Micromobility Vehicle Second-Life Battery Applications: Market Inventory and End Use Feasibility Analysis

I. Investigator Team
   a) Christopher Cherry: Professor, CEE
   b) Daniel Costinett: Associate Professor, EECS
   c) Optional ISSE collaboration if available (e.g., Nawei Liu)

II. Budget $50,000 (see budget worksheet and rationale)

III. Proposal Description: 
   Introduction, Objectives, and Rationale:

   Aiding a fast-growing electric vehicle industry, the current administration is aiming to achieve carbon pollution free electricity by 2035. Micromobility vehicles (e.g., e-bikes, e-scooters) have grown faster than EV cars in both the owned- and shared-vehicle markets. More than one million e-bikes were sold last year. E-scooter trips were the fastest growing shared mobility segment, beating out Uber in terms of trips taken in the first year after launch. Little attention has been paid to these vehicles from a battery end-of-life perspective. The e-bike industry launched an industry wide battery recycling program this year. Shared scooter and e-bike operators each have their own battery recovery and recycling systems. This proposed research will inventory and assess the market potential for e-bike and e-scooter battery reuse in both the shared and owned markets. Micromobility is distinct in challenges and opportunities from the EV car market. If viable, this work will be the foundation for successfully competing for future funding through the Department of Energy (DOE) and other agencies.

   The Bipartisan Infrastructure Law (BIL) is the cornerstone of the federal vision for low carbon electrification of transportation and the electricity grid and will invest $7 Billion into the battery supply chain between 2022-2026 to include sustainable sourcing of critical minerals from secondary and unconventional sources, reducing the need for new extraction and mining; sustainable processing of critical minerals; and the end-of-life battery collection and recycling.\(^1\) On this last area of focus, the DOE Office of Energy Efficiency & Renewable Energy on behalf of the Vehicle Technologies Office is providing $60 Million to research and develop electric drive vehicle battery recycling and second use applications. The Vehicle Technologies Office (VTO) works primarily within the scope of electric vehicles recently including e-bikes and other micromobility vehicles. Noting an overlooked battery supply in the micromobility sector, the PIs are starting this research initiative aimed at researching scope of battery market, reverse logistics, capacity/ health testing, and second-life battery applications.

   The environmental sustainability implications of battery reuse are many. Supply and demand disparities can be eased by reserving new (high capacity) battery production for motor propulsion while used (20-40% reduced capacity) batteries can be effectively repurposed for energy storage and other second life applications. Demand for EVs, and stationary energy storage is projected to increase the size of the lithium ion battery market 5 to 10 fold by the end of this decade\(^2\), while second-life extends life can extend 10 years or longer.\(^3\) Research into second life applications will highlight opportunity costs in untapped energy stores and remaining capacity wasted at present.

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1 Infrastructure Investment and Jobs Act, Public Law 117-58 (November 15, 2021)
Technical Approach and Research Plan:

The PIs have extensive industry contacts involved in the manufacture and distribution of micromobility vehicles. Specifically, we have worked on research directly with the Bicycle Product and Supplier Association (part of People for Bikes). That organization just launched a sustainability partnership with call2recycle, a battery recovery and recycling company to manage end-of-life batteries. We also have research partnerships with the largest shared micromobility operators in the world, including Lime, Bird, Spin, and Superpedestrian (Link). In some cases, the PIs have consulted with some of these companies on vehicle sustainability and end-of-life management. Moreover, the lead PI (Cherry) chairs the Society of Automotive Engineers (SAE) Powered Micromobility Vehicle Committee and regularly interfaces with industry members on vehicle sustainability standards. Cherry has past work on battery recovery economics, LCA, and pollution related to micromobility batteries in Asia⁴.

Task 1: Inventory - The primary research objective of this seed grant is to inventory the scale of battery capacity that is likely to be available for second-life applications. Specifically, what are the volumes, specifications, locations, and battery state for both owned e-bikes and shared micromobility (scooter) batteries. This inventory will include approximate volumes of battery capacity by manufacturer (e.g., Bosch⁵ batteries, Lime scooter batteries). The GRA on this project has worked for the largest e-bike manufacturer (Rad Power Bikes) in the USA and has significant industry knowledge. Shared micromobility batteries will vary by manufacturer and vehicle generation. New generation scooters have more advanced battery management systems, longer vehicle lifespans, and more modular battery systems. In all cases, contemporary micromobility battery packs are easily removable by consumers and operators and do not require specialized training or equipment for safe management. Indeed, removable battery packs are a consumer feature of most contemporary micromobility vehicles.

Task 2: Reverse Logistics - The collection or “reverse logistics” of battery packs from individual owners of e-bikes and scooters is challenging between the regulation barriers of shipping (LIBs are Class 9 hazardous material) to gaining cooperation on the individual’s part. While we focus on addressing these challenges, ongoing and past research partners in the e-bike industry (People for Bikes) and shared micromobility companies like Lime, Bird, and Superpedestrian (Link). The consolidation of battery packs to these central locations to stage for bulk shipping allows transportation cost per battery to be low, thus minimizing landed cost of each repurposed battery cell. This task will identify the most promising economic and regulatory approaches to reverse logistics challenges associated with batteries. The GRA’s (Barnhart) degree training and recent career has specialized in supply chain management.

Task 3: Testing - We will explore methods of testing battery health and capacity of whole batteries and individual cells by utilizing batteries (Figure 1) in the micromobility lab, employing health estimation and sensing algorithms, and assessing battery management systems (BMS) by (Costinett)⁶.

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⁴ https://doi.org/10.1016/j.trd.2008.11.003 and https://doi.org/10.1186/1476-069X-12-61 for example
⁵ Bosch was an industry partner on a recent NSF e-bike project.
⁶ Costinett has developed novel BMS systems and patents applied to car-scale battery packs. See https://www.osti.gov/biblio/1568285 and http://doi.org/10.1109/TPEL.2015.2513432
Task 4: Research and Demonstrate Second Life Battery Applications - Research will delve into current and developing applications primarily around energy storage. Energy storage applications can be divided into: 1) behind the meter (BTM) applications that provide backup power to reduce energy cost and provide energy in case of grid outages, and 2) front of the meter applications (FTM) that provide voltage support and storage for excess renewable energy. Average e-bike and scooter battery packs are 250-750 Wh so our initial research and demonstration will focus on smaller scale residential and commercial energy storage solutions or microgrids with capacity in the 10-15 kWh range.

Collaboration and Proposal Development Plan:

The PIs will be from the CEE (Cherry) and the EECS (Costinett) departments. They have collaborated through the LEVER institute (www.micromobilityresearch.com) that is led by Cherry. For external partners, we intend to engage with People for Bikes, particularly with their volunteer e-bike recycling program, and also micromobility industry partners (specifically ongoing partners Lime, Bird, Link). We are also interested in building direct collaboration with ISSE researchers. The PIs have verbal commitments from some of the main micromobility operators to collaborate on this project along with e-bike industry (People for Bikes); all longtime collaborators.

The main target for funding will be DOE. We are currently part of a small micromobility working group with researchers at NREL to identify funding opportunities in micromobility through DOE and upcoming NOFO’s. It is clear by the DOE funding opportunity announcement that further funding is available, particularly if the case for micromobility battery management is elevated. A current FOA (DE-FOA-0002680) focuses on battery second life for cars. We will be well-positioned to respond to future FOAs along a similar topic. The VTO has recently been open to transportation solutions that include micromobility modes. The PI has won grants from NSF CBET’s Environmental Sustainability (unsolicited) program and could aim for that program again.

Cherry is leading a USDOT UTC Tier 1 proposal (through CTR) on Micromobility. This work could lead to improved opportunities for collaboration between ISSE and CTR if both are funded.

Dissemination Plan:

This research will be disseminated through at least one journal publication on the inventory and supply chain aspects of micromobility batteries. Sustainability professionals and members of the shared and owned micromobility industry, particularly as producer-responsibility regulations and expectations are enacted. The industry partners will integrate the findings of this research into their battery management and their cradle to grave lifecycle analysis and strategies.

Timeline for Deliverables:
Q1: Inventory battery types for E-bike industry and shared micromobility industry
Q2: Conceptualize reverse logistics framework and battery pack economics
Q3: Conceptualize battery pack testing, consolidation, and battery management protocols
  Identify use cases and applications of second life battery packs
Q4: Draft journal article and target proposal submission

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