Life Cycle Assessment of Environmental and Economic Impacts of Deploying Alternative Urban Bus Powertrain Technologies in the South Coast Air Basin

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Project Objective

The objective of this project is to perform a life cycle characterization of greenhouse gas emissions, criteria pollutant emissions, and costs of conventional and alternative urban bus powertrains, for the purpose of identifying the benefits and needs for further improvements in these characteristics to better enable the use of alternative urban bus powertrains.

Problem Statement

The expanded use of public transit such as buses in urban settings can be important in supporting California's criteria pollutant and greenhouse gas emissions reduction goals, however, it is important that this expansion does not increase demand and subsequent impacts from fossil fuel use. Alternative powertrain buses such as battery electric buses (BEBs) and fuel cell electric buses (FCEBs) provide a means for decoupling expanded urban bus usage from fossil fuel dependence, however these buses have different operating constraints, costs, and life cycle environmental impact profiles compared to conventional buses. These must be understood in order to identify needs for better enabling the use of these technologies.

Research Methodology

This project leveraged material composition and life cycle inventory data for each bus type to perform a life cycle analysis of the environmental impact profile of BEBs and FCEBs in comparison to conventional buses using the Brightway2 LCA platform and the ReCiPe 2016 framework. The emissions and energy consumption were determined based on simulating drive cycles for each bus type specific to the South Coast Air Basin, representing the Orange County Transportation Authority and the UC Irvine Anteater Express. Finally, the total cost of ownership for each bus type by component was calculated and compared.

Results

For the comparison of environmental impacts, this project found that both BEBs and FCEBs reduced environmental impacts across all indicators relative to conventional buses, but the extent of these benefits depends strongly on the emissions intensity of the electric grid used to produce electricity or hydrogen fuel. An example is shown for Global Warming Potential benefits in Figure 1. When using hydropower, the benefits of BEBs and FCEBs are comparable to each other and significant compared to conventional buses. When using an electric grid mix that contains fossil fuels, BEBs tend to have better benefits, but overall benefits relative to conventional buses are reduced. This highlights the importance of using fossil fuel free energy inputs to fuel alternative powertrain buses.

For the comparison of total cost of ownership (Figure 2), alternative powertrain buses are currently slightly more expensive than conventional buses. This difference is largely caused by the higher initial purchase price of BEBs and FCEBs relative to diesel and natural gas buses, as well as the new infrastructure costs needed to support these relatively new bus types. The other components of the total cost of ownership are generally comparable between the different bus types. Moving into the future – economies of scale and technological advancements, as well as the proliferation of alternative vehicle infrastructure for supporting zero emission vehicles in other sectors, can serve to reduce the total cost of ownership and render it the more affordable option compared to conventional bus types.

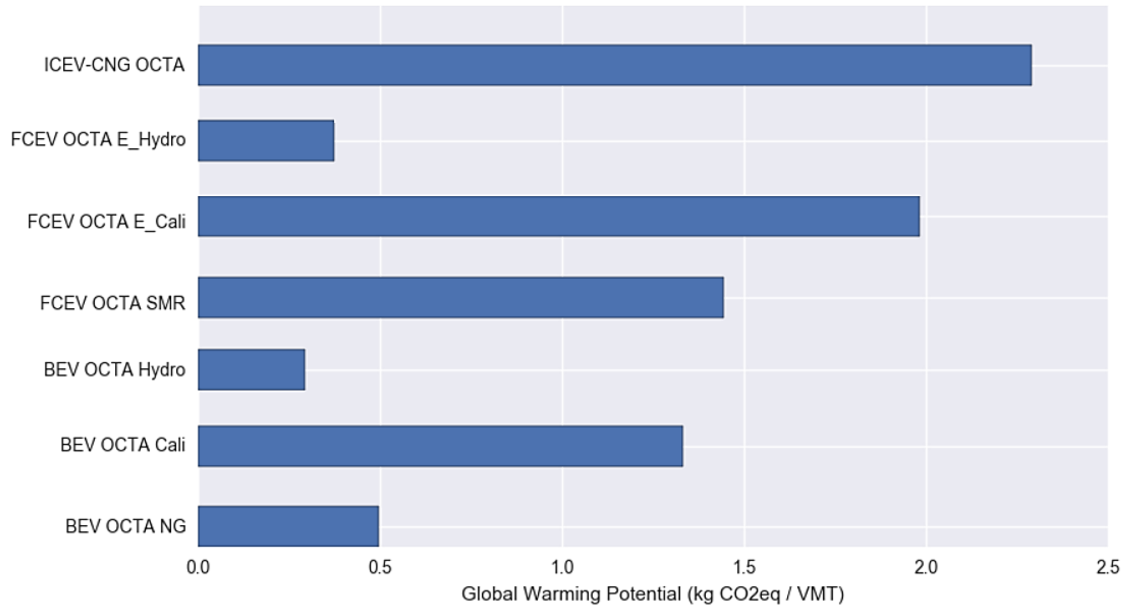

Figure 1. Global Warming Potential for Different Bus Types using Different Fuel Production Pathways

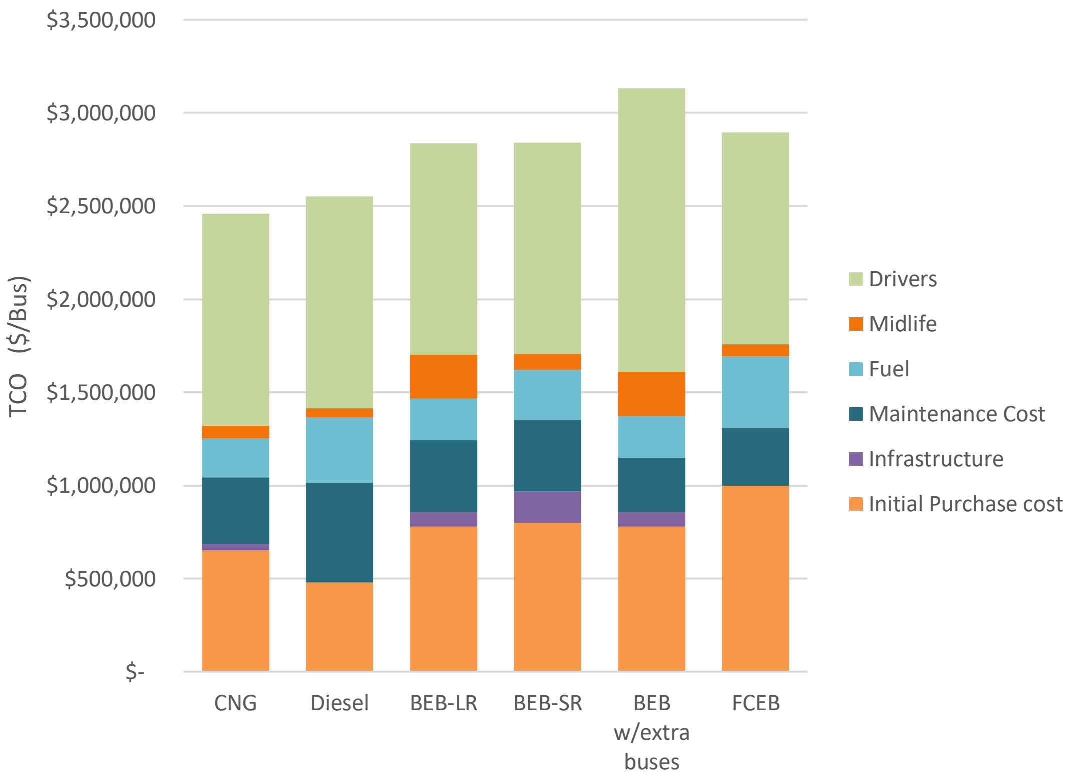

Figure 2. Total Cost of Ownership of zero-emission and conventional-fuel buses