: https://escholarship.org/uc/item/1rz9q7z9

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