

Manitoba Battery Electric Transit Bus Fleet Development & Demonstration

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**Next Generation Automobiles
in Miyagi**

Manitoba CANADA

- 49th to 60th parallel
- 548,000 km²
- ~1.3M people
- Ocean access (summer)
 - Net After-Tax Cost of Corporate R&D: 45¢ to 47¢ per \$1 of R&D
- Winnipeg (capital) weather
 - Extreme humid continental climate
 - 306 days with measureable sunshine
 - 521.1 mm precipitation annually
 - 132 days of snow cover – 110.6 cm average snowfall
 - -47.8°C (1879) to 42.2°C (1937) = 90°C difference
 - Windchill (temperature + wind) record = -57.1 (1996)
 - Humidex record (temperature + humidity) = 48 (2007)



Red River College

- Manitoba's largest institute of applied learning
- Over 200 full- & part-time academic programs
 - Personal Development to Trades to Degrees
- More than 30,000 enrolments across eight campuses
- Annual operating budget ~\$180M
- ***Applied Research & Innovation: Fuelling Manitoba's economic growth & community development***
 - Annual research support ~\$6M
 - Ranked as a TOP 10 Canadian Research College
- Flexible Intellectual Property Policy
 - Institutional ownership (for clarity)
 - Commercial rights routinely assigned to private-sector sponsors
 - Rights retained for future research & education

Vehicle Technology & Energy “Cluster”

- Focus on Off- and On-Highway Vehicle Technology
- Integrated approach
 - Applied research, education & training
 - Reflective of community needs
 - Partnerships are an essential component
 - Industry, government & academic
 - Ability to leverage cash and in-kind contributions
- Builds on existing College expertise and facilities
 - School of Transportation Aviation and Manufacturing
 - Research Centres, Research Chairs and Research Professionals
 - Technology Access Centre for Aerospace & Manufacturing
- Focused applied research program
 - Vehicle Development & Vehicle Performance

Vehicle Technology Infrastructure & Projects

Extreme (cold) & renewable energy focused



Electric Vehicle Technology & Education Centre

- Mission:
 - Support electric vehicle innovation in/by Manitoba's transportation sector
 - Enhance electric vehicle education at RRC & in the region
 - Increase public awareness of electric vehicle technology
- Provincial financial support (\$645,000) based upon RRC's track record of applied research & demonstrations in advanced transportation & energy
- Leads College engagement in the battery electric transit bus project



Battery Electric Transit (BET) Bus

- Public-Private Partnership – International Consortia
- 2011 to 2014: \$3 million, three-year project
 - Project development at NFI Winnipeg, Manitoba Hydro & RRC
- Goals
 - Develop a prototype advanced battery electric transit bus
 - Utilize MHI & NFI technologies
 - Demonstrate the bus & associated charging technologies
 - Test operational capabilities under Manitoba's extreme climatic conditions
 - Use demonstration as a showcase for other potential markets in N.A.
- 2012: Expanded scope (with SDTC & consortium partners)
 - \$10M five bus fleet multi-year trial in fare service with Winnipeg Transit

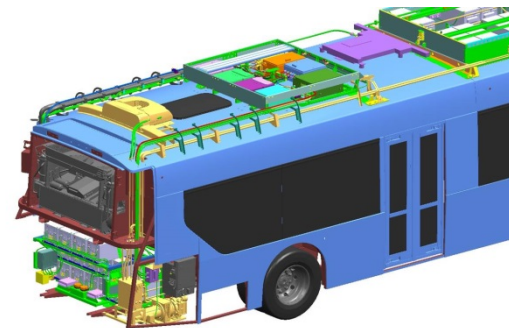
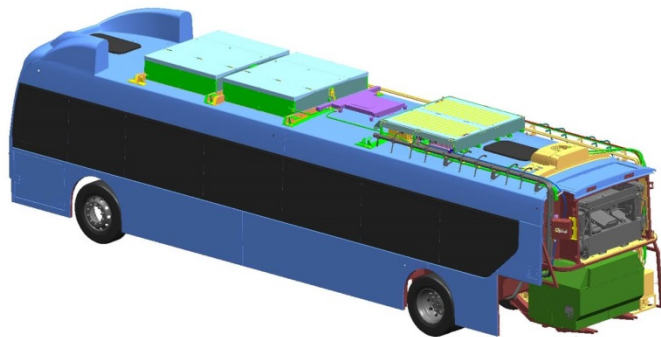


RRC Role: BET Bus Prototype & SDTC Phases

- Financial project management & administration
- Assembly & monitoring of lithium ion batteries
- Charging infrastructure involvement (Manitoba Hydro-led)
- Phase 3
 - Operation (drivers), troubleshooting & minor maintenance
 - Service manual input (for EV operation)
 - Monitoring & evaluation of field tests
- Public report drafting (of original consortium project)
- SDTC Phase
 - Redesign, testing & prototyping of MHI battery packs for integration into two NFI Xcelsior XE40 production coaches
 - Monitoring of MHI battery packs
 - Operational support

BET Bus Prototype Specifications

- NFI Xcelsior platform tested to standard industrial durability & life criteria (6X Altoona Durability Test)
- Energy-efficient electric permanent magnet traction motor
- MHI air-cooled lithium ion battery packs – 120 kWh (8 x 15 kWh)
- Bio-diesel heater for cold climates
- Similar weight to comparable diesel-electric hybrids
- Desired battery life – six to eight years



BET Charging Infrastructure

- Dual module charger
 - 300 to 500 kW
 - Utility friendly, outdoor enclosure for curb-side installation
 - Enhanced safety & wireless communication
 - Integrated fault & isolation detection
- Overhead rapid charging dock
 - Automated rooftop interface (pantograph) – no operator intervention
 - Easy drive-through ingress/egress for rapid charging
- Now at YWG to enable fare service with Winnipeg Transit
 - Route 20 (**Watt** Street)
- Target of 6 minute charge/hour = no net charge depletion
 - 300 kW charger, 20 kph average speed & 1.45 kWh per km



RESULTS: BET Bus Prototype (Original – Unit #1)

- MHI 120 kWh Li-on packs integrated in NFI Xcelsior coach
- Prototype completed June 2012, two-year field test/demo
 - Manitoba Hydro suburban-downtown shuttle - 15 kms round trip
 - ~20,981 kms (September 2015)
 - 300 kW charger = 20 minutes to full recharge
- Energy consumption (average of test & industry experience)
 - 2 kWh/mile – no air conditioning
 - 3 kWh/mile – with full air conditioning
 - 4 kWh/mile (estimated) – electric coach heating
 - Bio-diesel or diesel heater recommended
 - Less GHGs & 80-85% thermal efficiency
 - Overall average: 145 kWh /100 km
- blogs.rrc.ca/ar/2014/05/manitobas-new-electric-bus-and-charging-system-revolutionizing-clean-energy-public-transportation-systems



RESULTS: BET Bus Production Units (SDTC)

- SDTC Bus Production Units #2 to #5 (September 2015)
 - SDTC – MHI #1 (180 kWh) – 22,517 kms
 - SDTC – MHI #2 (180 kWh) – 17,599 kms
 - SDTC - XALT Energy #1 (200 kWh) – 9,755 kms
 - SDTC - XALT Energy #2 (200 kWh) – 27,102 kms
- Demonstrations and applications
 - Winnipeg Transit fare (revenue) service – operating reliably
 - Transit Property demonstrations across North America
 - “Altoona Test” per FTA – industry-leading results
- First NFI commercial sales (two) to Chicago Transit Authority
 - 28,852 kms and 27,887 kms (as of 2015 09 08)



SDTC BET Bus Milestones

- Production units (four) operational in 2014
- Reliability simulation – on route, schedule maintained, shadow service (no passengers)
- Battery duty cycle evaluation (Sept 2014 to March 2015)
 - 1.45 kWh/km (2.3 kWh/mile) energy consumption
 - 57.5 kWh of energy required to recharge (after 40 km route)
 - 29% of battery pack capacity
- Altoona Test very successful, no failures related to:
 - Axles
 - Batteries
 - Electric air compressor
 - Electric drive
 - Electric HVAC
 - Electric steering

Altoona Test Results (June 2014 to July 2015)

- Federal Transit Administration (FTA) Test Program
 - Testing in Service-Life Category 12 Years/500,000 Miles
- "SDTC" XE40 prototype
 - New Flyer Xcelsior bus platform
 - Siemens ELFA drive motor
 - XALT Energy batteries - 200 kWh
 - 76-person capacity
- Industry-leading results
 - Reliability
 - Fuel efficiency
 - Interior noise
 - Gross Vehicle Weight Rating

Altoona Test Results (June 2014 to July 2015)

- Failures = 21
 - Competitors: "A" @ 33 | "B" @ 49
- Unscheduled Repairs = 74.0 hours
 - Competitors: "A" @ 258.5 hours | "B" @ 278.5 hours
- Energy consumption overall average = 1.84 kWh/mi
 - Diesel equivalent fuel economy = 20.50 mpg
- Vehicle range average = 87.01 miles
- 0 to 35 mph interior noise average = 68.6 dBA
 - Competitors: "A" @ 70.4 dBA | "B" @ 75.2 dBA
- Highest passenger-carrying capacity of any electric bus in N.A.
- Federal Zero-Emission Bus Voucher Incentive Program registered, including California
- altoonabustest.psu.edu/buses/458

Takeaways

- “Clean Tech” offers socially rewarding & technically interesting opportunities for innovation
- Personal & corporate relationships are the foundation for project success
- Clear roles are necessary, especially in consortia
- Many partners & enablers have contributed over the last decade to project success - partnerships work
- Battery electric transit buses perform reliably & efficiently in Manitoba’s extreme climate, especially cold
- Altoona Test shows that “Made-in-Manitoba” electric vehicle technology is an industry leader

Enablers & Partners

- **Enablers – since 2003**

- Canada Foundation for Innovation
- Department of Foreign Affairs and International Trade
- Knowledge Infrastructure Program
- Manitoba Vehicle Technology Centre
- National Research Council Industrial Research Assistance Program
- Natural Sciences & Engineering Research Council (CCIP, IE, ARTI, TAC & ARD-2)
- Province of Manitoba (COPSE, ETT & IEM)
- Sustainable Development Technology Canada
- Western Economic Diversification

- **Partners – since 2011**

- New Flyer Industries
- Manitoba Hydro
- Mitsubishi Heavy Industries (Japan)
- Province of Manitoba (Energy Division)
- Red River College
- Winnipeg Transit

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Questions?

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AR&C Team: January 2014

