Battery Electric Bus Technology Review

Victoria Regional Transit Commission
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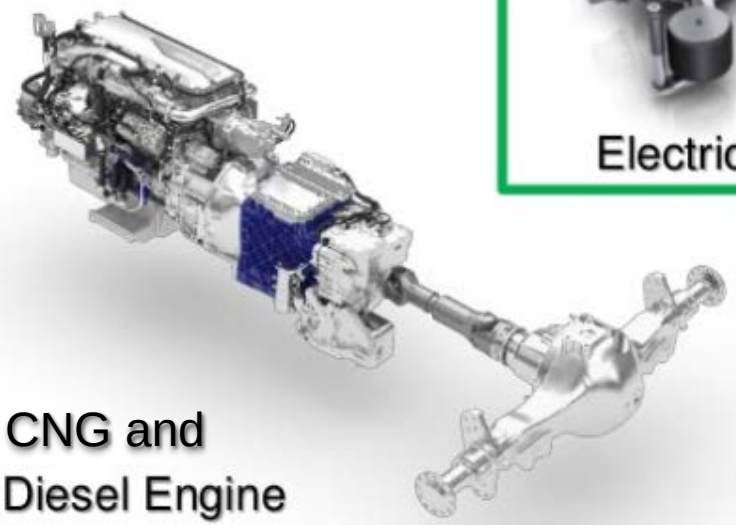
Outline

- Battery Electric Bus Technology
- Why Electric? Potential Benefits
- Industry Assessment
  - Demonstration and Trials
  - Challenges and Considerations
- Approach

Bus Engine Technologies

- Commercial propulsion technologies:
  - Diesel
  - Compressed Natural Gas
  - Gasoline
  - Electric Hybrid
- Emerging propulsion technologies:
  - Hydrogen Fuel Cell
  - **Battery Electric**

Electric HUB Motor



CNG and
Diesel Engine

Fuel Engine

Electric Motor

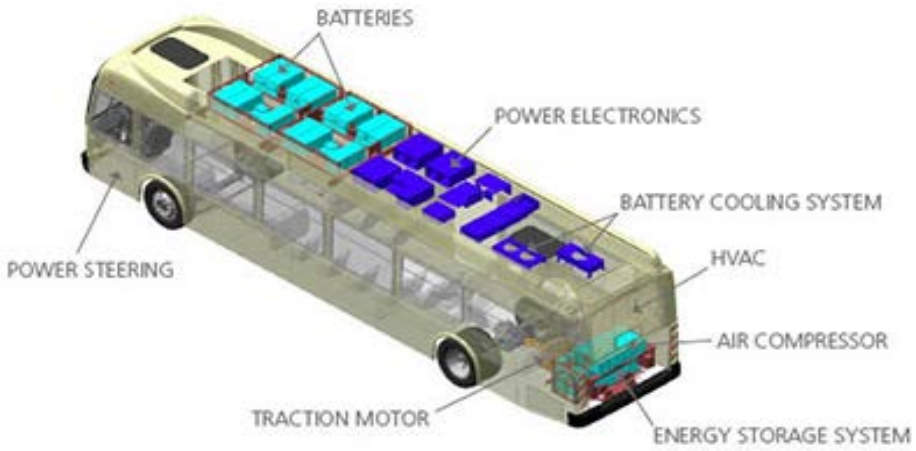
Why Electric?

<u>Potential</u> benefits:

- Reduced greenhouse gas (GHG) emissions
- Improved passenger and bus operator experience
  - Reduced ambient noise and exhaust smell
  - Less vibration
  - Smooth, progressive acceleration
- Operating savings
  - Less maintenance due to lack of engine, transmission, intake exhaust or cooling system
  - Regenerative braking
- Supporting the development of renewable resources is viewed favourably by public
- Point of differentiation in the tourism market

Electric Bus Technology

- Electric motor powered by on-board battery packs
- Two types of electric buses:
  - On-route charging
  - Off-route charging



Electric Bus Technology

On-route features:

- Small amount of battery capacity
- Shorter range (40-60km)
- Energy supplied while in service
- Conductive and inductive charging
- Overhead pantograph and road embedded charger
- Fast charge
  - 5-10 minutes

NEW FLYER

PROTERRA

NOVA BUS

Electric Bus Technology

On-route charging pros and cons:

Pros	Cons
• Open-protocols • Battery investment • Bus weight	• Expensive infrastructure • Complex route planning and city infrastructure • Electricity requirements on grid's peak loading times (unless side-by-side energy storage) • Bus range

Electric Bus Technology

Off-route features:

- Large amount of battery capacity
- Longer range (120-250km)
- Energy supplied while parked at depot
- Plug-in charger
- Slow and fast charge options
  - 2-8 hours charging time
  - Overnight or during downtime

NEW FLYER

PROTERRA

GreenPower Bus
The Future of Transportation

BYD

Electric Bus Technology

Off-route charging pros and cons

Pros	Cons
• Less-complex fleet deployment • Less-complex charging infrastructure • Alignment with incumbent technologies and operating systems • Electricity requirements on grid's off-peak times	• Closed-protocol systems • Requires garage upgrades

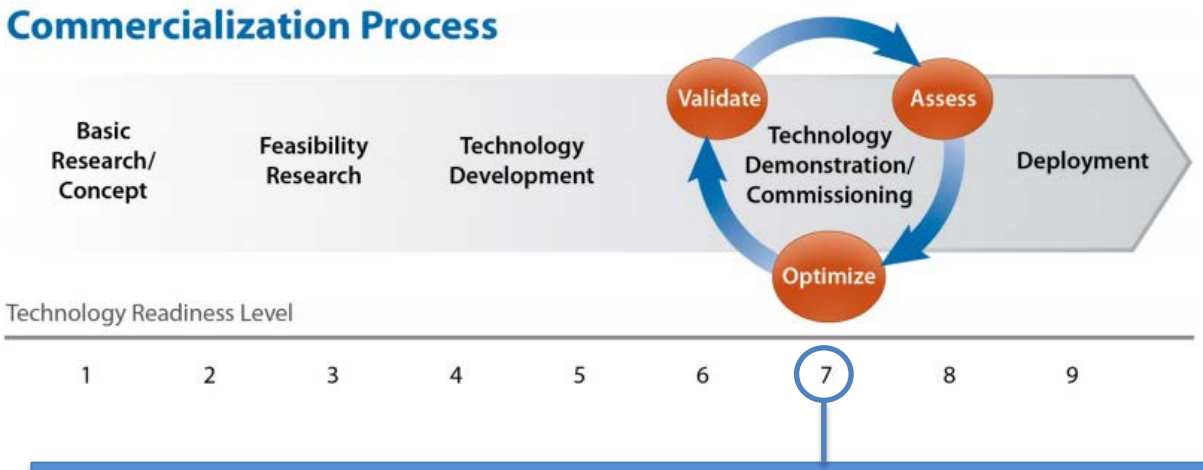
Industry Assessment Demonstrations & Trials

- Canadian Transit Agencies:
  - St. Albert Transit - 3 x BYD
  - Vancouver TransLink - 1 x BYD
  - Société de transport de Laval (STL) - 2 x Design Line, BYD
  - Société de transport de Montréal (STM) - 3 x Nova Bus
  - Edmonton Transit Service (ETS) - 2 x BYD, New Flyer
  - Winnipeg Transit - 4 x New Flyer
- Small quantity of buses
- Single route or shuttle service

Industry Assessment Demonstrations & Trials

- Foothills Transit:
  - Most mature and comprehensive electric bus demonstration in North America
  - One route, 12 x 35-foot Proterra buses with on-route fast-charge
  - Trial concluded battery electric buses rated 7 out of 9 in terms of Technical Readiness Level (TRL) developed by National Renewable Energy Laboratory (NREL)

Industry Assessment Demonstrations & Trials



NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Technology Demonstration and Commissioning Phase:

- Manufacturers' goals for the demonstration are to verify that the battery electric bus performance meets the technical targets and identify any issues that need to be resolved
- Full-scale demonstration and reliability testing of 5-10 buses at several locations

CUTRIC FASTER • SMARTER • GREENER

CRITUC RAPIDE • INTELLIGENT • VERT

- Canadian Urban Transit Research and Innovation Consortium
- BC Transit - founding member
- 91 Members
  - Public, Private, Transit, Electric Utility, Academic, Non-Profit

"Collaborative innovation is the best way to design, deliver and integrate clean technology solutions that lower transportation emissions and help Canada meet its climate change goals, while improving mobility options for all Canadians."

- CUTRIC Pan-Canadian Electric Bus Demonstration and Integration Trial

Phase 1	Phase 2

• 20 eBuses
  – Nova Bus and New Flyer
• 3 Transit Agencies
  – TransLink, Brampton, York
• 7 overhead chargers
  – ABB and Siemens
• 5 research organizations
• Total value: $45M
• Buses in service October 2018
	• 40-50 eBuses
	• 8 research organizations
	• Total value: $75M
	• Buses in service October 2019

Challenges & Considerations

- **Capital Cost**
  - 70-100 per cent more expensive than diesel buses
  - Charging infrastructure costs
    - Depot-based and/or on-route charging systems
    - Energy storage systems (if applicable)
  - Battery replacements
  - Transit facility upgrades
  - City infrastructure upgrades
  - BC Hydro infrastructure upgrades

Challenges & Considerations

- **Range**
  - Impacted by several variables:
    - Number of batteries on-board, energy storage capacity (kWh)
    - State of charge (SOC) buffer
    - Energy used for accessories (HVAC, electric heat)
    - Duty cycle
    - Topography
    - Climate
    - Bus weight
  - Every route is unique and must be analyzed individually to determine range

Challenges & Considerations

- **Charging Strategy**
  - No clear industry preference for type of charging system
  - Lack of standards - open protocol favoured for sustainability
  - High degree of coordination and partnership with BC Hydro and municipal infrastructure planning:
    - Coordination with BC Hydro to support charging strategy, grid upgrades, determine demand charges, energy consumption rates and energy storage technology (if required)
    - Coordination with Municipalities if on-route chargers need to be installed at transit exchanges; civil work project costs
  - Early adopters risk premature technology obsolescence

Challenges & Considerations

- **Transit Operations**
  - Depending on the battery size and charging strategy selected, all aspects of day to day operation must be reviewed and potentially adjusted:
    - Route structure/interlining
    - Bus operator and maintenance training
    - First responder training
    - Spare ratio
    - Business continuity plans
    - Facility and yard design

Conclusion

- Electric buses have made great progress in the last few years
- Viable zero-emission battery electric buses are near, but are not yet commercially viable on a large scale:
  - Upfront capital costs prohibitive for most transit agencies without special funding
  - Industry preference for bus type and charging strategy not solidified
  - Lack of North American industry charging standards (ie. SAE J3101)
  - Uncertainty surrounding “real-world” performance and total cost of ownership
  - Lack of parts continuity due to rapid technology advancement
- Significant investigation, strategic planning and coordination needed by BC Transit, BC Hydro and municipal partners to determine feasibility

Next Steps

- CUTRIC Participation:
  - Learn from Phase 1: Pan-Canadian Electric Bus Demonstration & Integration Trial
  - Participate in four technical planning sessions to learn about Phase 2 participation requirements (October 2017 to February 2018)
  - Conduct technology and economic modeling
  - Determine participation in Phase 2 demonstration (March 2018 to October 2019)
- APTA Expo
- Support manufacturer demonstrations at local level

Questions?