ELECTRIC BUS BASICS

FACTORS CONTRIBUTING TO INTEREST IN ELECTRIC BUSES

- Transportation - 28.5% of U.S. energy consumption.
- Petroleum accounts for 91.5% of that consumption.
- Buses consumed 98,000 barrels of petroleum per day, resulting in the consumption of 413 million gallons of diesel in a year.

FACTORS CONTRIBUTING TO INTEREST IN ELECTRIC BUSES

- 4 million tons of carbon dioxide emissions in a year
- 22.26 million tons of carbon monoxide
- 4.49 million tons of nitrogen oxides
- 2.16 million tons of volatile organic compounds
- 470,000 tons of particulate matter emissions

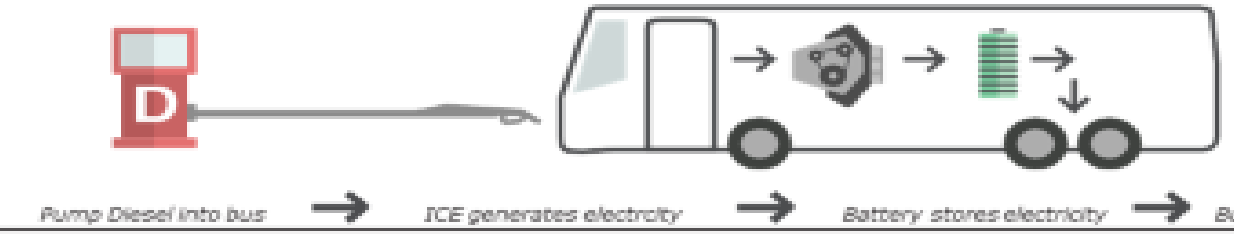
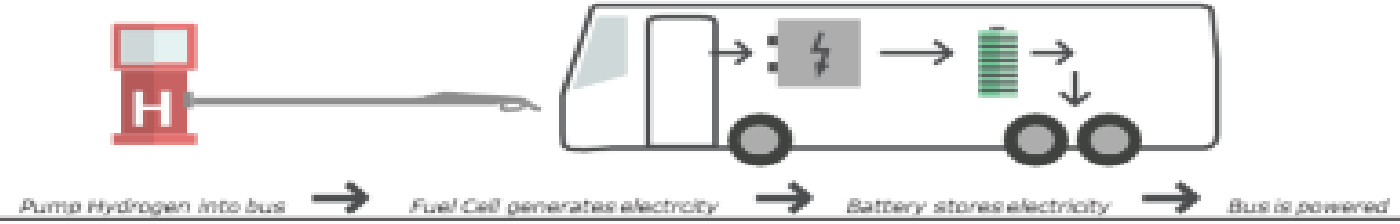
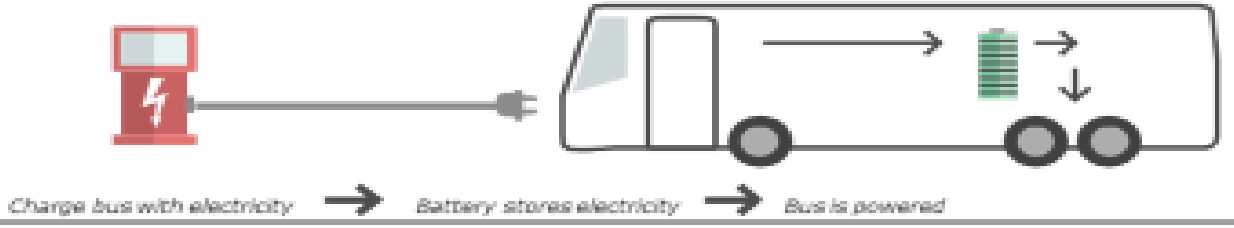
FACTORS CONTRIBUTING TO INTEREST IN ELECTRIC BUSES

The Altoona Bus Research and Testing Facility

- Average fuel economy for the electric bus (20.5 miles per diesel gallon equivalent [MPDGE]).
- The average for CNG (4.8 MPDGE).
- The average for hybrid bus (5.84 MPDGE).

FACTORS CONTRIBUTING TO INTEREST IN ELECTRIC BUSES

Reducing emissions and reliance on petroleum by transportation sector is seen as an important step in realizing health benefits, reducing global warming effects, improving national security interests, and creating jobs.

TYPES OF ELECTRIC BUSES	
HYBRID ELECTRIC BUS	
FUEL CELL ELECTRIC BUS	
BATTERY ELECTRIC BUS	

HYBRID ELECTRIC BUSES (HEB)

ADVANTAGES

Smaller technology changes, HEBs - comfortable transition for many, rely on much of the same technology as Diesel Buses (DB).

DISADVANTAGES

Capacity, increased weight decreases vehicle capacity due to maximum axle weight limits.
Reliability, battery capacity and useful life may be reduced by extreme temperatures.

FUEL CELL ELECTRIC BUSES (FCEB)

ADVANTAGES

Low tailpipe emissions, almost no criteria pollutants are created.

Increased availability, theoretically, less maintenance due to the absence of internal moving parts.

Customizable power output, fuel cells can be coupled to easily customize the power output.

Long range, hydrogen fuel cell vehicles do not suffer from the same range issues that currently restrict battery electric vehicles .

FCEB DISADVANTAGES

Infrastructure, extensive hydrogen storage and refueling infrastructure.

High cost, FCEBs are around seven-times more expensive than both DBs and electric buses and the cost of constructing a hydrogen refueling station is approximately $5 million.

System management, fuel cell components are very sensitive to heat changes, water concentration levels, and impurities within the hydrogen fuel.

FCEB DISADVANTAGES

Hydrogen density, hydrogen is less energy-dense than diesel, so more storage space is required to match the range of diesel buses.

BATTERY ELECTRIC BUSES (BEB)

ADVANTAGES

No tailpipe emissions, very low overall emissions if renewable energy sources are used.

Efficient, very high vehicle energy efficiency, the electric motor Is simpler to maintain due to less moving parts.

Reduced operating cost, based on current electricity prices, cost of operating BEBs would be much cheaper than DBs. This is true even if the current fuel tax was added to the electricity price.

Quieter to operate.

BATTERY ELECTRIC BUSES

DISADVANTAGES

Low distance range, current BEBs are limited to a reasonably small distance range. This can be reduced by rapid-charging on-route.

Heavy, current batteries are heavy, adding to the weight of the bus, potentially limiting what roads they would be able to operate on.

BATTERY ELECTRIC BUSES

DISADVANTAGES

Capacity, increased weight means the vehicle capacity is reduced to stay below maximum axle weight limits.

Infrastructure, require charging infrastructure (either at depots, bus stops, or both) resulting in higher capital costs.

Complicated Utility Rate Structures, leading to high electricity rate charges including demand charges.

The Three Main Components of a BEB are;

- Bus Configuration
- Battery Storage System
- Charging Infrastructure Known as Electric Vehicle Supply Equipment or EVSE

BUS CHARGING METHODS

BEBs are “fueled” through charging. Three types of charging are used in the United States today:

- Plug-in charging
- Overhead conductive charging
- Wireless inductive charging.

BUS CHARGING METHODS – PLUG IN CHARGING

Aattributes of plug-in charging

- Typically installed at the transit garage.
- Typically used to charge overnight.
- Typically used as sole charging method for buses with large battery packs and higher range. – Charge type: AC or DC. – Charge power: 40–120 kW. – Recharge times (depending on charge power and battery pack size): 1–8 hours.

BUS CHARGING METHODS– PLUG IN CHARGING

The pros of plug-in charging:

- Minimal infrastructure and installation requirements.
- Lower cost per charger than other options.
- Take advantage of lower off-peak electricity rate when charging overnight.
- More flexibility for route selection and future route changes.

BUS CHARGING METHODS – PLUG IN CHARGING

The cons of plug-in charging:

- Buses must be taken out of service to charge.
- Buses use larger, heavier battery packs that can reduce bus efficiency, reduce passenger capacity, and increase wear on suspension components.
- Charging process is manually intensive (plugging in and monitoring).

BUS CHARGING METHODS – PLUG IN CHARGING

The cons of plug-in charging:

- Charging is typically slower than other options.
- Charging can require a lot of space with a charger for each bus.
- Charging can require a lot of power with each bus charging at the same time.

BUS CHARGING METHODS – OVERHEAD CONDUCTIVE CHARGING

The attributes of overhead conductive charging (automated connection using an overhead conductive coupler) are:

- Typically installed on route or at transit center where layovers occur, allowing for opportunity charging; may also be installed at the bus depot or yard.
- Typically serve multiple BEBs operating on routes or from transit centers.
- Typically used with buses with smaller battery packs and less range. – Charge type: DC. – Charge power: 175–450 kW. – Recharge times: 5–20 minutes.

BUS CHARGING METHODS – OVERHEAD CONDUCTIVE CHARGING

The pros of overhead conductive charging:

- Buses use smaller, lighter battery packs.
- There is full-range charge in 5–20 minutes.
- Can support 24-hour bus operation if implemented correctly.

BUS CHARGING METHODS – OVERHEAD CONDUCTIVE CHARGING

The cons of overhead conductive charging:

- Higher cost of charging infrastructure.
- Requires charging infrastructure, equipment, and civil work.
- Peak demand charges significantly affect operational costs.
- Land use and/or rights must be obtained at deployment sites.
- Overhead systems may interfere with road clearances or require dedicated/restricted pull-off.
- Fixed infrastructure constrains route changes in the future or can be costly to relocate.

BUS CHARGING METHODS – WIRELESS/INDUCTIVE CHARGING

The attributes of wireless or inductive charging:

- Typically installed on route or at transit center where layovers occur but could also be used at bus depot.
- Typically serve multiple buses operating on routes or from transit centers.
- Typically used with buses with medium-to-large battery packs and medium range. – Charge power: 50 kW (up to 250 kW planned).

BUS CHARGING METHODS - WIRELESS/INDUCTIVE CHARGING

The pros of wireless or inductive charging:

- Can remain in service while charging on route.
- Decreased infrastructure footprint.
- Charging interface does not interfere with road clearances or require dedicated/restricted pull-off.
- No manual connection or moving parts.

BUS CHARGING METHODS - WIRELESS/INDUCTIVE CHARGING

The cons of wireless or inductive charging:

- Slightly less efficient than conductive methods (90%-95%)
- Higher cost of charging infrastructure.
- Requires charging infrastructure, equipment, and civil work.
- Peak demand charges significantly affect operational costs.
- Land use and/or rights must be obtained at deployment sites.
- Fixed infrastructure constrains route changes in future or can be costly to relocate.

NO ONE SIZE FITS ALL SOLUTION

There is no one-size-fits-all solution with electric buses and charging infrastructure; thus, procurement and planning decisions must be made carefully based on the individual needs and characteristics of the transit agency in order to achieve and maximize the benefits of all-electric technology