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Research Notes

Hydrogen or Electric Transit Vehicles – Why not Both? Investigating the Economic Viability of Mixed-Technology Zero-Emission Bus Networks

The research is to assist transit agencies in determining the most cost-effective mix of battery electric buses and fuel cell electric buses for their zero-emission bus fleet.

Modal

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Project Title: Hydrogen or Electric Transit Vehicles – Why not Both? Investigating the Economic Viability of Mixed-Technology Zero-Emission Bus Networks

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WHAT IS THE NEED?

In the transit bus industry, there is a significant movement towards transitioning from conventional fossil-fuel vehicles to zero-emission buses (ZEBs), which encompass both fuel cell electric buses (FCEBs) and battery electric buses (BEBs). This transition has been identified as an effective strategy for reducing greenhouse gas emissions in the transit sector. In December 2018, the California Air Resources Board (CARB) implemented the Innovative Clean Transit (ICT) regulation, mandating that transit fleets begin transitioning to ZEBs starting in 2023. Since then, several transit agencies in the United States (U.S.) have planned or completed full-scale transitions to ZEBs. However, these transitions pose several challenges to transit fleets, ranging from high upfront technology and infrastructure costs to a lack of operational knowledge of new technologies, fuel (Hydrogen) cost and availability, maintenance, and upkeep. A key concern for these agencies is choosing between FCEBs and BEBs. This study examines factors influencing this decision for U.S. networks and explores hybrid-network solutions that achieve cost-effective transitions by leveraging both technologies.

Each technology has its own set of advantages and disadvantages compared to each other and to traditional fossil-fueled buses. BEBs generally come with a lower upfront cost compared to FCEBs, with some companies even offering lease options to alleviate the burden on agencies. The range of BEBs varies widely, from smaller models with shorter driving ranges to larger models equipped with battery

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packs comparable to those of FCEBs, although neither currently matches the range of fossil-fueled buses. Deploying pilot projects with BEBs is relatively straightforward since the supporting infrastructure is scalable. However, transitioning from pilots to full-scale deployment has posed challenges due to infrastructure costs and grid connection issues faced by transit agencies.

In contrast to BEBs, FCEBs offer more flexibility in route assignments, operating more similarly to traditional fossil-fueled buses, especially in terms of refueling. Typically, FCEBs require just one approximately ten-minute refueling session per day to fulfill route service requirements. However, FCEBs are more expensive than BEBs due to their less mature technology. Moreover, the current infrastructure for hydrogen production and distribution is inadequate to support a large-scale transition to FCEBs. This lack of infrastructure poses challenges for networks considering the deployment of FCEBs soon, as they must choose from a limited selection of costly solutions.

WHAT ARE WE DOING?

A comprehensive literature review will be conducted that will summarize key findings from existing studies on bus fleet transitions, focusing on optimizing fleet composition and infrastructure requirements. This review will also identify best practices, challenges, and potential solutions for fleet electrification, culminating in a report that compiles key references and their relevance to the ZEB transition. The literature review will also focus on gathering comprehensive insights into the operational costs of training and maintenance for both BEBs and FCEBs. This research will seek to identify documented challenges and solutions in managing mixed fleets and will inform the assumptions used in the optimization model. It will also identify transit agencies operating mixed zero-emission vehicle (ZEV) fleets using public reports, databases, and agency disclosures, with additional input from stakeholders. Additionally, it will compile research on challenges related to mixed medium- and heavy duty ZEV fleets, including operations, infrastructure, and costs.

The key part of the research will be to develop an optimization model to minimize the total cost of transitioning the transit bus network to a 100% ZEV fleet, comprising three main components: capital costs, operating costs, and mixed-operation costs. The model will then be used to compare the cost-effectiveness of fuel requirements with four scenarios. The scenarios are based on all Internal Combustion Engine Vehicle (ICEV) Buses, all BEBs, all FCEBs, and a mixed fleet of BEBs and FCEBs.

These scenarios allow for a comparison of the costs associated with decisions about how to meet the energy needs of a transit network during a ZEB transition. ICEV buses will be modeled as the base scenario so that they can be used as a validation and reference point. The analysis will provide a detailed comparison of the cost-effectiveness and feasibility of different fleet compositions and operational strategies, presented in a report with insights into the most viable options for ZEB transitions. A sensitivity analysis will be conducted to model future cost reductions, particularly for FCEBs, reflecting the expected decrease in capital costs as the technology matures. This analysis will consider both current and projected future costs for FCEBs and BEBs.

WHAT IS OUR GOAL?

This study aims to investigate the economic feasibility of ZEB and ZEB-hybrid fleets and what circumstances could allow for fair-market and subsidized-market competitiveness. More specifically, by developing a model applicable to various transit networks and using standardized, publicly available data, this study seeks to assess the cost-effectiveness of mixed-technology solutions for deploying ZEBs. The developed model can assist transit agencies to make more informed decisions about deploying these two technologies and their respective energy supply infrastructure in a cost-optimal manner.

WHAT IS THE BENEFIT?

At the end of the study, a comprehensive and user-friendly fleet composition optimization tool will be developed based on the optimization model, designed to assist transit agencies in determining the most cost-effective mix of BEBs and FCEBs for their fleets. This tool will be functional and tested with feedback from stakeholders to ensure its practicality. Additionally, the fully documented application source code, along with documentation, compiler, copy of the executable, and a user guide, will be provided as well as a detailed final report that summarizes all findings, including the results of the scenario analyses. This report will provide actionable recommendations for transit agencies and policymakers.

WHAT IS THE PROGRESS TO DATE?

During the current reporting period, the project team completed the initial literature review, documented in Deliverable 2A (Annotated Bibliography) and Deliverable 2B (Literature Review Report), covering zero-emission transit bus technology performance, infrastructure costs, hydrogen supply pathways, workforce training, and mixed-fleet optimization.

The review informed the identification of California transit agencies planning or operating mixed battery emission bus/fuel cell electric bus fleets under their California Innovative Clean Transit Rollout Plans. The team has compiled a targeted contact list and is actively reaching out to solicit agency participation in the stakeholder engagement workshops. Early-stage data collection and model development are also underway, using the cost and performance parameters from the literature review as initial baseline assumptions pending agency-specific data from stakeholder engagement.