FTA Standards Development Program:
Procuring and Maintaining Battery Electric Buses and Charging Systems – Best Practices
&
Safety and Security Certification of Electric Bus Fleets – Industry Best Practices

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Agenda

Industry Best Practices and Findings

- Procuring and Maintaining Battery Electric Buses and Charging Systems – Best Practices
- Safety and Security Certification of Electric Bus Fleets

Methodology for Each Report

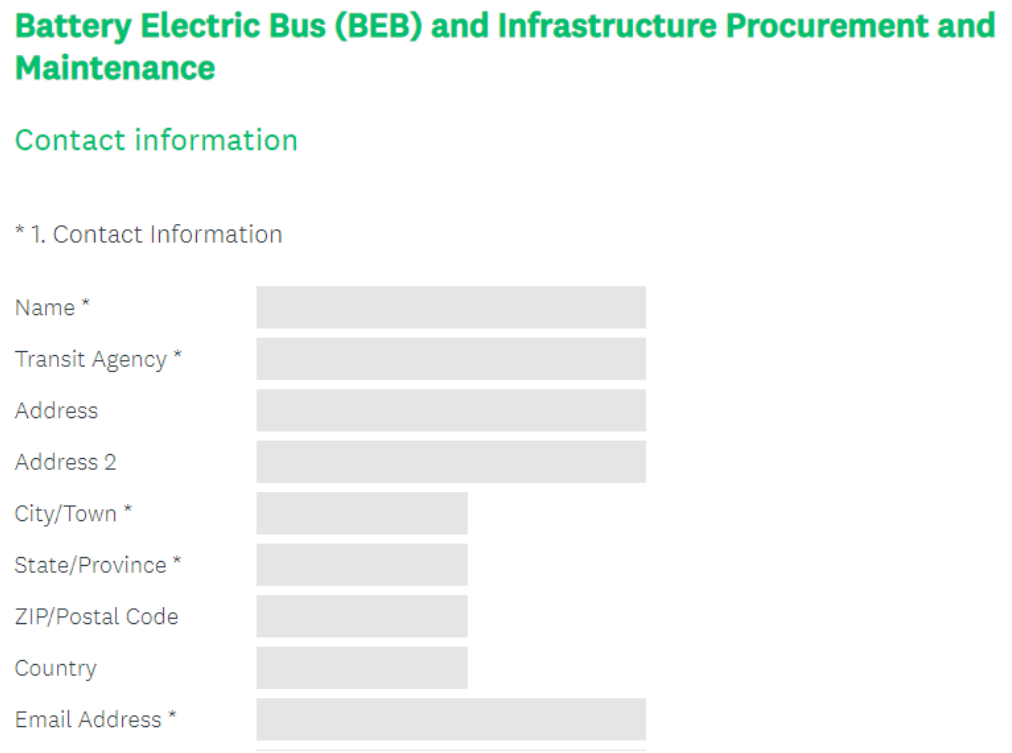
- Literature review
- Identification of existing standards, recommended practices, and guidance documents
- Gap analysis for standards, recommended practices, and other resources
- Standards development organization (SDO) coordination during report development and in implementation options
- Conclusions and findings

Procuring and Maintaining Battery Electric Buses and Charging Systems – Best Practices

Transit Agency Survey Responses

Survey Topics

- BEB procurements
- Procurement terms/warranty
- Partnerships
- Planning
- Vehicle types/support infrastructure
- Operating environment
- Training
- Lessons learned



Battery Electric Bus (BEB) and Infrastructure Procurement and Maintenance

Contact information

* 1. Contact Information

Name *

Transit Agency *

Address

Address 2

City/Town *

State/Province *

ZIP/Postal Code

Country

Email Address *

Survey Respondent Reported Challenges - Procurement

New vendor challenges

- Unproven technology
- Knowledge curve
- Determining desired specification and requirements

Costs – funding and time

- Production delays
- Infrastructure bids were higher than estimates
- Lead times for charging infrastructure

Range considerations

- Matching infrastructure technology to support all routes
- Schedule modifications to accommodate range
- Power capacity evaluation, required improvements

Working with the power company

- Timing the charging infrastructure to precede the BEB delivery
- Installation time for wayside depot charging infrastructure
- On-route charging locations not on transit property
- Integration with facility power needs and existing infrastructure footprint

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Survey Respondent Challenges – BEB Deployment

Timing

- Training
- Parts delays
- Route considerations/accommodations

Cost and space

- Support
- Funding
- Space for charging infrastructure

Vendor challenges

- Vendor challenges with typical bus configuration
- Vendor communication
- Unmet expectations

Other challenges

- Software challenges/bugs
- Interoperability challenges
- Connection challenges

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Transit Agency Case Studies

1	AC Transit	Oakland	CA
2	Foothill Transit	West Covina	CA
3	LYNX	Orlando	FL
4	Pinellas Suncoast Transit Authority	St. Petersburg	FL
5	Port Authority of Allegheny County	Pittsburgh	PA
6	SEPTA	Philadelphia	PA
7	TriMet	Portland	OR
8	Valley Regional Transit	Boise	ID

Challenges Noted by Case Study Agencies

- Bus design defects
- Water intrusion

Quality issues

- Estimating total cost of ownership for BEBs
- Tooling costs
- Space constraints

Costs

- BEB limitations
- Battery specifications
- Impacts to battery state of charge

Learning curve with BEB technologies

- Bus production delays
- Charging infrastructure installation delays
- Delays with OEM communications, support response, bus delivery, repairs, and parts

Delays

- Charger connection / communication fallouts
- Electrical capacity at depot
- Layover location for on-route charger
- Electricity rates

Charging challenges

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Lessons Learned by Case Study Agencies

- Incorporate additional tooling, PPE, and training in procurement contract
- Install a third-party analytic system on the BEBs and charging equipment
- Technology is still maturing

BEB learning curve

- Hiring a consultant
- Utility and transit partnership
- Work with OEMs and submit feedback
- Work with the utility early on

Partnerships

- Anticipate worst-case scenarios
- Future-proof charging infrastructure
- Plan and build out early for future charging expansion

Planning ahead

- Avoiding peak charges
- Consider various specifications for bus and charging infrastructure
- Diversifying fuel sources
- Managed charging
- On-route charging
- Reducing charge time

Charging considerations

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Findings – Literature Review and Stakeholder Engagement

Parts availability is a challenge

- Agencies that include original equipment manufacturer (OEM) parts availability expectations in contract negotiations/procurement language may reduce associated challenges with the unavailability of necessary replacement parts.

Regional or state procurement coordination could leverage economies of scale

- Regional or state procurement contracts provide agencies with an opportunity to leverage the benefits of economies of scale, negotiated procurement language, and pooled funding when available.

Battery warranty ambiguity

- Requesting clear language in the battery warranty that dictates whether the warranty applies to the battery system versus the individual battery packs, cells, and/or battery management systems within the system could reduce the ambiguity of the warranty.

Battery disposal processes unclear

- It is beneficial to include battery storage, disposal, and/or recycling details in procurement language to reduce unexpected issues associated with repurposing or disposal when the battery system or individual battery packs reach the end of their useful life.

Route design methodology may need to change

- Depending upon fleet conversion goals, it may be necessary to redesign routes and/or operating parameters to accommodate BEB performance capabilities (or to accommodate on-route charging); additionally, performance capabilities may vary with extreme weather, thus route design methodology may need to vary by season in some geographies.

Standardized training would be beneficial

- Operator training beyond the general vendor-provided training may improve operator performance and increase BEB efficiency.
- Technician training beyond the general vendor-provided training may improve the confidence of technicians who work on BEBs, which may in turn reduce the technician shortages that many agencies are experiencing. It would also reduce the risks associated with BEB system (buses and charging infrastructure) maintenance.
- Route planning and control center training to clarify the capabilities and limitations of BEBs for both route planners and control center personnel may align the expectations of the BEB with its performance ability and may in turn reduce unexpected state of charge challenges.
- First responder training to provide familiarization of BEB designs may reduce unanticipated hazards and challenges when emergencies occur.

Facility upgrades and space are necessary

- Whether planning for the first BEB procurement or a BEB fleet expansion, facilities require charging infrastructure installation, lifts that are rated for the weight of a BEB, fire suppression systems, and storage space for batteries and spare parts, all of which accumulate space, especially when transitioning to larger fleets. BEBs that have roof-mounted equipment also require personnel lifts for top-of-bus maintenance and additional fall protection.

Interoperability challenges will exacerbate space limitations for charging infrastructure

- As agencies begin to mix fleets during their second and third BEB procurements, the need for interoperability regardless of the make/manufacturer of the vehicle or charging system will be more pronounced, thus it may be beneficial to require interoperability in the procurement language.

Resiliency and backup power source considerations

- Fuel diversification and availability of backup power may be beneficial when power is unavailable for extended periods of time, such as during hurricane events or other natural disasters, to ensure that an agency can provide the necessary transportation. Other considerations include partnering with utilities to expand grid connections and implementing battery storage and microgrids. Agencies may benefit from States developing backup power plans to assist locally when needed.

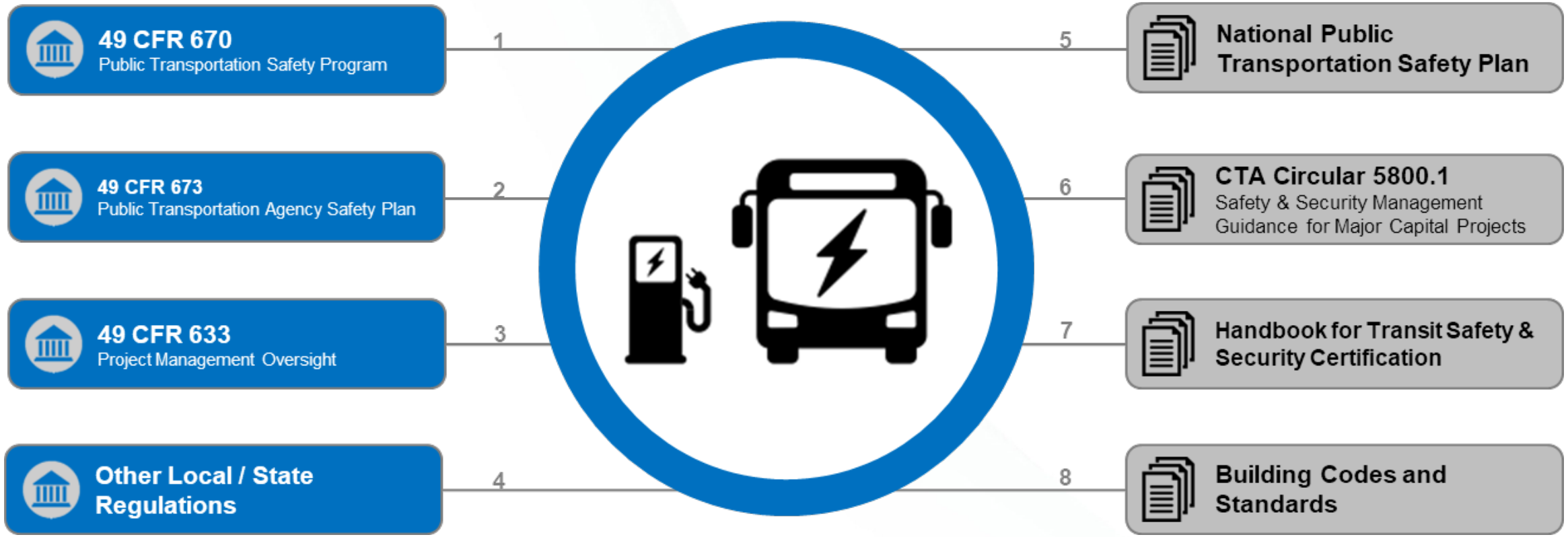
Variable utility rates lead to inconsistent charging costs

- Agencies may have limited negotiating powers with utility providers and should therefore consider variations in utility rates by time of day.

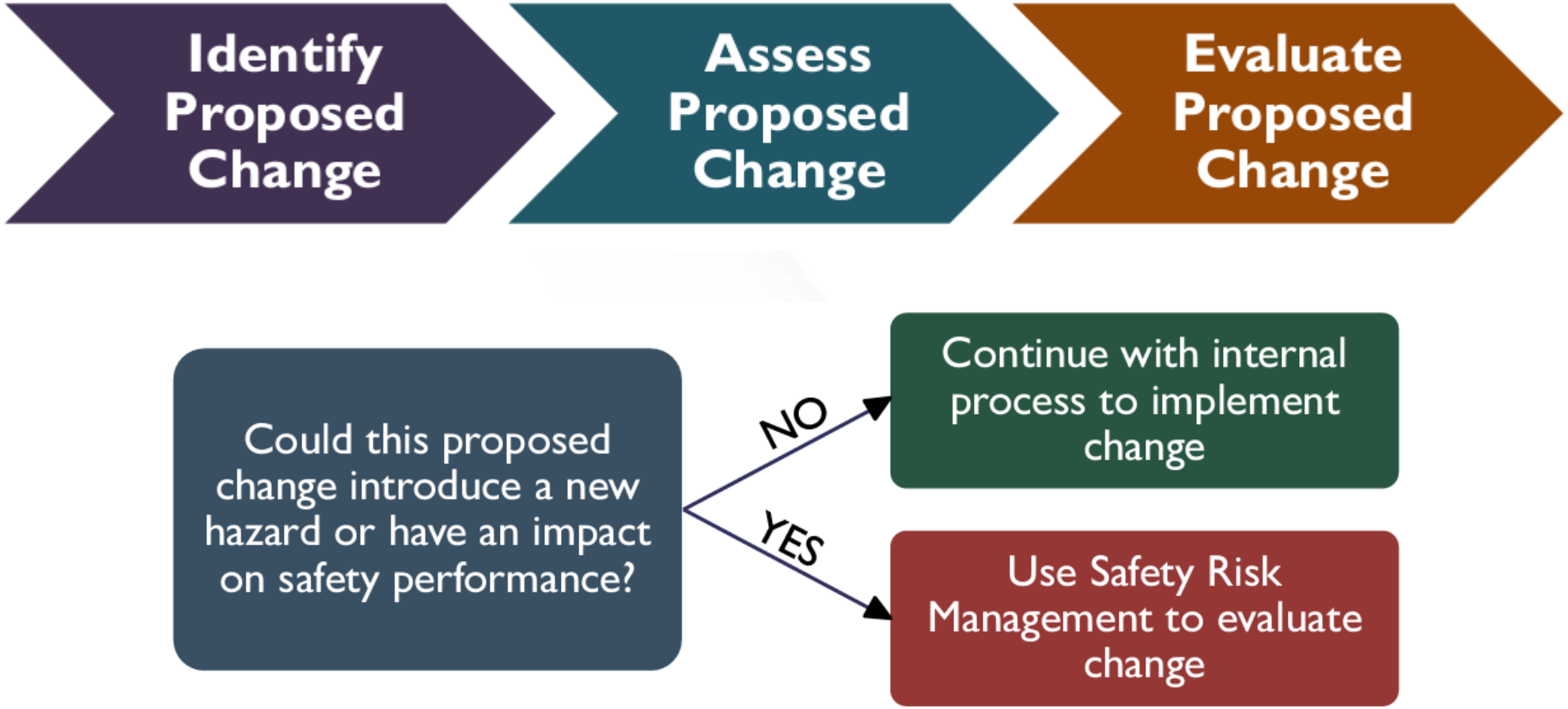
Industry Best Practices – Fleet Certification

Safety and Security Certification of Electric Bus Fleets

Requirements for Safety Certification



Change Management



BEB Change Management Considerations

- Operating rules and procedures
- Inspections, testing, and maintenance
- Training
- Emergency preparedness
  - Facilities
  - Service and operations

Safety and Security Certification Process

- Identifies the key activities
- Highlights resources necessary to develop and implement a certification program for safety and security
- Incorporates safety and security more fully into transit projects
- Provides tools and sample forms to promote the implementation of the safety and security certification process

10-Step Safety and Security Certification Process

Step #	Description	Timeline Phase	Critical SCC Outputs
Step 1	Identify Certifiable Elements	Engineering / Design	▪ Certifiable Elements List ▪ Preliminary Hazard Analysis ▪ Threat and Vulnerability Assessment ▪ Certifiable Items List
Step 2	Develop Safety and Security Design Criteria	Engineering / Design	▪ None
Step 3	Develop and Complete Design Criteria Conformance Checklists	Engineering / Design Construction / Installation / Testing	▪ Design Criteria Conformance Checklist (DCCC)
Step 4	Perform Construction Specification Conformance	Construction / Installation / Testing	▪ Construction / Installation Specification Conformance Checklist ▪ Operational Hazard Analysis
Step 5	Identify Additional Safety and Security Test Requirements	Construction / Installation / Testing	▪ Testing Specification Conformance Checklist (TSCC)
Step 6	Perform Testing and Validation in Support of the SSC Program	Construction / Installation / Testing	▪ None
Step 7	Manage Integrated Tests for the SSC Program	Construction / Installation / Testing	▪ None
Step 8	Manage "Open Items" in the SSC Program	Construction / Installation / Testing	▪ Hazard Tracking Log
Step 9	Verify Operational Readiness	Start-up / Pre-revenue Service	▪ Operational Readiness Conformance Checklist ▪ Temporary Use Permits
Step 10	Conduct Final Determination of Project Readiness and Issue SSC	Start-up / Pre-revenue Service	▪ Final Certificates ▪ Safety and Security Certification Verification Report (SSCVR)

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8 Certifiable Elements List

Element	Sub-Elements	Items
Charging System	▪ Chargers ▪ Transformers	• Fail-Safe Design • Impact Protection • Training and Maintenance • Security Considerations • Codes and Standards • BEB and facility interfaces
BEB Vehicles	▪ Battery Modules ▪ Electrical ▪ Traction Power Motors ▪ High Voltage Electrical ▪ Low Voltage Electrical ▪ Controllers ▪ Emergency Evacuation	• Fail-Safe Design • Codes and Standards • Facility and Charging Interfaces • Emergency releases • Escape hatches
Yards	▪ Parking/Charging Layout ▪ Physical Security ▪ Fire Life Safety ▪ Drainage ▪ Signage ▪ Damaged Vehicles/Batteries	• Bus Separation Distance • Security Considerations • Fire Suppression • Slope considerations • Applicable Signage • Isolation Area & Procedures
Facilities	▪ Parking/Charging Layout ▪ Physical Security ▪ Fire Life Safety ▪ Signage	• Bus Separation Distance • Security Considerations • Fire Suppression • Applicable Signage • Charging Infrastructure Interfaces

8 Certifiable Elements List

Cybersecurity	▪ Network Security	• Firmware Updates
Communications	▪ Vehicle – Charger ▪ Battery Management	• Vital Hazard Management
Testing/Integration	▪ Charging ▪ Electrical	• Interoperability • Commissioning Tests
Operational Readiness	▪ BEB Towing ▪ Maintenance ▪ Training ▪ Staffing ▪ Routes ▪ Spare Parts ▪ Public Outreach ▪ First Responders ▪ Emergency Exercise Program[8] ▪ Battery/Bus Disposal ▪ Service Contracts	• Training • Procedures • Operators and Maintenance • Training and Certification • Recharging Considerations • Availability and Delivery Time • Fleet Safety Tips for the Public • Awareness of Unique Hazards • Exercise AARs • Procedures • Warranty and Maintenance

Threat and Vulnerability Assessments

- Ensure vendors provide a list of the internet-accessible systems and software
  - Examples of potential vulnerabilities include
    - Preventing the vehicle from charging
    - Unlocking doors and windows
    - Starting the vehicle
    - Disabling the security system
- Ask questions of the vendor
  - What safeguards are implemented in the BEB system to reduce the potential for cyber-attacks?
  - Have their buses been involved in a cyber incident? If yes, what was learned, and what was done to prevent future incidents?

Potential BEB Hazards - Vehicles

BATTERY ELECTRIC BUS PRELIMINARY HAZARD LIST		
PHL No.	Hazard Description	
	Sub-System / Elements	Potential Hazard
BEB-01	GVW	GVW exceeds tire factor limits causing tire failure/accidents
BEB-02	Engineering Staff Training	Staff are not knowledgeable of the hazards with the BEB, resulting in injury or damages
BEB-03	Maintenance Managers Training	Staff are not knowledgeable in maintenance aspects of the bus resulting in injury or damages
BEB-04	Driving Instructors Training	Staff are not knowledgeable in operational aspects of the bus resulting in injury or damages
BEB-05	Technical Instructors Training	Staff are not knowledgeable of the hazards with the BEB, resulting in injury or damages

Potential BEB Hazards – Chargers/Systems

BATTERY ELECTRIC BUS PRELIMINARY HAZARD LIST		
PHL No.	Hazard Description	
	Sub-System / Elements	Potential Hazard
CGR-01	Charger System	Charging System is not compatible with the bus resulting in the bus not charging and able to enter into revenue service
CGR-02	Charger System	Charging System is not compatible with the bus resulting in the batteries being overcharged and a thermal runaway event occurs
CGR-03	Cybersecurity	Charging system does not meet cybersecurity requirements and leads to an attack that allows the bus to be charged at an unsafe rate
CGR-04	Software	Updates to charger software result in incompatibility with the charging of other manufacturer's buses
CGR-05	Hardware	Updates to charger hardware result in incompatibility with the charging other manufacturer's buses

Common gaps in the certification process for BEBs

- Late coordination with the electric company
- Absence of specific codes and standards
- Some BEB certifiable items may change during assembly
- Parts availability issues hamper BEB operation
- Specific BEB fleet fire protection code requirements
- Most agencies do not utilize a complete safety certification process for BEBs
- Many agencies have not developed safety and security design criteria
- Missing input/coordination from all agency departments and local first responders
- No coordination with other transit agencies to identify issues/lessons learned
- Acquisition of any new PPE and tools

Resource Page

- Procuring and Maintaining Battery Electric Buses and Charging Systems – Best Practices (FTA Report 0253)
- Safety and Security Certification of Electric Bus Fleets – Industry Best Practices (FTA Report 0252)
- Guidebook for Deploying Battery Electric Buses (FTA Report 0254)

Thank You

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