# Electrifying a Bus Network

A UVX Case Study

Hayden Atchley

13 December 2022

## Introduction

Recently, electric vehicles (EVs) have gained significant public awareness and various levels of support. Generally the adoption of EVs is seen as a good thing, as there are many clear benefits over internal combustion engine (ICE) vehicles. Perhaps the most obvious is that EVs have no emissions, since they are driven entirely by electric motors. Another important advantage is efficiency: while an ICE vehicle will convert around 20% of the fuel's stored energy into motion (Department of Energy 2022b), EVs are around 90% efficient (Department of Energy 2022a). Electric motors are also efficient over a large range of rotational speeds, whereas ICEs are only efficient at a much narrower range of speeds. Because of these reasons, several transit agencies have deployed battery-electric (BE) buses in their fleets <><><>.

However, EVs are not always universally superior to ICE vehicles. One major consideration is that the range of EVs is lower than may be practical in certain applications. Though EVs are more efficient at converting stored energy into motion, gasoline and diesel are more energy-dense than batteries, and so that energy becomes harder to store in an EV by comparison. What truly makes this a concern is the time required to recharge an EV's battery compared to the time to refuel an ICE vehicle's tank. Though there are relatively fast charging standards available, as of now none of them are nearly as fast as refueling at a gas pump (Environmental Protection Agency 2022), especially for a vehicle as large as a bus.

Another major consideration is the source of electricity used to power EVs. While EVs themselves have no emissions, electricity generation often does. In fact, in areas such as Utah where coal is the major source of electricity <><><>, the per-mile emissions of EVs (accounting for electricity generation) can be higher than of hybrid vehicles <><><>. However, especially with recent legislation such as the Infrastructure Investment and Jobs Act <><> and the Inflation Reduction Act <><>, electricity generation is on the path to becoming greener overall.

This paper, therefore, is not focused on comparing vehicles based on emissions. Rather, the focus is to provide a list of considerations that a transit agency should take into account when migrating to a BE bus fleet. Additionally, this paper presents an application of these considerations to Utah Transit Authority's (UTA's) Utah Valley Express (UVX) bus line as a case study.

## Background

Any transit agency operating a bus network will need to take into account several considerations. -fuel cost -fleet size -routing -fleet rotation? (addt'l for ev buses) -charging

Both electric and fuel-powered vehicles have limited range, but it is generally much faster to add fuel than to recharge a battery. Because of this, charging considerations become paramount in any deployment of BE buses. There are currently several options available for EV charging. Level 1 and 2 charging as well as DC fast charging use a plug-in connector to transfer power (Environmental Protection Agency 2022), and other options such as wireless inductive charging exist and are being developed upon (Klontz et al. 1993; Panchal, Stegen, and Lu 2018). Perhaps somewhat unique to buses are overhead chargers, where a rail on the bus extends to make contact with an overhead power supply at a bus stop (or vice versa, as in the OppCharge standard <><><>).

While the level 1 and level 2 EV charging standards work well for personal vehicles, which sit idle for large parts of the day, these are relatively slow standards. A personal vehicle can expect about 25 miles of range per hour of level 2 charging (Environmental Protection Agency 2022). A bus, which weighs several times that of a personal vehicle (Nealon and Kempken 2022), would get a fraction of that range. Many bus routes run for most of the day, and even with an 8-hour daily level 2 charge a bus may only gain about 50 miles of daily range. A city bus running for 12 hours per day with an average speed of 12mph would need more than double that. Exclusively using level 2 charging would in many cases necessitate at least a doubling of fleet size to maintain those routes, which is impractical.

DC fast charging, on the other hand, can charge vehicles on the order of 10 times as fast as level 2 charging (Environmental Protection Agency 2022). Depending on the implementation, this standard can charge as fast as 350kW. This is certainly fast enough to fully recharge an electric bus overnight, so seems to be a viable way to solve the charging problem. However, standard plug-in DC fast charging overnight may not be enough on its own due to battery sizes. EV range is directly a function of battery pack size, and so a larger pack will provide more range. A typical electric bus with a battery pack size of 350kWh and energy consumption of about 3kWh per mile would have around 100 miles of range (Schabert 2022). This may be sufficient for many routes, but depending on the fleet size it may not be viable to install enough charging stations to fully recharge every vehicle every day.

Overhead charging allows chargers to be installed almost anywhere, so buses would potentially be able to charge mid-route. While this could also be accomplished with plug-in charging, the additional burden on the driver in exiting the vehicle to access the charger adds delay. By contrast, the OppCharge overhead charging standard is automatic and charges at up to 450kW <><><>, so 6 minutes of charging can add 10–20 miles of range to a 3kWh per mile bus. For a local bus route, this could enable short charging sessions at each end of the route during the day, reducing the need for overnight charging.

Wireless inductive charging has the potential to obviate "charging stops" entirely. This technology involves installing…. Inductive charging tends to be much slower than the other options at around 80kW <><><>, but the ability to charge while in operation can mitigate this concern.

## References


Department of Energy. 2022a. "Where the Energy Goes: Electric Cars." 2022. https://fueleconomy.gov/feg/atv-ev.shtml.

———. 2022b. "Where the Energy Goes: Gasoline Vehicles." 2022. https://fueleconomy.gov/feg/atv.shtml.

Environmental Protection Agency. 2022. "Plug-in Electric Vehicle Charging | US EPA." 2022. https://www.epa.gov/greenvehicles/plug-electric-vehicle-charging.

Klontz, K. W., A. Esser, R. R. Bacon, D. M. Divan, D. W. Novotny, and R. D. Lorenz. 1993. "An Electric Vehicle Charging System with 'Universal' Inductive Interface." *Proceedings of Power Conversion Conference - Yokohama 1993*, 227–32. https://doi.org/10.1109/PCCON.1993.264219.

Nealon, Lizzie, and Maggie Kempken. 2022. "Average Car Weight." 2022. https://www.bankrate.com/insurance/car/average-car-weight/.

Panchal, Chirag, Sascha Stegen, and Junwei Lu. 2018. "Review of Static and Dynamic Wireless Electric Vehicle Charging System." *Engineering Science and Technology, an International Journal* 21 (October): 922–37. https://doi.org/10.1016/J.JESTCH.2018.06.015.

Schabert, Alexander. 2022. "Electric Bus Range, Focus on Electricity Consumption." 2022. https://www.sustainable-bus.com/news/electric-bus-range-electricity-consumption/.