Overview of BEB Energy Analysis

USDOT Volpe Center Federal Fleet Support

Electric Transit User Group (ETUG)

September 21, 2022

Contents

- Background
- BEB Considerations
- Process Overview
- BEB Assessment
  - Implementation Assistance
  - Safety Considerations
  - Risk Mitigation

Background

- Volpe has a legacy of successful support enabling National Park Service fleets' adoption of alternative fuel technologies
  - Propane-powered Island Explorer Bus System at Acadia (1999)
    - Original manufacturer stopped producing transit propane engines
    - Solution was a custom-built vehicle with propane conversion
  - Propane-powered Bus System at Zion
    - Volpe analyzed fleet recapitalization options, including initial consideration of electrification
    - Subsequent efforts, including an electrification and charging analysis with NREL,
    - Culminated in Zion receiving $33M from the USDOT Nationally Significant Lands and Tribal Program.

Background Cont'd

- Compressed Natural Gas Bus System at the Grand Canyon South Rim
  - Volpe supported efforts to rehabilitate the aging fuel system and add redundancy to provide for continuous operations.
- Follow-on Volpe support included a phased electrification analysis that has become a model of our electrification process.
  - Initial high-level, mileage-based route assessment to assess potential viability
  - Energy modeling of suitable routes, relying on basic inputs

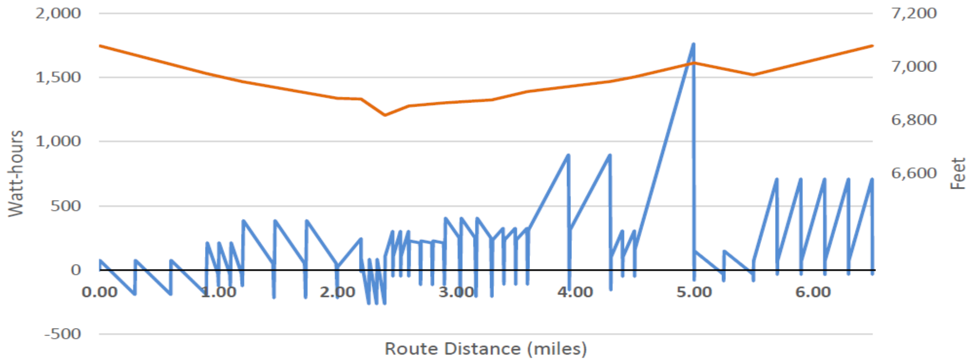
Table 1: 2021 BEB Suitability by Route

Route	Maximum Mileage Potential	BEB Planning Range (miles)	Stops on Route	Buses Required	2021 Slow Charge Suitability*
Village	145	165	14	6	Suitable
Village Express	70	165	2	2	Suitable
Kaibab	170	165	7	4	Potentially Suitable
Tusayan	300	165	4	2	Not Suitable
Hermits Rest	200	165	13	10	Not Suitable

* Suitability based on BEB technology available in 2021, subject to change.

Figure 1: Modeled Energy Demand for One Loop of the Village Route (Challenging Day)

Source: Volpe Center



BEB & Electrification Considerations

- Energy management and optimization: critical, emerging best practices
  - Facilities and Vehicles require common, cohesive energy management planning
    - On-site solar / renewable power generation, energy storage, backup power requirements
- Buses and EVSE maturing
  - 2nd generation models available with solutions to address historic problem areas
    - DCFC, bidirectional, wireless and on-route charging solutions;
    - Charge management
- With any transition, position BEBs for success!
  - Overarching facility and fleet transition plan, think big picture
    - Make your facility EV Ready, even if you start small. Civil Construction is expensive.
    - Hardware options, energy demand implications and potential mitigation solutions
  - Strong relationships with the Utility & bus OEM are critical to success

Process Overview

- Site Mapping
- Local Conditions and Limitations
- Service Scheduling Information
- Mileage Based Range Assessment
- Energy Demand Modeling
- BEB Assessment
- Implementation & Mitigation

Site Mapping

- In order to accurately represent routes in order to model energy demand, the various transit routes and location of infrastructure including bus maintenance facilities, wash bays, and fueling facilities are documented.
  - Routes are plotted for distance and route information is gathered including bus stops, stop signs/lights, pedestrian crossings, railroad crossings, or other locations that may require the bus to stop.
    - Often a manual process using Google street view or reviewing video
  - GIS information from the park, or manually plotted lat/long and elevation information.

Local Conditions and Limitations

- Once infrastructure and routes are well understood, other local conditions or limiting factors are documented. These can include:
  - Limits on installation of new infrastructure, projects may presume EVSE, or chargers, are located at the maintenance facility and cannot be located on route.
  - Physical limits along the route, including height and width restrictions, turning movement limitations, challenging break-over or approach / departure angles.

Service Schedule Information

- The transit service schedule with departure and arrival times along with ridership information helps to understand the utilization of each individual bus throughout the service day.
  - Informs the total "capacity" of the transit system
  - Enables modifications to be made and subsequent impacts to capacity or bus mileage, etc. better understood
  - Alternate route(s), schedules, or vehicle types can be analyzed

Mileage-based range estimate

- Initial examination of fixed-routes based on mileage can help define where to focus further analysis
- Requires fleet operational data inputs (typical scheduling, route, and fleet data)
- Determine the “Maximum Potential Mileage” that a “first-out, last-in” vehicle would accumulate
- Compare with current bus options and their range estimates
  - Typically employ a “planning range” that is significantly below manufacturer-claimed range estimates (~66% of claimed)
    - Accounts for challenging terrain, poor driver behavior, high auxiliary loads, and battery degradation

Energy demand modeling

Inputs

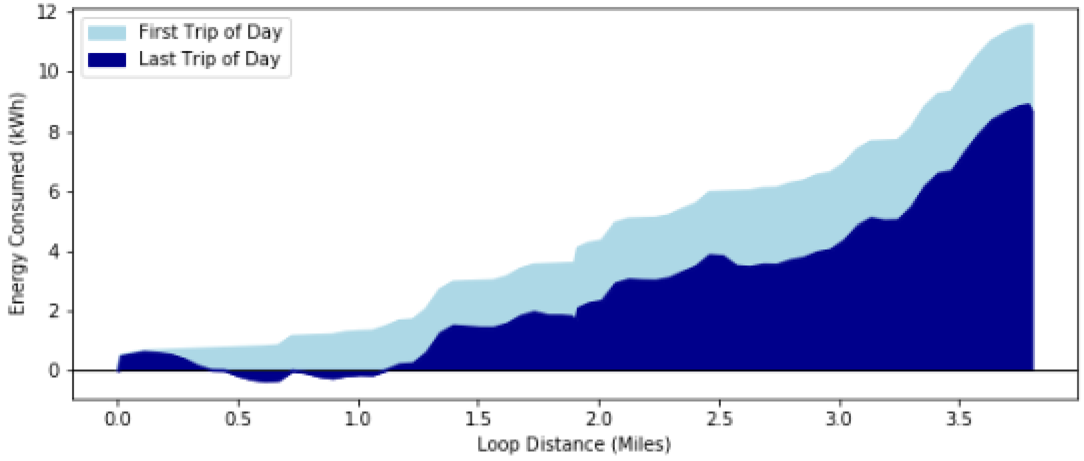
- **Route and schedule information**
  - Distance, travel time, elevation change
  - Number of trips per day
  - Deadhead
  - Intermediate stops (e.g., stop signs)
- **Model specifications**
  - Bus curb weight
  - Number of passengers
  - Acceleration/deceleration rate
  - HVAC energy intensity
  - Other technical inputs

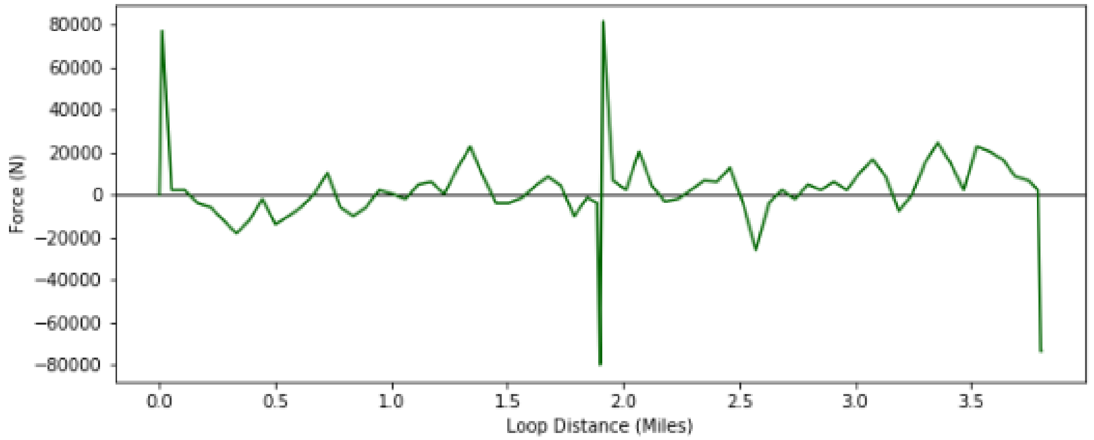
Outputs

- **Trip summary**
  - Total distance and travel time
  - State of Charge
  - Trip energy (kWh)
  - HVAC/auxiliary energy (kWh)
  - Overall energy intensity (kWh/mi)
- **Data Visualization**
  - Force, Energy Use, Route Elevation plots/graphs
- **Options for scenario analysis**
  - Different route assumptions (e.g., loop variations, number of loops, depot locations)

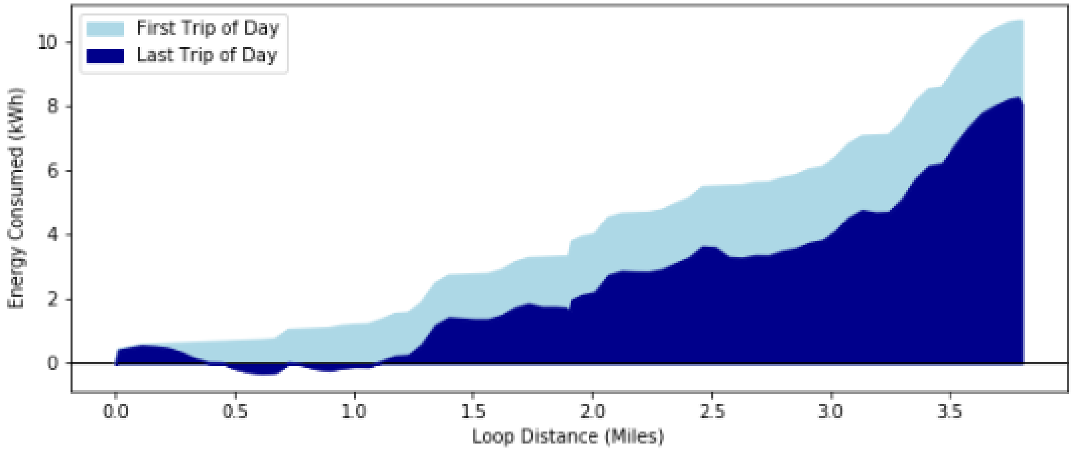
Model outputs

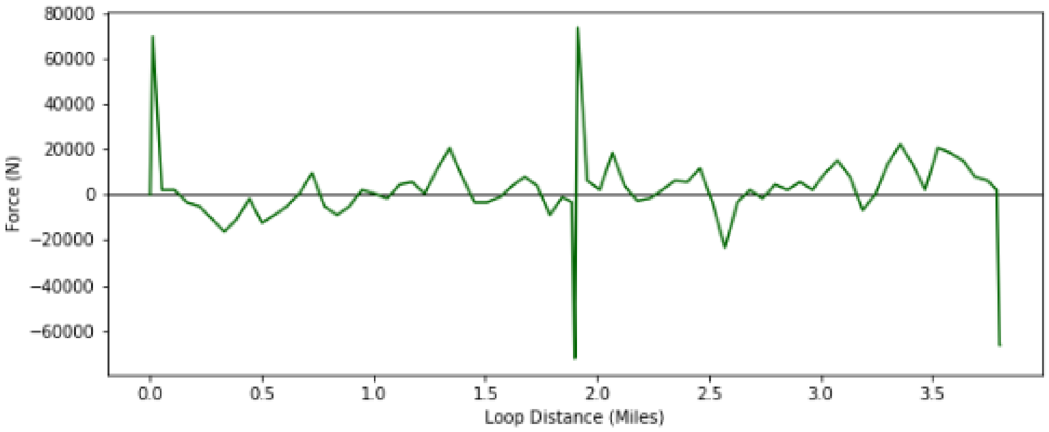
35' Transit Bus, HAFE





30' Transit Bus, HAFE





Route Analysis - Energy Needs by Route

#	Route	Bus Type in Use	Max Daily Mileage*	Daily Energy Consumed (kWh)	Comparative BEB Options
1	Giant Forest	Bus	119	316	**Extended Range (500 kWh+)**
2	Moro Rock / Crescent Meadow	Bus (weekend) Shuttle (weekday)	104	287	**Standard Range** (450 kWh)
3	Wuksachi / Dorst / Lodgepole	Shuttle	290	456	***No Shuttle Available***
4	Wolverton	Bus	145	358	**Standard Range** (450 kWh)
	Gateway (to park)	Shuttle	124	139	**Standard Range Shuttle** (160 kWh)

High-level Assessment, Notes and Mitigation

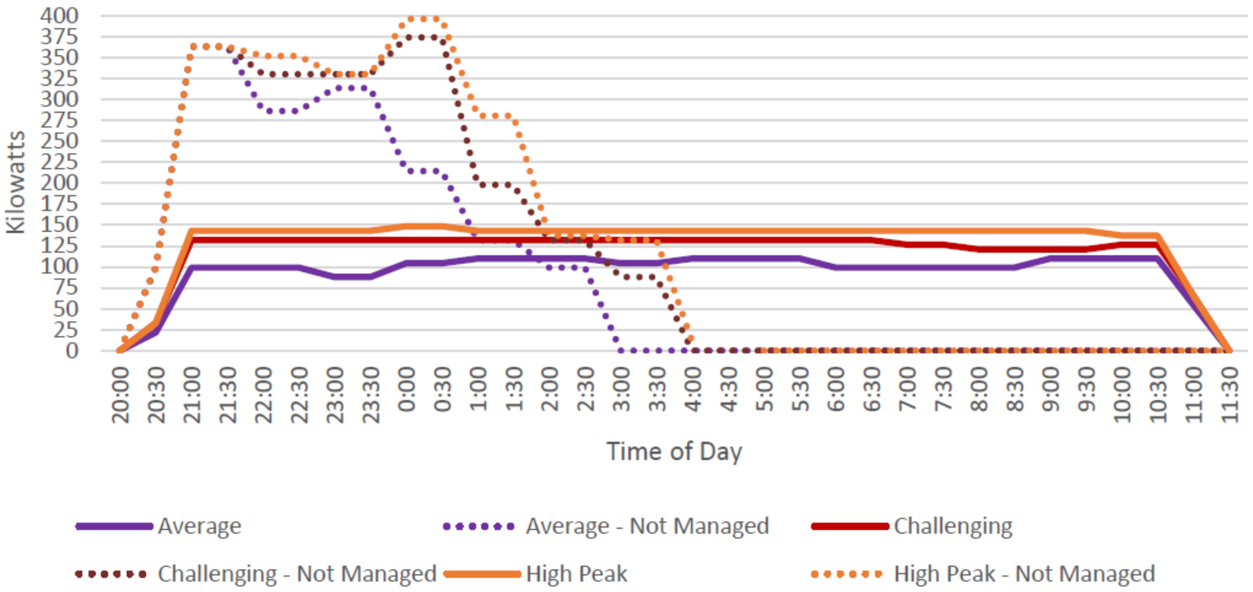
Route	Notes or Mitigation
1 Giant Forest	Standard transit bus battery is adequate (~450-kWh), avoiding max battery option can save on purchase costs or future replacement, less weight to carry while empty.
2 Moro Rock/Crescent Meadow	Both transit and shuttle bus options appear adequate for this route. No expected change in fleet size.
3 Wuksachi / Dorst / Lodgepole	Not feasible with current technology available on shuttle bus platforms, with limited range options "up to" 150 or 160-miles. May require additional fleet vehicles or consider hybrid- or plug-in hybrid retrofits for E450/F450/F550 based chassis.
4 Wolverton	Standard transit bus with 450-kWh battery is adequate, no mitigation. No expected change in fleet size.
Gateway	None needed.

Implementation and mitigation

- Charging analysis
  - Managed charging is key
- On-route DCFC if possible
  - Strategically located DCFC can "top up" range
- Hybrids or H2 FC for long-range applications
- Demand Reduction Strategies
  - Onsite power generation and/or energy storage
- Considerations
  - Resiliency plans for power outages
  - Fire protection or fire-fighting needs
  - System safety plans

Figure 2: Energy Demand Comparison, Managed vs. Unmanaged Charging

Source: Volpe Center



Questions?

F. Scott Lian

General Engineer, USDOT Volpe Center

Supporting the Joint Program Office & NEVI Program

617-494-2811 – scott.lian@dot.gov