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Research Notes

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NOVEMBER 2024

Project Title: Battery Technologies for Current and Future Heavy-Duty and Transit Electric Vehicles

Task Number: 3382

Start Date: December 1, 2023

Completion Date: December 31, 2024

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Battery Technologies for Current and Future Heavy-Duty and Transit Electric Vehicles

Develop a guide to better understand the current and future battery technologies for heavy duty vehicles and transit vehicles.

WHAT IS THE NEED?

California Air Resources Board (CARB) mandated the Innovative Clean Transit (ICT) regulation. CARB's ICT regulation requires transit agencies to purchase 100% zero-emission vehicles (ZEV) by 2029, with ZEVs required to comprise increasing percentages of annual new bus purchases until then, and fully convert their fleets to ZEVs by 2040. California transit agencies are therefore spending hundreds of millions of dollars on purchasing such ZEVs, which today cost approximately twice as much as their Compressed Natural Gas (CNG) counterparts. These vehicles are run on battery and hydrogen fueling systems that are constantly evolving, seeing new and exciting technologies invented at a rapid pace. Some of these technologies are steady state batteries and other forthcoming advances could extend vehicle range, lengthen battery life, and shorten charging times sufficiently to make battery-electric buses a feasible option for a broader range of transit services, such as routes that are longer or traverse hilly terrain. At the same time, the cost of hydrogen has plateaued after years of falling prices. Transit agencies therefore are facing a lot of uncertainty as to which type of bus to purchase, with this choice deciding how substantial amounts of funding will be spent and having a significant impact on the future of their services.

WHAT ARE WE DOING?

The first major task in this project will be a comprehensive review of the literature pertinent to the development of high energy density batteries. The review will consider primary developments in the U.S. and China. The researchers will

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also attempt to obtain some prototype high energy density cells to test. Those tests would be done in the Green Technology lab in the UC Davis Mechanical Engineering Department Testing to gain a better understanding of the newer battery technology. Then, the performance of the advanced batteries will be modeled starting from the physical dimensions of the cells and properties of the materials in the electrodes of the cell. Finally, electric vehicle simulations will be run for medium-duty (MD) and heavy-duty (HD) vehicles that use the advanced batteries. The characteristics the batteries used in the simulations will be based on the results of the first major task.

The second major task in this project is to review all current electric trucks and what is in production in the near term and projected long term, identify cost issues, operations that electric trucks will be able to perform given the constraints of range, charging times, location of charging stations, etc. This portion will also plan to review comparisons with the use of current diesel trucks with respect to costs, performance, infrastructure support, etc. There will be a review of low-cost battery technologies which despite performance limitations may be suitable for many transit vehicle operations. The next task will be identifying truck routes in the Southern California Los Angeles county region and use them as an example to identify the infrastructure requirements. We plan to review HD electric vehicle routing and scheduling approaches which can be used to satisfy the constraints imposed by current and advanced battery technologies to minimize operating costs. Finally, the researchers will identify methods to make changes to routing decisions to minimize overall cost under the constraints of charging station locations, charging times, and range based on the results of the second major task.

WHAT IS OUR GOAL?

The goal of this research is to provide a summary of the role of advanced batteries in the design, operation and charging, and cost of heavy-duty trucks from 2025 through 2040. The research will also address how the new advanced battery technologies impact the versatility and costs of each vehicle type, and which types of heavy-duty vehicles will benefit most from and be more suitable for use of the advanced batteries.

WHAT IS THE BENEFIT?

The product will be a report that answers some questions regarding zero-emission vehicles and outlines which types of technologies are more appropriate in which service environments as compared to others. It will give detailed explanations of the cutting-edge technologies and how they may impact the capabilities of and market for electric buses.

This resulting research report will hopefully give a better understanding of the medium-duty and heavy-duty electric technology that will be able to translate to transit. The benefit might lead to future research and help drive the conversation with policy makers, transit agencies, and the transit research community.

WHAT IS THE PROGRESS TO DATE?

Task 1: The research team has prepared a draft literature review and is currently working on completing it. They have developed a roadmap for advanced battery development, reviewed lithium-ion cathodes (lithium nickel manganese cobalt oxide, nickel-cobalt-aluminum, lithium cobalt oxide), silicone-carbon anodes, lithium metal, solid-state batteries, rechargeable lithium-air, sodium-ion, and battery manufacturing and production scale-ups. They have received over 1,000 slides of solid-state battery information and data from Shmuel De-leon Energy, Ltd, Israel that they are processing.

Task 2: The research team is still trying to obtain some prototype high energy density cells to test. They have contacted Group 14 in Seattle to obtain a new silicone-carbon material, Prologium in Taiwan to obtain some of their solid-state cells that use a ceramic electrolyte (these are close to large scale production) and will be testing a superbattery from Skeleton Technologies in Germany. This device can be charged and discharged in 60 seconds. It has an energy density of 65 Wh/kg, power density over 1 kW/kg, and cycle life of 50,000 cycles.

Task 3: The performance of the advanced batteries will be modeled starting from the physical dimensions of the cells and properties of the materials in the electrodes of the cell. The analysis will consider lithium with silicone, a lithium metal anode and a solid-state separator, and metal anode (zinc, magnesium, lithium) batteries with air-electrodes.

Task 4: Electric vehicle simulations will be run for MD/HD vehicles that use the advanced batteries. The characteristics the batteries use in the simulations will be based on the results of Task 3. We will include in the simulations transit buses, MD delivery trucks and long-haul trucks with ranges of 500-600 miles. We will also simulate selected California Department of Transportation (Caltrans) vocational trucks using the advanced batteries. Advisor simulations of sec-by-sec operation will be performed for appropriate driving cycles for each type of electric vehicle.

Task 5: This task is going to be a detailed evaluation of a zero-emission cement truck mixer.